DOE/NV/11718--388

Nevada
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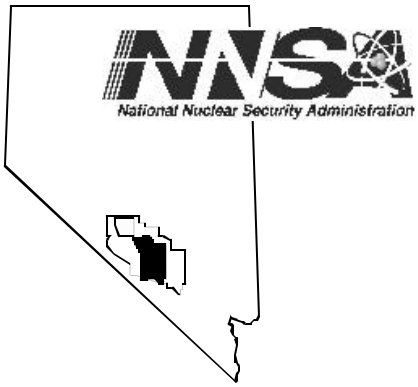

Completion Report for Well ER-18-2

September 2003

Environmental Restoration
Division

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

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Completion Report for Well ER-18-2

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

Prepared by:
Bechtel Nevada
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Las Vegas, Nevada

September 2003

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DOE/NV/11718--388

COMPLETION REPORT FOR WELL ER-18-2

Approved by: Robert M. Bangerter Jr. Date: 4/2/04

Robert M. Bangerter, Project Manager,
Underground Test Area Project

Approved by: Robert M. Bangerter Jr. Date: 4/2/04

for Janet L. Appenzeller-Wing, Acting Director
Environmental Restoration Division

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Completion Report for Well ER-18-2
DOE/NV/11718--388

ABSTRACT

Well ER-18-2 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. This well, located on Buckboard Mesa in the western part of the Nevada Test Site, was drilled in the spring of 1999 as part of the U.S. Department of Energy's hydrogeologic investigation well program in the Western Pahute Mesa - Oasis Valley region just west of the Test Site. A 44.5-centimeter surface hole was drilled and cased off to the depth 408.1 meters below the surface. The hole diameter was then decreased to 31.1 centimeters for drilling to a total depth of 762.0 meters.

A preliminary composite, static, water level was measured at the depth of approximately 369.7 meters approximately two months after the completion string was installed. One completion string with three isolated, slotted intervals was installed in the well.

Detailed lithologic descriptions with preliminary stratigraphic assignments are included in the report. These are based on composite drill cuttings collected every 3 meters and 15 sidewall samples taken at various depths below 420 meters, supplemented by geophysical log data and results of detailed chemical and mineralogical studies of rock samples. The upper part of the well penetrated Tertiary-age basalt, underlain by tuffaceous moat-filling sediments interbedded with ash-flow tuff units of the Thirsty Canyon Group and the Beatty Wash Formation. The lower half of the drill hole penetrated ash-flow tuff of the mafic-rich Ammonia Tanks Tuff. The geologic interpretation of data from Well ER-18-2 indicates that this site is located inside the structural margin of the Ammonia Tanks caldera.

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List of Acronyms and Abbreviations

BHA	Bottom-hole assembly
BN	Bechtel Nevada
cm	centimeter(s)
C	Celsius
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
EC	electrical conductivity
F	Fahrenheit
FMP	Fluid Management Plan
ft	foot (feet)
ft^3	cubic feet
gpm	gallons per minute
in.	inch(es)
IT	IT Corporation
km	kilometer(s)
lpm	liters per minute
LANL	Los Alamos National Laboratory
LiBr	lithium bromide
m	meter(s)
m^3	cubic meters
mi	mile(s)
NAD	North American Datum
NNSA/NSO	National Nuclear Security Administration Nevada Site Office
NTS	Nevada Test Site
TD	total depth
TFM	Thermal Flow Meter
TMCC	Timber Mountain caldera complex
TWG	Technical Working Group
UDI	United Drilling, Inc.
UGTA	Underground Test Area
USGS	United States Geological Survey
WPM-OV	Western Pahute Mesa - Oasis Valley

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1.0 Introduction

1.1 Project Description

Well ER-18-2 was drilled for the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Site Office (NNSA/NSO; formerly Nevada Operations Office, DOE/NV) in support of the Nevada Environmental Restoration Project at the Nevada Test Site (NTS), Nye County, Nevada. Well ER-18-2 is the third in a series of wells drilled as part of the hydrogeologic investigation well program in the Western Pahute Mesa - Oasis Valley (WPM-OV) region of Nye County, Nevada. This program is part of the NNSA/NSO Environmental Restoration Division's Underground Test Area (UGTA) project at the NTS. The goals of the UGTA 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 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 migration pathways, migration rates, and quality.

The goal of the WPM-OV program is to collect subsurface geologic and hydrologic data in a large, poorly characterized area down-gradient from Pahute Mesa where underground nuclear tests were conducted, and up-gradient from groundwater discharge and withdrawal sites in Oasis Valley northeast of Beatty, Nevada (Figure 1-1). Data from these wells will allow more accurate modeling of groundwater flow and radionuclide migration in the region. Some of the wells may also function as long-term monitoring wells.

Well ER-18-2 is located northeast of Timber Mountain and south of Pahute Mesa (Figure 1-1). The well site is located on Buckboard Mesa in the central part of Area 18, approximately 6.4 kilometers (km) (4 miles) inside the western boundary of the NTS. The elevation of the dirt-fill drill pad at the wellhead is 1,657.2 meters (m) (5,437.1 feet [ft]) above sea level. The Nevada State Planar coordinates (North American Datum [NAD] 1983) at the wellhead are North (N) 6,261,201.2 and East (E) 526,033.9 m (N 20,541,957.7 and E 1,725,829.6 ft). Additional site data are listed in Table 1-1.

IT Corporation (IT) was the principal environmental contractor for the project, and IT personnel collected geologic and hydrologic data during drilling. The drilling contractor was United Drilling, Inc. (UDI), a subcontractor to Bechtel Nevada (BN). Site supervision, engineering,

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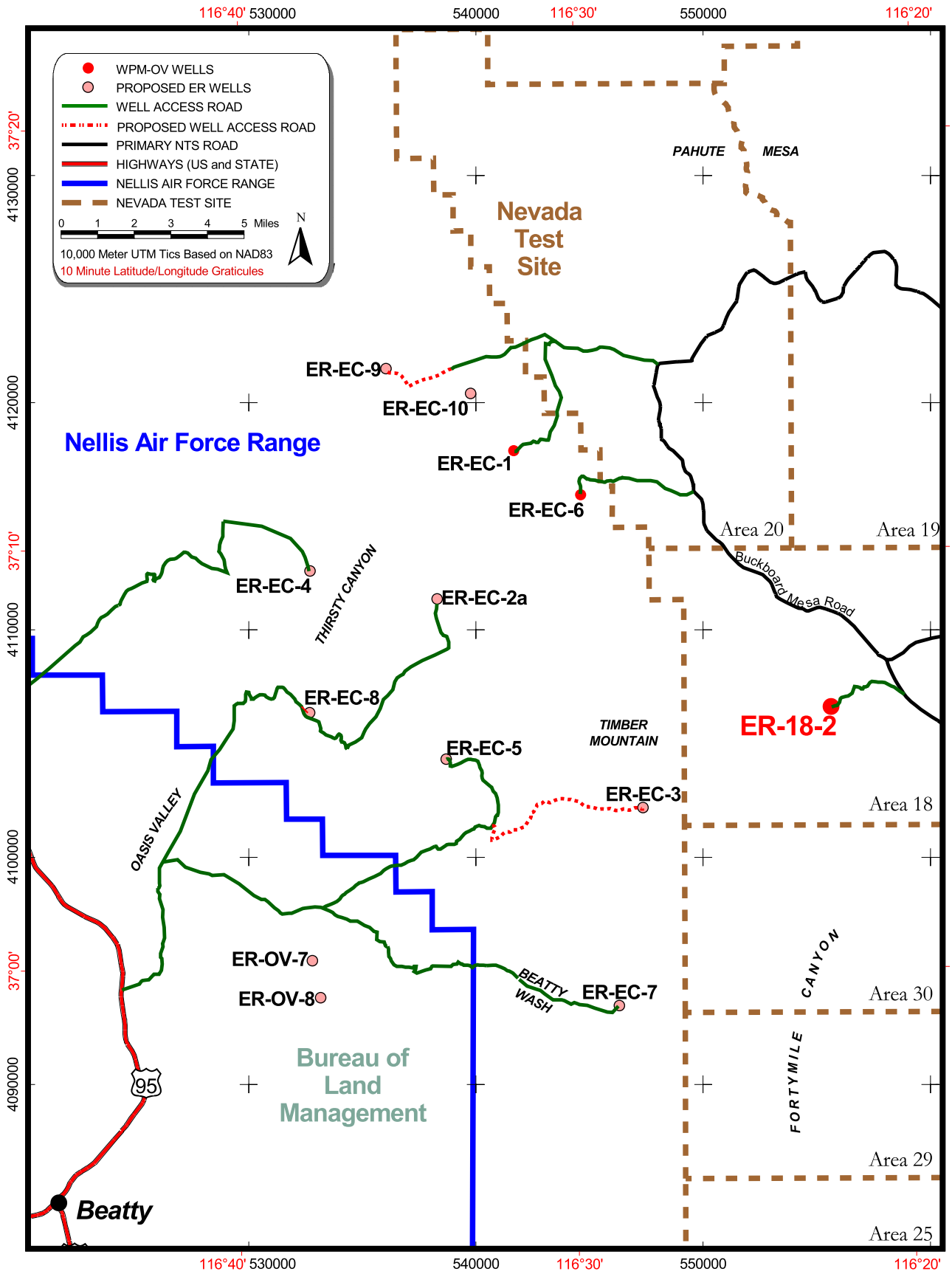

Figure 1-1
Reference Map Showing Location of Well ER-18-2.
(Proposed wells not drilled at time Well ER-18-2 was drilled.)

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Table 1-1
Well ER-18-2 Site Data Summary

Well Designation	ER-18-2
Site Coordinates [a]	Central Nevada State Planar (NAD 83): N 6,261,201.2 m (N 20,541,957.7 ft) E 526,033.9 m (E 1,725,829.6 ft) Central Nevada State Planar (NAD 27): N 856,955.5 ft E 585,673.0 ft Universal Transverse Mercator (Zone 11)(NAD 83): N 4,106,585.8 m E 555,644.6 m
Surface Elevation [b]	1,657.2 m (5,437.1 ft)
Drilled Depth	762.0 m (2,500 ft)
Fluid-Level Depth [c]	369.7 m (1,212.9 ft)
Fluid-Level Elevation	1,287.5 m (4,224.2 ft)

a Measurement by BN Survey.
b Measurement by BN Survey. Elevation at top of drill pad. National Geodetic Vertical Datum, 1929.
c Measured by IT on July 17, 1999, approximately two months after completion string was installed (IT, written communication, 1999).

construction, inspection, and geologic support were provided by BN. The roles and responsibilities of these and other contractors involved in the project are described in Contract Number DE-RP08-95NV11808, and in BN Drilling Work Plan Number D-005-001.99 (BN, 1999a). The UGTA Technical Working Group (TWG), a committee of scientists and engineers comprising NNSA/NSO, Lawrence Livermore National Laboratory, Los Alamos National Laboratory (LANL), and contractor personnel, provided additional technical advice during the design, drilling, and construction of the well. See *Western Pahute Mesa-Oasis Valley Hydrogeologic Investigation Wells Drilling and Completion Criteria* (IT, 1998) for descriptions of the general plan and goals of the WPM -OV project, as well as specific goals for each planned 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) (DOE, 1996a), an attachment to the UGTA Waste Management Plan (DOE, 1996b). Estimates of fluid and cuttings production for the WPM-OV holes are given in Appendix N of the drilling and completion criteria document for the WPM-OV project (IT, 1998), along with sampling

requirements and contingency plans for management of any hazardous waste produced. All activities were conducted in accordance with the Nevada Environmental Restoration Project Health and Safety Plan (DOE, 1998), and the BN Site-Specific Health and Safety Plan for WPM-OV Investigation Wells (BN, 1999b).

This report presents construction data and summarizes scientific data gathered during drilling and installation of the completion string. Some of the information in this report is preliminary and unprocessed, but is being released with the drilling and completion data for convenient reference. A well data report prepared by IT (1999) contains additional information on fluid management, waste management, and environmental compliance. Information on well development, aquifer testing, and groundwater analytical sampling will be disseminated after any such work is performed.

1.2 Objectives

The primary purpose of Well ER-18-2 was to provide groundwater information in an area that is potentially down-gradient from Pahute Mesa. Individual objectives, as discussed in Appendix M of the drilling criteria document (IT, 1998), include the following:

- Obtain water level data to better define the potentiometric surface south of Pahute Mesa.
- Evaluate the potential for a southward groundwater flow path from Pahute Mesa along the east side of Timber Mountain.
- Define the hydraulic properties of rocks within the Timber Mountain caldera moat.

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

1.3 Project Summary

This paragraph summarizes Well ER-18-2 construction operations; the details can be found in sections 2 through 7. Hole construction began January 14, 1999, when a BN crew used a Mobile Drill to auger a 21.6-centimeter (cm) (8.5-in.) hole to a depth of 4.6 m (15.0 ft). At that point the rock became too hard for this equipment and the Mobile Drill was moved off location. On April 12, 1999, the BN Auger 2 rig was brought in, and the hole was reamed with a 91.4-cm (36-in.) auger bit to a depth of 4.0 m (13 ft). A section of 36-in. casing was set, without cementing, at 3.7 m (12 ft) on the same day. A 76.2-cm (30-in.) hole was drilled using a BN

"CP" rig and a hammer bit to a depth of 12.2 m (40 ft) on April 19 to 22, 1999, and a string of 20-in. conductor casing was set at 10.7 m (35 ft) on April 26, 1999. The annulus outside the conductor casing was cemented to the surface. Drilling of the main hole with 17½-in. rotary and hammer bits, using air-foam/polymer in conventional circulation, began on May 3, 1999. A suitable depth to set surface casing was reached at 411.8 m (1,351 ft) on May 9, 1999. The 13⅜-in. surface casing was landed at 408.1 m (1,339 ft) below the surface, approximately 38.4 m (126 ft) below the static water level. Drilling continued with a 12¼-in. bit to a total depth (TD) of 762.0 m (2,500 ft), reached on May 14, 1999. Material sloughed from the borehole wall fills the lower 3.7 m (12 ft) of the hole.

Water production was first noted at the depth of approximately 367.3 m (1,205 ft), and reached an estimated maximum of about 151 liters per minute (lpm) (40 gallons per minute [gpm]) near the bottom of the hole. Fluid levels measured after drilling was completed slowly rose over the 36 hours of geophysical logging conducted before installation of the completion string, from depths of about 427.9 m to 395.9 m (1,404 to 1,299 ft). Two months later, the fluid level was tagged by IT at the depth of 369.7 m (1,212.9 ft) (IT, 1999). No radionuclides above background levels were encountered during drilling of Well ER-18-2.

Composite drill cuttings were collected every 3.0 m (10 ft) from 12.2 m (40.0 ft) to TD, with one interval missed due to poor returns. Fifteen rotary sidewall core samples were recovered from various depths below 420.3 m (1,379 ft). Open-hole geophysical logging of the well was conducted to help verify the geology and characterize the hydrology of the rocks; some logs also aided in the construction of the well by indicating borehole volume and condition, and cement location. The well penetrated Tertiary-age basalt, tuffaceous sediments, and tuff of the Thirsty Canyon and Timber Mountain Groups. The bottom 376 m (1,234 ft) of the hole was drilled in welded Ammonia Tanks ash-flow tuff.

A single completion string was installed in Well ER-18-2 on May 17, 1999. Stainless-steel, 5½-in. production casing was landed at 653.2 m (2,143.0 ft), and comprises alternating slotted and blank joints through the interval 588.4 to 640.3 m (1,930.4 to 2,100.8 ft). Fiberglass 5⅝-in. casing extends, via a crossover sub, from the top of the stainless-steel casing at 576.0 m to 450.2 m (1,889.9 to 1,476.9 ft). Internally epoxy-coated, 7⅝-in. carbon-steel casing extends via crossover subs from the top of the fiberglass casing to the ground surface.

The attempt to emplace a gravel pack in the well was aborted after approximately 6.1 cubic meters (m^3) (217 cubic feet [ft^3]) of gravel had been pumped down the hole. Water introduced

during the stemming process was displaced up the borehole by the gravel to within about 19.5 m (64 ft) of the ground surface before stemming was halted. Apparently the water could not infiltrate the low transmissivity rocks quickly enough and the resulting high hydrostatic pressure in the borehole prevented emplacement of additional gravel without long delays. The fluid level dropped slowly after stemming was halted. The top of the gravel is estimated to be at 684.3 m (2,245 ft), approximately 31.1 m (102 ft) below the bottom of the completion string. The string remains in the open hole, and no pump had been installed at the time of this writing.

1.4 Project Manager

Inquiries concerning Well ER-18-2 should be directed to the UGTA Project Manager at:

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

2.0 Drilling Summary

This section contains detailed descriptions of the drilling process and fluid management issues.

2.1 Introduction

The general drilling requirements for all WPM-OV wells were provided in *Western Pahute Mesa-Oasis Valley Hydrogeologic Investigation Wells Drilling and Completion Criteria* (IT, 1998), which also includes criteria for Well ER-18-2 in Appendix M. Specific requirements for Well ER-18-2 are outlined in the Drilling Work Plan number D-005-001.99 (BN, 1999a). The drilling history (Section 2.2) was compiled primarily from the BN daily drilling reports. Figure 2-1 shows the layout of the drill site. Figure 2-2 is a chart of the drilling and completion history for Well ER-18-2. A summary of drilling statistics for Well ER-18-2 is given in Table 2-1. Fluid management information (Section 2.4) was obtained primarily from IT's preliminary well data report (IT, 1999).

2.2 Drilling History

On January 14, 1999, BN construction crews moved a Mobile Drill B-59 auger rig onto the Well ER-18-2 drill pad. Drilling of a 21.6-cm (8.5-in.) hole with the hollow-stem auger commenced on the same day, but drilling through the near-surface rocks proved too difficult for this type of rig, so drilling operations ceased after reaching 4.6 m (15 ft). On April 12, 1999, the BN Auger 2 rig was brought on site, and the hole was reamed to 91.4 cm (36 in.) by dry augering to a depth of 4.0 m (13 ft). On the same day, a section of 36-in. casing was set at 3.7 m (12 ft) and the annulus was back-filled to ground level with native fines. Between April 19 and April 22, 1999, a BN "CP" rig with a 76.2-cm (30-in.) hammer bit was used to drill to 12.2 m (40 ft) using compressed air in direct circulation. Progress was slowed as a result of four separate incidents of failure of hydraulic hoses. During augering and hammering operations, a small amount of water was introduced into the hole as spray for dust control. The 20-in. conductor casing was set at 10.7 m (35 ft) and cemented on April 26, 1999. The casing annulus was cemented to the surface; the top of cement inside the casing was tagged at the depth of 9.8 m (32 ft) when drilling resumed.

Preparations for the drilling of the main hole, including delivering and setting up equipment on site, began April 27, 1999. The UDI Wilson Mogul 42B drilling rig arrived at the Well ER-18-2 site on May 2, 1999. Crews began working three shifts a day on May 3, 1999, when drilling

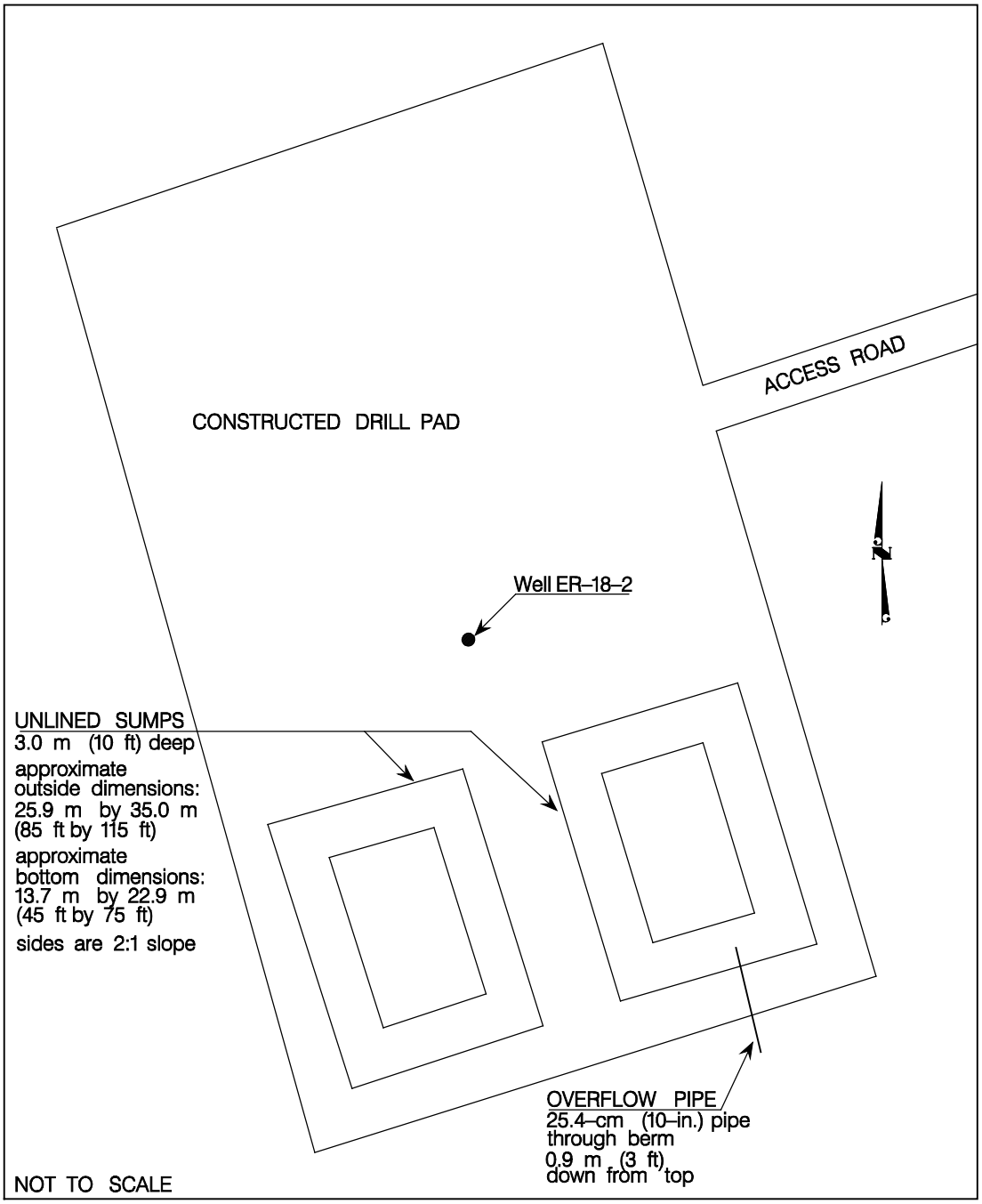

Figure 2-1
Drill Site Configuration for Well ER-18-2

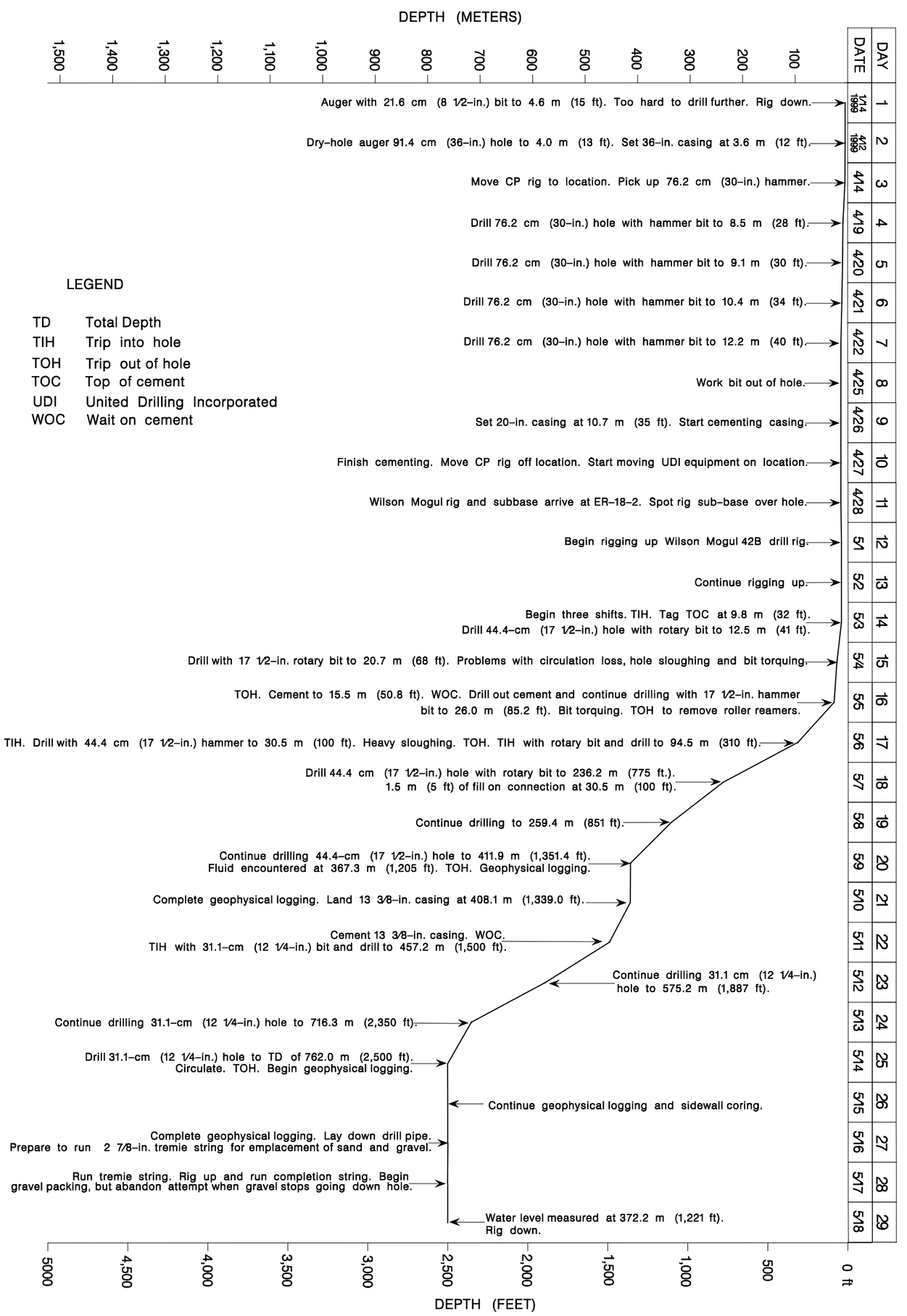

FIGURE 2–2
WELL ER–18–2
DRILLING AND COMPLETION HISTORY

WELL ER–18–2 SUMMARY

Activity	Date
Begin drilling conductor hole:	1/14/1999
Conductor hole completed and cased to 10.7 m (35 ft)	4/26/1999
Begin drilling 17 1/2–in. surface hole:	5/3/1999
Surface casing set at 408.1 m (1,339.0 ft)	5/10/1999
Begin drilling 12 1/4–in. hole:	5/11/1999
Reach total drilled depth of 762.0 m (2,500 ft):	5/14/1999
Completion string landed:	5/17/1999
Rig released:	5/18/1999

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Table 2-1
Abridged Drill Hole Statistics for Well ER-18-2

LOCATION DATA:	
Coordinates:	Central Nevada State Planar: NAD 83: N 6,261,201.2 E 526,033.9 m NAD 27: N 856,955.5 E 585,673.0 ft Universal Transverse Mercator: NAD 83: N 4,106,585.8 E 555,644.6 m
Surface Elevation [a]:	1,657.2 m (5,437.1 ft)
DRILLING DATA:	
Spud Date:	5/03/1999 (main hole drilling)
Total Depth (TD):	762.0 m (2,500 ft)
Date TD Reached:	5/14/1999
Date Completed:	Completion string landed 5/17/1999
Hole Diameter:	91.4 cm (36 in.) from surface to 4.0 m (13.0 ft); 76.2 cm (30 in) from 4.0 to 12.2 m (14 to 40 ft.); 44.5 cm (17.5 in.) from 12.2 to 411.9 m (40 to 1,351.4 ft); 31.1 cm (12.25 in.) from 411.9 m (1,351.4 ft) to TD of 762.0 m (2,500 ft).
Drilling Techniques:	Dry-hole auger from surface to 4.0 m (13.0 ft). Drill with 76.2-cm (30-in.) hammer to 12.2 m (40 ft). Rotary drill 44.5-cm (17½-in.) hole from top of cement in conductor casing at 9.8 m (32 ft) to 25.9 m (85 ft) with air-foam/polymer in direct circulation. Drill with 17½-in. hammer to 30.5 m (100 ft). Drill with 17½-in. rotary bit from 30.5 m to 411.8 m (100 to 1,351 ft). Drill with 12¼-in. rotary bit from float collar in surface casing at 393.8 m (1,292 ft) to TD.
CASING DATA:	20-in. conductor casing from surface to 10.7 m (35.0 ft). 13⅜-in. surface casing from surface to 408.1 m (1,339.0 ft).
WELL COMPLETION DATA:	The completion string consists of 7⅝-in. carbon-steel casing with an internal epoxy coating, connected to 5⅝-in. fiberglass casing via two crossover subs. The carbon-steel casing extends through the unsaturated zone, approximately 79.6 m (261 ft) into the top of the saturated zone; the fiberglass casing extends to a point approximately 206 m (676 ft) below the water table, and is connected via crossover subs to 5½-in. stainless steel casing. The 5½-in. stainless steel casing extends from the depth of 576.0 m (1,889.9 ft) to the bull-nose at 653.2 m (2,143.0 ft). The 14.0-cm (5½-in.) outside-diameter casing has a 12.83-cm (5.05-in.) inside diameter, and has three slotted joints, as listed below. Detailed data for the completion intervals are provided in Section 7 of this report.
Total Depth:	653.2 m (2,143.0 ft)
Depth of Slotted Sections:	588.4 to 597.3 m (1,930.4 to 1959.7 ft); 609.7 to 618.9 m (2,000.2 to 2,030.4 ft); 631.2 to 640.3 m (2,070.9 to 2,100.8 ft)
Depth of Gravel Pack:	Approximately 684.3 to 758.3 m (2,245.0 to 2,488.0 ft) (not completed)
Depth of Pump:	None installed at time of completion.
Fluid Depth [b]:	369.7 m (1,212.9 ft)
DRILLING CONTRACTOR:	United Drilling, Inc.
GEOPHYSICAL LOGS BY:	Barbour Well Surveying, Schlumberger Logging Services, Colog, Desert Research Institute, Gyrodata, Inc.
SURVEYING CONTRACTOR:	Bechtel Nevada

a Elevation of ground level at wellhead. 1929 National Geodetic Vertical Datum.
b Measured by IT on July 17, 1999, approximately 2 months after completion string was installed (IT, 1999).

commenced with a 17½-in. rotary bit. Drilling proceeded through the cement in the conductor casing to 10.7 m (35 ft), and then into hard basalt formation to 14.9 m (49 ft). At that point a new bottom-hole assembly (BHA) with a 17½-in. rotary bit and 10-in. drill collar was made up in an attempt to increase the weight of the drill string, and drilling continued with conventional circulation using air-foam and polymer. Circulation was lost at 19.2 m (63 ft) and drilling continued with no returns to 20.7 m (68 ft). The drill string was then tripped out and the bottom of the hole was cemented on May 5, 1999, with 13.3 m^3 (470 ft^3) of Type II cement and 45 bags of cedar fiber to plug the lost-circulation zone. The loss of fluids in this zone is believed to be due to the presence of open fractures in the basalt formation. A BHA with a 17½-in. downhole hammer bit and a near-bit roller reamer was made up, the top of cement was tagged at 15.5 m (51 ft), and drilling continued through the cement to 20.7 m (68 ft) and into the formation to a depth of 25.9 m (85 ft). At that depth a loose rock in the hole caused the bit to torque up, but the BHA was successfully removed from the hole, and a new BHA was made up with a 17½-in. downhole hammer, but no roller reamers. Drilling continued to 30.5 m (100 ft) with heavy sloughing. The drill string was again tripped out of the hole, and the 17½-in, hammer bit was replaced with a 17½-in. tri-cone rotary bit. The hole was reamed with this new BHA from 25.9 m (85 ft) to 30.5 m (100 ft), and drilling continued without problems until the bottom of the surface hole was reached at 411.8 m (1,351 ft) on May 9, 1999.

Water production was first noted at a depth of approximately 367.3 m (1,205 ft), based on visual examination of the fluid discharge and dilution of the lithium bromide (LiBr) tracer. As a precaution against sloughing of the unsaturated volcanic rocks, surface casing was installed when a competent formation for supporting the casing was reached, at 411.8 m (1,351 ft), in Ammonia Tanks welded ash-flow tuff. When drilling was halted, the hole was estimated to be producing water at a rate of about 23 to 38 lpm (6 to 10 gpm).

Drilling was suspended for two days during geophysical logging prior to installation of the surface casing. Then a casing subcontractor landed 13⅜-in. carbon-steel casing with four centralizers and two cement baskets, at 408.1 m (1,339.0 ft); a float guide shoe and a stab-in float collar were located at the lower end of the casing string. Drill pipe with a stab-in sub was lowered in the hole and seated in the stab-in shoe; the seal was checked by pumping air down the drill pipe; and pre-flush clear water was pumped down the casing prior to cementing. The bottom of the casing was then cemented with 11.3 m^3 (400 ft^3) Type II Portland cement, which was pumped down the drill pipe into the casing, followed by water to displace the cement. The top of cement in the casing annulus was estimated to be at the depth of 289.6 m (950 ft). After the drill pipe was tripped out of the hole, the annulus above the cement baskets (located at

18.3 m [60 ft]) was cemented to ground level with 2.8 m^3 (100 ft^3) of Type II cement with 25 percent sand.

When drilling resumed with a 12¼-in. bit, the top of cement inside the casing was tagged at 393.8 m (1,292 ft). Drilling of the 31.1-cm (12.25-in.) hole continued through cement to the depth of 411.8 m (1,351 ft), and then into the formation, continuing with no problems to the TD of 762.0 m (2,500 ft).

Immediately after reaching TD, the drillers circulated fluid to condition the hole and then the second suite of geophysical logs was run. The bottom of the hole was found be filled to the depth of 758.3 m (2,488 ft) with material sloughed from the borehole wall, as determined during geophysical logging on May 16, 1999. The completion string was installed and gravel-packing began on May 17, 1999. Gravel-packing was not completed (see Section 7.3), and the drill rig was released on May 18, 1999.

The directional survey run in Well ER-18-2 on October 11, 1999 indicates that at the lowest surveyed depth of 653.2 m (2,143 ft), the hole had drifted 3.4 m (11.2 ft) to the southeast of the collar location, and that the hole is relatively straight (no severe "dog legs") .

A graphical depiction of drilling parameters, including penetration rate, revolutions per minute, pump pressure, and weight on the bit, is presented in Appendix A-1. See Appendix A-2 for a list of casing materials. Drilling fluids and cements used in Well ER-18-2 are listed in Appendix A-3.

2.3 Drilling Problems

No significant problems were encountered during the drilling of Well ER-18-2. However, it was necessary to cement a lost-circulation zone between 16.5 and 25.9 m (54 to 85 ft). Also, intermittent fill of generally less than 3.0 m (10 ft) was encountered periodically throughout the drilling of Well ER-18-2. This sloughing did not result in significant drilling delays, though approximately 3.7 m (12 ft) of fill remained in the bottom of the hole prior to installation of the completion string. The drilling work plan (BN, 1999a) contained provisions for setting intermediate casing in the event that sloughing hole conditions or high water production caused drilling difficulties; however, cementing the upper part of the hole and redrilling solved the hole stability problems, and no intermediate casing was required.

2.4 Fluid Management

Drilling effluent was monitored in accordance with the methods prescribed in the UGTA FMP (DOE, 1996a). The air-foam/polymer drill fluid was circulated down inside the drill string and back up the hole through the annulus ("conventional" or direct circulation) and then discharged into a sump. Water used to prepare drilling fluids came from Water Well 20 located on Pahute Mesa at the NTS, and a LiBr tracer was added as a means of estimating groundwater production.

To manage water production, two unlined sumps were constructed prior to drilling (Figure 2-1). Sump # 1 has an overflow pipe; sump #2 has no overflow pipe and was to be lined and used (if necessary) if concentrations of radionuclides or other contaminants in the fluid exceeded specified fluid-quality objectives. All fluids were discharged into sump #1, and the fluid never rose to the level of the overflow pipe. Sump #2 remained inactive during drilling operations. Samples of drilling effluent were tested hourly for the presence of tritium, and every eight hours for lead. Fluid-management samples were taken from sump #1 during drilling and after drilling was completed to demonstrate compliance with the FMP (IT, 1999). Water-quality data from these two samples are given in Appendix B.

The results of analyses on samples of drilling fluid collected at Well ER-18-2 during drilling operations indicate that all fluid quality objectives were met, as shown on the fluid management reporting form dated August 6, 1999 (Appendix B). The form lists volumes of solids (drill cuttings) and fluids produced during well-construction operations, Stages I and II (vadose- and saturated-zone drilling; well-development and aquifer-testing will be conducted at a later date). 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 volume of fluids listed in the report is an estimate of total fluid production, and does not account for any infiltration or evaporation of fluids from the sump.

3.0 Geologic Data Collection

3.1 Introduction

This section describes the types of geologic data obtained from Well ER-18-2 and the methods of data collection. Improving the understanding of local groundwater flow regime for this area south of Pahute Mesa, one of the primary objectives of this drilling project, requires knowledge of the structure, stratigraphy, and hydrogeology of this area. Thus the proper collection of geologic and hydrogeologic data from Well ER-18-2 was considered fundamental to successful completion of the project.

Geologic data collected at Well ER-18-2 consisted of drill cuttings, sidewall core samples, and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed in accordance with applicable contractor procedures.

3.2 Collection of Drill Cuttings

Composite drill cuttings were collected continuously from Well ER-18-2 at 3.05-m (10-ft) intervals as drilling progressed from the depth of 10.7 m (35 ft) to the TD of the well at 762.0 m (2,500 ft). No samples were collected from depths 18.3 to 21.3 m (60 to 70 ft), due to loss of circulation. Triplicate samples were collected from 236 intervals, and in addition, the IT field representative collected two sets of reference samples from each of the cuttings intervals. One set was examined at the drill site for use in preparing the field lithologic descriptions, and remains in the custody of IT. The other set was sent to R. G. Warren (LANL), where it remains. All other samples (i.e., three sets of 236 samples) are stored under controlled conditions at the U.S. Geological Survey (USGS) Core Library. One set of samples 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 in accordance with standard USGS Core Library procedures.

3.3 Sidewall Core Samples

Sidewall core samples were collected from Well ER-18-2 immediately prior to installation of the completion string to verify the stratigraphy and lithology penetrated below 420.3 m (1,379 ft). Sample locations were selected by the IT field representative on the basis of field lithologic logs (with consideration of borehole conditions determined from caliper logs) to obtain adequate representation of the rocks encountered in the well. An attempt to collect percussion gun sidewall samples from the upper 411.8 m (1,351 ft) of the hole on May 10, 1999, failed due to malfunction of the tool. Schlumberger recovered 15 out of 21 attempted core samples with the

mechanical (rotary) sidewall coring tool on May 15, 1999. Table 3-1 lists the recovery and stratigraphic assignment for each of the 15 samples recovered. All samples are stored at the USGS Core Library in Mercury, Nevada.

3.4 Sample Analysis

Twenty-one samples of drill cuttings from various depths in Well ER-18-2 were submitted to the Earth and Environmental Sciences Division Geology and Geochemistry laboratories at LANL for petrographic, mineralogic, and chemical analyses to aid in stratigraphic identification and for characterization of mineral alteration. All planned sample analyses have been completed, as shown on Table 3-2.

3.5 Geophysical Data

Geophysical logs were run to further characterize the lithology, structure, and water content of the rocks encountered in Well ER-18-2. In addition, logs were run to evaluate borehole conditions, to determine fluid levels during the course of drilling, and to monitor completion progress. Geophysical logging was conducted during three stages of drilling and completion: prior to setting surface casing; prior to installing the completion well casing; and during well installation (annulus investigation log). Some logs were run in both the saturated and unsaturated zones of the borehole, while some (e.g., oriented color video) were run only above the fluid level, and others (e.g., thermal flow log, chemistry log, acoustic borehole televiewer log, etc.) were run only in the saturated interval. A complete listing of the logs, dates run, depths, and service company is provided in Table 3-3. Preliminary geophysical data from the logs are reproduced in Appendix D.

Overall, the quality of the geophysical data collected was acceptable. Oscillation that degraded some of the logs in wells ER-EC-6 and ER-EC-1 (DOE, 2000a; 2000b) did not appear on the logs from Well ER-18-2.

Table 3-1
Sidewall Core Samples from Well ER-18-2

Core Depth [a] meters (feet)	**Length Recovered** centimeters (inches)	**Stratigraphic Unit**
420.4 (1,379.3)	2.9 (1.15)	mafic-rich Ammonia Tanks Tuff
421.8 (1,384.0)	4.4 (1.75)	
431.0 (1,414.0)	3.3 (1.30)	
449.0 (1,473.0)	3.8 (1.50)	
475.8 (1,561.0)	4.4 (1.75)	
542.2 (1,779.0)	3.2 (1.25)	
577.3 (1,894.0)	3.0 (1.20)	
622.3 (2,041.8)	4.1 (1.60)	
630.3 (2,067.9)	4.2 (1.65)	
654.7 (2,148.0)	3.2 (1.25)	
709.6 (2,328.0)	4.6 (1.80)	
725.6 (2,380.5)	3.2 (1.25)	
748.1 (2,454.5)	4.1 (1.60)	
753.5 (2,472.0)	4.1 (1.60)	
755.0 (2,477.0)	3.8 (1.50)	

a All samples obtained by Schlumberger using a rotary mechanical sidewall coring tool.

Table 3-2
Status of Rock Sample Analyses for Well ER-18-2

Depth [a] meters (feet)	Sample Type [b]	Analyses Performed [c]				
		Petrographic	Mineralogic		Chemical	
		PTS	MP	XRD	XRF	Fe^{2+}/Fe^{3+}
88.4 (290)	DA	C	NP	C	C	C
109.7 (360)	DA	C	NP	C	C	C
149.4 (490)	DA	C	NP	C	C	C
198.1 (650)	DA	C	NP	C	C	C
213.4 (700)	DA	C	NP	C	C	C
222.5 (730)	DA	C	NP	C	C	C
237.7 (780)	DA	C	NP	C	C	C
262.1 (860)	DA	C	NP	C	C	C
286.5 (940)	DA	C	NP	C	C	C
350.5 (1,150)	DA	C	NP	C	C	C
365.8 (1,200)	DL	C	NP	C	C	C
378.0 (1,240)	DA	C	NP	C	C	C
405.4 (1,320)	DA	C	NP	C	C	C
457.2 (1,500)	DA	C	NP	C	C	C
502.9 (1,650)	DA	C	NP	C	C	C
554.7 (1,820)	DA	C	NP	C	C	C
600.5 (1,970)	DA	C	NP	C	C	C
646.2 (2,120)	DA	C	NP	C	C	C
691.9 (2,270)	DA	C	NP	C	C	C
734.6 (2,410)	DA	C	NP	C	C	C
762.0 (2,500)	DA	C	NP	C	C	C

a Depth represents base of 3.0-m (10-ft) sample interval.

b **DA** = drill cuttings that represent lithologic character of interval; **DL** = lithic fragments separated from cuttings.

c **PTS** = polished thin section; **MP** = electron microprobe; **XRD** = x-ray diffraction; **XRF** = x-ray fluorescence; **Fe^{2+}/Fe^{3+}** = wet chemical analysis for iron; **C** = analysis complete; **NP** = analysis not planned.

Table 3-3
Well ER-18-2 Geophysical Log Summary
Page 1 of 2

Geophysical Log Type [a]	Log Purpose	Logging Service	Date Logged	Run Number	Bottom of Logged Interval [b] meters (feet)	Top of Logged Interval [b] meters (feet)
Gamma Ray/Four Arm Caliper	Stratigraphic correlation/borehole conditions, cement volume calculation	Schlumberger	5/9/1999	GR-1/CA4-1	411.8 (1,351)	10.7 (35)
*Array Induction/Spontaneous Potential/ Gamma Ray/ *Natural Gamma Ray Spectroscopy	Rock porosity, lithologic determinations/stratigraphic correlation, mineralogy, natural and man-made radiation	Schlumberger	5/9/1999	IND-1/SP-1 GR-2/SGR-1	411.8 (1,351)	10.7 (35)
Oriented Color Video	Lithologic characterization, fracture and void analysis, stratigraphic correlation, hole conditions	Barbour Well Survey	5/10/1999	TV-1	381.3 (1,251)	0
*Compensated Density/ *Epithermal Neutron/Gamma Ray/Caliper	Lithologic determination, porosity, total water content, borehole conditions	Schlumberger	5/10/1999 5/15/1999	CDL-1/ENP-1 GR-3/CAL-1 CDL-2/ENP-2 GR-6/CAL-2	410.9 (1,348) 755.6 (2,479)	10.7 (35) 408.4 (1,340)
Temperature Log/Four Arm Caliper/ *Gamma Ray	Saturated zone: Groundwater temperature/ borehole conditions/ stratigraphic correlation	Schlumberger	5/14/1999	TL-1 CA4-2/GR-4	748.0 (2,454)	204.2 (670)
*Dual Laterolog/*Gamma Ray/ *Spontaneous Potential	Saturated zone: water saturation, stratigraphic correlation	Schlumberger	5/14/1999	DLL-1/GR-5 SP-2	754.1 (2,474)	418.8 (1,374)
Ultrasonic Borehole Imager/ *Natural Gamma Ray Spectroscopy	Saturated zone: lithologic characterization/fracture and void analysis/ stratigraphic correlation	Schlumberger	5/15/1999	BHTV-1 SGR-2	755.0 (2,477)	406.6 (1,334)
Mechanical Sidewall Coring Tool	Geologic samples	Schlumberger	5/15/1999	MSCT-1	755.0 (2,477)	420.4 (1,379.3)

Table 3-3
Well ER-18-2 Geophysical Log Summary
Page 2 of 2

Geophysical Log Type [a]	Log Purpose	Logging Service	Date Logged	Run Number	Bottom of Logged Interval [b] meters (feet)	Top of Logged Interval [b] meters (feet)
Digital Array Sonic A. Wave-form and variable density presentations B. Sonic porosity and travel time (STC) computations	Saturated zone: A. Porosity, lithologic determination B. Fracture identification	Schlumberger	5/16/1999	AC-1	752.8 (2,470)	408.4 (1,340)
*Thermal Flow Log	Rate and direction of groundwater flow in borehole	Desert Research Institute	5/16/1999	1	746.8 (2,450)	458.7 (1,505)
*Chemistry Log (temperature, pH, electrical conductivity)	Groundwater chemistry, formation transmissivity	Desert Research Institute	5/16/1999	1	755.6 (2,479)	396.2 (1,300)
Nuclear Annulus Investigation Log	Well construction monitoring	Colog	5/17/1999	1	652.6 (2,141)	182.9 (600)
Directional Survey	Borehole deviation	Gyrodata Incorporated	10/11/1999	1	653.2 (2,143)	7.6 (25)

a Logs presented in geophysical log summary, Appendix D, are indicated by *.
b Depth below ground surface. Depths given for log combinations are those reported by the respective logging companies in the log heading data and may not be applicable to each logging tool individually.

4.0 Geology and Hydrogeology

This section summarizes the geology and hydrogeology of Well ER-18-2. Bechtel Nevada geologists prepared the detailed lithologic log presented in Appendix C, incorporating information from field lithologic descriptions by IT well-site geologists (IT, 1999) and geophysical logs (Appendix D). Stratigraphic assignments and identification of alteration mineralogy presented here are based primarily on data and interpretations provided by R. G. Warren (LANL) (Warren, 1999) on the basis of analyses listed in Table 3-2.

Interpretations of data from this well have been incorporated into the hydrostratigraphic model for the Pahute Mesa - Oasis Valley area (BN, 2002).

4.1 Geology

Well ER-18-2 is located on Buckboard Mesa, between Timber Mountain and Pahute Mesa, in Area 18 of the NTS (Figure 1-1). The well lies within the Timber Mountain moat, a topographic feature resulting from the collapse of the Timber Mountain caldera complex (TMCC) followed by resurgence of a central dome (Timber Mountain). Figure 4-1 shows the surface geology in the vicinity of Well ER-18-2. The well was collared in the Pliocene basalt that caps Buckboard Mesa, and reached TD in welded ash-flow tuff of the mafic-rich Ammonia Tanks Tuff.

Based on the volcano-tectonic setting and depositional history of this area, the geologic units penetrated by Well ER-18-2 can be grouped into three general stratigraphic assemblages related mainly to the development of the Ammonia Tanks caldera, the youngest caldera of the TMCC. These assemblages are (from oldest to youngest): Ammonia Tanks caldera-forming deposits; caldera-filling deposits erupted immediately after the collapse of the Ammonia Tanks caldera; and moat-filling units deposited within the topographic depression (moat) during and after resurgent doming (Figure 4-2).

Moat-filling units were penetrated from the ground surface to 230.1 m (755 ft). The uppermost moat-filling unit is Pliocene basalt penetrated to 36.0 m (118 ft), which though occupying the moat, is not directly related to caldera formation. The basalt is underlain by the upper of two intervals of Tertiary caldera moat-filling sediments to 81.7 m (268 ft). These sediments are very tuffaceous and generally made up of clay and fine- to medium-grained sand consisting of quartz and feldspar crystals, biotite, fragments of devitrified welded tuff and rhyolitic lava, glass shards, and fine vitric ash. Coarser sand- and gravel-size fragments present in lesser abundance consist

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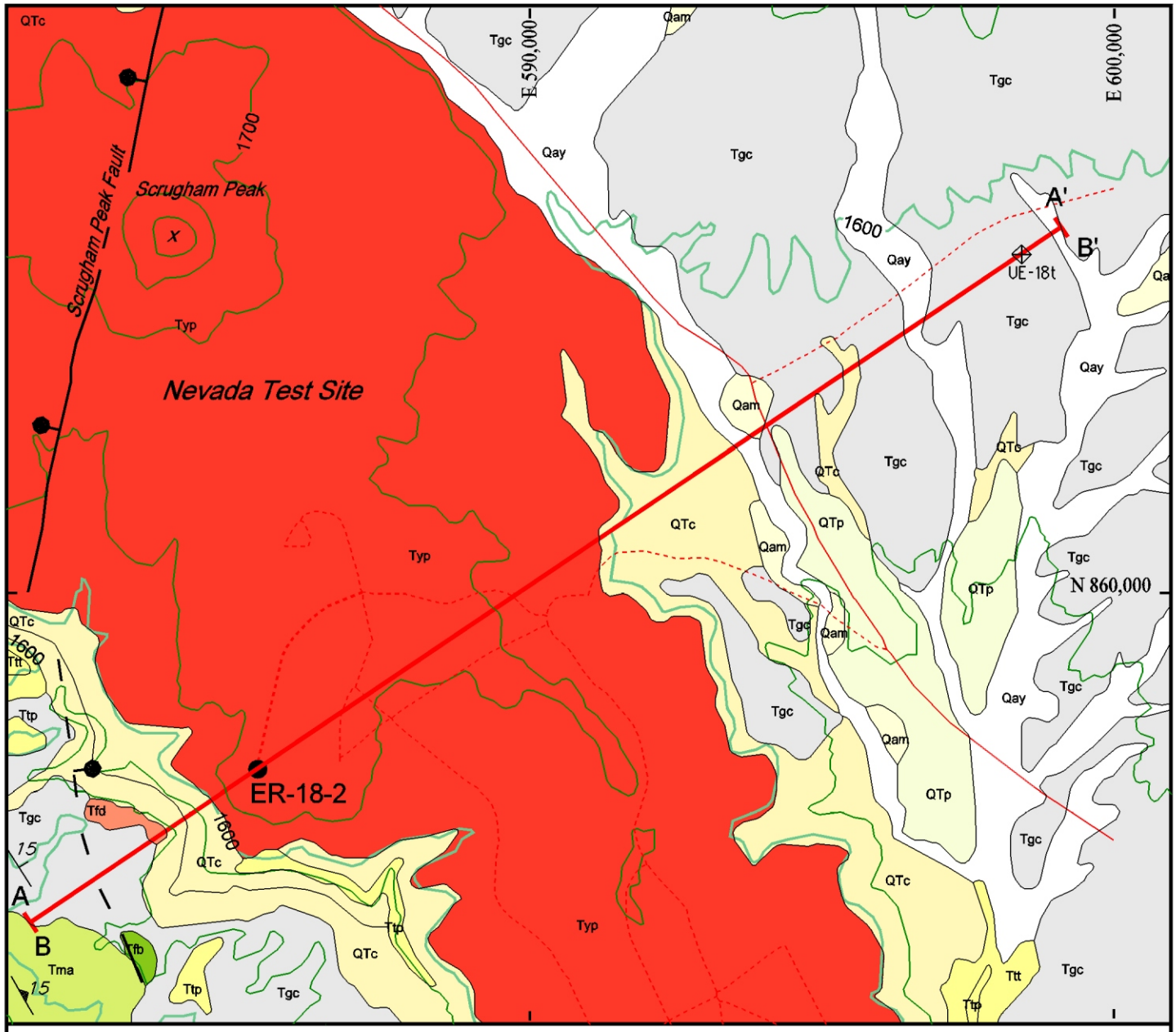

Source: Wahl et al., 1997

Figure 4-1
Geologic Map of the Well ER-18-2 Site

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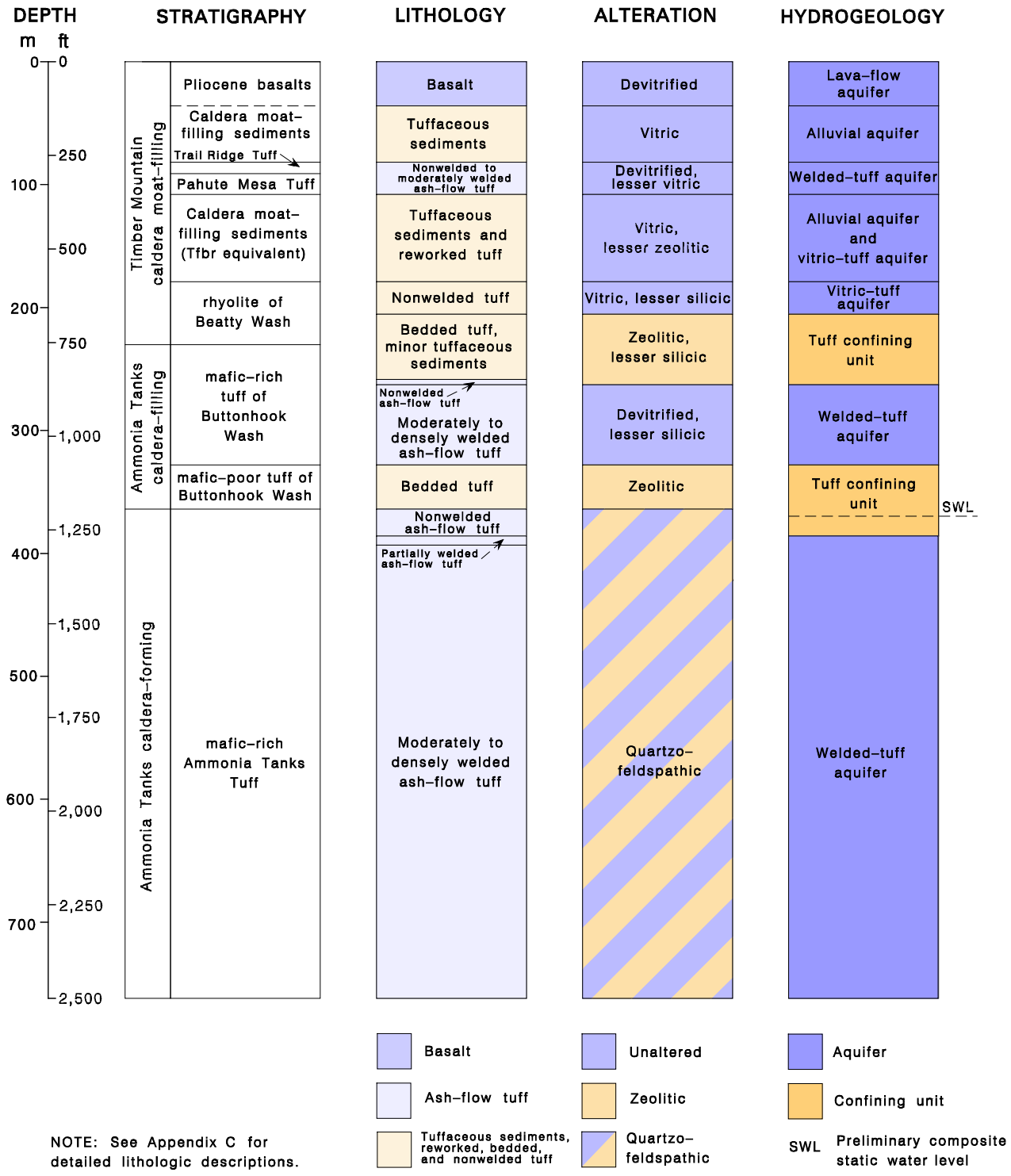

Figure 4-2
Geology and Hydrogeology of Well ER-18-2

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of various volcanic lithologies including devitrified, vitric, and zeolitized welded tuff and lava, and vitric and zeolitic pumice clasts. Between the two units of moat-filling sediments, are nonwelded to moderately welded ash-flow tuffs assigned to two formations of the Thirsty Canyon Group: Trail Ridge Tuff to 91.1 m (299 ft), and Pahute Mesa Tuff to 107.9 m (354 ft). The lower interval of Tertiary caldera moat-filling sediments was penetrated from 107.9 to 178.9 m (354 to 587 ft), and is probably the time-equivalent of the rhyolite of Chukar Canyon of the Beatty Wash Formation. Data from geophysical logs and petrographic analyses indicate that this interval of tuffaceous sediments may also contain beds of reworked tuff. The lowermost moat-filling unit, penetrated from 178.9 to 230.1 m (587 to 755 ft), consists of vitric nonwelded and zeolitic bedded tuff assigned to the rhyolite of Beatty Wash.

The only caldera-filling unit encountered in Well ER-18-2 is the tuff of Buttonhook Wash. In Well ER-18-2, this unit is 133.8 m (439 ft) thick; it consists of bedded tuff and minor tuffaceous sediments from 230.1 m to 258.5 m (755 to 848 ft), nonwelded to densely welded ash-flow tuff to 328.0 m (1,076 ft), and bedded tuff to 363.9 m (1,194 ft). The lower-density bedded and nonwelded tuffs and tuffaceous sediments are zeolitic, while the interval of higher-density, welded ash-flow tuff is mostly devitrified, and weakly vitrophyric in the upper portion. Conspicuous flow-banded textures observed in some intervals of the welded ash-flow tuff suggest that rheomorphism may have caused the rocks to flow after initial deposition.

Ammonia Tanks caldera-forming deposits were encountered directly beneath the tuff of Buttonhook Wash. Well ER-18-2 penetrated 398.1 m (1,306 ft) of ash-flow tuff assigned to the mafic-rich Ammonia Tanks Tuff. The lower 376.1 m (1,234 ft) of the unit is moderately to densely welded, but a thin (21.9 m [72 ft]) interval of nonwelded and partially welded tuff is present at the top. The Ammonia Tanks Tuff at Well ER-18-2 has been mildly altered by hydrothermal processes, resulting in a quartzo-feldspathic mineral assemblage consisting of secondary microcrystalline quartz, feldspar, and calcite. The moderately and densely welded tuffs contain numerous fractures filled with silica, as indicated by the presence of single hairline fractures in cuttings samples. Some fractures were observed up to 7 millimeters wide, with fillings of a fine-grained silica matrix containing clasts of moderately welded ash-flow tuff, giving the rock a brecciated appearance. Other textures observed include flow banding (indicating possible rheomorphism) and weakly developed spherulites.

Well ER-18-2 penetrated three major alteration zones (Figure 4-2). Above 205.4 m (674 ft), the rocks are mainly vitric or devitrified; from 205.4 to 363.9 m (674 to 1,194ft), alteration is mostly zeolitic or devitrified; and below 363.9 m (1,194 ft), rocks are quartzo-feldspathic, due to mild

hydrothermal alteration. Although evidence of higher temperature alteration is present in Well ER-18-2, the alteration is considerably less intense than that observed approximately 16.1 km (10 mi) to the northwest in wells ER-EC-1 and ER-EC-6 (DOE, 2000a, b).

4.2 Predicted Versus Actual Geology

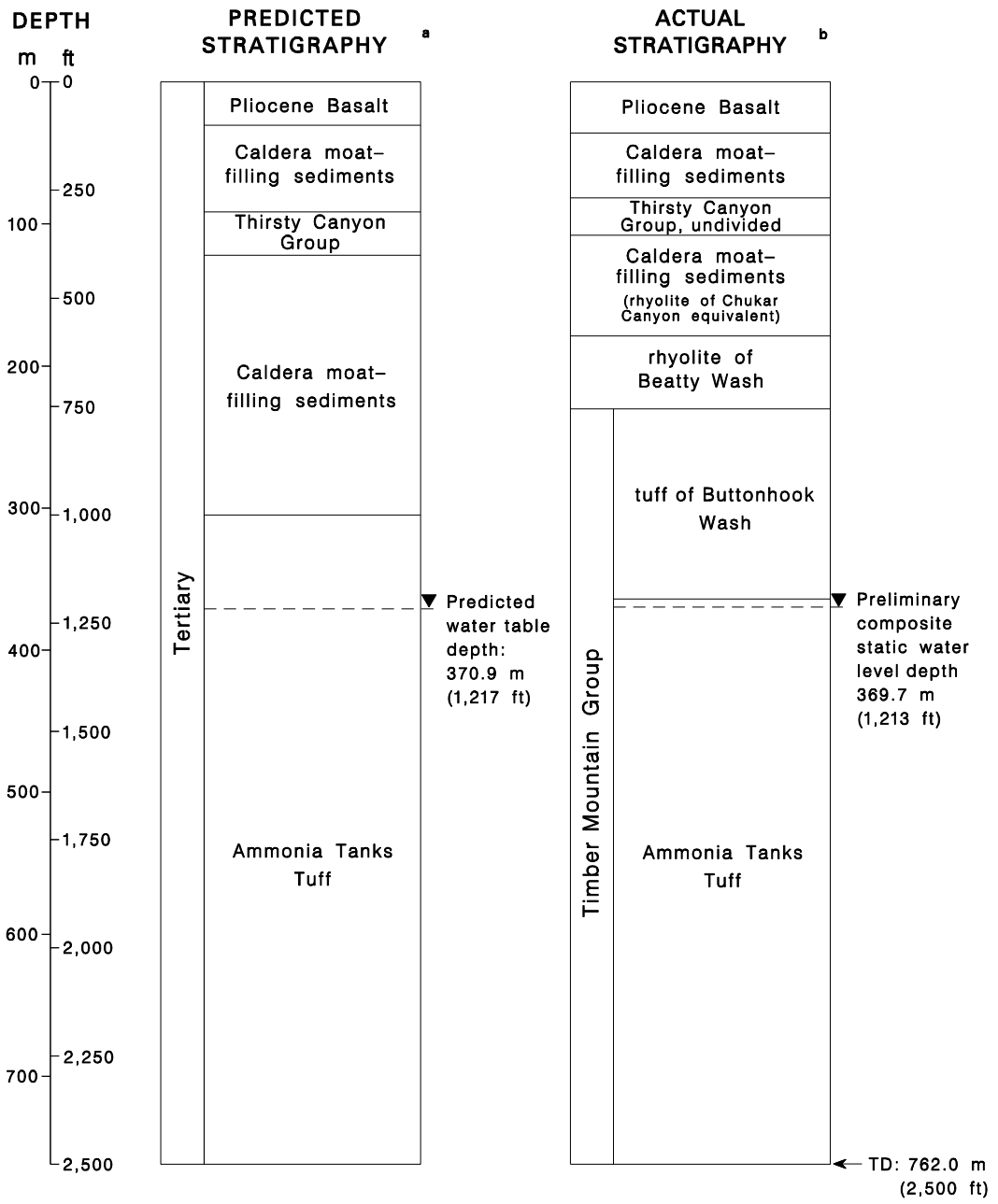
The stratigraphy penetrated in Well ER-18-2 is generally as predicted in IT (1998) and illustrated in Figure 4-3. Two units were encountered directly above the Ammonia Tanks tuff which were not predicted, 51.2 m (168 ft) of the rhyolite of Beatty Wash, underlain by 133.8 m (439 ft) of the tuff of Buttonhook Wash. The presence of these units resulted in a significantly thinner section of Tertiary caldera moat-filling sediments and slightly deeper Ammonia Tanks Tuff than expected. The presence of the rhyolite of Beatty Wash and the tuff of Buttonhook Wash in Well ER-18-2 is not entirely unanticipated, as both crop out approximately 8.1 to 16.1 km (5 to 10 mi) southwest of the drill hole. The rhyolite of Beatty Wash is present at the surface in the Timber Mountain moat south of Timber Mountain, and the tuff of Buttonhook Wash is exposed along the western base and on top of Timber Mountain.

As predicted, Well ER-18-2 reached TD in the Ammonia Tanks Tuff. The well penetrated a total thickness of 398.1 m (1,306 ft) of mafic-rich Ammonia Tanks Tuff and never reached the underlying mafic-poor zone, indicating that Well ER-18-2 was likely drilled inside the structural margin of the Ammonia Tanks caldera (Figure 4-4).

Based on surface geology, Well ER-18-2 was not predicted to encounter any major fault zones, however, the moderately to densely welded ash-flow tuffs of the tuff of Buttonhook Wash and Ammonia Tanks Tuff contain features which may indicate the presence of one or more faults nearby or intersecting the well. Evidence for faulting includes more intense zones of quartzo-feldspathic alteration, slickensides, numerous fractures, brecciation, iron oxide staining, and honeycomb textures.

4.3 Hydrogeology

Well ER-18-2 penetrated three intervals of aquifers separated by two confining units (Figure 4-2). As expected, the only saturated aquifer is the welded-tuff aquifer of the Ammonia Tanks Tuff. Figure 4-5 is a hydrogeologic cross section through the Well ER-18-2 vicinity, which illustrates the predicted extent and thickness of hydrogeologic units in the area.



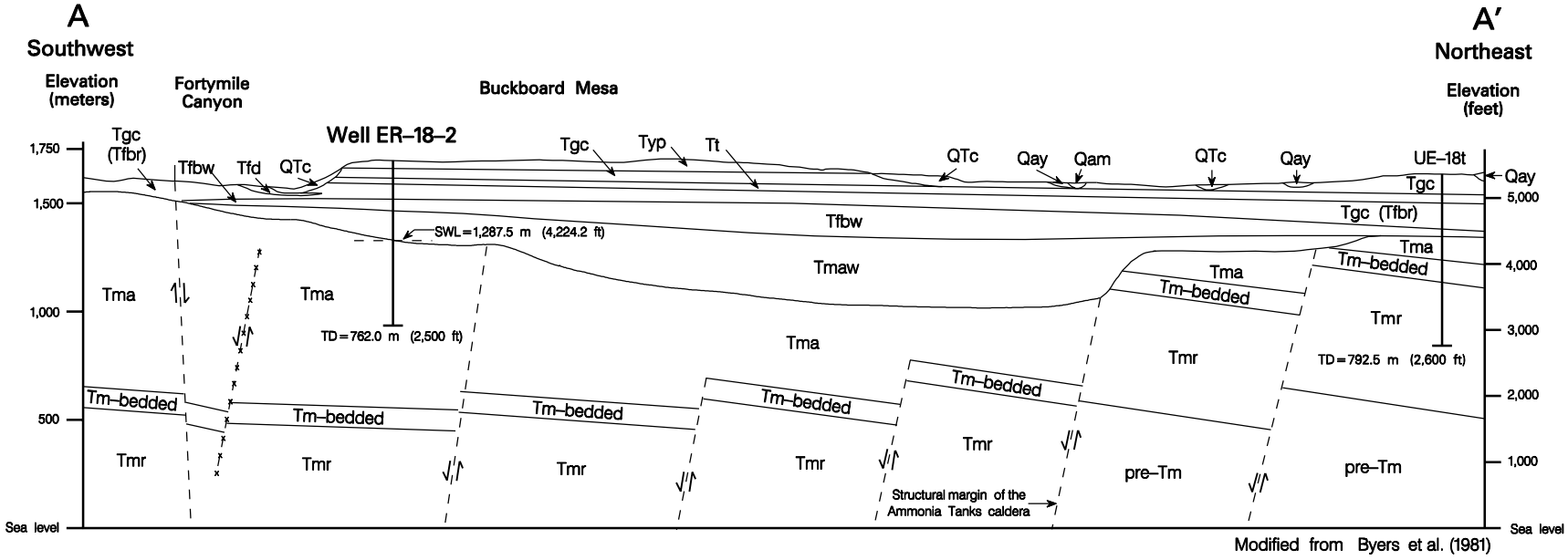
NOTES:

a IT, 1998

b See Appendix C for detailed lithologic descriptions.

Surface Elevation (pad): 1,657.2 m (5,437.1 ft)
Nevada Coordinates (NAD 1983): N 20,541,957.7 ft; E 1,725,829.6 ft
Completed: 5/18/1999

Figure 4-3
Predicted and Actual Stratigraphy at Well ER-18-2



Modified from Byers et al. (1981)

SWL	Preliminary composite static water level
TD	Total depth
	Fault showing relative sense of movement
	Tuff dike zone

No vertical exaggeration

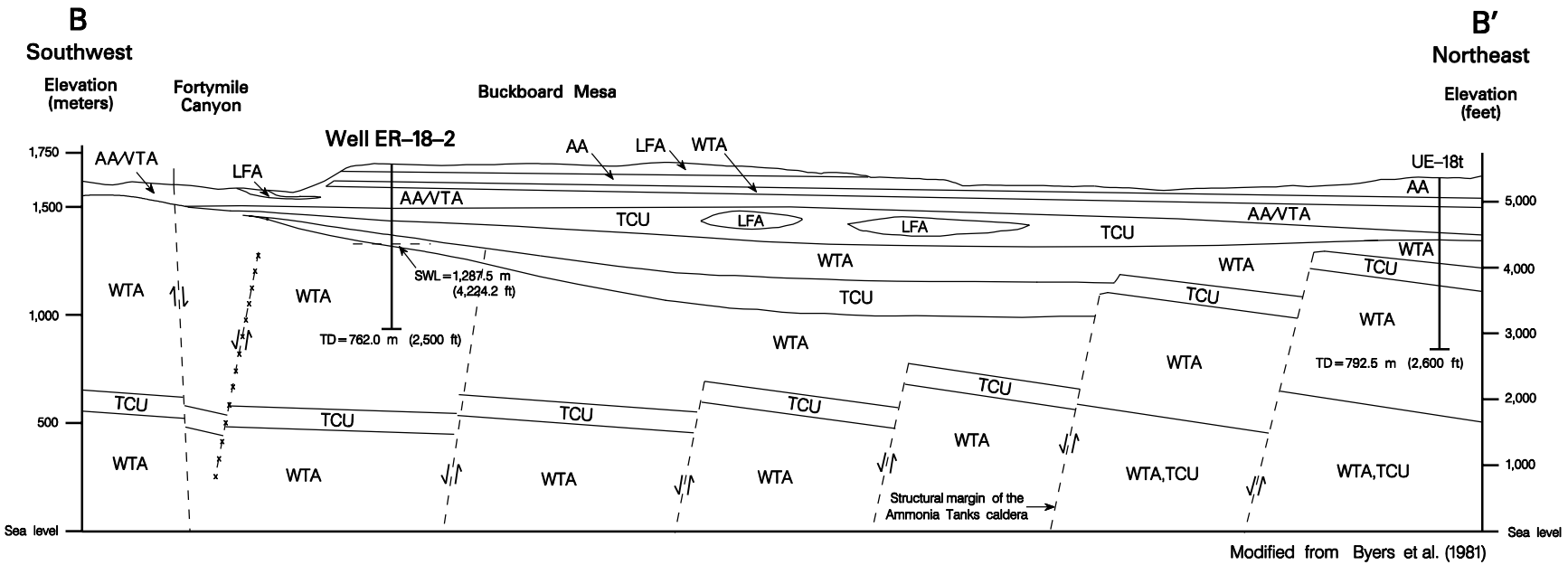
0 2,000 4,000 Feet

0 500 1,000 Meters

Scale

Qay	Young Alluvium
QTc	Colluvium
Qam	Middle Alluvium
Typ	Pliocene and youngest Miocene basalts
Tt	Thirsty Canyon Group
Tgc	Moat–filling deposits
Tgc (Tfbr)	Moat–filling deposits (equivalent to rhyolite of Chukar Canyon [after Warren, 1999])
Tfd	Lavas of Dome Mountain
Tfbw	rhyolite of Beatty Wash
Tmaw	Tuff of Buttonhook Wash
Tma	Ammonia Tanks Tuff
Tm–bedded	Ammonia Tanks and Rainier Mesa bedded tuffs
Tmr	Rainier Mesa Tuff
pre–Tm	Pre–Rainier Mesa volcanic rocks

Figure 4–4
Geologic Cross Section A–A′ Through Well ER–18–2
See map on Figure 4–1 for cross section location.



No vertical exaggeration

0 2,000 4,000 Feet

0 500 1,000 Meters

Scale

SWL	Preliminary composite static water level
TD	Total depth
	Fault showing relative sense of movement
	Tuff dike zone

AA	Alluvial Aquifer
VTA	Vitric–tuff aquifer
WTA	Welded–tuff aquifer
LFA	Lava–flow aquifer
TCU	Tuff confining unit

Figure 4-5
Hydrogeologic Cross Section B-B' Through the Well ER-18-2 Vicinity
See map on Figure 4-1 for cross section location.

Five unsaturated aquifer lithologies make up the upper aquifer interval. They include a lava-flow aquifer (basalt), overlying an alluvial aquifer made up of tuffaceous sediments, followed by a welded-tuff aquifer of partially to moderately welded ash-flow tuff from the Thirsty Canyon Group, and a lower alluvial aquifer composed of tuffaceous sediments and vitric reworked tuff. Although the alluvial aquifers are mostly vitric, the presence of lesser zeolitic components and very fine-grained material may significantly reduce the transmissivity and give the aquifers, at least in part, hydraulic characteristics of a tuff confining unit. The upper aquifer interval is separated from the middle aquifer by a tuff confining unit made up of the zeolitic bedded and nonwelded tuffs of the lower part of the rhyolite of Beatty Wash and the upper part of the tuff of Buttonhook Wash. The middle aquifer, also unsaturated, is a welded-tuff aquifer in the devitrified ash-flow tuff of the tuff of Buttonhook Wash. The static water level occurs within the second, lower tuff confining unit. This tuff confining unit is composed of the zeolitic bedded tuff at the base of the tuff of Buttonhook Wash and the quartzo-feldspathic nonwelded ash-flow tuff at the top of the mafic-rich Ammonia Tanks Tuff.

Beneath the lower tuff confining unit is the welded-tuff aquifer in the Ammonia Tanks Tuff, composed mostly of devitrified moderately to densely welded ash-flow tuff. This welded-tuff aquifer was the only water-producing unit penetrated by Well ER-18-2, however water production was much lower than expected: the aquifer produced only about 114 to 151 lpm (30 to 40 gpm) during drilling. Moderately and densely welded tuffs typically make good aquifers due to high fracture permeability, however, in Well ER-18-2, many of the fractures observed in the Ammonia Tanks Tuff were filled with secondary minerals which could decrease fracture permeability, and thus overall transmissivity.

5.0 Hydrology

5.1 Preliminary Water-Level Information

Groundwater was first detected (based on dilution of LiBr tracers) at approximately 367.3 m (1,205 ft). After the surface hole was drilled (to the depth of 411.8 m [1,351 ft]) fluid depths between 376.7 and 381.4 m (1,236.0 and 1,251.4 ft) were obtained from various geophysical logs run on May 10, 1999. After TD was reached and before the completion string was installed, generally rising fluid levels, from the depth of 427.9 to 395.9 m (1,404 and 1,299 ft), were measured over a period of approximately 36 hours.

The elevation of the water table at Well ER-18-2 was projected to be approximately 1,287 m (4,223 ft) above mean sea level, as derived from sparse hydrologic data for this region (IT, 1998). Based on the pre-construction estimate of surface elevation at the site, depth to water was expected at approximately 371 m (1,217 ft) (IT, 1998). Two months after the completion string was installed, on July 17, 1999, IT obtained a fluid level in the well of 369.7 m (1,212.9 ft) (IT, 1999). Based on this latest fluid level and the surface elevation of 1,657.2 m (5,437.1 ft), the fluid level elevation at Well ER-18-2 is 1,287.5 m (4,224.2 ft), about a half meter higher than predicted prior to drilling (IT, 1998).

5.2 Water Production

Water production was calculated on the basis of LiBr dilution data as measured by IT field personnel. Water production began at the depth of approximately 367.3 m (1,205 ft) in the partially to moderately welded, mafic rich part of the Ammonia Tanks Tuff. The production rate remained low (less than 38 lpm [10 gpm]) to the depth of about 670.6 m (2,200 ft), then gradually increased to about 151 lpm (40 gpm) to TD. Estimated water production rates are presented graphically in Appendix A-1.

5.3 Preliminary Thermal Flow Meter Data

Thermal flow meter (TFM) data, along with temperature, electrical conductivity (EC), and pH measurements can characterize borehole fluid variability, which may indicate inflow and outflow zones. These data were used in part to develop the design of the completion string. Desert Research Institute (DRI) personnel made TFM measurements at eight locations between the depths of 458.7 and 746.8 m (1,505 and 2,450 ft) in Well ER-18-2 before the completion string was installed. In addition, DRI ran a chemistry log, which includes temperature, EC, and pH measurements, from 396.2 to 755.6 m (1,300 to 2,479 ft). Groundwater temperature gradually increased from 47.82 degrees Celsius (C) (118.08 degrees Fahrenheit [F]) at the top of the fluid

column to 60.38 degrees C (140.68 degrees F) at the bottom of the hole. Preliminary analysis of the TFM data indicates a downward flow of water in the borehole at all eight measurement points. Plots of the TFM and chemistry logs are reproduced in Appendix D.

5.4 Radionuclide Monitoring

Samples of fluid from the well were tested for tritium every hour during drilling. These analyses indicated only background levels, and no other man-made radionuclides were encountered during drilling of Well ER-18-2.

5.5 Preliminary Groundwater Characterization Sample

Following geophysical logging, DRI collected two 5-liter (1.3-gallon) samples of fluid from the open borehole at the depth of 585.2 m (1,920 ft). Analytical data from this initial sample, collected before formal well development, will provide a basis for comparison with future groundwater chemistry data.

6.0 Precompletion and Open-Hole Development

The only precompletion development conducted in Well ER-18-2 consisted of circulating fluid for about an hour to condition the hole. This process was conducted immediately after TD was reached and 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 pipe 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 interval, and impervious materials such as cement between the open intervals to isolate them. The casing serves as a conduit for insertion of a pump in the well, and for inserting devices for measuring the fluid level and for sampling, so that accurate potentiometric and water chemistry data can be obtained from a known portion of the borehole.

Completion activities at Well ER-18-2 took place on May 17, 1999. Figure 7-1 is a schematic of the final well-completion design for Well ER-18-2, Table 7-1 is a construction summary for the well, and Figure 7-2 shows plan and profile views of the wellhead surface completion. Data for this section were obtained from daily operations and activity reports and tubing/casing records provided by the BN Drilling Department. Information from IT (IT, 1999) was also consulted for preparation of this section.

7.2 Well Completion Design

The final completion design for Well ER-18-2 differs somewhat from the proposed design, as described in the following paragraphs.

7.2.1 Proposed Completion Design

The original completion design (IT, 1998) was based on the presumption that Well ER-18-2 would reach TD in the welded-tuff aquifer of the Ammonia Tanks Tuff. The well was expected to penetrate several different aquifer lithologies higher in the well, but only the welded-tuff aquifer of the Ammonia Tanks Tuff was expected to be saturated. The well was intended to be completed with a single interval open to the welded-tuff aquifer; the completion string was to be made up of stainless-steel 5½-in. casing (below the fluid level) with every other joint slotted, suspended from carbon-steel 7⅝-in. casing. The completion plan called for gravel-packing the slotted interval and then emplacing a layer of 6-9 Colorado silica sand on top of the gravel, and a layer of 20/40 silica sand on top of the coarse sand. The borehole was then to be cemented from the top of the 20/40 sand to a point no less than 61 m (200 ft) above the fluid level.

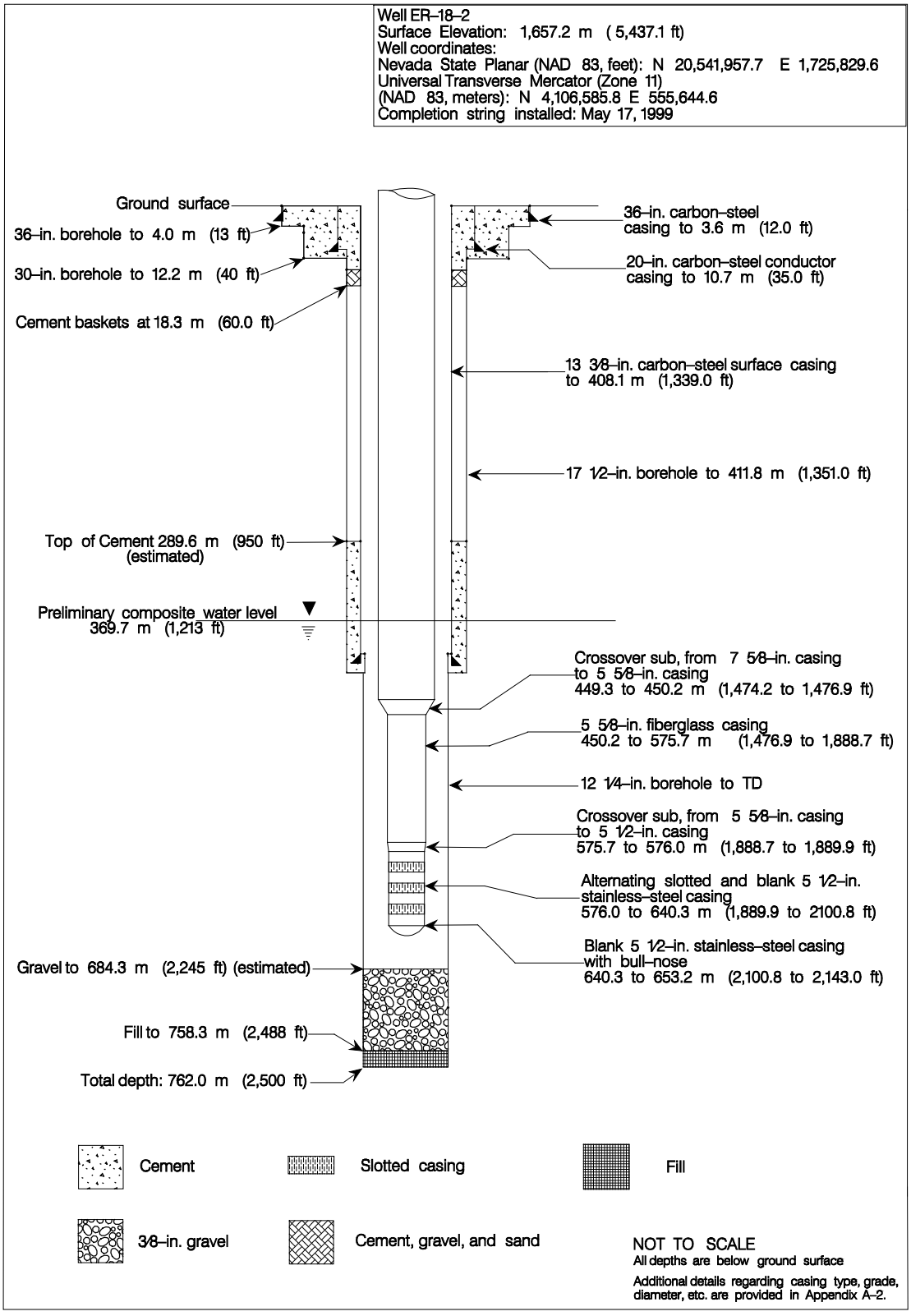
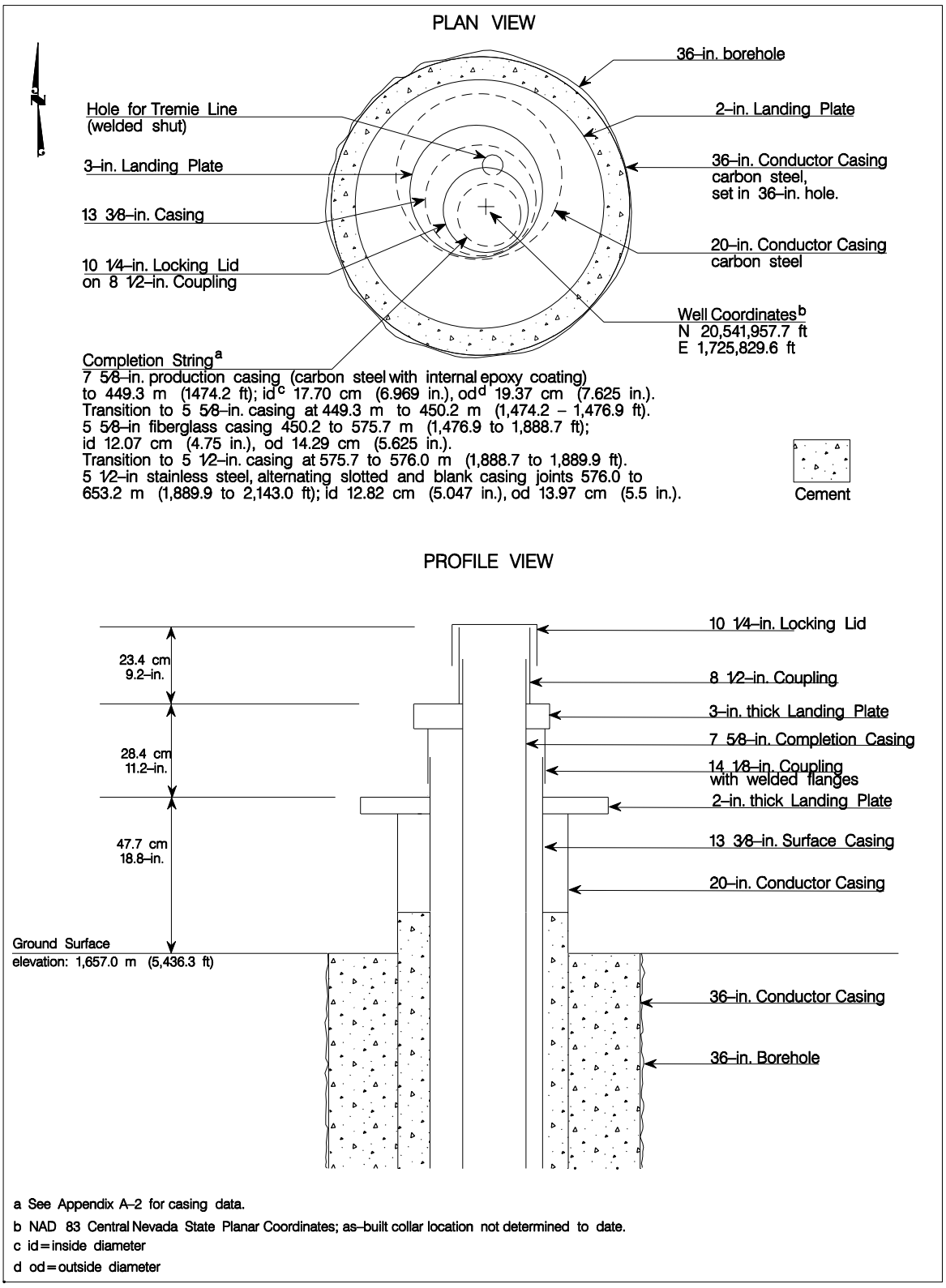


Figure 7–1
As–built Completion Schematic for Well ER–18–2

Table 7-1
Well ER-18-2 Completion String Construction Summary

Casing Type	Configuration meters (feet)	
7⅝-in. carbon-steel production casing with internal epoxy coating	0 to 449.3 (0 to 1,474.2)	Blank
7⅝-in. to 5⅝-in. carbon-steel crossover sub	449.3 to 450.2 (1,474.2 to 1,476.9)	
5⅝-in. fiberglass	450.2 to 575.7 (1,476.9 to 1,888.7)	
5⅝-in. to 5½-in stainless-steel crossover sub	575.7 to 576.0 (1,888.7 to 1,889.9)	
5½-in. stainless-steel production casing	576.0 to 653.2 (1,889.9 to 2,143.0)	Blank 576.0 to 588.4 (1,889.9 to 1,930.4)
		Slotted 588.4 to 597.3 (1,930.4 to 1,959.7)
		Blank 597.3 to 609.7 (1,959.7 to 2,000.2)
		Slotted 609.7 to 618.9 (2,000.2 to 2,030.4)
		Blank 618.9 to 631.2 (2030.4 to 2,070.9)
		Slotted 631.2 to 640.3 (2,070.9 to 2,100.8)
		Blank 640.3 to 652.7 (2,100.8. to 2,141.3)
		Bull-nose 652.7 to 653.2 (2,141.3 to 2,143.0)



a See Appendix A–2 for casing data.

b NAD 83 Central Nevada State Planar Coordinates; as–built collar location not determined to date.

c id = inside diameter

d od = outside diameter

Figure 7-2
Wellhead Diagram for Well ER-18-2

7.2.2 As-Built Completion Design

The final design of the Well ER-18-2 completion was determined on the basis of on-site evaluation of a variety of data, including lithologic and water-production data, as well as information derived from various geophysical logs, the thermal-flow log, and the water chemistry log. Members of the UGTA TWG were also consulted during the design process.

The as-built completion design for Well ER-18-2 specifies one open (slotted) interval (Figure 7-1), as originally proposed. The open interval of the completion string is stainless-steel casing with every other joint slotted; the casing has an outside diameter of 14.0 cm (5.5 in.) and an inside diameter of 12.82 cm (5.047 in.). The bottom joint is a blank bull-nose which will serve as a sediment sump. The top of the 5½-in. casing is approximately 206.0 m (676 ft) below the static fluid level. At that point, the 5½-in. stainless-steel casing is connected to 5⅝-in. fiberglass casing via a short stainless-steel crossover sub. The blank fiberglass casing has an outside diameter of 14.29 cm (5.625 in.) and an inside diameter of 12.07 cm (4.75 in.). Another short crossover sub connects the fiberglass casing to the upper part of the completion string, approximately 79.6 m (261 ft) below the fluid level. The upper section of the string is 7⅝-in. carbon-steel production casing with an internal epoxy coating. This casing has an outside diameter of 19.37 cm (7.625 in.) and an inside diameter of 17.70 cm (6.969 in.). The composition of the string summarized here is detailed on Table 7-1, and the casing materials are listed in Appendix A-2.

The open interval of the stainless-steel casing consists of three slotted joints, each approximately 9.1 m (30 ft) long, separated by blank joints, each approximately 12.2 m (40 ft.) long. The slotted joints are positioned between 588.4 and 640.3 m (1,930.4 to 2,100.8 ft.). The slots are 0.198 cm (0.078 in.) wide and 5.1 cm (2 in.) long, cut in rings of 18 slots (spaced 20 degrees apart around the joint). The rings are spaced 15.2 cm (6 in.) apart, and the longitudinal centers of the slots in each ring are staggered 10 degrees from the slot centers in the next ring. No slots are cut within 0.6 m (2 ft) of the ends of the slotted joints to assure that the strength of the connections is not degraded. The final design called for gravel to be emplaced from the bottom of the hole to the depth of 405.4 m (1,330 ft), and capped with 9.1 m (30 ft) of sand; the annulus was then to be cemented from the top of the sand at 396.2 m (1,300 ft) to the depth of 320.0 m (1,050 ft).

7.2.3 Rationale for Differences between Actual and Proposed Well Design

The hydrostratigraphy encountered in Well ER-18-2 was close to expectations; therefore, the proposed plan of installing a completion string with a single interval open to the welded-tuff aquifer of the Ammonia Tanks Tuff was retained. The proposed installation of a single completion string consisting of larger diameter carbon-steel casing above the water table and smaller diameter stainless-steel casing in the saturated zone was accomplished, with the exception that fiberglass casing was substituted for the upper part of the stainless steel section because of material availability.

The well stemming was not installed as originally planned because of technical difficulties during emplacement of the gravel pack (see Section 7.3).

7.3 Well Completion Method

A "tremie" line and the completion string were landed after geophysical logging was completed. Well-construction materials were inspected in accordance with relevant procedures, and standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

Stemming of the hole began with emplacement of ¼-in. by ⅜-in. gravel through the "tremie" line. After 9,843 kilograms (21,700 pounds) of gravel had been added, the fluid level was measured at 19.5 m (64 ft), and the gravel stopped going down the hole. This was because water introduced during the stemming process could not infiltrate the low transmissivity rocks, and was displaced up the borehole by the gravel. Stemming operations were shut down, the completion string was not gravel-packed or cemented, and the drill rig was released. The top of the gravel is estimated to be at the depth of 684.3 m (2,245 ft) based on borehole volume data from the caliper log and estimated gravel volume.

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

8.0 Actual versus Planned Costs and Scheduling

The BN cost model developed for the Well ER-18-2 in the WPM-OV drilling program baseline projected that it would require 22 days to accomplish drilling, logging, and completion for each well. The actual time spent (after construction of the conductor hole) on drilling and completion of Well ER-18-2 was 15 days. A graphical comparison, by day, of planned and actual well-construction activities is presented in Figure 8-1.

The cost analysis for Well ER-18-2 begins with the construction of the conductor hole, which was auger-drilled to 12.2 m (40 ft) and cased. The construction cost for Well ER-18-2 includes all drilling costs: charges by the drilling company; charges by other support subcontractors (including compressor services, drilling fluids, bits, casing services, down-hole tool and down-hole camera services, and geophysical logging); and charges by BN for mobilization and demobilization of equipment, cementing services, completion materials, radiation technicians, inspection services, and geotechnical consultation. The cost of building roads, the drill pad, and sumps is not included.

The total planned cost for Well ER-18-2 was $1,204,052. The actual cost was $1,379,455, or 14.6 percent more than the planned cost. Figure 8-2 presents a comparison of the planned (baseline task plan) and actual costs, by day, for drilling and completing Well ER-18-2. The well was constructed in less time than planned, but the additional cost can be attributed to the effort to handling borehole sloughing problems, including cementing and redrilling the upper part of the hole.

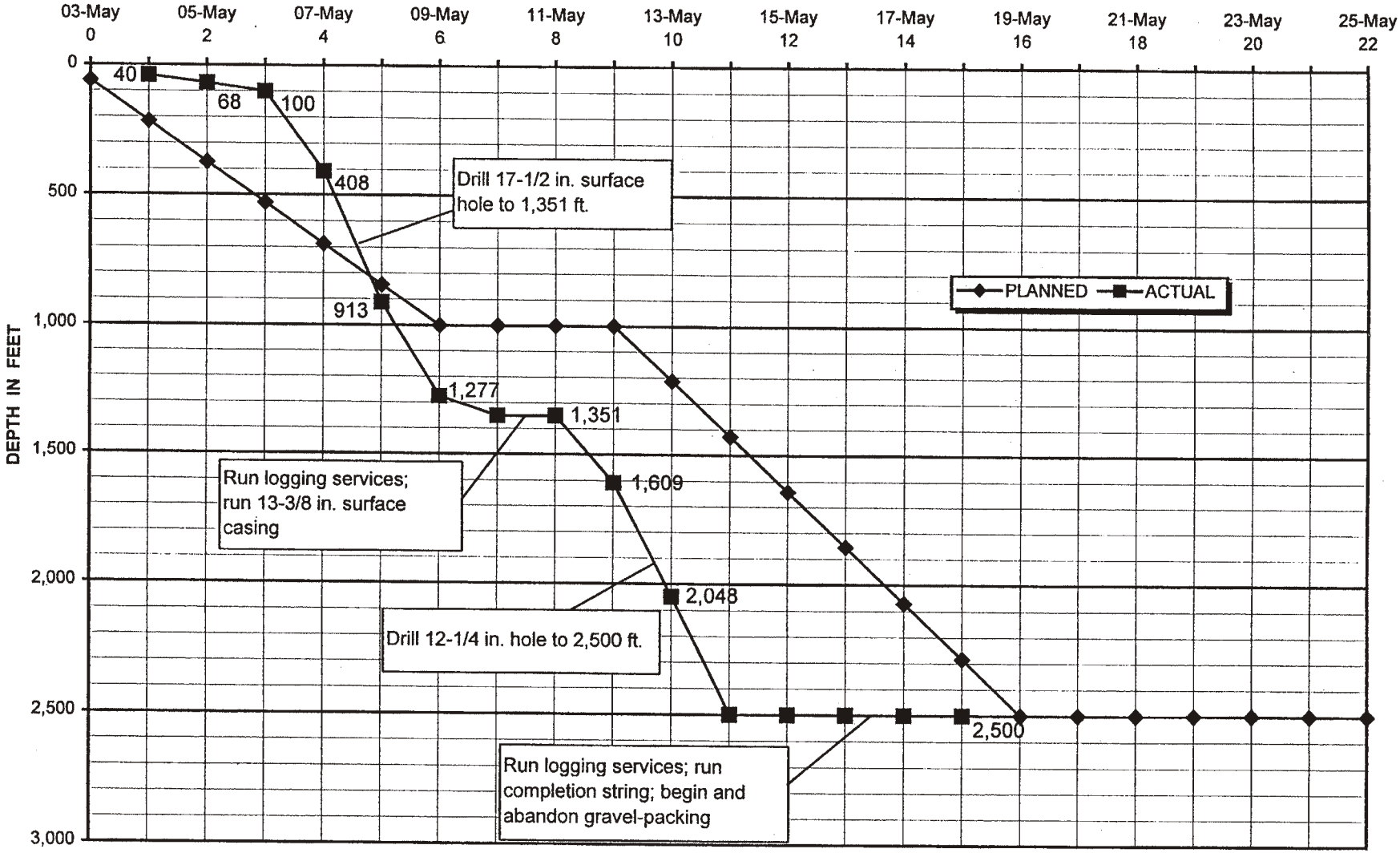


Figure 8-1
Planned versus Actual Drilling Progress for Well ER-18-2

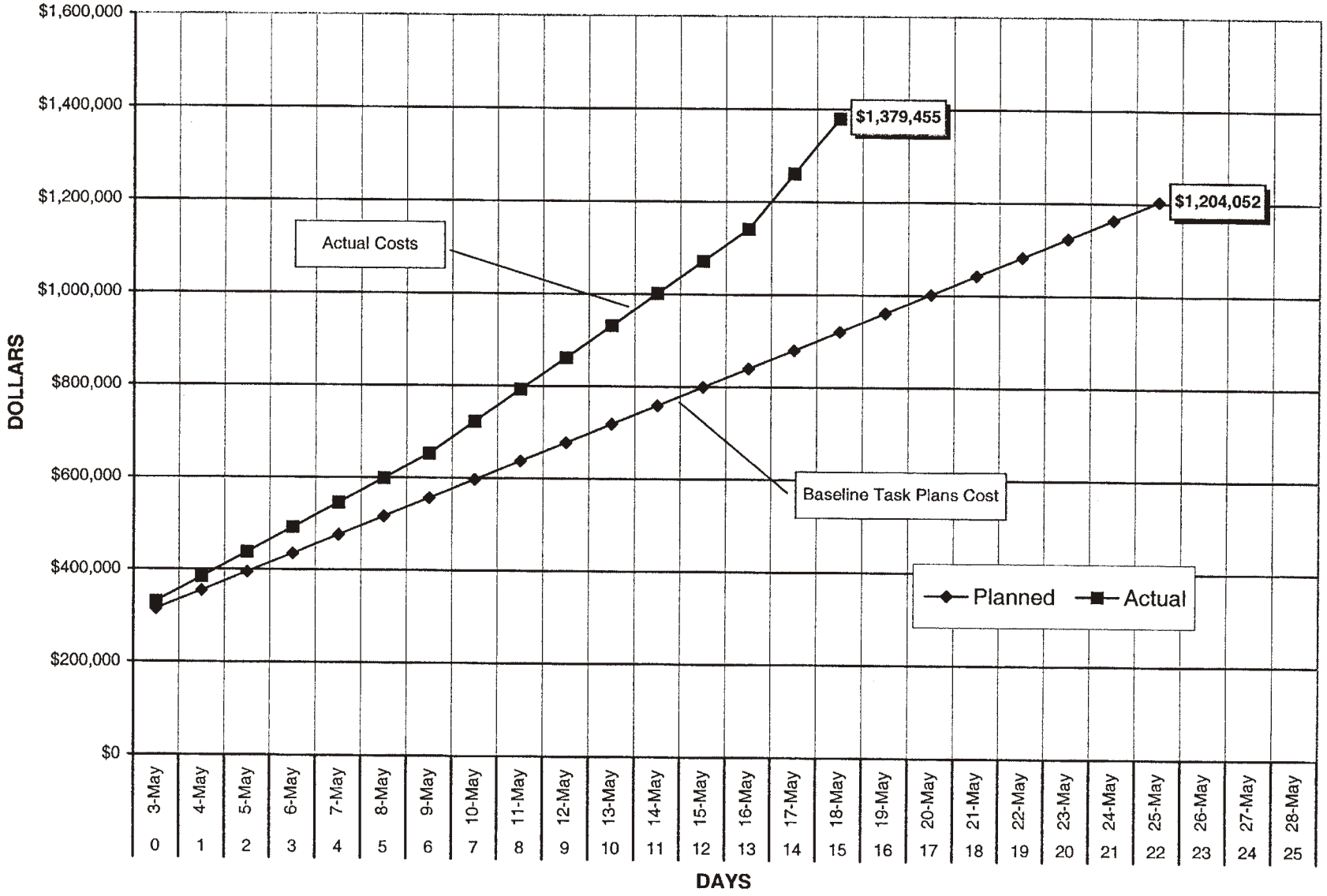


Figure 8-2
Planned versus Actual Costs for Drilling Well ER-18-2

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9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Drilling of the main hole commenced at Well ER-18-2 on May 3, 1999, and concluded on May 14, 1999, when the planned TD of 762.0 m (2,500 ft) was reached. After geophysical logging, the completion string was installed, but gravel-packing was not completed, and cementing operations were suspended on May 17, 1999. Crews worked on a 7-days-a-week, 24-hour-a-day schedule for most of the operation. Fifteen working days were expended on drilling, logging, and completion activities. The only significant problem encountered during drilling was a zone of lost circulation which required cementing and redrilling of approximately 5.2 m (17 ft) of the upper part of the borehole.

No radionuclides above background levels were encountered in the groundwater produced from Well ER-18-2. The fluid level measured two months after installation of the completion string was at the depth of 369.7 m (1,212.9 ft).

Composite drill cuttings were collected every 3 m (10 ft) from 9.1 m (30 ft) to TD, with the exception of the one interval in the upper part of the hole, for which there were no returns. Fifteen sidewall core samples were collected in the interval 425.9 to 755.0 m (1,379.3 to 2,477.0 ft). Geophysical logging was conducted in the upper part of the hole before installation of the surface casing, and in the lower part of the hole before installation of the completion string. Some of these logs were used to aid in construction of the well, while others help to verify the geology and characterize the hydrologic characteristics of the rocks.

A single completion string with one slotted interval was installed in Well ER-18-2. A string of 5½-in. stainless-steel and 5⅝-in. fiberglass casing was installed below the water table, suspended from 7⅝-in. carbon-steel casing (with an internal epoxy coating) which extends to the surface. The slotted interval in the 5½-in. stainless-steel casing is positioned between 588.4 and 640.3 m (1,930.4 and 2,100.8 ft). This interval is open to the welded-tuff aquifer of the Ammonia Tanks Tuff. Because of high hydrostatic pressure in the hole during the stemming attempt, only 74 m (243 ft) of the planned gravel pack was emplaced. The top of the gravel is estimated to be at the depth of 684.3 m (2,245 ft), or approximately 31 m (102 ft) below the bottom of the completion string; the annulus of the well is open above that level.

9.2 Recommendations

The planned pump installation, well development, groundwater sampling, and hydrologic testing can be accomplished without adding the rest of the originally planned stemming materials. These field activities must be conducted at Well ER-18-2 to accomplish the remaining objectives for this well-construction effort.

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. Yet each new well produces some "lessons learned" that can be applied to improve future well-construction projects. The paragraphs below describe two primary lessons learned during construction of Well ER-18-2.

- In low transmissivity lithologies, it may be possible to emplace gravel from the surface by simple gravity feed rather than through use of a "tremie" line.

- In the future, it may be possible to construct a simple well of this type (single string in a well with one producing aquifer) more efficiently by not gravel packing and stemming the annulus of the well. Water-level measurements and sampling conducted through the unpacked string will represent composites of all formation water entering the borehole. However, this type of simplified stemming plan is not suitable for wells in which it is desired to isolate one aquifer from other producing zones. In that case, cementing is needed to prevent cross-flow between aquifers penetrated by the borehole.

10.0 References

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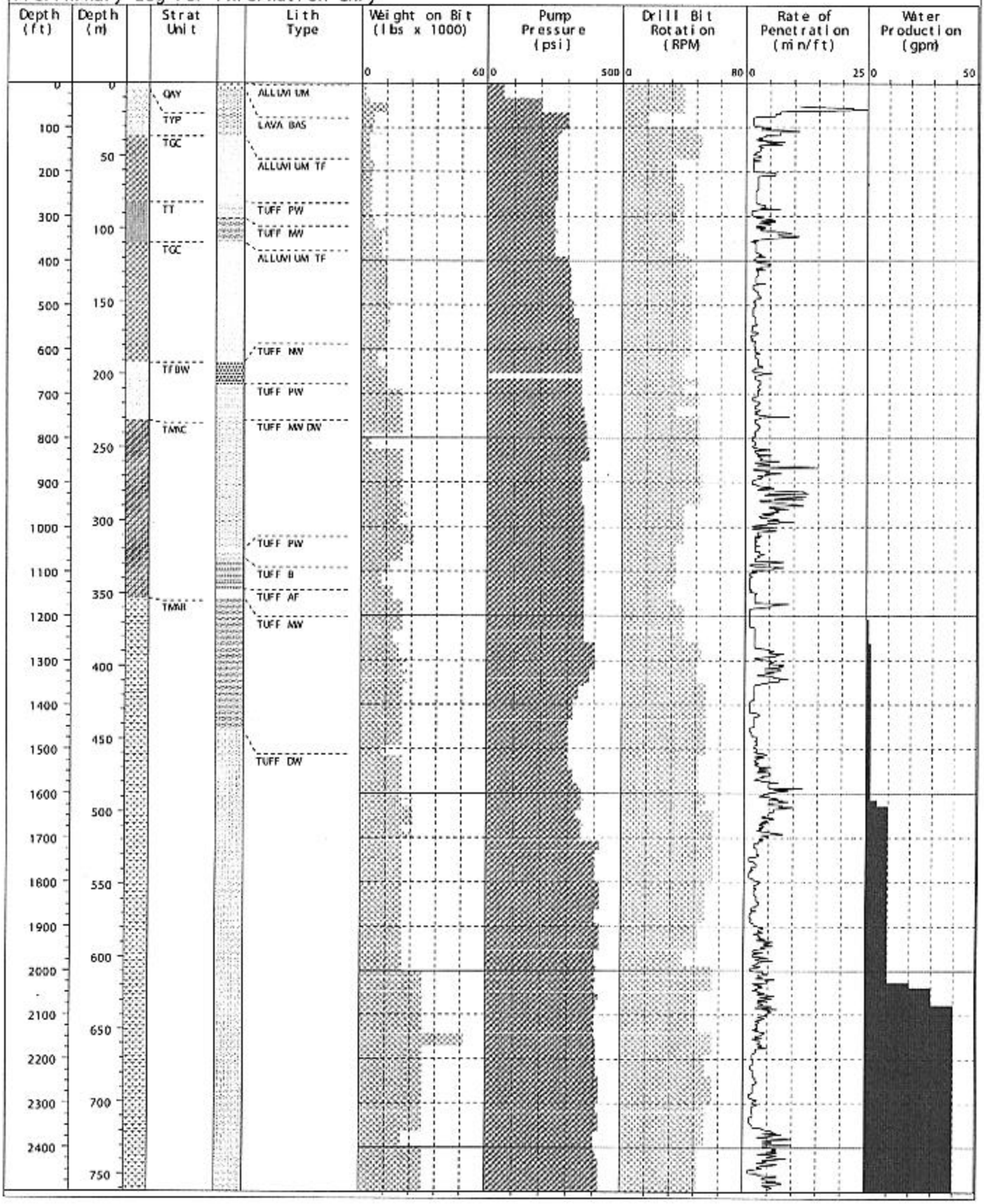
Appendix A
Drilling Data

Appendix A-1
Drilling Parameter Logs for Well ER-18-2

Well Name: ER-18-2	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 41065 85.8 m
Date: 7/28/99	Start Date: 5/3/99	Stop Date: 5/17/99	Easting: 55564 4.6 m
Environmental Contractor: UGTA/IT		Proj No: 776706.02.08.04.02	Surface Elevation: 543 7.1 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft.

Preliminary Log for Information Only



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Appendix A-2
Casing Data for Well ER-18-2

Table A-2
Casing Data for Well ER-18-2

Casing	**Depth Interval** meters (feet)	**Type**	**Grade**	**Outside Diameter** centimeters (inches)	**Inside Diameter** centimeters (inches)	**Wall Thickness** centimeters (inches)	**Weight per foot** pounds
36-inch Conductor Casing	0 to 3.6 (0 to 12.0)	Carbon Steel	H40	91.44 (36.0)	89.54 (35.25)	0.95 (0.375)	142.68
20-inch Conductor Casing	0 to 10.7 (0 to 35.0)	Carbon Steel	K55	50.80 (20.0)	48.57 (19.124)	1.11 (0.438)	94.0
13⅜-inch Surface Casing	0 to 408.7 (0 to 1,341.0)	Carbon Steel	K5	33.97 (13.375)	32.04 (12.615)	0.97 (0.380)	54.5
7⅝-inch Completion Casing (with crossover)	0 to 450.2 (0 to 1,476.9)	Carbon Steel with internal epoxy coating	N80	19.37 (7.625)	17.70 (6.969)	0.83 (0.328)	26.4
5⅝-inch Completion Casing (with crossover)	450.2 to 576.0 (1,476.9 to 1,889.9)	Fiberglass	rated at 2,000 psi[a]	14.29 (5.625)	12.07 (4.75)	1.11 (0.438)	7.60
5½-inch Completion Casing	576.0 to 653.2 (1,889.9 to 2,143.0)	Stainless Steel	T304L	13.97 (5.5)	12.83 (5.05)	0.58 (0.227)	14.6

a psi = pounds per square inch

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Appendix A-3
Well ER-18-2 Drilling Fluids and Cement Composition

Table A-3-1
Well ER-18-2 Drilling Fluids

Air-Foam/Polymer (Typical [a])
15 to 23 liters (4 - 6 gallons) Acrylafoam [b] and 4 to 11 liters (1 - 3 gallons) Acrylavis [b] per 7,949 liters (50 barrels) water

a Various proportions of polymer were added to suit drilling conditions during air-foam drilling.
b Acrylafoam and Acrylavis are products of Enterprise Drilling Fluids, Inc.

NOTES:
1. All water used to mix drilling fluids for Well ER-18-2 came from Water Well 20.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of approximately 17 to 27 milligrams per liter.

Table A-3-2
Well ER-18-2 Cement Composition

Cement Composition	**20-inch Conductor Casing**	**Lost-circulation Zone**	**13⅜-inch Surface Casing**
Type II (neat)	0 to 10.7 m [a] (0 to 35.0 ft [b])	Not used	289.6 to 411.8 m (950 to 1,351 ft)
Type II plus 25 percent sand	Not used	Used with cedar fiber to cement hole from 167.6 to 20.7 m (50 to 68 ft)	In annulus: To surface above gravel/sand on cement baskets at 15.8 m (52 ft).

a meters b feet

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Appendix B
Well ER-18-2 Fluid Management Data

Fluid Disposition Reporting Form

Site Identification: ER-18-2
Site Location: Nevada Test Site, Area 18
Site Coordinates: N: 4,106,591; E: 555,642 (UTM, NAD83, meters)
Well Classification: ER
Project Number: 776706.02.08.04.

Report Date: August 6, 1999
DOE/NV Project Manager: Bob Bangerter
IT Project Manager: Janet Wille
IT Site Representative: Jeff Wurtz
IT Waste Coordinator: Patty Gallo

Well Activity	Activity Duration		#Ops Days[a]	Well Depth (m)	Import Fluid (m^3)	Sump #1 Volumes (m^3)		Sump #2 Volumes (m^3)		Infiltration Area (m^3)[c]	Other[d] (m^3)	Fluid Quality Objectives Met?
	From	To				Solids[b]	Liquids	Solids	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	5/03/99 17:00	5/09/99 06:00	5.5	370	558	199	433	0	0	NA	NA	YES
Phase I: Saturated-Zone Drilling	5/09/99 06:00	5/14/99 07:05	5	762	434	150	267	0	0	NA	NA	YES
Phase II: Initial Well Development	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phase II: Aquifer Testing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phase II: Final Development	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cumulative Production Totals to Date:			**10.5**	**1,132**	**992**	**349**	**700**	**0**	**0**	**NA**	**NA**	

[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 additional volume attributed to rock bulking factor (*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 AIP = Analysis in Process

Total Facility Capacities: Sump #1 = 1,158 m3 Sump #2 = 1,185 m3
Infiltration Area (assuming very low/no infiltration) = NA m3
Approximate Remaining Facility Capacity as of 5/14/99: Sump #1 = 109 m^3 (9.4%) Sump #2 = 1,185 m^3 (100%)

Current Average Tritium = 0 pCi/L
Notes: _____

IT Authorizing Signature/Date: Janet Wille 8-16-99

Preliminary Analytical Results for Fluid Management Samples: Well ER-18-2

Sample Number	Date & Time Collected	Comment		RCRA Metals (mg/L)								Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury			
ER-18-05099-1	05/09/1999 16:10	Sample collected from unlined sump	Total [a]	0.0321	0.473	ND	0.0217	0.026	0.0097	ND	0.0167	5.97	9.27	176
			Dissolved [b]	0.0128	0.0284	ND	ND	ND	0.0069	ND	0.00025	NA	NA	NA
ER-18-05169-3	05/16/1999 20:45	Sample collected from unlined sump	Total	0.0333	0.603	ND	0.0482	0.0267	0.0082	ND	0.00099	10.8	7.4	63.9
Nevada Drinking Water Standard (NDWS)				0.05	2.0	0.005	0.1	0.015	0.05	0.1	0.002	15	50	20,000
5 Times NDWS				0.25	10	0.025	0.5	0.075	0.25	0.5	0.01	75	250	100,000

Data provided by IT (IT, 1999).

a Initial analysis for total RCRA metals.
b Analysis of dissolved RCRA metals on a resubmitted sample fraction.

RCRA = Resource Conservation and Recovery Act of 1976
NA = not analyzed
ND = not detected
QA/QC = quality assurance and quality control
mg/L = milligrams per liter
pCi/L = picocuries per liter

Appendix C
Detailed Lithologic Log for Well ER-18-2

Detailed Lithologic Log for ER-18-2

Logged by H. M. Noto (Bechtel Nevada Geology/Hydrology)
and R. G. Warren (Los Alamos National Laboratory)
September 22,1999

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit** [d]
0 - 36.0 (0 - 118)	36 (118)	DA	None	**Basalt:** Grayish-black (N2); vesicular in lower portion; weakly hematitic; very abundant, very tiny, felsic crystals including lath-shaped plagioclase; very fine grained, moderate-yellowish-brown (10YR 5/4), argillic and calcareous tuffaceous material and calcite partially fills some vesicles.	Typ
36.0 - 81.7 (118 - 268)	45.7 (150)	DA	None	**Tuffaceous Sediments:** Moderate-yellowish-brown (10YR 5/4); moderately indurated; moderately calcareous; mostly medium and fine sand, and clay, with lesser coarse sand and gravel. Medium and fine sand is poorly to moderately sorted, subangular to subrounded, and is composed of quartz and feldspar crystals, biotite, devitrified welded tuff and rhyolitic lava fragments, glass shards, and fine ash. Gravel and coarse sand consist of angular to subangular clasts of devitrified welded tuff, devitrified lava, vitric and zeolitic nonwelded tuff, and vitric pumice fragments.	Tgc
81.7 - 87.5 (268 - 287)	5.8 (19)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Partially Welded Ash-Flow Tuff:** Dark-yellowish-brown (10YR 2/2) and moderate-brown (5YR 3/4); devitrified with vapor-phase crystallization; minor olive-gray (5Y 4/1), scoriaceous dusky-brown (5YR 2/2), and medium-gray (N5) pumice up to 12 mm; common felsic phenocrysts of feldspar; minor mafic minerals of clinopyroxene and lesser olivine; rare brownish-black (5YR 2/1) lithic fragments.	Ttt
87.5 - 91.1 (287 - 299)	3.7 (12)	DA	None	**Nonwelded Ash-Flow Tuff:** Dark-yellowish-brown (10YR 4/2); vitric; common yellowish-gray (5Y 7/2) to yellowish-gray (5Y 8/1) pumice; minor felsic phenocrysts of feldspar; minor mafic minerals of olivine and clino-pyroxene; minor lithic fragments; very abundant dark-gray (N3) glass shards.	
91.1 - 103.3 (299 - 339)	12.2 (40)	DA	None	**Partially Welded Ash-Flow Tuff:** Pale-brown (5YR 5/2) to brownish-gray (5YR 4/1); mostly devitrified with vapor-phase mineralization, partially vitric; minor light-gray (N7) and scoriaceous brownish-black (5YR 2/1) pumice; minor felsic phenocrysts of feldspar; minor altered olivine; rare brownish-black (5YR 2/1), devitrified, lithic fragments. There may be a thin, vitric, nonwelded tuff at top of interval, based on geophysical logs.	Ttp

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit** [d]
103.3 - 107.9 (339 - 354)	4.6 (15)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately Welded Ash-Flow Tuff:** Grayish-brown (5YR 3/2) and moderate-brown (5YR 4/4); devitrified with vapor-phase crystallization; minor very-dusky-red (10R 2/2) and medium-dark-gray (N4) pumice; rare felsic phenocrysts of feldspar; scarce pseudomorphs of olivine and clinopyroxene; rare very-dusky-red (10R 2/2) lithic fragments. Welding increases towards base of interval.	Ttp
107.9 - 178.9 (354 - 587)	71.0 (233)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Tuffaceous Sediments and Reworked Tuff:** Moderate-yellowish-brown (10Y/R 5/4); moderately consolidated; weakly to moderately calcareous; clay and fine to medium sand matrix with lesser coarse sand and gravel, more gravelly above 128.0 m (420 ft) and below 167.0 m (548 ft). Sand matrix is very tuffaceous, mostly vitric, lesser zeolitic, poorly to moderately sorted, subangular to subrounded, and consists of quartz and feldspar crystals, including chatoyant sanidine, biotite flakes, devitrified welded tuff and rhyolitic lava fragments, glass shards, and fine ash. Coarser sands and gravels are angular to subangular and consist of welded tuff, nonwelded tuff, lava, and mostly vitric, lesser zeolitic pumice clasts.	Tgc (Tfbr equivalent)
178.9 - 197.8 (587 - 649)	18.9 (62)	DB1, DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Tuff:** Light-brown (5YR 6/4); vitric; common grayish-orange-pink (5YR 7/2) and pinkish-gray (5YR 8/1) pumice; rare felsic phenocrysts of feldspar; minor biotite; rare lithic fragments; sphene is present.	Tfbw
197.8 - 205.4 (649 - 674)	7.6 (25)	DA	None	**Nonwelded Tuff:** Grayish-orange-pink (5YR 7/2); vitric, lesser silicic; common grayish-orange-pink (5YR 7/2) pumice; minor felsic phenocrysts of feldspar; common biotite; sphene is present; common grayish-brown (5YR 3/2), moderate-reddish-brown (10R 4/6), and pale-brown (5YR 5/2) lithic fragments of various volcanic lithologies.	
205.4 - 220.4 (674 - 723)	14.9 (49)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Bedded Tuff:** Light-brown (5YR 6/4) and pale-yellowish-brown (10YR 6/2); mostly zeolitic, partially silicic; common light-brown (5YR 5/6) to very-pale-orange (10YR 8/2) pumice; felsic phenocrysts include minor feldspar and trace quartz; common biotite; common grayish-red-purple (5RP 4/2) and dusky-brown (5YR 2/2) volcanic lithic fragments; sphene is present.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit** [d]
220.4 - 230.1 (723 - 755)	9.8 (32)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Bedded Tuff:** Grayish-orange (10YR 7/4) and yellowish-gray (5Y 8/1); mostly zeolitic, partially silicic; common yellowish-gray (5Y 8/1) pumice; minor felsic phenocrysts of feldspar; common biotite; common grayish-red-purple (5RP 4/2) and dusky-brown (5YR 2/2) lithic fragments of various volcanic lithologies; sphene is present.	Tfbw
230.1 - 241.7 (755 - 793)	11.6 (38)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Bedded Tuff:** Pale-reddish-brown (10R 5/4), pale-red (10R 6/2), and grayish-yellow (5Y 8/4); zeolitic, weakly silicic throughout; minor pale-reddish-brown (10R 5/4), yellowish-gray (5Y 8/1), and white (N9) pumice; common felsic phenocrysts of feldspar and lesser quartz; common biotite; pseudomorphs after sphene are present; common lithic fragments of various colors and volcanic lithologies. Moderately well developed honeycomb textures and iron oxide staining.	Tmawr
241.7 - 258.5 (793 - 848)	16.8 (55)	DA	None	**Bedded Tuff and Tuffaceous Sediments:** Bedded tuff intervals at 241.7 to 250.5 m (793 to 822 ft) and 256.6 to 258.5 m (842 to 848 ft); tuffaceous sediments from 250.5 to 256.6 ft (822 to 842 ft). *Bedded Tuff:* Grayish-yellow (5Y 8/4) and very-pale-orange (10YR 8/2); zeolitic; common moderate-yellow (5Y 7/6) and very-pale-orange (10YR 8/2) pumice; minor felsic phenocrysts of quartz and feldspar; abundant biotite; minor very-dusky-red (10R 2/2), brownish-black (5YR 2/1), and moderate-brown (5YR 4/4) lithic fragments. *Tuffaceous Sediments:* Moderate-brown (5YR 4/4), light-brown (5YR 6/4), and light-brown (5YR 5/6); moderately to strongly consolidated; not calcareous; medium to coarse sand with lesser very coarse sand and gravel. Sand is very tuffaceous, poorly to moderately sorted, subangular to subrounded, and consists of quartz and feldspar crystals, biotite flakes, welded tuff and rhyolitic lava fragments, and fine ash. Coarser sands and gravels are angular to subangular and consist of welded tuffs, nonwelded tuffs, lavas, and zeolitic pumice clasts.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit** [d]
258.5 - 262.7 (848 - 862)	4.3 (14)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Ash-Flow Tuff:** Grayish-orange-pink (5YR 7/2), and light-brown (5YR 6/4); zeolitic, weakly argillic; common white (N9) to yellowish-gray (5Y 8/1) pumice; common felsic phenocrysts of feldspar and lesser quartz; abundant biotite; minor very-dusky-red (10R 2/2) lithic fragments; sphene is present. Honeycomb textures and iron oxide staining were observed.	Tmawr
262.7 - 328.0 (862 - 1,076)	65.2 (214)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately to Densely Welded Ash-Flow Tuff:** Moderate-brown (5YR 4/4), moderate-brown (5YR 3/4), and light-brown (5YR 5/6); devitrified and silicic above 305.7 m (1,003 ft), becoming mostly devitrified and much less silicic below; weakly vitrophyric in upper portion; conspicuous flow texture above 304.8 m (1,000 ft), remnant perlitic texture below; minor medium-gray (N5) pumice; common felsic phenocrysts of quartz and feldspar; very abundant biotite; rare lithic fragments; sphene is present. Slickensides observed at depth 268.2 to 271.3 m (880 to 890 ft); honeycomb textures and iron oxide staining observed throughout; sample at 280.4 to 283.5 m (920 to 930 ft) contains abundant light-brownish-gray (5YR 6/1), altered fragments with bronze-colored biotite; fractures observed up to approximately 9 mm wide filled with an iron oxide stained, fine-grained silica matrix with clasts of moderately welded ash-flow tuff.	
328.0 - 363.9 (1,076 - 1,194)	36.0 (118)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Bedded Tuff:** Very-pale-orange (10YR 8/2); zeolitic, weakly argillic; minor white (N9) to very-pale-orange (10YR 8/2) pumice; minor to common felsic phenocrysts of feldspar and quartz; rare to minor biotite; abundant angular, dark-reddish-brown (10R 3/4), moderate-brown (5YR 3/4), dusky-yellowish-brown (10YR 2/2), and very-dusky-red (10R 2/2), lithic fragments of dense, devitrified and silicic, moderately to densely welded tuff and peralkaline lava. Very lithic-rich zones occur at 328.0 to 334.7 m (1,076 to 1,098 ft), 348.4 to 353.3 m (1,143 to 1,159 ft), and 356.9 to 359.1 m (1,171 to 1,178 ft) (Lithic-rich intervals picked off the induction and gamma ray logs.)	Tmawp
363.9 - 373.1 (1,194 - 1,224)	9.1 (30)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Tuff:** Light-brown (5YR 6/4); mildly quartzo-feldspathic; common white (N9) to very-pale-orange (10YR 8/2) pumice; minor felsic phenocrysts of feldspar and conspicuous quartz; abundant biotite. Samples contain abundant lithic fragments, however, they are probably contamination from the overlying bedded tuff.	Tmar

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit** [d]
373.1 - 385.9 (1,224 - 1,266)	12.8 (42)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Ash-Flow Tuff:** Moderate-reddish-orange (10R 6/6); mildly quartzo-feldspathic; common grayish-orange-pink (10R 8/2) pumice; common felsic phenocrysts of feldspar and quartz (some dipyramidal); common biotite; rare lithic fragments.	Tmar
385.9 - 393.2 (1,266 - 1,290)	7.3 (24)	DA	None	**Partially Welded Ash-Flow Tuff:** Light-brown (5YR 6/4); quartzo-feldspathic, weakly argillic; rare pumice; minor to common felsic phenocrysts of feldspar and conspicuous quartz; abundant biotite; minor moderate-brown (5YR 3/4) and dusky-brown (5YR 2/2) lithic fragments (probably from up-hole), some partially coated with a white (N9) to very-pale-orange (10YR 8/2) zeolitic matrix. Numerous hairline fractures filled with silica.	
393.2 - 445.6 (1,290 - 1,462)	52.4 (172)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately Welded Ash-Flow Tuff:** Moderate-brown (5YR 4/4); mildly quartzo-feldspathic; weakly spherulitic; common pumice; common felsic phenocrysts of feldspar and conspicuous quartz; abundant biotite; rare brownish-black (5YR 2/1) lithic fragments. Numerous hairline fractures filled with silica.	
445.6 - 469.1 (1,462 - 1,539)	23.5 (77)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately Welded Ash-Flow Tuff:** Brownish-gray (5YR 4/1), medium-dark-gray (N4), grayish-brown (5YR 3/2), and moderate-brown (5YR 3/4); moderately quartzo-feldspathic; minor pumice; common felsic phenocrysts of feldspar, many partially altered, pseudomorphs after feldspar, and conspicuous quartz; minor biotite; numerous hairline fractures filled with silica.	
469.1 - 762.0 (1,539 - 2,500) TD	292.9 (961)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately to Densely Welded Ash-Flow Tuff:** Moderate-brown (5YR 4/4), moderate-reddish-brown (10R 4/6), and pale-red-purple (5RP 6/2); mildly to moderately quartzo-feldspathic, weakly calcareous in lower portion; common, pale- reddish-brown (10R 5/4), moderate-yellowish-brown (10YR 5/4), and moderate-brown (5YR 4/4) pumice; common felsic phenocrysts of partially altered feldspar, pseudomorphs after feldspar, and conspicuous quartz; very abundant biotite; rare dark-reddish-brown (10R 3/4), very-dusky-red (10R 2/2), and pale-red (5R 6/2) lithic fragments; numerous hairline fractures filled with silica; fractures observed up to approximately 7 mm wide filled with iron-oxide-stained, fine grained silica matrix with clasts of moderately welded ash-flow tuff.	

NOTES

a **DA** = drill cuttings that represent lithologic character of interval; **DB1** = cuttings enriched in hard components; **SC** = sidewall core.

b **PTS** = polished thin section; **XRD** = X-ray diffraction; **XRF** = X-ray fluorescence; Fe^{2+}/Fe^{3+} = wet chemical analysis for iron.

c Descriptions are based mainly on visual examination of lithologic samples using a 10x- to 40x-zoom binocular microscope and geophysical logs. Additional data from laboratory analyses have been incorporated into the descriptions. Colors describe wet sample color.
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%

d **Typ** = Pliocene basalts; **Tgc** = Pliocene through Oligocene Alluvium; **Ttt** = Trail Ridge Tuff; **Ttp** = Pahute Mesa Tuff; **Tfbr** = rhyolite of Chukar Canyon; **Tfbw** = rhyolite of Beatty Wash; **Tmawr** = mafic-rich tuff of Buttonhook Wash; **Tmawp** = mafic-poor tuff of Buttonhook Wash; **Tmar** = mafic-rich Ammonia Tanks Tuff.

Appendix D
Geophysical Logs Run in Well ER-18-2

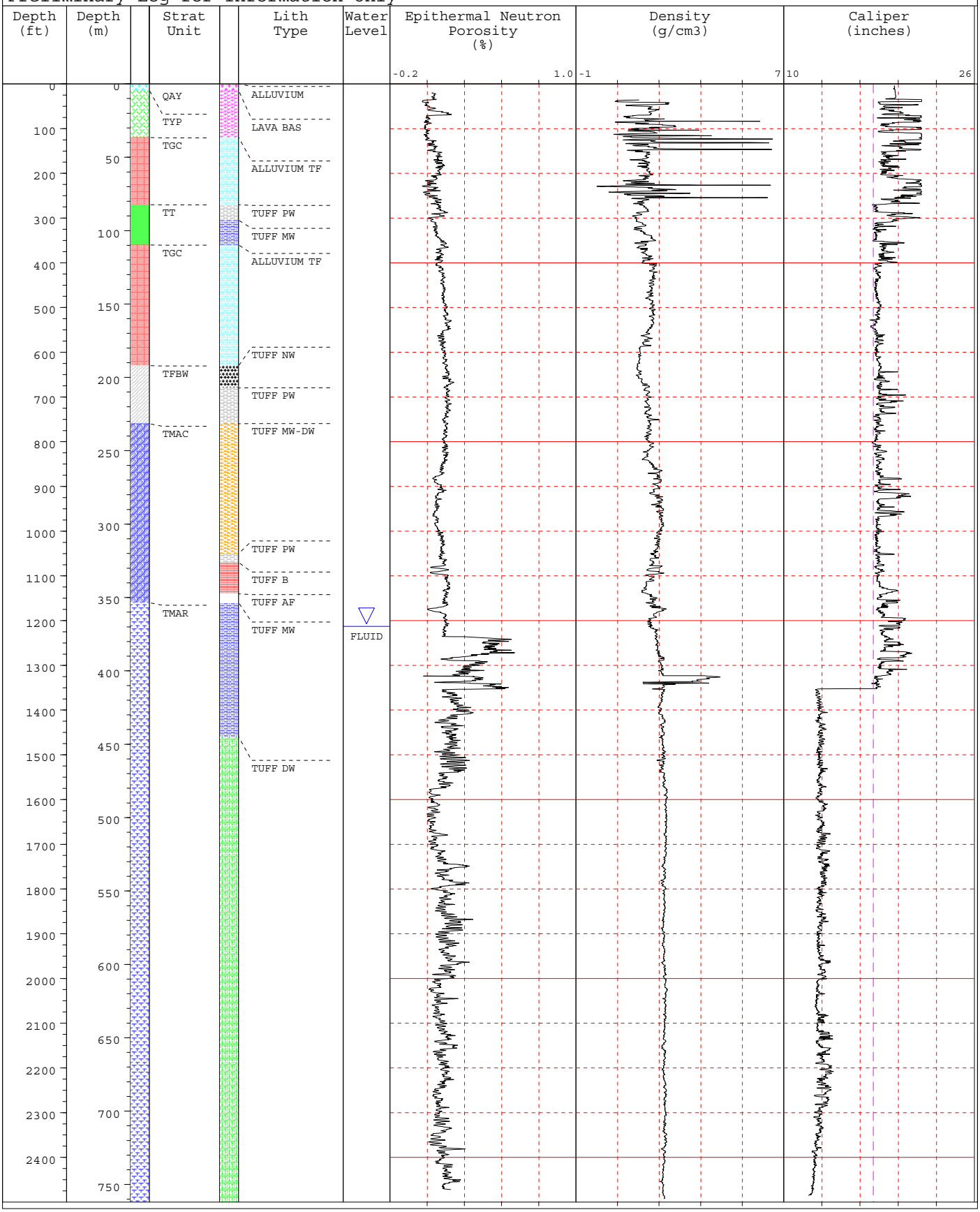
Appendix D contains unprocessed data presentations of selected geophysical logs run at Well ER-18-2. Table D-1 summarizes the logs presented. See Table 3-3 for more information on logs run in Well ER-18-2.

Table D-1
Well ER-18-2 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval meters	Log Interval feet
Epithermal Neutron Porosity	ENP-1 ENP-2	5/10/1999 5/15/1999	10.7 - 410.9 408.4 - 755.6	35 - 1,348 1,340- 2,479
Density	CDL-1 CDL-2	5/10/1999 5/15/1999	10.7 - 410.9 408.4 - 755.6	35 - 1,348 1,340- 2,479
Array Induction and Dual Laterolog (resistivity)	IND-1 DLL-1	5/10/1999 5/14/1999	10.7 - 411.8 418.8 - 754.1	35 - 1,351 1,374 - 2,474
Spontaneous Potential	SP-2	5/14/1999	418.8 - 754.1	1,374 - 2,474
Gamma Ray	GR-1 GR-4	5/9/1999 5/14/1999	10.7 - 411.8 204.2 - 748.0	35 - 1,351 670 - 2,454
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2	5/10/1999 5/15/1999	10.7 - 411.8 406.6 - 755.0	35 - 1,351 1,334 - 2,477
Chemistry (temperature, pH, electrical conductivity)	1	5/16/1999	396.2 - 755.6	1,300 - 2,479
Thermal Flow	1	5/16/1999	458.7 - 746.8	1,505 - 2,450

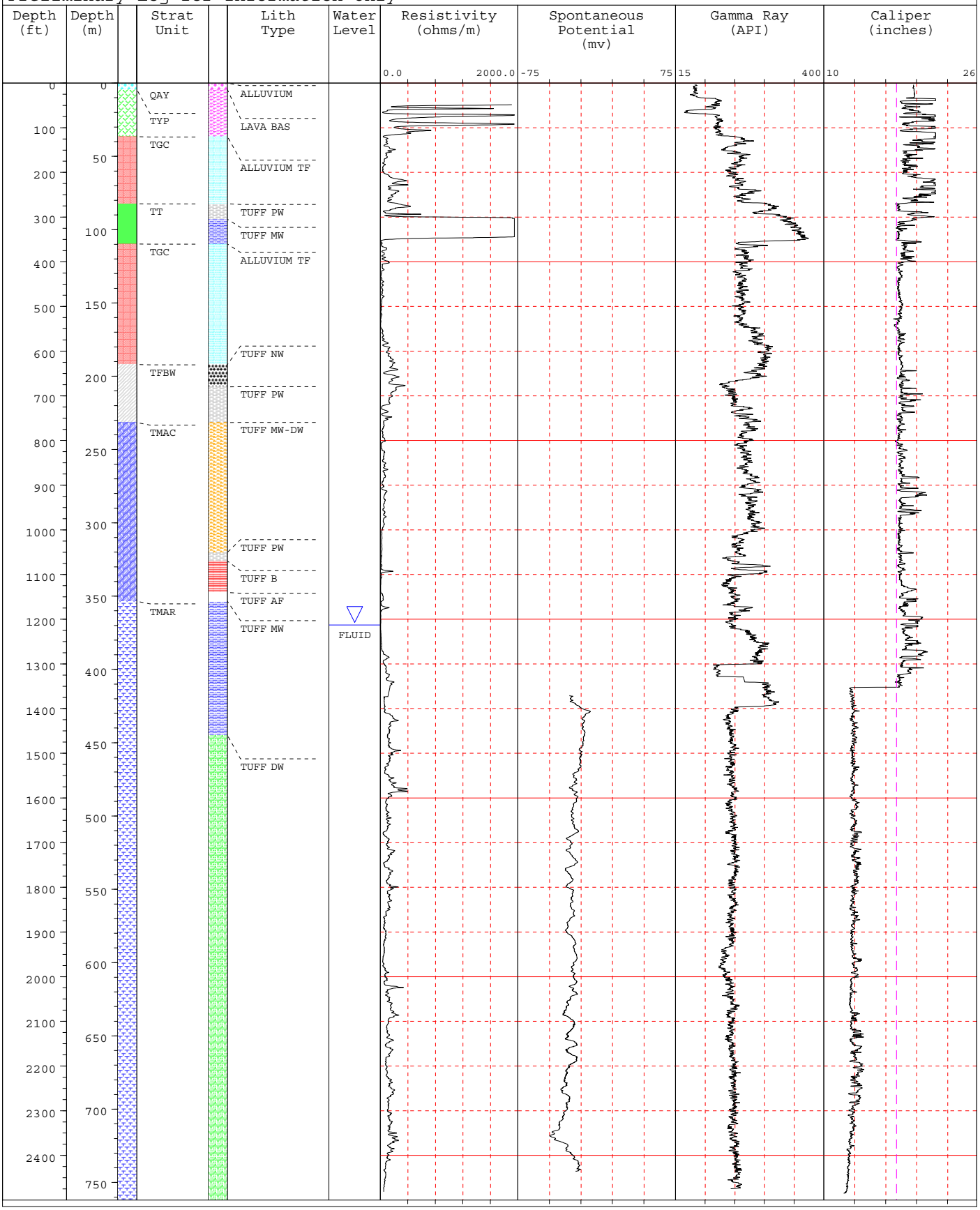
Well Name: ER-18-2	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4106585.8 m
Date: 7/28/99	Start Date: 5/3/99	Stop Date: 5/17/99	Easting: 555644.6 m
Environmental Contractor: UGTA/IT		Proj No: 776706.02.08.04.02	Surface Elevation:5437.1 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft.

Preliminary Log for Information Only



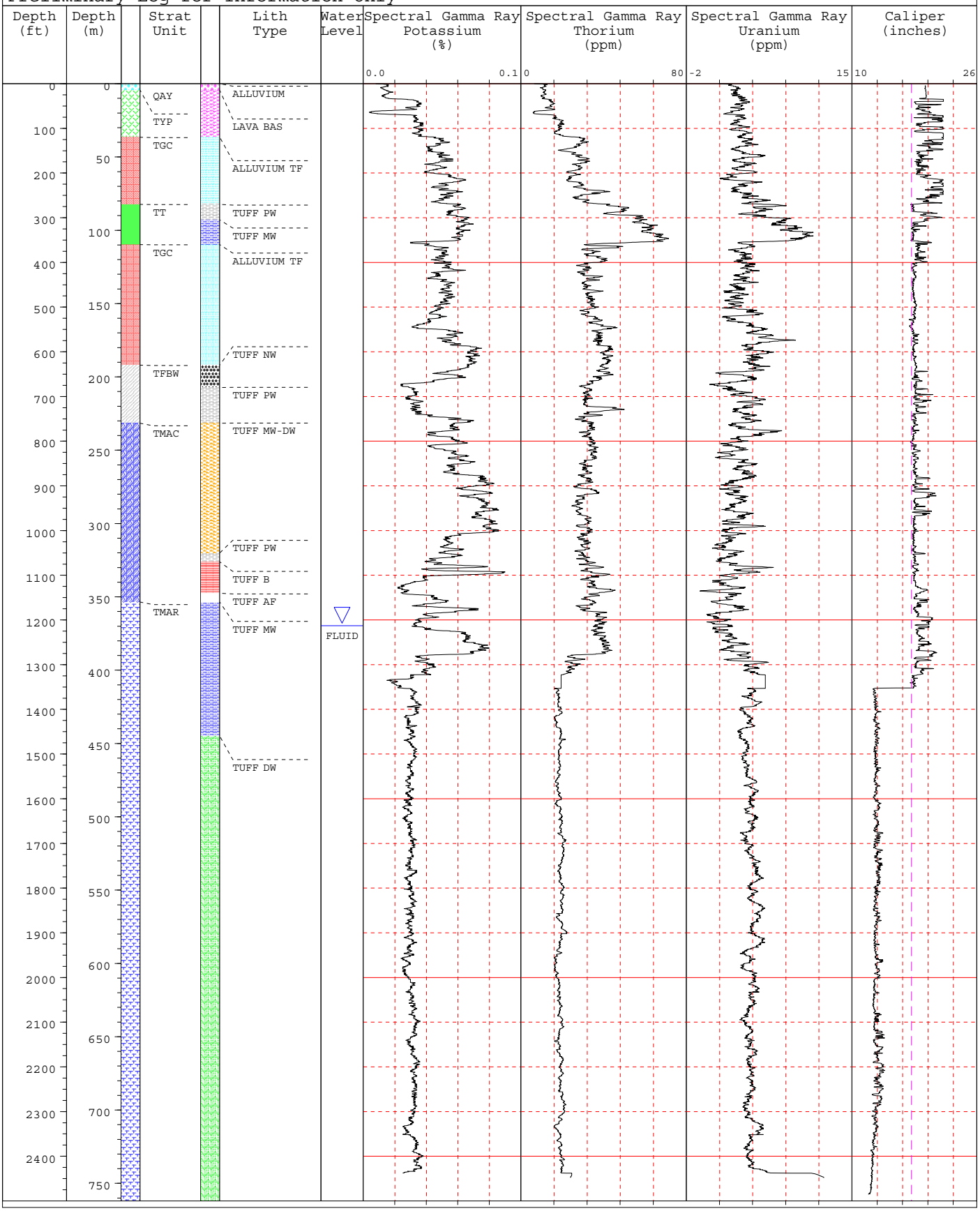
Well Name: ER-18-2	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4106585.8 m
Date: 7/28/99	Start Date: 5/3/99	Stop Date: 5/17/99	Easting: 555644.6 m
Environmental Contractor: UGTA/IT		Proj No: 776706.02.08.04.02	Surface Elevation:5437.1 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft.

Preliminary Log for Information Only



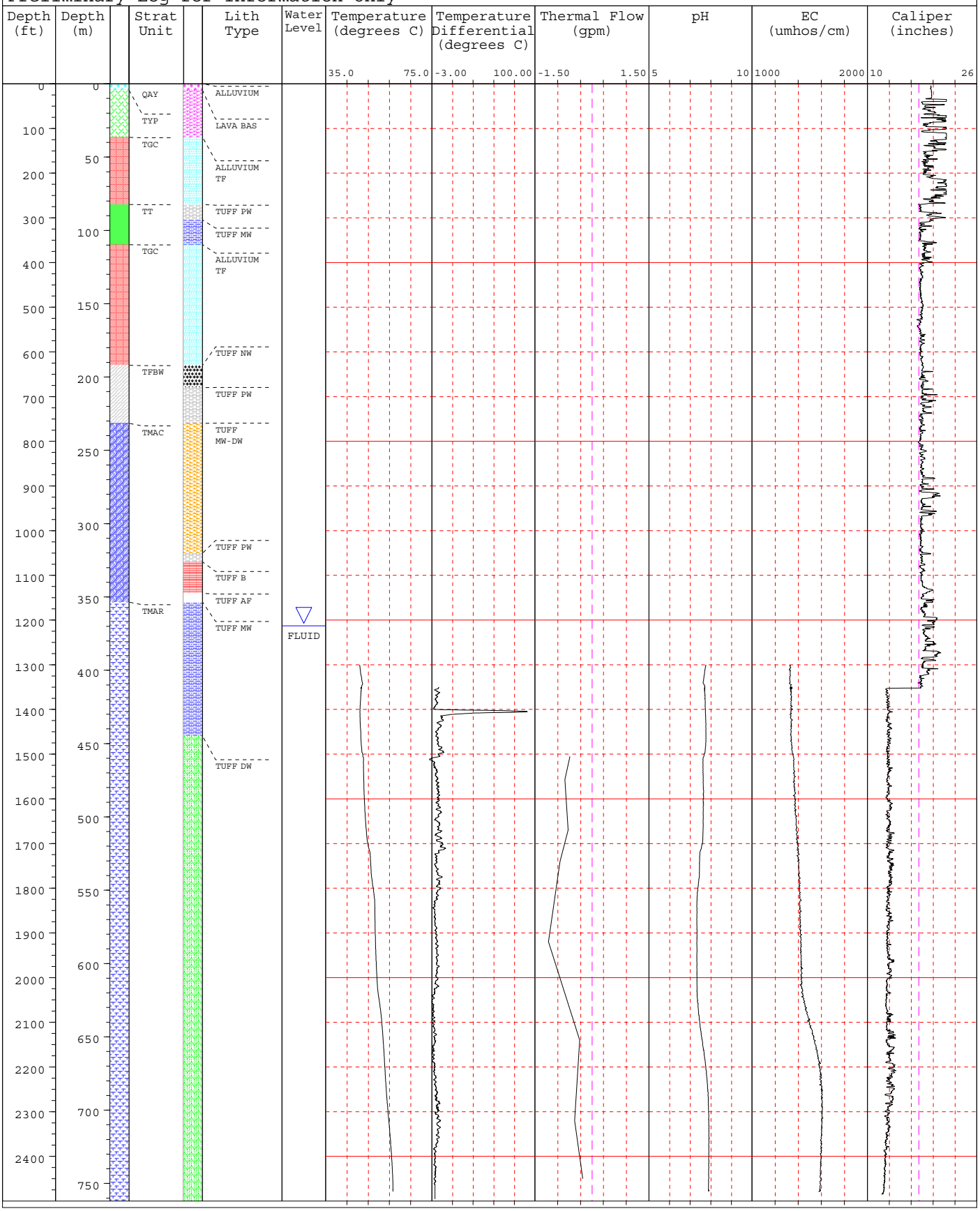
Well Name: ER-18-2	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4106585.8 m
Date: 7/28/99	Start Date: 5/3/99	Stop Date: 5/17/99	Easting: 555644.6 m
Environmental Contractor: UGTA/IT		Proj No: 776706.02.08.04.02	Surface Elevation:5437.1 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft.

Preliminary Log for Information Only



Well Name: ER-18-2	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4106585.8 m
Date: 7/28/99	Start Date: 5/3/99	Stop Date: 5/17/99	Easting: 555644.6 m
Environmental Contractor: UGTA/IT		Proj No: 776706.02.08.04.02	Surface Elevation:5437.1 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft.

Preliminary Log for Information Only



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