DOE/NV/11718--424

Nevada
Environmental
Restoration
Project

Completion Report for Well ER-EC-5

October 2004

Environmental Restoration
Division

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

DOE/NV/11718--424

Completion Report for Well ER-EC-5

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

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Las Vegas, Nevada

October 2004

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COMPLETION REPORT FOR WELL ER-EC-5

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Completion Report for Well ER-EC-5
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ABSTRACT

Well ER-EC-5 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 was drilled in the summer of 1999 as part of the U.S. Department of Energy's hydrogeologic investigation program in the Western Pahute Mesa - Oasis Valley region just west of the Nevada Test Site. A 44.5-centimeter surface hole was drilled and cased off to a depth of 342.6 meters below ground surface. The borehole diameter was then decreased to 31.1 centimeters for drilling to a total depth of 762.0 meters.

One completion string with three isolated slotted intervals was installed in the well. A preliminary composite, static water level was measured at the depth of 309.9 meters, 40 days after installation of the completion string.

Detailed lithologic descriptions with stratigraphic assignments are included in the report. These are based on composite drill cuttings collected every 3 meters, and 18 sidewall samples taken at various depths below 349.6 meters, supplemented by geophysical log data and results from detailed chemical and mineralogical analyses of rock samples. The well penetrated Tertiary-age tuffs of the Thirsty Canyon Group, caldera moat-filling sedimentary deposits, lava of the Beatty Wash Formation, and landslide breccia and tuffs of the Timber Mountain Group. The well reached total depth in welded ash-flow tuff of the Ammonia Tanks Tuff after penetrating 440.1 meters of this unit, which is also the main water-producing unit in the well. The geologic interpretation of data from this well constrains the western margin of the Ammonia Tanks caldera to the west of the well location.

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List of Acronyms and Abbreviations

BHA	bottom-hole assembly
BN	Bechtel Nevada
C	Celsius
cm	centimeter(s)
DOE	U.S. Department of Energy
DRI	Desert Research Institute
E	East
EC	Electrical Conductivity
F	Fahrenheit
FMP	Fluid Management Plan
ft	foot (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)
Ma	million years ago
mi	mile(s)
N	North
NAD	North American Datum
NNSA/NSO	U.S. Department of Energy, 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-EC-5 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-EC-5 is the fifth in a series of wells to be 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 for more accurate modeling of groundwater flow and radionuclide migration in the region. Some of the wells may also function as long-term monitoring wells.

Well ER-EC-5 is located within the Nellis Air Force Range complex, approximately 10.5 kilometers (km) (6.5 miles [mi]) west of the NTS (Figure 1-1), in the Timber Mountain caldera complex, near the western structural margin of the Ammonia Tanks caldera. The elevation of the dirt-fill drill pad at the wellhead is 1,547.5 meters (m) (5,077.0 feet [ft]) above mean sea level. The Nevada State Planar coordinates (North American Datum [NAD] 1983) at the wellhead are North (N) 6,259,008.5 and East (E) 508,998.3 m (N 20,534,763.8, E 1,669,938.7 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 company was United Drilling, Incorporated (UDI), a subcontractor to Bechtel Nevada (BN). Site supervision, engineering,

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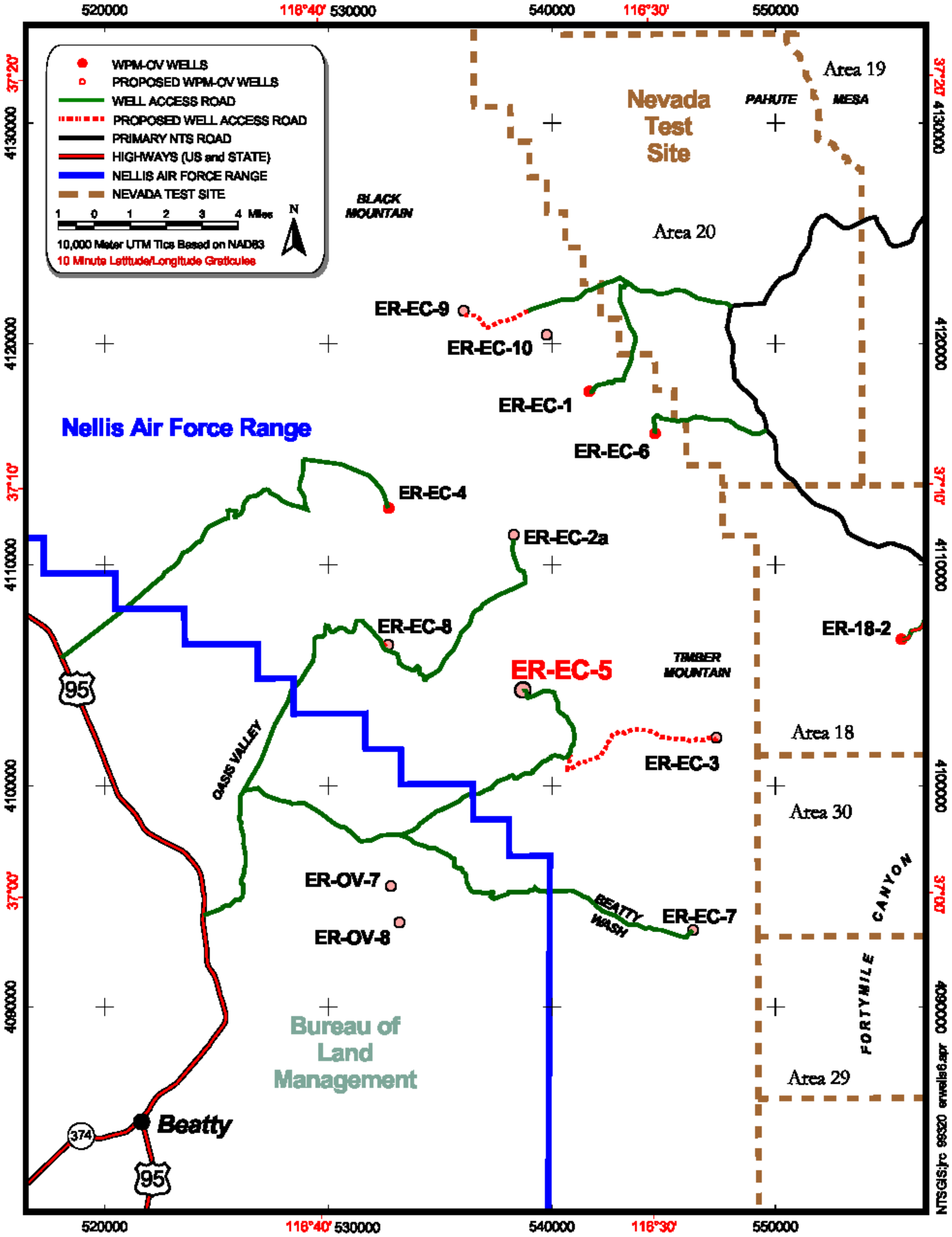

Figure 1-1
Reference Map Showing Location of Well ER-EC-5
(Proposed wells not drilled at time Well ER-EC-5 was drilled.)

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Table 1-1
Well ER-EC-5 Site Data Summary

Well Designation	ER-EC-5
Site Coordinates [a]	Central Nevada State Planar (NAD 83): N 6,259,008.5 m (N 20,534,763.8 ft) E 508,998.3 m (E 1,669,938.7 ft) Central Nevada State Planar (NAD 27): N 849,762.4 ft E 529,783.0 ft Universal Transverse Mercator (Zone 11)(NAD 83): N 4,104,333.9 m E 538,621.6 m
Surface Elevation [b]	1,547.5 m (5,077.0 ft)
Drilled Depth	762.0 m (2,500 ft)
Fluid-Level Depth [c]	309.9 m (1,016.8 ft)
Fluid-Level Elevation	1,237.5 m (4,060.2 ft)

a Measurement BN Survey.
b Measurement by BN Survey. Elevation at top of drill pad. 1929 National Geodetic Vertical Datum.
c Measured by IT on August 19, 1999, approximately 40 days after completion string was installed (IT, 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-RP-08-95NV11808 and in BN Drilling Work Plan Number D-006-002.99 (BN, 1999b). 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 drilling, design, and construction of the well. See *FY99 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 according to the Nevada

Environmental Restoration Project Health and Safety Plan (DOE, 1998) and the Site-Specific Health and Safety Plan for WPM-OV Investigation Wells (BN, 1999a).

This report presents construction data and summarizes scientific data gathered during drilling and installation of the completion string in Well ER-EC-5. A preliminary well data report prepared by IT (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 compiled and disseminated after any such work is performed.

1.2 Objectives

The primary purpose of Well ER-EC-5 is to provide information about hydrostratigraphic units, geologic structures, and bulk hydraulic properties in this part of the WPM-OV area. Well-specific scientific objectives, as discussed in Appendix E of the drilling criteria document (IT, 1998), include the following:

- Provide hydrogeologic information on the east side of a geophysically inferred, north-northeast striking structure which may be a hydraulic barrier.
- Investigate the effects that rocks filling the moat of the Timber Mountain caldera have on local groundwater flow.

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

1.3 Project Summary

This section summarizes Well ER-EC-5 construction operations; the details are provided in sections 2 through 8 of this report.

The surface conductor hole was prepared in June 1999, by augering a 91.4-centimeter (cm) (36-inch [in.]) hole to a depth of 10.7 m (35 ft) and then deepening the hole to 21.8 m (71.5 ft) at a diameter of 66.0 cm (26 in.). A section of 20-in. conductor casing was set at 21.3 m (70.0 ft) below ground level, and cementing was completed on June 10, 1999.

Drilling of the main hole with a 17½-in. rotary bit, using air-foam and polymer in conventional (direct) circulation, began on June 24, 1999, after completion of Well ER-EC-4. A suitable depth to set casing was reached at 346.3 m (1,136 ft). At this point, drilling was suspended for geophysical logging, and then 13d-in. surface casing was landed at the depth of 342.6 m (1,124.1 ft), approximately 32.7 m (107.3 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), which was reached on July 4, 1999.

Water production was first noted at the depth of approximately 306.9 m (1,007 ft), and reached a maximum of over 4,542 liters per minute (lpm) (1,200 gallons per minute [gpm]) near the bottom of the hole. The preliminary, composite static water level prior to installation of the completion string was approximately 310.3 m (1,018 ft) below ground surface. On August 19, 1999, over a month after installation of the completion string, the fluid level was tagged by IT at a depth of 309.9 m (1,016.8 ft). No radionuclides above natural background levels were encountered during drilling of Well ER-EC-5.

Composite drill cuttings were collected every 3.0 m (10 ft) from 21.3 m (70 ft) to TD, and 18 sidewall core samples were taken at various depths below 349.6 m (1,147 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 tuffs of the Thirsty Canyon Group, caldera moat-filling sedimentary deposits, lava of the Beatty Wash Formation, and landslide breccia and tuffs of the Timber Mountain Group. Welded ash-flow tuff of the Ammonia Tanks Tuff, penetrated in the lowest 440.1 m (1,444 ft) of the well, was the main water-producing unit.

A single completion string was installed in Well ER-EC-5 on July 9, 1999. Stainless steel, 5½-in. production casing was landed at 746.5 m (2,449.0 ft). The bull-nosed string has three slotted intervals, at 684.5 to 736.8 m (2,245.7 to 2,417.2 ft), 576.8 to 638.3 m (1,892.4 to 2,094.0 ft), and 364.7 to 426.3 m (1,196.6 to 1,398.5 ft). Internally epoxy-coated, 7e-in. carbon-steel casing extends (via a crossover sub) from the top of the 5½-in. casing at 352.4 m (1,156.2 ft) to the ground surface. The completion string was gravel-packed across the slotted intervals, and the remaining annular space was sealed with sand and cement to 219.5 m (720 ft) on July 10, 1999. No pump was installed at the time of completion.

1.4 Project Manager

Inquiries concerning Well ER-EC-5 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 are described in *FY99 Western Pahute Mesa-Oasis Valley Hydrogeologic Investigation Wells Drilling and Completion Criteria* (IT, 1998), which also includes criteria for Well ER-EC-5 in Appendix E. Specific requirements for Well ER-EC-5 are outlined in Drilling Work Plan Number D-006-002.99 (BN, 1999b). The following information was compiled primarily from 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-EC-5. A summary of drilling statistics for the well 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

Field operations at Well ER-EC-5 began on June 3, 1999, when a BN crew rigged up the "Auger 2" drill rig and augered a 66.0-cm (26-in.) hole to a depth of 9.1 m (30 ft). On June 7, 1999, the hole was opened using a 36-in. auger bit to the depth of 10.7 m (35 ft). The 36-in. auger was then exchanged for the 26-in. auger, and drilling continued to the depth of 21.8 m (71.5 ft). On June 10, 1999, a section of 20-in. conductor casing was set at a depth of 221.3 m (70.0 ft). The bottom of the casing was cemented inside to a depth of 18.9 m (62 ft), and the annulus was cemented from the bottom of the casing up to ground level on the same day. The auger rig was then moved off location.

Preparations for the drilling of the main hole, including delivering and setting up equipment on site, began June 21, 1999. A Wilson Mogul 42B drilling rig was mobilized to the Well ER-EC-5 site, and the UDI crew made up a bottom-hole assembly (BHA) with a 17½-in rotary bit; drilling began on June 24, 1999. Cement inside the conductor casing was drilled from the depth of 18.9 m (62.0 ft) to 21.8 m (71.5 ft) where rock was encountered. Conventional circulation was used with compressed air, water and soap (i.e., air-foam), and polymer drilling fluid. The amounts of soap and polymer in the air-foam/polymer mix and the fluid injection rate were adjusted as necessary during drilling to maintain superior circulation and penetration rate, and to minimize borehole sloughing.

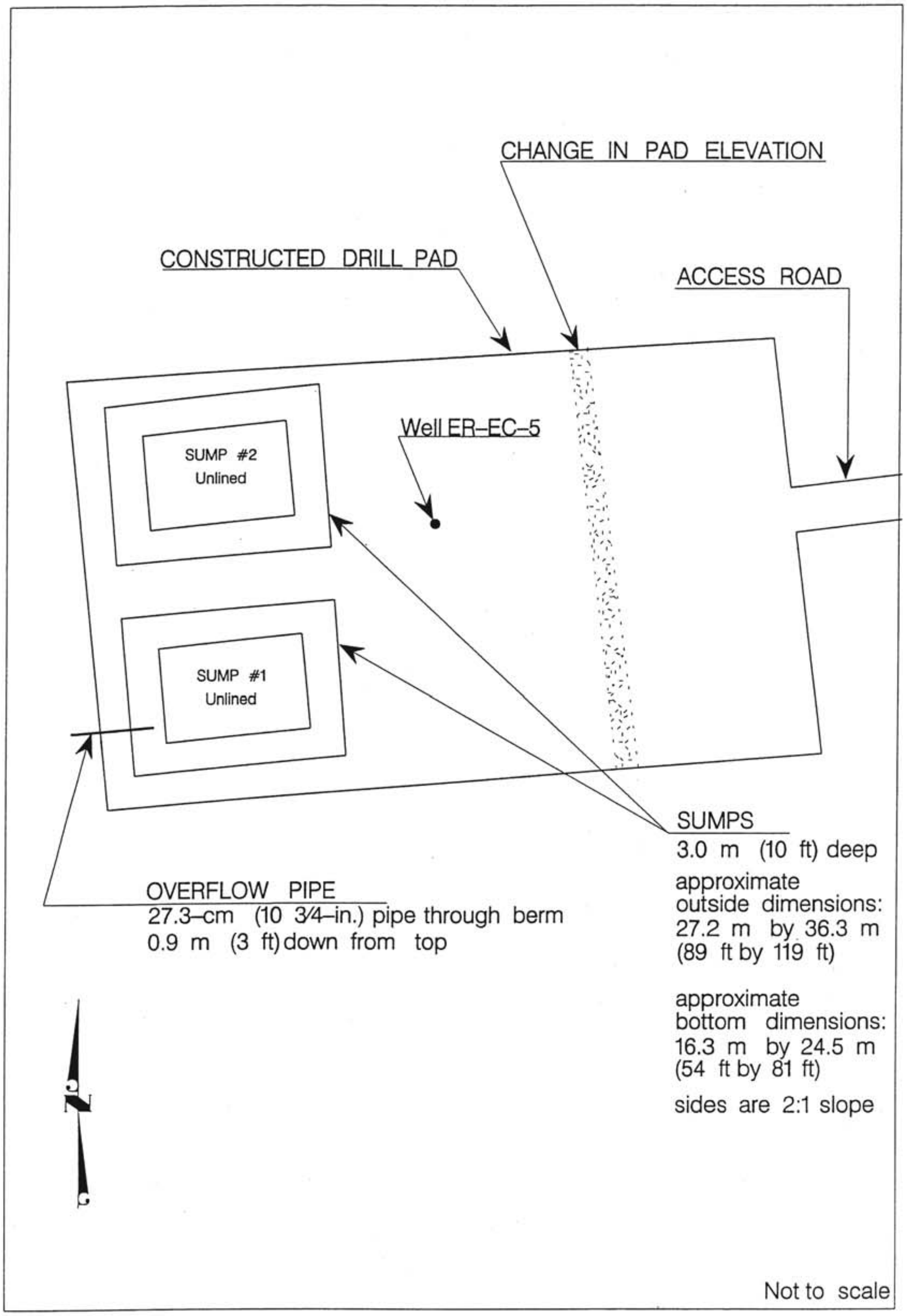
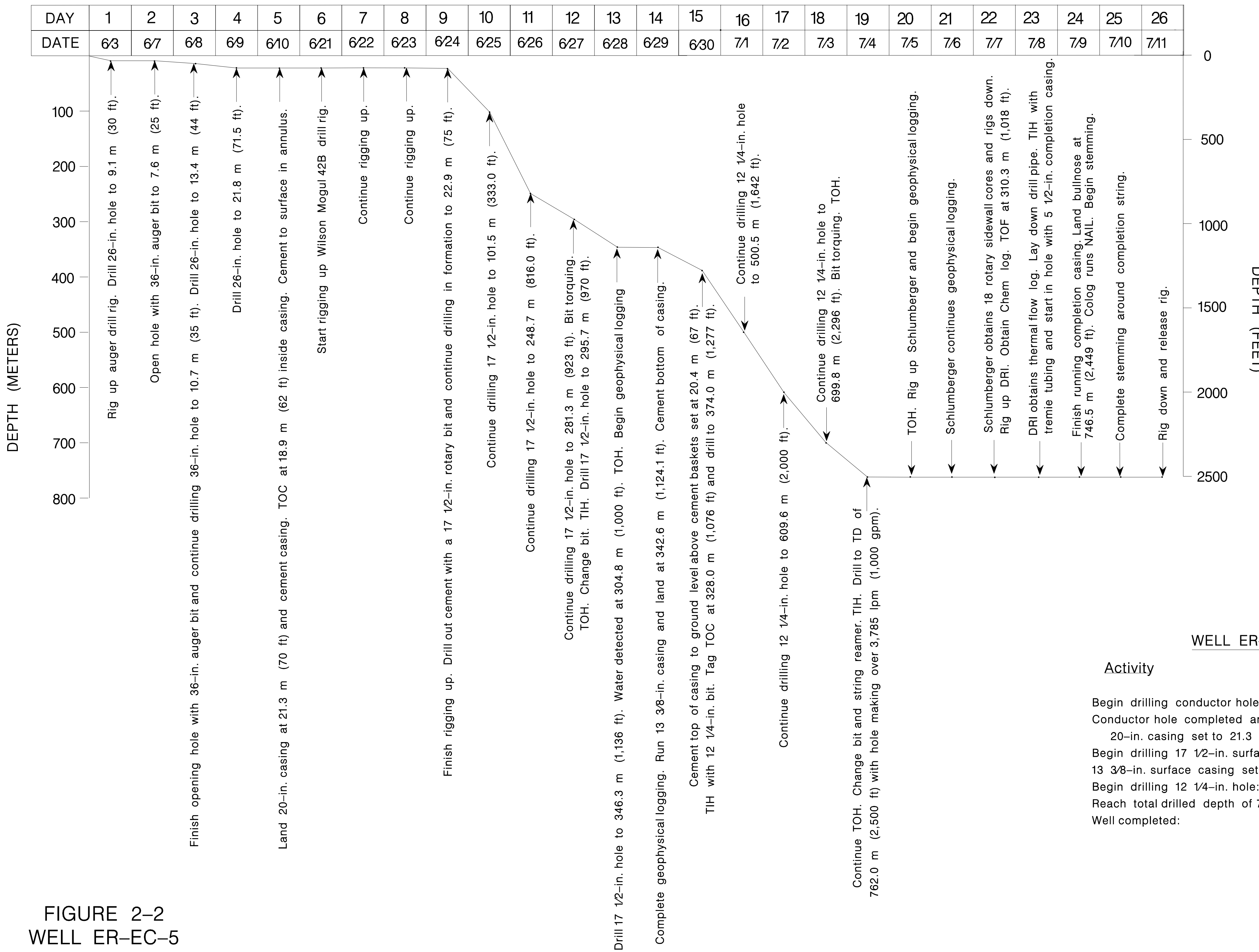


Figure 2-1
Drill Site Configuration for Well ER-EC-5



LEGEND

DRI	Desert Research Institute
NAIL	Nuclear Annulus Investigation Log
TD	Total depth
TIH	Trip into hole
TOH	Trip out of hole
TOC	Top of cement
TOF	Top of fluid
lpm	Liters per minute
gpm	Gallons per minute

WELL ER–EC–5 SUMMARY

Activity	Date
Begin drilling conductor hole:	6/3/1999
Conductor hole completed and 20–in. casing set to 21.3 m (70 ft):	6/10/1999
Begin drilling 17 1/2–in. surface hole:	6/24/1999
13 3/8–in. surface casing set at 342.6 m (1,124.1 ft):	6/29/1999
Begin drilling 12 1/4–in. hole:	6/30/1999
Reach total drilled depth of 762.0 m (2,500 ft):	7/4/1999
Well completed:	7/10/1999

FIGURE 2–2
WELL ER–EC–5
DRILLING AND COMPLETION HISTORY

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Table 2-1
Abridged Drill Hole Statistics for Well ER-EC-5

LOCATION DATA:

Coordinates:	Central Nevada State Planar:	NAD 83:	N 6,259,008.5	E 508,998.3 m
		NAD 27:	N 849,762.4	E 529,783.0 ft
	Universal Transverse Mercator:	NAD 83:	N 4,104,333.9	E 538,621.6 m

Surface Elevation [a]: 1,547.5 m (5,077.0 ft)

DRILLING DATA:

Spud Date:	6/24/1999 (main hole with Wilson Mogul 42B rig)
Total Depth (TD):	762.0 m (2,500 ft)
Date TD Reached:	7/4/1999
Date Well Completed [b]:	7/11/1999
Hole Diameter:	91.4 cm (36 in.) from 0 to 10.7 m (35 ft); 66.0 cm (26 in.) from 10.7 to 21.8 m (35 to 71.5 ft); 44.4 cm (17.5 in.) from 21.8 to 346.3 m (71.5 to 1,136 ft); 31.1cm (12.25 in.) from 346.3 m (1,136 ft) to TD of 762.0 m (2,500 ft).
Drilling Techniques:	Dry-hole auger from surface to 21.8 m (71.5 ft.); rotary drilling with 17½-in. bit and air-foam/polymer in direct circulation from 21.8 to 346.3 m (71.5 to 1,136 ft), and with 12¼-in. bit from 346.3 to 762.0 m (1,136 to 2,500 ft) (TD).

CASING DATA: 20-in. conductor casing from surface to 21.3 m (70.0 ft.); 13**d**-in. surface casing from surface to 342.6 m (1,124.1 ft).

WELL COMPLETION DATA:

The completion string consists of 7 **e**-in. carbon-steel casing with an internal epoxy coating, connected to 5½-in. stainless-steel casing via an internally coated carbon-steel crossover sub. The carbon-steel casing extends through the unsaturated zone approximately 42 m (139 ft) into the top of the saturated zone. The 14.0-cm (5½-in.) outside-diameter casing has a 12.83-cm (5.05-in.) inside diameter, is bull-nosed, and has three slotted intervals that each consist of alternating blank and slotted joints. Detailed data for the completion intervals are provided in Section 7 of this report.

Total Depth:	746.5 m (2,449 ft)		
Depth of Slotted Sections:	364.7 to 426.3 m (1,196.6 to 1,398.5 ft)	576.8 to 638.3 m (1,892.4 to 2,094.0 ft)	684.5 to 736.8 m (2,245.7 to 2,417.2 ft)
Depth of Sand Pack:[c]	356.3 to 361.8 m (1,169 to 1,187 ft)	559.3 to 565.4 m (1,835 to 1,855 ft)	668.7 to 677.6 m (2,194 to 2,223 ft)
Depth of Gravel Pack:[c]	361.8 to 440.1 m (1,187 to 1,444 ft)	565.4 to 654.1 m (1,855 to 2,146 ft)	677.6 to 755.9 m (2,223 to 2,480 ft)
Depth of Pump:	None installed at time of completion.		
Water Depth:[d]	309.9 m (1,016.8 ft)		

DRILLING CONTRACTOR: United Drilling, Inc.

GEOPHYSICAL LOGS BY: Barbour Well Surveying, Schlumberger Logging Services, Colog, Inc. Desert Research Institute, Gyrodata

SURVEYING CONTRACTOR: Bechtel Nevada

a Elevation of ground level at wellhead. 1929 National Geodetic Vertical Datum.
b Date completion string was cemented. Pump will be installed as needed.
c Gravel adjacent to slotted intervals only. Additional gravel layers were used as stemming outside blank casing sections. See Table 7-1.
d Measured on August 19, 1999, 40 days after completion string was installed (IT, 1999).

Drilling was slow between the depths of 247 and 305 m (810 and 1,000 ft) as various intervals of gravel and landslide breccia were encountered. At the depth of 281.3 m (923 ft), on June 27, 1999, the penetration rate slowed considerably and the bit began torquing, so the bit was replaced. Drilling continued to be slow until thick sections of bedded and ash-flow tuff were encountered below 305.4 m (1,002 ft). The first significant water production was noted at a depth of approximately 306.9 m (1,007 ft).

As a precaution against sloughing of the upper section of unsaturated volcanic rocks, it was planned to install surface casing when a competent formation for supporting the casing was reached. The bottom of the surface hole was reached in moderately welded ash-flow tuff at 346.3 m (1,136 ft) on June 28, 1999. The drillers circulated fluid to condition the hole for 30 minutes, then pulled four stands of pipe and waited 30 minutes before tagging bottom again. Only 0.6 m (2 ft) of fill was found, so the drillers pulled the drilling tools out of the hole. Drilling was suspended for approximately 20 hours during geophysical logging prior to installation of casing.

A casing subcontractor landed 13d-in. casing with centralizers installed above the guide shoe, at the middle and top of the first joint, and at the top of the second joint. A float collar was installed between the first and second joints. Two metal-petal cement baskets are located at 20.4 m (67.0 ft) below ground level. The casing was landed at 342.6 m (1,124.1 ft.) on June 29, 1999, and pre-flush clear water was pumped down the casing prior to cementing. A stab-in sub was seated in the float collar, and type II Portland cement was pumped inside the casing through the stab-in sub, followed by water to displace the cement. The annulus above the cement baskets was cemented to ground level in five stages, using a mix of cement and sand ("75/25"). Cementing of the surface casing was completed on June 30, 1999. The top of cement in the casing annulus was later determined from geophysical logs to be at the depth of 225.9 m (741 ft). The top of cement inside the casing was tagged at 328.0 m (1,076 ft) when drilling resumed.

A BHA made up with a 12¼-in. bit was used to drill the remainder of the borehole. Cement was drilled from 328.0 to 342.9 m (1,076 to 1,125 ft), and drilling continued through 3.4 m (11 ft) of fill before entering the formation. The bit was replaced again at the depth of 699.8 m (2,296 ft), and drilling of the 31.1-cm (12.25-in.) hole continued without major problems to the TD of 762.0 m (2,500 ft), reached on July 4, 1999.

Immediately after reaching TD, the drillers circulated fluid for an hour to condition the hole before the second phase of geophysical logging, which took place July 5 to 8, 1999. Installation of the completion string began on July 8, 1999. Demobilization from the Well ER-EC-5 site began after gravel-packing and cementing were completed on July 11, 1999.

A directional survey was run in the completion string of Well ER-EC-5 on October 19, 1999. The survey indicates that at the lowest surveyed depth of 737.3 m (2,419.0 ft), the hole had drifted 4.2 m (13.9 ft) to the east-southeast of the collar location. The hole is relatively straight, with 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 listing of casing materials. Drilling fluids and cements used in Well ER-EC-5 are listed in Appendix A-3.

2.3 Drilling Problems

No significant problems were encountered during the drilling of Well ER-EC-5. The rate of penetration was generally low between about 248.7 m (816 ft) and 304.8 m (1,000 ft) within an interval of gravel deposits and landslide breccias. Fluid circulation was temporarily lost at the depths of 163.4 and 751.3 m (536 and 2,465 ft), but was regained when the amounts of soap and polymer in the drilling fluid were increased, and the injection rate was increased.

Fill encountered (due to sloughing of the borehole wall) was minimal. No fill was found on most connections, though up to 1.5 m (5 ft) of fill was encountered on a few connections, and 3.4 m (11 ft) of fill was encountered when drilling resumed after cementing of the 13**d**-in casing. This sloughing did not result in significant drilling delays. However, an obstruction (or “bridge”) was encountered at the depth of 501.7 m (1,646 ft) during geophysical logging. The drillers used the drill bit to push the material to the bottom of the borehole, where approximately 6.1 m (20 ft) of fill remained prior to installation of the completion string.

2.4 Fluid Management

Drilling effluent was monitored according to the methods prescribed in the UGTA FMP (DOE, 1996a). The air-foam/polymer drill fluid was circulated down the inside of the drill string and back up the hole through the annulus (“conventional” circulation) and then discharged into a sump. Water used to prepare drilling fluids came from the Coffer Well located approximately 16 km (10 mi) north-northeast of Beatty, and a lithium bromide (LiBr) tracer was added as a means of estimating groundwater production.

To manage the expected high water production, two unlined sumps were constructed prior to drilling (Figure 2-1). One of the sumps was to be lined with plastic if concentrations of radionuclides or other contaminants in the fluid exceeded FMP requirements. Samples of drilling effluent were tested hourly for the presence of tritium, and every eight hours for lead. Monitoring results indicated tritium at natural background levels and no detectable lead, so the sumps were left unlined. Samples from the sumps were also analyzed by an off-site facility during and after drilling to verify on-site analyses and to demonstrate compliance with the FMP.

On July 1, 1999, fluid discharge was diverted from sump 1 to sump 2 (before the fluid level in sump 1 reached the overflow pipe), pending the results of the analysis of a fluid sample taken from the sump. The analysis showed values for analytes below the allowable FMP discharge levels, so on July 3, 1999, when both sumps were full, discharge was again routed to sump 1. Fluid was allowed to flow through the overflow pipe to the ground surface after sump fluid analysis results were relayed to the Nevada Division of Environmental Protection. Water-quality data from the FMP samples are given in Appendix B.

The results of analyses of samples of drilling fluid collected at Well ER-EC-5 during drilling operations indicate that all fluid quality objectives were met, as shown on the fluid management reporting form dated November 23, 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 fluid listed on the report is an estimate of total fluid production, and does not account for any infiltration or evaporation of fluids from the sumps.

3.0 Geologic Data Collection

3.1 Introduction

This section describes the sources of geologic data obtained from Well ER-EC-5 and the methods of data collection. Improving the understanding of the subsurface structure, stratigraphy, and hydrogeology of the area southwest of Pahute Mesa was among the primary objectives of Well ER-EC-5, so the proper collection of geologic and hydrogeologic data from Well ER-EC-5 was considered fundamental to successful completion of the project.

Geologic data collected at Well ER-EC-5 consist of drill cuttings, sidewall core samples, and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures.

3.2 Collection of Drill Cuttings

Composite drill cuttings were collected from Well ER-EC-5 at 3.05-m (10-ft) intervals as drilling progressed from the depth of 21.3 m (70 ft) to the TD of the well at 762.0 m (2,500 ft). Triplicate samples were collected from 243 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 field lithologic descriptions, and remains in the custody of Stoller-Navarro Joint Venture, the current environmental contractor for NNSA/NSO and IT's successor. The other set was sent to R. G. Warren (LANL), where it remains. All other samples (i.e., three sets of 243 samples) are stored under secure, environmentally controlled conditions at the U.S. Geological Survey (USGS) Geologic Data Center and Core Library in Mercury, Nevada. One of these sample sets was sealed with custody tape at the rig site and remains sealed as an archive sample; one set was left unsealed in the original sample containers; and the third set was washed and stored according to standard USGS Core Library procedures.

3.3 Sidewall Core Samples

No sidewall sampling was attempted from the surface hole at Well ER-EC-5 before installation of 13**d**-in. surface casing. On July 7, 1999, after TD was reached and before the completion string was installed, Schlumberger collected sidewall samples with a rotary coring tool. Eighteen samples were successfully collected out of 20 attempted between 349.6 and 745.2 m (1,147 and 2,445 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 below the depth of 346.3 m (1,136 ft). These samples will help verify the stratigraphy and lithology penetrated. A list of samples, including sample recovery and the stratigraphic assignment of each sample, is given in Table 3-1.

3.4 Sample Analysis

Twenty-three samples of drill cuttings from various depths in Well ER-EC-5 were submitted to the LANL Earth and Environmental Sciences Division - Geology and Geochemistry laboratories for petrographic, mineralogic, and chemical analyses to aid in stratigraphic identification and for characterization of mineral alteration. All planned 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 addition, logs were run to evaluate borehole conditions, to determine the 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 casing, and during stemming of the well (annulus investigation log). Some logs were run in both the saturated and unsaturated zones of the borehole, while others (e.g., thermal flow log, chemistry log, ultrasonic borehole imager 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.

A delay of over 13 hours during the second stage of logging was caused by a bridge in the hole (see Section 2.3). Several attempts were made to run the logging tools past the obstruction or knock it loose, but eventually it was necessary to pull out the logging tools and run the 12 ¼-in. bit into the hole to push the material down hole. Schlumberger was then rigged up again and logging continued. Over 11 hours of time was also lost due to the need to repair and/or replace several faulty Schlumberger logging tools. Overall, the quality of the geophysical data collected, however, was acceptable.

Table 3-1
Sidewall Core Samples from Well ER-EC-5

Core Depth [a] meters (feet)	**Length Recovered** cm (in.)	**Stratigraphic Unit** [b]
349.6 (1,147)	2.29 (0.9)	Tmar
365.8 (1,200)	4.06 (1.6)	
373.4 (1,225)	3.56 (1.4)	
376.4 (1,235)	3.56 (1.4)	
388.6 (1,275)	4.57 (1.8)	
438.9 (1,440)	4.06 (1.6)	
472.4 (1,550)	3.81 (1.5)	
528.8 (1,735)	3.81 (1.5)	
565.7 (1,856)	4.06 (1.6)	
580.0 (1,903)	3.81 (1.5)	
605.3 (1,986)	2.79 (1.1)	
624.8 (2,050)	3.56 (1.4)	
641.6 (2,105)	3.81 (1.5)	
648.3 (2,127)	3.05 (1.2)	
656.2 (2,153)	4.83 (1.9)	
711.4 (2,334)	2.29 (0.9)	Tmap
736.1 (2,415)	3.81 (1.5)	
745.2 (2,445)	4.32 (1.7)	

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

b Tmar =mafic-rich Ammonia Tanks Tuff; Tmap =mafic-poor Ammonia Tanks Tuff. See Appendix C for more information on the stratigraphy and lithology of Well ER-EC-5.

Table 3-2
Status of Rock Sample Analyses for Well ER-EC-5

Depth [a] meters (feet)	**Sample Type** [b]	**Analyses Performed** [c]			
		Petrographic	Mineralogic	Chemical	
		PTS	XRD	XRF	Fe^{2+}/Fe^{3+}
39.6 (130)	DP	C	C	C	C
70.1 (230)	DA	C	C	C	C
76.2 (250)	DA	C	C	C	C
88.4 (290)	DA	C	C	C	C
118.9 (390)	DA	C	C	C	C
131.1 (430)	DA	C	C	C	C
167.6 (550)	DA	C	C	C	C
240.8 (790)	DA	C	C	C	C
253.0 (830)	DA	C	C	C	C
271.3 (890)	DA	C	C	C	C
280.4 (920)	DA	C	C	C	C
298.7 (980)	DA	C	C	C	C
320.0 (1,050)	DA	C	C	C	C
347.5 (1,140)	DA	C	C	C	C
408.4 (1,340)	DA	C	C	C	C
463.3 (1,520)	DA	C	C	C	C
530.4 (1,740)	DA	C	C	C	C
582.2 (1,910)	DA	C	C	C	C
652.3 (2,140)	DA	C	C	C	C
685.8 (2,250)	DA	C	C	C	C
698.0 (2,290)	DA	C	C	C	C
743.7 (2,440)	DA	C	C	C	C
762.0 (2,500)	DA	C	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; **DP** = pumice fragment.
c **C** = analysis complete. Analysis type: **PTS** = polished thin section; **XRD** = x-ray diffraction; **XRF** = X-ray fluorescence; **Fe^{2+}/Fe^{3+}** = wet chemical analysis for iron.

Table 3-3
Well ER-EC-5 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)
* Natural Gamma Ray Spectroscopy	Stratigraphic correlation, mineralogy, natural and man-made radiation	Schlumberger	6/28/1999 7/6/1999	SGR-1 SGR-2	329.8 (1,082) 752.6 (2,469)	21.3 (70) 310.9 (1,020)
* Gamma Ray/Four Arm Caliper	Stratigraphic correlation/borehole conditions, cement volume calculation	Schlumberger	6/28/1999 7/5/1999	SGR-1/CA4-1 GR-2/CA4-2	344.4 (1,130) 761.7 (2,499)	21.3 (70) 342.6 (1,124)
* Epithermal Neutron/Density/ Gamma Ray/ Caliper	Total water content/borehole conditions	Schlumberger	6/28/1999 7/5/1999	ENP-1/CDL-1/ GR-1/CAL-1 ENP-2/CDL-2/ GR-3/CAL-2	338.3 (1,110) 761.4 (2,498)	21.3 (70) 173.1 (568)
* Array Induction Log/Caliper/Gamma Ray	Rock porosity, lithologic determination/stratigraphic correlation/borehole conditions	Schlumberger	6/28/1999	IND-1/GR-1/CAL-1	340.2 (1,116)	21.3 (70)
Oriented Color Video	Lithologic characterization, fracture and void analysis/ stratigraphic correlation/ hole conditions	Barbour Well Surveying	6/29/1999	1	332.2 (1,090)	Ground Level
* Dual Laterolog/Gamma Ray	Saturated zone: water saturation/ stratigraphic correlation	Schlumberger	7/5/1999	GR-4/DLL-1	757.4 (2,485)	342.6 (1,124)
Ultrasonic Borehole Imager/ Gamma Ray	Saturated zone: lithologic characterization, fracture and void analysis/stratigraphic correlation	Schlumberger	7/6/1999	BHTV-1/ SGR-2	752.6 (2,469)	556.0 (1,824)
Micro-resistivity Electronic scanner	Saturated zone: lithologic characterization/fracture and void analysis/stratigraphic correlation	Schlumberger	7/7/1999	FMS-1	576.1 (1,890)	342.6 (1,124)
Temperature/Gamma Ray	Saturated zone: groundwater temperature/ stratigraphic correlation	Schlumberger	7/5/1999	TL-1/GR-2	761.7 (2,499)	0

Table 3-3
Well ER-EC-5 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)
Gamma Ray/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	7/7/1999	GR-5/AC-1	753.8 (2,473) 753.8 (2,473)	304.8 (1,000) 304.8 (1,000)
Mechanical Sidewall Coring Tool	Geologic samples	Schlumberger	7/7/1999	MSCT-1	745.2 (2,445)	349.6 (1,147)
* Thermal Flow Log	Rate and direction of groundwater flow in borehole	Desert Research Institute	7/7/1999	1	755.9 (2,480)	310.6 (1,019)
* Chemistry Log	Groundwater chemistry, formation transmissivity	Desert Research Institute	7/7/1999	1	755.9 (2,480)	310.6 (1,019)
Nuclear Annulus Investigation Log	Well construction monitoring	Colog	7/9-10/1999	1	746.2 (2,448)	121.9 (400)
Gyroscopic Survey	Borehole deviation	Gyrodata	10/19/1999	1	737.3 (2,419)	7.6 (25)

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

b Depth below ground surface.

c Logging interval recorded on print of log. Discrete measurements were made at seven locations between the depths of 387.1 and 749.2 m (1,270 and 2,458 ft).

4.0 Geology and Hydrogeology

This section describes the geology and hydrogeology of Well ER-EC-5. The basis for the discussions in Section 4.0 is the detailed lithologic log presented in Appendix C. The detailed lithologic log was developed using drill cuttings and sidewall core samples, geophysical logs, drilling parameters, and nearby geologic exposures (Wahl et al., 1997). Interpretations by R. G. Warren of LANL (Warren 2003; Warren et al., 2003) of petrographic, mineralogic, and chemical analyses of selected lithologic samples from the well were evaluated and where appropriate, incorporated into the lithologic log.

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-EC-5 is located approximately 9.2 km (5.7 mi) west of the north peak of Timber Mountain, within the moat of the Timber Mountain caldera complex (TMCC) (Figure 4-1). The TMCC is composed of at least two nested calderas, the Rainier Mesa caldera and the younger Ammonia Tanks caldera. The formation of these calderas is the result of the eruption of the Rainier Mesa Tuff (erupted 11.6 million years ago [Ma] [Sawyer et al., 1994]) and the Ammonia Tanks Tuff (erupted 11.45 Ma [Sawyer, et al., 1994]), and both tuffs are considered part of the Timber Mountain Group. Following the collapse of the Ammonia Tanks caldera, resurgence of a central dome created the present topographic expression of the TMCC, including Timber Mountain and the surrounding “moat” (Figure 4-1). Younger volcanic rocks partially filled the moat, burying most of the Timber Mountain Group rocks within the moat. Moat-filling units exposed at the surface near Well ER-EC-5 (Figure 4-2; see also Lipman et al., 1966) consist mainly of tuff and lava of the Volcanics of Fortymile Canyon, erupted from various vents near the TMCC shortly after collapse of the Ammonia Tanks caldera, and younger ash-flow tuffs assigned to the Thirsty Canyon Group, erupted approximately 9.4 Ma (Sawyer et al., 1994) from the Black Mountain caldera located about 23 km (14 mi) north-northwest of the well (Figure 4-1).

The mapped surface geology in the vicinity of Well ER-EC-5 indicates that drilling started in the Pahute Mesa Tuff of the Thirsty Canyon Group (Figure 4-2). Rocks of the Thirsty Canyon Group are characterized by their general peralkaline mineralogy and lack of quartz phenocrysts (Wahl et al., 1997). So, based on the presence of clinopyroxene and olivine and lack of biotite (characteristics of

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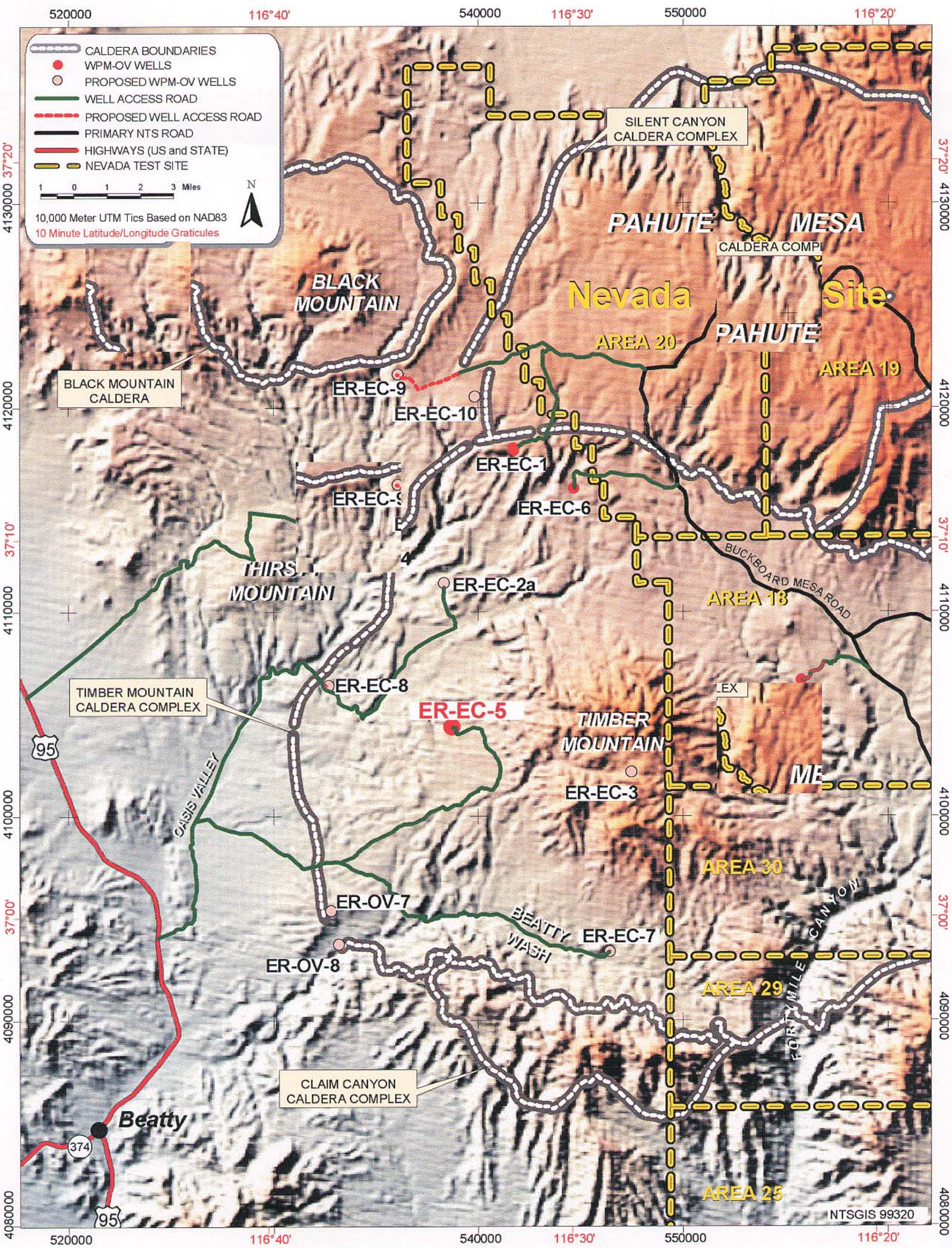

Figure 4-1
Map of Western Pahute Mesa - Oasis Valley Area Showing Theorized Locations of Caldera Boundaries (after Wahl et al., 1997)

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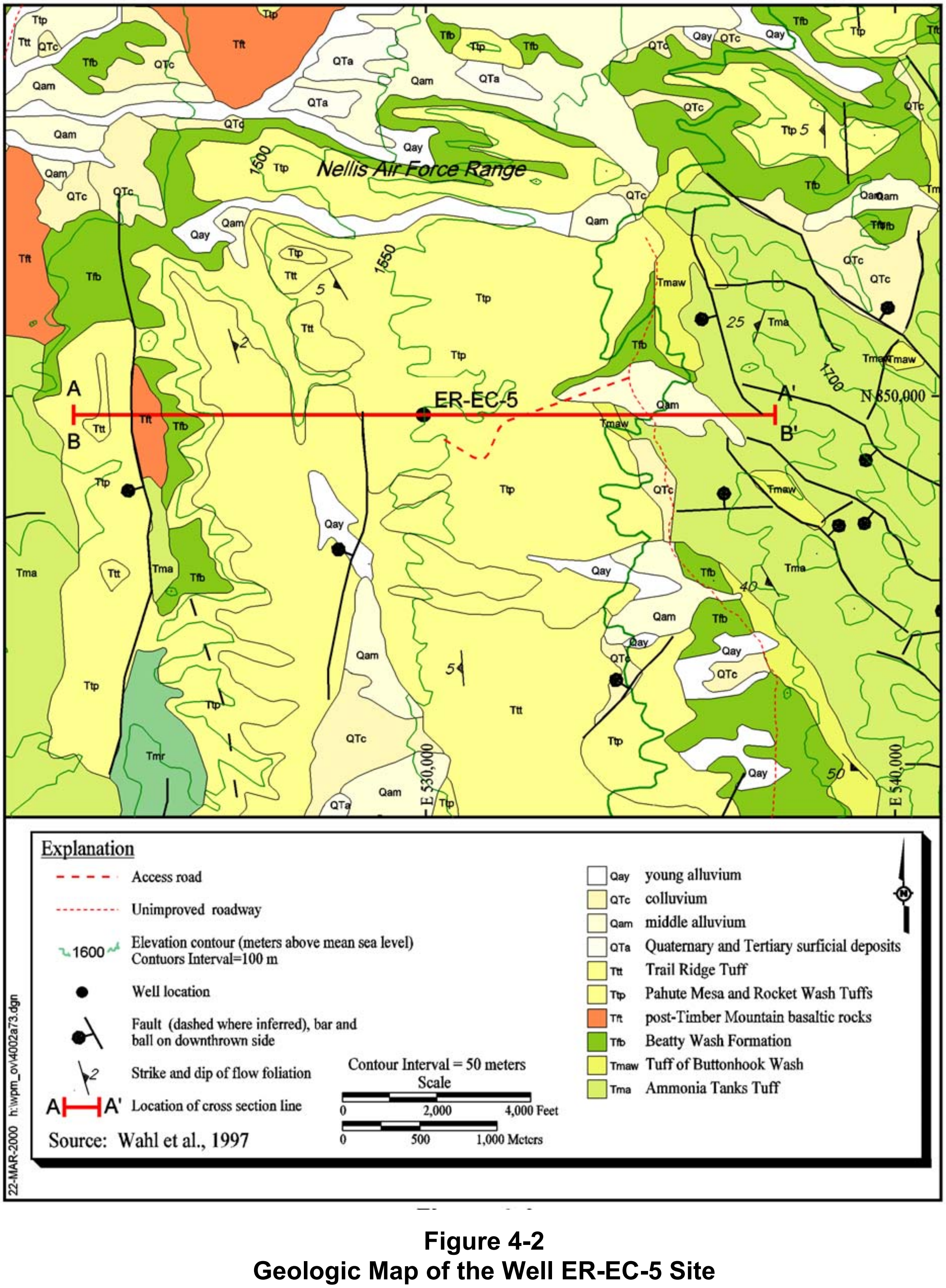

Figure 4-2
Geologic Map of the Well ER-EC-5 Site

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peralkaline mineralogy) and lack of quartz, the rocks encountered to the depth of 64.9 m (213 ft) in Well ER-EC-5 are assigned to the Thirsty Canyon Group. Below the partially to moderately welded Pahute Mesa ash-flow tuff, a thin, vitric, pumice-rich, nonwelded tuff was logged at the depth of 32.3 to 37.5 m (106 to 123 ft). This bed is interpreted to be a tephra, or pumice-fall, erupted as a precursor to the overlying Pahute Mesa Tuff. Based on this interpretation, the nonwelded ash-flow tuff below the depth of 37.5 m (123 ft) is assigned to the Rocket Wash Tuff of the Thirsty Canyon Group.

After penetrating 27.4 m (90 ft) of Rocket Wash Tuff, Well ER-EC-5 penetrated 56.4 m (185 ft) of mostly reworked tuff characterized by sand-size material in a finer grained zeolitic and weakly to moderately calcareous matrix. Sand-size material consists of pumice fragments, biotite flakes, sphene, hornblende, frosted feldspar and quartz grains, and subangular to subrounded lithic fragments of various tuffaceous volcanic rocks. Based on the location of Well ER-EC-5 within the moat of the TMCC and the stratigraphic position of this reworked tuff beneath the Thirsty Canyon Group, this interval is interpreted to be Miocene in age and therefore assigned to the Tertiary caldera moat-filling sedimentary deposits ("Tgc" in Wahl et al., 1997). Similar beds were encountered in the same stratigraphic position in wells ER-18-2 (DOE, 2003), UE-18r (Carr et al., 1968), and UE-18t (Byers and Hawkins, 1981), all drilled within the moat of the TMCC.

Beneath the moat-filling deposits, Well ER-EC-5 penetrated 125.6 m (412 ft) of nonwelded tuff assigned to the rhyolite of Beatty Wash (Figure 4-3), a subunit of the Beatty Wash Formation of the Volcanics of Fortymile Canyon. The assignment of this interval to the rhyolite of Beatty Wash is based on the presence of minor to common biotite and pseudomorphs after sphene, and the absence of quartz phenocrysts. Three distinct intervals of pumice-rich nonwelded tuff were identified, each separated by a thin (less than 6.1 m [20 ft] thick) reddish-brown bed. The reddish-brown beds are clearly indicated on geophysical logs by an increase in density and gamma ray radiation, and abrupt changes in electrical resistivity.

An interval of landslide breccia, tuffaceous gravels, and bedded and reworked tuffs 75.0 m (246 ft) thick was logged between the rhyolite of Beatty Wash and the Ammonia Tanks Tuff (Figure 4-3). These rocks are interpreted to be coarse alluvial and landslide debris shed from Timber Mountain during resurgence. From 246.9 to 268.2 m (810 to 880 ft), Well ER-EC-5 penetrated two intervals of landslide breccia separated by an interval of tuffaceous gravel. The cuttings samples for these intervals are dominated by angular (landslide breccia) to subangular and subrounded (tuffaceous gravel) clasts of biotite-poor, densely welded ash-flow tuff with a very sparse, coarse-grained, granular,

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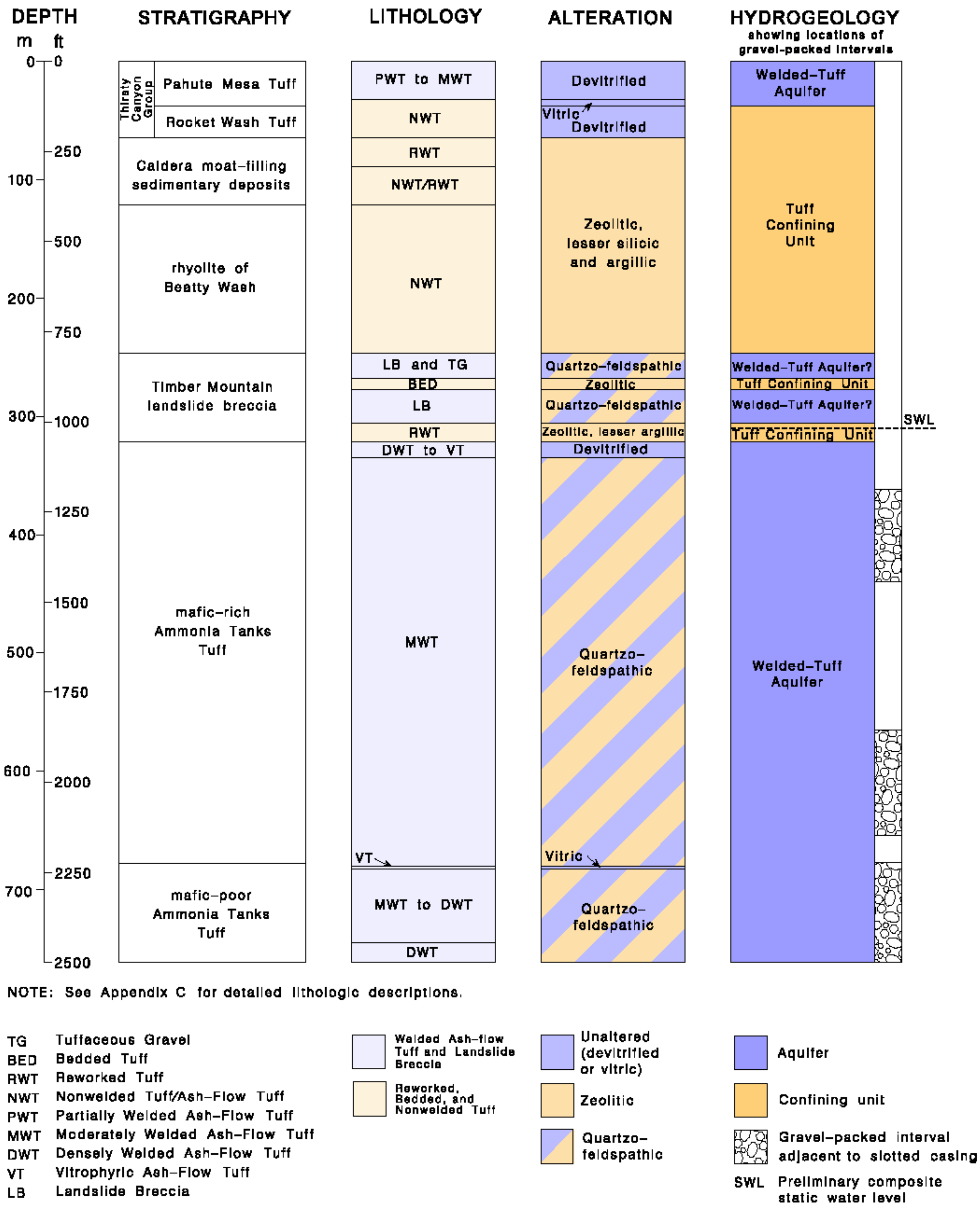

Figure 4-3
Geology and Hydrogeology of Well ER-EC-5

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tuffaceous matrix present on some of the fragments. Another landslide breccia with similar composition is present from 277.4 to 305.4 m (910 to 1,002 ft), separated from the upper landslide breccia by 9.1 m (30 ft) of bedded tuff. The cuttings samples of the bedded tuff are a mixture of tuffaceous lithologies consisting mostly of nonwelded and reworked tuff containing common zeolitic pumice fragments, quartz and feldspar phenocrysts, and biotite. Between the lowermost landslide breccia and the top of the Ammonia Tanks Tuff, from 305.4 to 321.9 m (1,002 to 1,056 ft), Well ER-EC-5 penetrated a very lithic-rich reworked tuff consisting of very abundant subangular to subrounded fragments of mafic-poor, densely welded tuff in a zeolitic, argillic, and moderately calcareous matrix.

The entire interval from 246.9 to 321.9 m (810 to 1,056 ft) described above, is given the stratigraphic assignment of Timber Mountain landslide breccia (Tmx) after Wahl et al. (1997) (Figure 4-3). As described by Wahl et al. (1997), this unit includes breccia emplaced as debris flows shed from the caldera walls during and after collapse of the Rainier Mesa and Ammonia Tanks calderas. A landslide breccia resulting from caldera collapse typically contains clasts of the older volcanic rocks that made up the caldera wall, such as the Paintbrush Group. However, the clasts in the breccia penetrated by Well ER-EC-5 all appear to be Ammonia Tanks-related (i.e., Tuff of Buttonhook Wash or Ammonia Tanks Tuff) based on the presence of biotite, trace sphene, and a significant abundance of quartz phenocrysts. The lack of clasts of older volcanic rocks implies that the clasts were not shed from a caldera wall, but rather were eroded from Timber Mountain during resurgence and uplift after the collapse of the Ammonia Tanks caldera.

Directly beneath the landslide breccia, Well ER-EC-5 penetrated 356.3 m (1,169 ft) of moderately welded to vitrophyric ash-flow tuff belonging to mafic-rich Ammonia Tanks Tuff; the well reached TD at 762.0 m (2,500 ft) within densely welded ash-flow tuff of the mafic-poor Ammonia Tanks Tuff (Figure 4-3). A total thickness of 440.1 m (1,444 ft) of welded Ammonia Tanks Tuff was penetrated by Well ER-EC-5, recognized by abundant felsic phenocrysts including feldspar and quartz, the presence of clinopyroxene, and a conspicuous increase in biotite content from the Beatty Wash Formation above. The transition from mafic-rich to mafic-poor Ammonia Tanks Tuff at 678.2 m (2,225 ft) is represented by a decrease in biotite content and a conspicuous increase in thorium and decrease in potassium on the natural spectral gamma ray log. Two intervals of vitrophyric ash-flow tuff were identified, one near the top of the mafic-rich Ammonia Tanks Tuff, and the other near the top of the mafic-poor section (Figure 4-3).

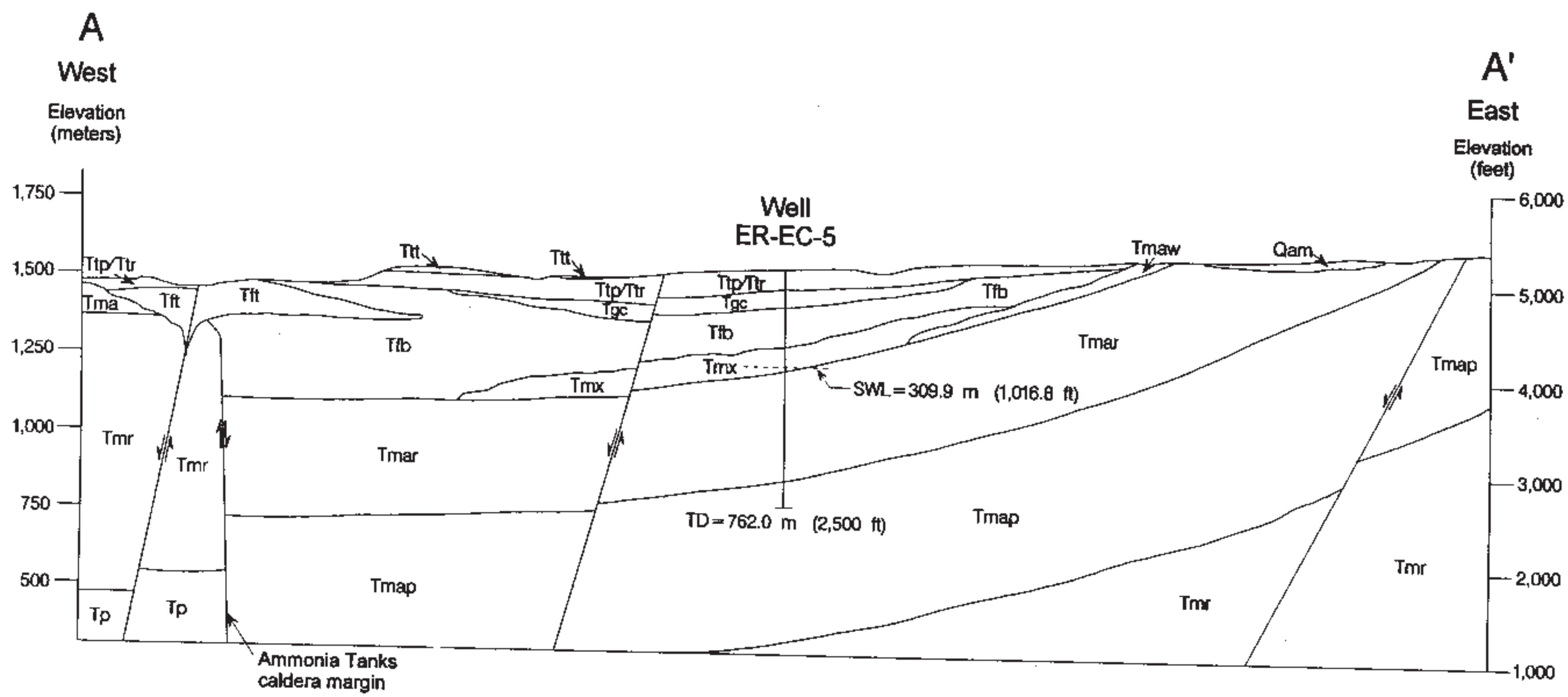
Although Well ER-EC-5 did not penetrate a complete section of Ammonia Tanks Tuff, stratigraphic information from the well strongly suggests that the well is located within the Ammonia Tanks caldera.

Ammonia Tanks Tuff within the Ammonia Tanks caldera is at least 762 m (2,500 ft) thick (see stratigraphic data for UE-18r in Warren et al. [2003]). At Well ER-EC-5, 440.1 m (1,444 ft) of Ammonia Tanks Tuff was penetrated before the hole reached TD just 83.8 m (275 ft) into the mafic-poor Ammonia Tanks Tuff, the lower subunit of the formation. In addition, the top of the mafic-rich Ammonia Tanks Tuff in Well ER-EC-5 is strongly welded, indicating that the less welded upper portion is missing, having probably been eroded off as a result of caldera resurgence. This suggests that Well ER-EC-5 is located within the Ammonia Tanks caldera, and that the caldera margin must be west of the well. This is consistent with previous interpretations (Wahl et al., 1997; Grauch et al., 1997; and Warren et al., 2000) that place the Ammonia Tanks caldera margin west of Well ER-EC-5 along the east side of the Transvaal Hills.

Alteration has a significant effect on both the general hydraulic character of volcanic rocks and on how radionuclides migrate through these rocks. The predominant type of mineralogic alteration observed in each stratigraphic unit encountered in Well ER-EC-5 is illustrated on Figure 4-3. Above the depth of 64.9 m (213 ft), the nonwelded to moderately welded ash-flow tuff of the Thirsty Canyon Group is mostly devitrified. Below 64.9 m (213 ft), to the base of the rhyolite of Beatty Wash at 246.9 m (810 ft), reworked and nonwelded tuffs are predominantly zeolitic, with lesser silicic and argillic alteration also present. Drill cuttings samples from the landslide breccia and the tuffaceous gravel intervals between the rhyolite of Beatty Wash and the Ammonia Tanks Tuff are mostly a concentrate of quartzo-feldspathic, densely welded tuff fragments with very little tuffaceous matrix visible. The lateral extent of these lithic-rich zones is unknown, however they are likely emplaced within an overall zeolitic matrix, as indicated by the interbedded zeolitic bedded and reworked tuffs within this interval. Underlying the Timber Mountain landslide breccia, to the bottom of the hole, rocks show higher temperature quartzo-feldspathic alteration except for the two thin intervals of vitrophyre from 321.9 to 335.0 m (1,056 to 1,099 ft) and from 680.6 to 682.8 m (2,233 to 2,240 ft), which are vitric to partially devitrified.

4.2 Predicted Versus Actual Geology

The predicted geology for Well ER-EC-5 (IT, 1998) was based on surface exposures (Wahl et al., 1997; Figure 4-2) and the locations of caldera margins as interpreted by Warren (1994). A comparison of the predicted and the actual stratigraphy is provided in Figure 4-5. Located within the Southwestern Timber Mountain Moat structural block, a structural block characterized by thick intra-caldera Ammonia Tanks and Rainier Mesa tuffs (Warren, 1994; Warren et al., 2000), the well was



SWL	Preliminary composite static water level
TD	Total depth
(fault symbol)	Fault showing relative sense of movement

Qam	Middle Alluvium
Ttt	Trail Ridge Tuff
Ttp/Ttr	Pahute Mesa Tuff/Rocket Wash Tuff
Tgc	Caldera moat-filling sedimentary deposits
Tft	Post-Timber Mountain Group basalts and andesites
Tfb	Beatty Wash Formation
Tmx	Timber Mountain landslide breccia
Tmaw	tuff of Buttonhook Wash
Tma	Ammonia Tanks Tuff, undivided
Tmar	mafic-rich Ammonia Tanks Tuff
Tmap	mafic-poor Ammonia Tanks Tuff
Tmr	Rainier Mesa Tuff
Tp	Paintbrush Group

Scale

0 2,000 4,000 Feet

0 500 1,000 Meters

No vertical exaggeration

Figure 4-4
Geologic Cross Section A-A' Through Well ER-EC-5

predicted to reach TD within the Ammonia Tanks Tuff after penetrating approximately 609.6 m (2,000 ft) of Ammonia Tanks Tuff welded ash-flow tuff. Due mainly to the presence of a 56.4-m (185-ft) thick interval of Tertiary caldera moat-filling sediments and 75.0 m (246 ft) of Timber Mountain landslide breccia, the top of the Ammonia Tanks Tuff was penetrated almost 200 m (655 ft) deeper than expected. As a result, only 440.1 m (1,444 ft) of Ammonia Tanks Tuff was actually drilled in Well ER-EC-5 at the planned TD of 762.0 m (2,500 ft). As discussed above, it is likely the well has penetrated only the upper portion of a very thick intra-caldera sequence of Ammonia Tanks Tuff, placing Well ER-EC-5 within the Ammonia Tanks caldera (Figure 4-4), consistent with pre-drilling interpretations.

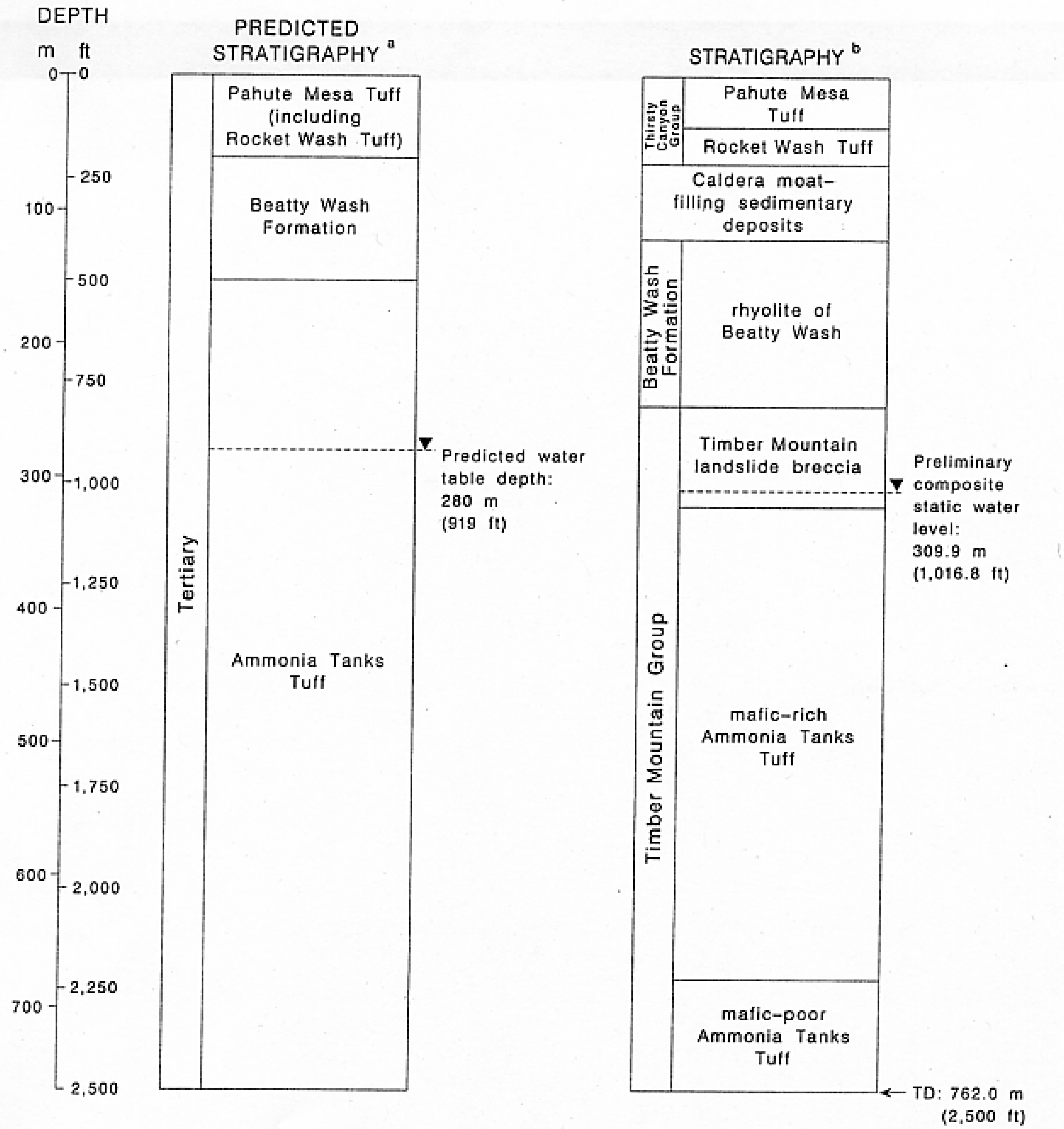
Although Tertiary caldera moat-filling sediments were not predicted to occur in Well ER-EC-5, their presence is not surprising because these sediments are exposed extensively at the surface within the moat of the TMCC. Moat-filling sediments are also present in the same stratigraphic position in wells ER-18-2, UE-18r, and UE-18t, all located within the moat.

Also not predicted was the interval of landslide breccia directly overlying the Ammonia Tanks Tuff. No similar interval has been recognized above the Ammonia Tanks Tuff in other holes drilled within the moat; however, the presence of this unit in Well ER-EC-5 is not surprising due to its proximity to the rising Timber Mountain dome.

4.3 Hydrogeology

As predicted (IT, 1998), the only saturated aquifer encountered in Well ER-EC-5 consists of the moderately welded to vitrophyric ash-flow tuffs of the Ammonia Tanks Tuff (Figure 4-3). This welded-tuff aquifer is at least 440.1 m (1,444 ft) thick in the Well ER-EC-5 vicinity. Although the welded ash-flow tuffs are dense and have very low primary permeability, they are expected to support a well-interconnected fracture system through which groundwater can flow. Lithologic observations and data from geophysical logs suggest that fracture zones may be present in the welded tuff near the depths of 503 and 594 m (1,650 and 1,950 ft), two intervals where increases in water production were noted during drilling.

The characterization of unsaturated units is important because they may be saturated in other portions of the model area, and thus may affect groundwater flow elsewhere. Rocks in the unsaturated zone of Well ER-EC-5 have hydrologic properties of either welded-tuff aquifer or tuff confining unit (Figure 4-3). The partially to moderately welded ash-flow tuffs of the Pahute Mesa Tuff are



NOTES:

a IT, 1998
b See Appendix C for detailed lithologic descriptions.

Surface Elevation (pad): 1,547.5 m (5,077.0 ft)
Nevada Coordinates (NAD 1983): N 20,534,763.8 ft; E 1,669,938.7 ft
Completed: 7/11/1999

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

grouped as a welded-tuff aquifer. However, most of this interval is partially welded ash-flow tuff which may be less supportive of fractures, and thus have a lower transmissivity than an aquifer made up of higher density tuffs. Underlying this welded-tuff aquifer is a thick tuff confining unit made up mostly of zeolitic nonwelded and reworked tuffs of the rhyolite of Beatty Wash and Tertiary caldera moat-filling sedimentary deposits. The devitrified, nonwelded tuff of the overlying Rocket Wash Tuff is also included with the tuff confining unit because it is not expected to bear open fractures.

Separating this tuff confining unit from the welded-tuff aquifer of the Ammonia Tanks Tuff is an interval consisting of landslide breccia, tuffaceous gravel, and bedded and reworked tuff. The bedded and reworked tuffs are zeolitic, forming two thin (9.1 m [30 ft] and 16.5 m [54 ft] thick) tuff confining units. The cuttings samples of the landslide breccia and tuffaceous gravels consist mostly of pieces of densely welded ash-flow tuff with very little matrix apparent. Therefore, in the immediate vicinity of Well ER-EC-5, these rocks will likely have hydrologic properties equivalent to a welded-tuff aquifer. However, the well may have been drilled into a very lithic-rich lens of an otherwise more matrix-supported zeolitic bedded tuff, or into a single very large boulder emplaced within a zeolitic matrix, and the overall properties may be more similar to those of a tuff confining unit.

Figure 4-6 is a hydrogeologic cross section through the Well ER-EC-5 vicinity, illustrating the complexities associated with predicting the lateral continuity of hydraulic properties of volcanic rocks in caldera settings. See the discussion of general hydraulic properties of expected WPM-OV units in IT (1998), Section E.6.2 and Table E.6-1. Proposed hydrologic testing in the WPM-OV wells will verify the actual hydraulic character of these units.

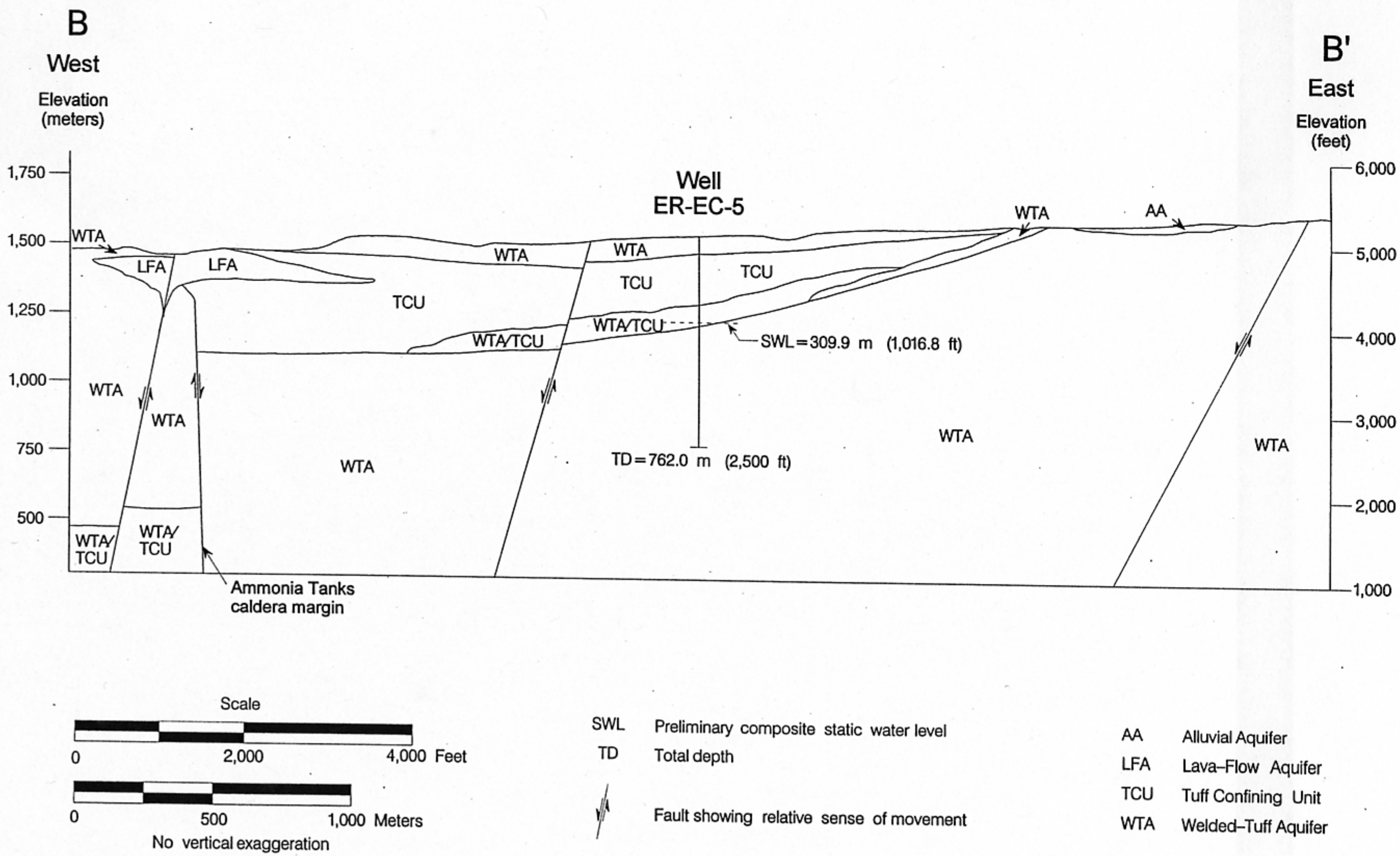


Figure 4-6
Hydrogeologic Cross Section B-B' Through Well ER-EC-5

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5.0 Hydrology

5.1 Preliminary Water-Level Information

The elevation of the water table at Well ER-EC-5 was projected to be approximately 1,268 m (4,161 ft), 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 to be approximately 280 m (919 ft) (IT, 1998). Groundwater was first detected at approximately 306.9 m (1,007 ft). On June 29, 1999, before the 13d-in. surface casing was set, a fluid depth of 332.2 m (1,090 ft) was obtained from a down-hole camera survey. A fluid depth of 310.3 m (1,018 ft) was obtained from the chemical log obtained July 7, 1999, before the completion string was installed. On July 19, 1999, after the completion string was set, IT obtained a fluid-level depth in the well of 310.0 m (1,017.3 ft). On August 19,1999, over a month after installation of the completion string, IT measured the depth to fluid at 309.9 m (1,016.8 ft) (IT, 1999). Based on this last composite fluid level depth and the as-built surface elevation of 1,547.5 m (5,077.0 ft), the fluid level elevation at Well ER-EC-5 is 1,237.5 m (4,060.2 ft). This is approximately 30 m (100 ft) below the predicted elevation of 1,268 m (4,161 ft).

5.2 Water Production

Water production was estimated by IT field personnel during drilling, on the basis of how much the LiBr additive was diluted (IT, 1999). The Ammonia Tanks Tuff was the primary water-producing unit at this location, as expected (see Section 4.0). Detectable water production, estimated at about 7.6 lpm (2 gpm), began at the depth of approximately 306.9 m (1,007 ft) within the Timber Mountain landslide breccia. Water production remained low until a depth of approximately 365.8 m (1,200 ft) was reached in welded, mafic-rich Ammonia Tanks Tuff, where it began steadily to increase. Water production reached about 946 lpm (250 gpm) at a depth of about 411 m (1,350 ft); it remained fairly steady to the depth of about 503 m (1,650 ft), then began to increase again. The production rate again increased at the depth of about 594 m (1,950 ft) and continued to rise steadily during drilling of the rest of the hole. Water production reached a maximum of over 3,785 lpm (1,000 gpm) below the depth of 701.6 m (2,302 ft), in the mafic-poor Ammonia Tanks Tuff. 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. The design of the completion string for Well ER-EC-5 was based in part on these data. Desert Research Institute (DRI) personnel made thermal flow meter (TFM) measurements at seven locations between the depths of 387.1 and 749.2 m (1,270 and 2,458 ft) in Well ER-EC-5 before the completion string was installed. In addition, DRI ran a chemistry log, including temperature, EC, and pH, from 310.6 to 755.9 m (1,019 to 2,480 ft). Groundwater temperature gradually increased, with only slight fluctuations, from 29.04 degrees Celsius (degrees C) (84.3 degrees Fahrenheit (degrees F) at the top of the fluid column to 30.08 degrees C (86.1 degrees F) at the depth of 755.9 m (2,480 ft).

Preliminary analysis of a plot of the discrete TFM data points indicates upward groundwater flow at the upper five measurement points, between the depths of 387.1 and 656.7 m (1,270 and 1,856 ft). The lower two measurement points at the depths of 682.7 and 749.2 m (2,240 and 2,458 ft) indicated downward groundwater flow. Plots of the TFM and chemistry log data 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 natural background levels of tritium, and no man-made radionuclides were encountered during drilling of Well ER-EC-5.

5.5 Preliminary Groundwater Characterization Sample

On July 8, 1999, after completion of geophysical logging operations, DRI collected a preliminary groundwater characterization sample (two 5-liter [1.3-gallon] containers) from the open borehole at the depth of 442.0 m (1,450 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-EC-5 consisted of circulation and conditioning of 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 intervals 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, 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-EC-5 took place on July 8 to 10, 1999, with the exception of a submersible pump which will be installed at a later date. Figure 7-1 is a schematic of the final well-completion design for Well ER-EC-5; Figure 7-2 shows a plan view and profile of the wellhead surface completion; and Table 7-1 is a construction summary for the well. Data for this section were obtained from daily operations and activity reports, casing records, and cementing records provided by the BN Drilling Department. Information from IT's well data report (IT, 1999) was also reviewed for preparation of this section.

7.2 Well Completion Design

The final completion design differs slightly 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 assumption that Well ER-EC-5 would penetrate and reach TD in the thick welded-tuff aquifer of the Ammonia Tanks Tuff. The nominal well design called for a single completion string consisting of 5½-in. stainless steel casing with every other joint slotted, suspended on carbon-steel 7e-in. casing. The slotted portion of the well completion string was to extend through the welded-tuff aquifer of the Ammonia Tanks Tuff. The proposed completion design also called for the isolation (using non-slotted casing) of low transmissivity zones within the completion interval, if such zones could be identified.

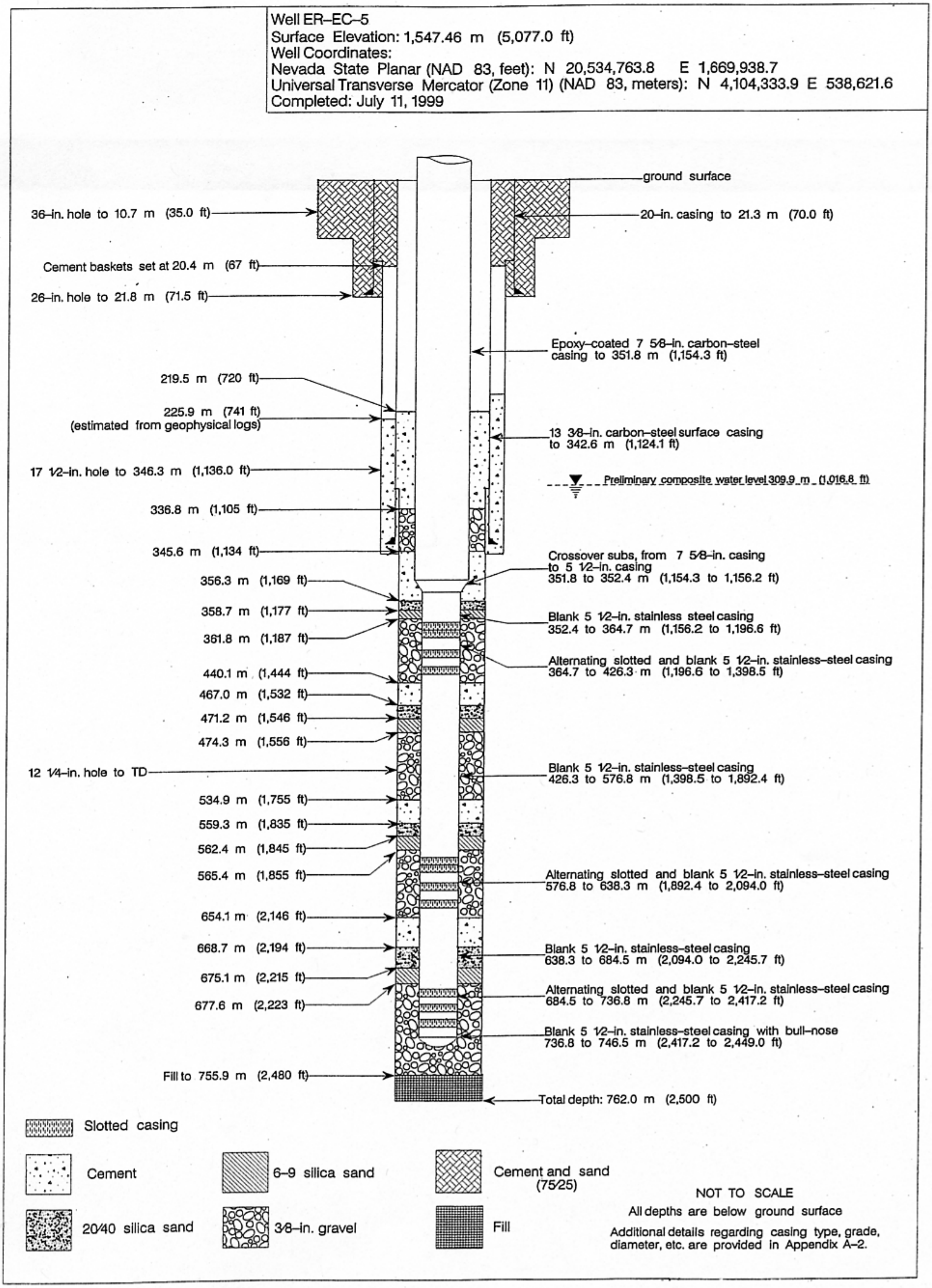
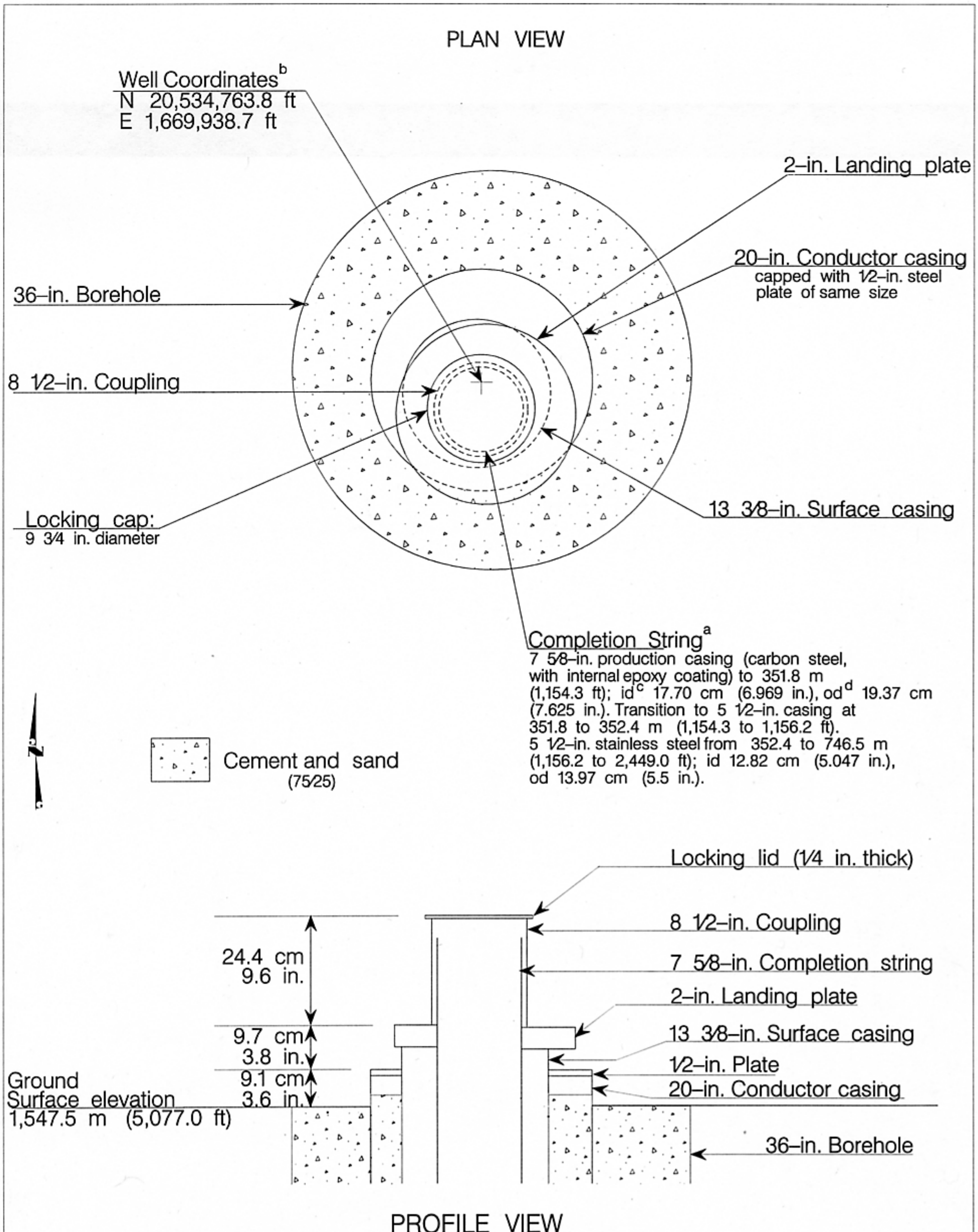


Figure 7-1
As-Built Completion Schematic for Well ER-EC-5



a See Appendix A-2 for casing data.
b NAD 83 Central Nevada State Planar Coordinates
c id = inside diameter
d od = outside diameter

Figure 7-2
Wellhead Diagram for Well ER-EC-5

Table 7-1
Well ER-EC-5 Completion String Construction Summary

<table>
<tr><th>Casing Type</th><th colspan="2">Configuration
meters (feet)</th><th>Cement</th><th>Sand/Gravel</th></tr>
<tr><td>7 e-in. carbon-steel production casing with internal epoxy coating</td><td>0 to 351.8
(0 to 1,154.3)</td><td>Blank</td><td rowspan="2">Type II

219.5 to 336.8
(720 to 1,105)

345.6 to 356.3
(1,134 to 1,169)</td><td rowspan="2">3/8-in. x 4 Gravel
336.8 to 345.6
(1,105 to1,134) [a]</td></tr>
<tr><td>7 e-in. to 5½-in. crossover sub, carbon-steel, with stainless-steel double pin</td><td>351.8 to 352.4
(1,154.3 to 1,156.2)</td><td>Blank</td></tr>
<tr><td rowspan="7">5½-in.
Stainless steel production casing</td><td rowspan="7">352.4 to 746.5
(1,156.2 to 2,449.0)</td><td>Blank
352.4 to 364.7
(1,156.2 to 1,196.6)</td><td rowspan="7">Type II

440.1 to 467.0
(1,444 to 1,532)

534.9 to 559.3
(1,755 to 1,835)

654.1 to 668.7
(2,146 to 2,194)</td><td rowspan="7">20/40 Sand

356.3 to 358.7
(1,169 to 1,177)

467.0 to 471.2
(1,532 to 1,546)

559.3 to 562.4
(1,835 to 1,845)

668.7 to 675.1
(2,194 to 2,215)

6-9 Sand

358.7 to 361.8
(1,177 to 1,187)

471.2 to 474.3
(1,546 to1,556)

562.4 to 565.4
(1,845 to 1,855)

675.1 to 677.6
(2,215 to 2,223)

3/8-in. x 4 Gravel

361.8 to 440.1
(1,187 to 1,444)

474.3 to 534.9
(1,556 to 1,755) [a]

565.4 to 654.1
(1,855 to 2,146)

677.6 to 755.9
(2,223 to 2,480)</td></tr>
<tr><td>2 slotted joints alternating with 2 blank joints overlain by 2 consecutive slotted joints
364.7 to 426.3
(1,196.6 to1,398.5)</td></tr>
<tr><td>Blank
426.3 to 576.8
(1,398.5 to 1,892.4)</td></tr>
<tr><td>2 slotted joints alternating with 2 blank joints, overlain by 2 consecutive slotted joints
576.8 to 638.3
(1,892.4 to 2,094.0)</td></tr>
<tr><td>Blank
638.3 to 684.5
(2,094.0 to 2,245.7)</td></tr>
<tr><td>3 slotted joints alternating with 2 blank joints

684.5 to 736.8
(2,245.7 to 2,417.2)</td></tr>
<tr><td>Blank and bull-nosed
736.8 to 746.5
(2,417.2 to 2,449.0)</td></tr>
</table>

a Gravel section not adjacent to slotted interval.

7.2.2 As-Built Completion Design

The design of the Well ER-EC-5 completion was determined through consultation with members of the UGTA TWG, on the basis of on-site evaluation of data such as lithology and water production, drilling data (lost circulation, etc.), data from geophysical logs (particularly caliper, down-hole video, acoustic fracture log), and from thermal-flow and water chemistry logs.

The as-built completion design for Well ER-EC-5 provides access to three different parts of the Ammonia Tanks Tuff welded-tuff aquifer (Figure 7-1). The composition of the string summarized here is detailed on Table 7-1, and the casing materials are listed in Appendix A-2. The lower section of the completion string, from 352.4 m to 746.5 m (1,156.2 to 2,449.0 ft), is type T304L stainless-steel casing with an outside diameter of 14.0 cm (5.5 in.) and an inside diameter of 12.819 cm (5.047 in.). The top of the 5½-in. casing is approximately 42 m (139 ft) below the static fluid level. The bottom 0.5-m (1.65-ft) joint is a blank with a bull-nose sub which served as a guide shoe so that the string did not catch on ledges, etc., as it was inserted in the open hole. Above the 5½-in. casing, a 0.6-m (1.95-ft) long crossover sub serves as the transition to the upper part of the string, which is 7e-in. carbon-steel production casing with an internal epoxy coating.

All three screened intervals are located in welded ash-flow tuff. The lowest zone was constructed in moderately to densely welded, mafic-poor Ammonia Tanks Tuff, and the upper two zones were installed in moderately welded mafic-rich Ammonia Tanks Tuff (see Figure 4-3 for an illustration of gravel-pack locations relative to hydrogeologic units). The casing in the lowest screened interval, 684.5 to 736.8 m (2,245.7 to 2,417.2 ft), consists of three slotted joints alternating with two blank joints. The middle slotted interval, 576.8 to 638.3 m (1,892.4 to 2,094.0 ft), spans a region where water production was found to increase during drilling. The string in this interval consists of two slotted joints alternating with two blank joints, overlain by two consecutive slotted joints. The uppermost slotted interval, 364.7 to 426.3 m (1,196.6 to 1,398.5 ft), also spans an area of increased water flow, and consists of two slotted joints alternating with two blank joints overlain by two consecutive slotted joints.

The openings in each slotted casing joint 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 (center to center), 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.

7.2.3 Rationale for Differences between Actual and Proposed Well Design

Well ER-EC-5 was completed as planned in the Ammonia Tanks Tuff. The basic plan of installing a single string consisting of larger diameter carbon-steel casing above the water table and smaller diameter stainless-steel casing in the saturated zone was accomplished. However, information obtained about water production and water flow during and after drilling allowed the selection of three intervals within the welded-tuff aquifer with potentially differing hydraulic character as isolated completion zones.

7.3 Well Completion Method

A “tremie” line and the completion string were landed after a brief period of circulation and conditioning of the hole. The three completion zones were gravel-packed and then isolated from each other with sand and cement barriers. Caliper logs were used to calculate the volumes of cement needed during well completion. Well-construction materials were inspected according to relevant procedures; standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

The filter pack around each open interval consists of 0.95-cm (**d**-in.) by 4-mesh washed gravel, with 6-9 Colorado silica sand directly above the gravel, and 20/40 silica sand on top of the 6-9 sand. In this stemming design, developed by the UGTA program at the NTS, the layer of 20/40 sand serves as a barrier to any fluids that might seep from the cement above, preventing cement fluids from contaminating the groundwater (fluids from the cement would have the effect of drastically raising the pH of the groundwater). The underlying layer of 6-9 sand prevents the 20/40 sand from infiltrating the gravel-pack. All cement used in the well completion was type II Portland cement with no additives. A clear-water pre-flush and back-flush were made at each stage of cement emplacement. Gravel, sand, and cement were emplaced through a 2 **f**-in. Hydril® tremie line that was withdrawn as the completion process progressed. A Nuclear Annulus Investigation Log was used to monitor the emplacement of stemming materials. As-built positions of the well materials are shown on Figure 7-1 and listed in Table 7-1.

Stemming of the hole began with the first gravel pack emplaced from 755.9 to 677.6 m (2,480 to 2,223 ft), outside the lowest slotted interval, on top of 6.1 m (20 ft) of fill at the bottom of the hole. This gravel pack is topped by a sand barrier to the depth of 668.7 m (2,194 ft), followed by cement, poured in one stage up to 654.1 m (2,146 ft). The second gravel pack was placed between 654.1 and 565.4 m (2,146 and 1,855 ft), adjacent to the middle slotted interval; this gravel was topped with sand to the depth of 559.3 m (1,835 ft), and cement to 534.9 m (1,755 ft). A layer of gravel was placed between 534.9 m and 474.3 m (1,755 and 1,556 ft), adjacent to a blank casing interval, and is capped with a sand barrier to the depth of 467.0 m (1,532 ft), and cement to 440.1 m (1,444 ft). Another gravel pack, adjacent to the uppermost slotted interval, extends from 440.1 to 361.8 m (1,444 to 1,187 ft), and is capped by sand to the depth of 356.3 m (1,169 ft). During emplacement of the upper cement cap (above the depth of 356.3 m [1,169 ft]), the volume of cement used was significantly greater than calculated for the volume of the borehole interval. To save time waiting on cement deliveries and to stem any voids that might be taking the excess cement, a stage of gravel was placed outside blank 7**e**-in. casing in the interval 345.6 to 336.8 m (1,134 to 1,105 ft). This gravel is capped directly by cement to the depth of 219.5 m (720 ft).

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

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8.0 Actual versus Planned Costs and Scheduling

The BN cost model developed on the basis of the Well ER-EC-5 drilling plan projected that it would require 22 days to drill the surface and main holes, log, and complete the well. The actual time spent to construct the well was 17 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-EC-5 begins with drilling of the surface hole, after construction of the conductor hole. The construction cost for Well ER-EC-5 includes all drilling costs: charges by the drilling subcontractor; charges by other support subcontractors (including compressor services, drilling fluids, bits, casing services, down-hole tools, and geophysical logging); and charges by BN for mobilization and demobilization of equipment, cementing services, completion materials, radiation technicians, inspection services, and geotechnical consultation. The cost of building the access road, the drill pad, and the sumps is not included, and the cost of well-site support by IT is not included.

The total planned cost for Well ER-EC-5 was $1,063,081. The actual cost was $1,139,633, or 6.7 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-EC-5.

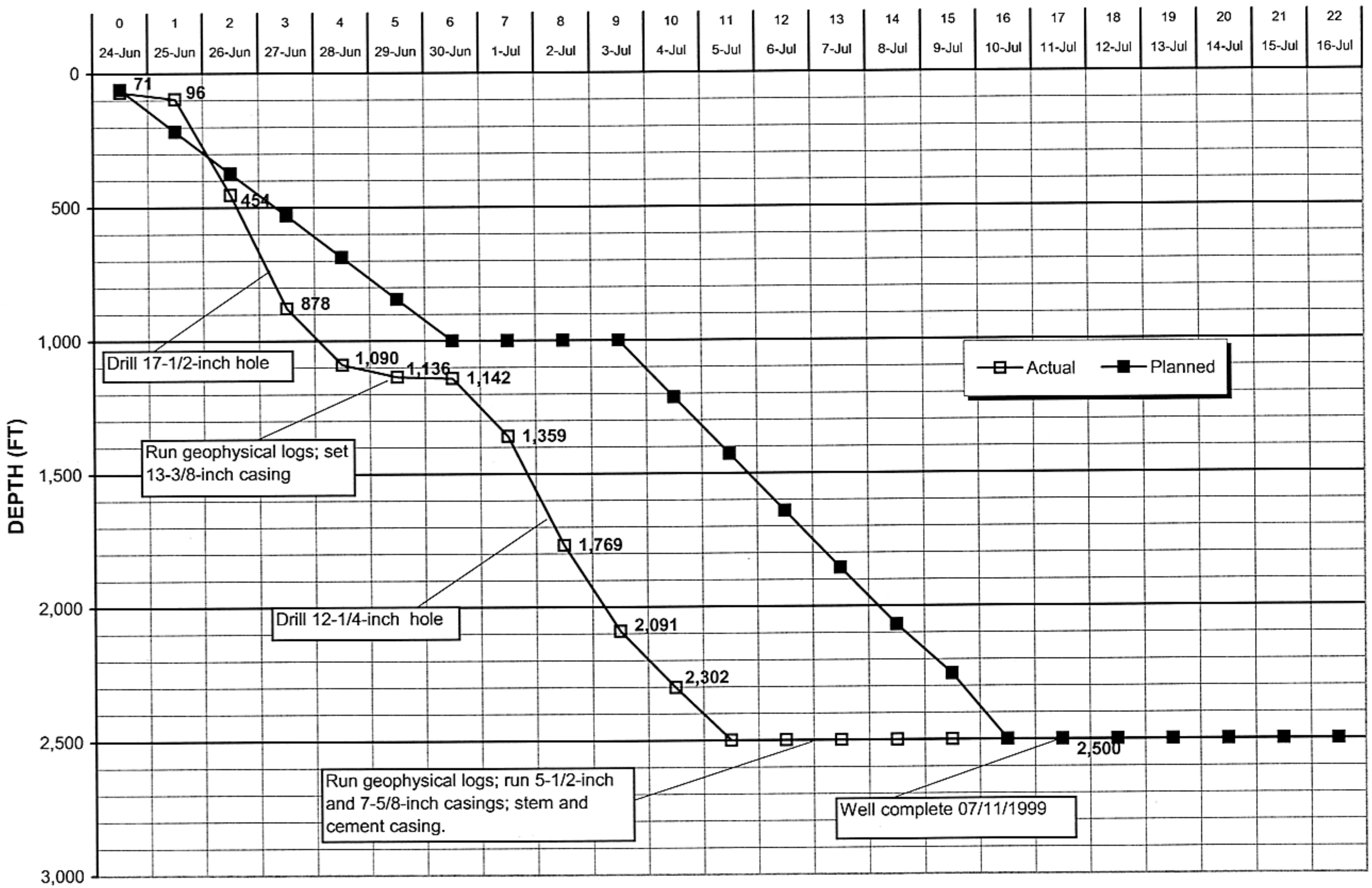

Figure 8-1
Planned versus Actual Construction Progress for Well ER-EC-5

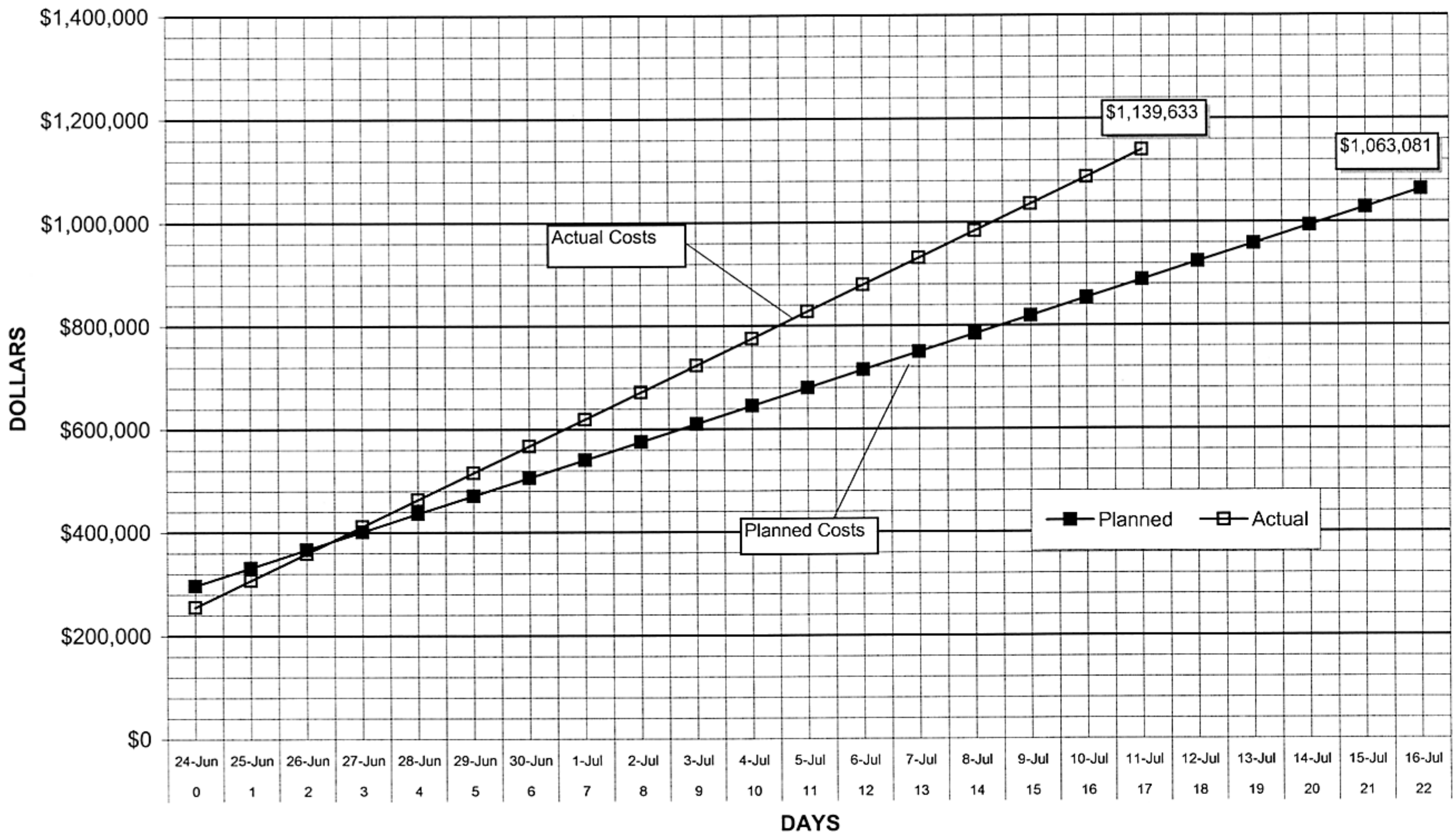

Figure 8-2
Planned versus Actual Cost for Constructing Well ER-EC-5

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9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Drilling subcontractor activities at Well ER-EC-5 commenced on June 24, 1999, and concluded on July 4, 1999, when the planned TD of 762.0 m (2,500 ft) was reached. After geophysical logging, the completion string was installed and gravel-packed, and the hole was stemmed to the depth 219.5 m (720.0 ft) on July 8 to 10, 1999. Crews worked on a 7-days-a-week, 24-hours-a-day schedule for most of the operation. Seventeen working days were expended to drill the surface and main holes, conduct geophysical logging, and install the completion string. No significant problems were encountered during construction of Well ER-EC-5.

No radionuclides above background were encountered in the groundwater produced from Well ER-EC-5. The static fluid level consistently stabilized at the depth of approximately 310.2 m (1,018 ft) during drilling. IT personnel obtained a fluid level of 309.9 m (1,016.8 ft) on August 19, 1999, 40 days after the completion string was installed (IT, 1999).

Composite drill cuttings were collected every 3 m (10 ft) from 21.3 m (70 ft) to TD. Eighteen sidewall core samples were collected in the interval 349.6 m to 745.2 m (1,147 to 2,445 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 determine the hydrologic characteristics of the rocks.

A single completion string with three gravel-packed, slotted intervals was installed in Well ER-EC-5. The string of 5½-in. stainless-steel casing installed below the water table is suspended from 7e-in. carbon-steel casing (with an internal epoxy coating) which extends to the surface. The open intervals in the 5½-in. casing are centered within the gravel-pack intervals located at 361.8 m to 440.1 m (1,187 to 1,444 ft); 565.4 m to 654.1 m (1,855 to 2,146 ft); and 677.6 m to 755.9 m (2,223 to 2,480 ft). The two uppermost intervals are open to welded-tuff aquifers of the mafic-rich Ammonia Tanks Tuff. The lowermost interval is open to a welded-tuff aquifer of the mafic-poor Ammonia Tanks Tuff.

9.2 Recommendations

The planned pump installation, well development, groundwater sampling, and hydrologic testing must be conducted at Well ER-EC-5 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. Very few problems were encountered during construction of Well ER-EC-5, however, the following items were noted:

- The success in drilling this hole again demonstrated the value of maintaining the correct balance of air volume, foam, and polymer in the upper unsaturated zone when using air-foam drill fluid in direct circulation. In volcanic rocks, careful attention to the amount of soap and polymer in the fluid mix prevents most borehole sloughing problems and results in savings in drilling time and cost.

- It was noted that the geophysical logging subcontractor arrived to conduct the second logging suite (in the saturated zone) with several tools in inoperable condition. The delays caused by trouble-shooting and repair of logging tools, waiting for shipments of working tools, and re-running logs in intervals where data quality was poor, might have been avoided if the tools had been tested for operability before they were brought to the job.

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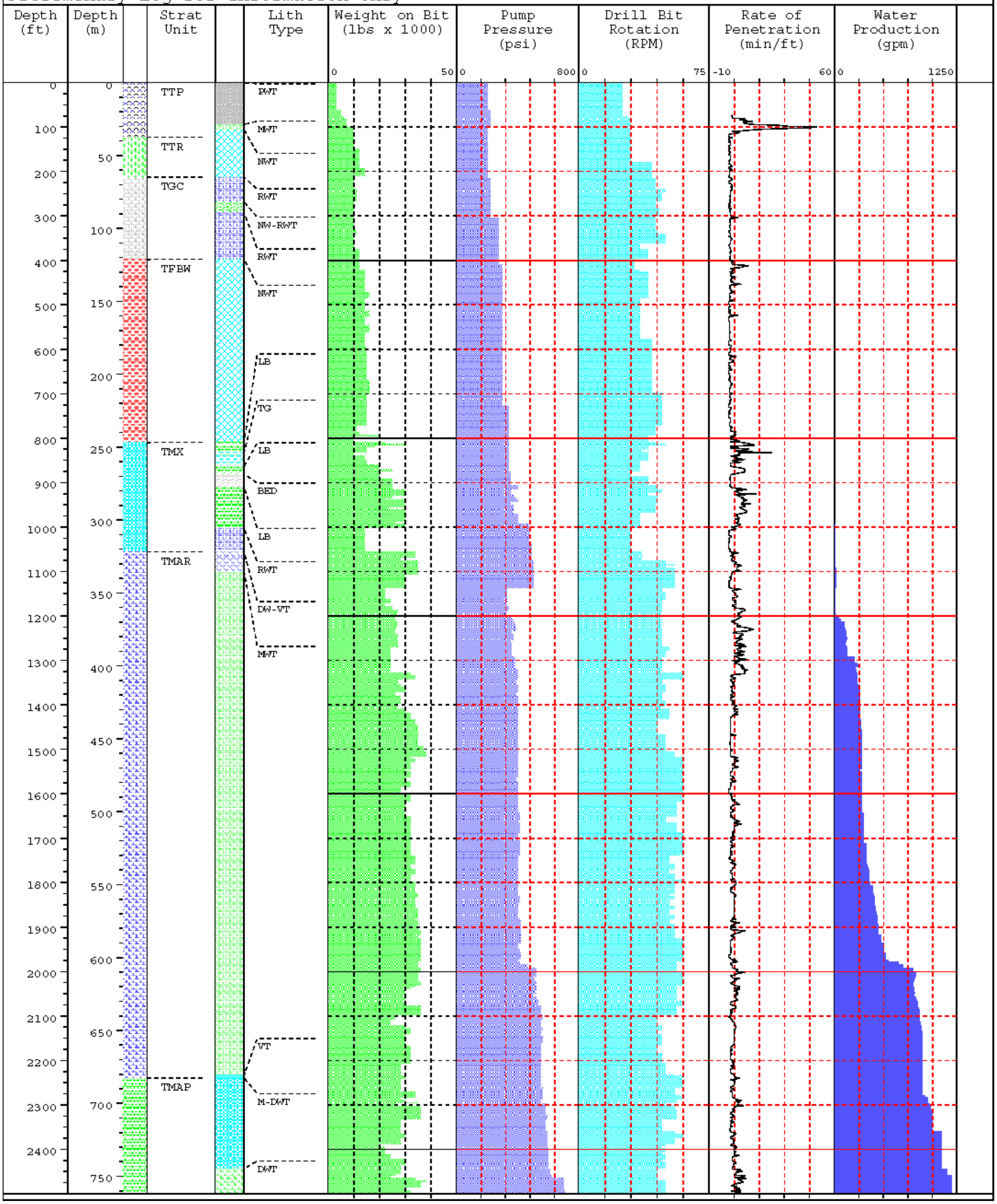
Appendix A
Drilling Data

Appendix A-1
Drilling Parameter Log for Well ER-EC-5

Well Name: ER-EC-5	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4104333.9 m
Date: 12/20/99	Start Date: 6/24/99	Stop Date: 7/11/99	Easting: 538621.6 m
Environmental Contractor: UGTA/IT		Proj No: 779115.02.08.08.02	Surface Elevation:5077.0 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-EC-5

Casing Data for Well ER-EC-5

CASING	**Depth Interval** meters (feet)	**Type**	**Grade**	**Outside Diameter** centimeters (inches)	**Inside Diameter** centimeters (inches)	**Wall Thickness** centimeters (inches)	**Weight per foot** (pounds/ foot)
Conductor Casing	0 to 21.3 (0 to 70.0)	Carbon Steel	K55	50.80 (20)	48.575 (19.124)	1.113 (0.438)	94
Surface Casing	0 to 342.6 (0 to 1,124.1)	Carbon Steel	K5	33.97 (13.375)	31.788 (12.515)	1.092 (0.430)	61.0
Completion Casing and crossover sub	0 to 352.4 (0 to 1,156.2)	Carbon Steel, epoxy coated	N80	19.37 (7.625)	17.701 (6.969)	0.833 (0.328)	26.4
Completion Casing	352.4 to 746.5 (1,156.2 to 2,449.0)	Stainless Steel	T304L	13.97 5.5	12.819 (5.047)	0.577 (0.227)	14.6

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Appendix A-3
Well ER-EC-5 Drilling Fluids and Cement Composition

Table A-3-1
Well ER-EC-5 Drilling Fluids

Typical Air-Foam/Polymer Mix [a]
8 to 28 liters (2 to 7 gallons) Acrylafoam® [b] and 4 to 11 liters (1 to 3 gallons) Acrylavis® [b] per 7,949 liters (50 barrels) water

a During air-foam /polymer drilling below 21.8 meters (71.5 feet), various proportions of polymer were added to suit conditions.

b Acrylafoam® foaming agent and Acrylavis® polymer additive are products of Enterprise Drilling Fluids, Inc.

NOTES:

1. All water used to mix drilling fluids for Well ER-EC-5 came from the Coffer Well.

2. Air with water spray for dust control was used while augering the conductor hole from the ground surface to the depth of 21.8 m (71.5 ft).

3 . A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of 17 to 27 milligrams per liter (17 to 27 parts per million).

Table A-3-2
Well ER-EC-5 Cement Composition

Cement Composition	20-inch Conductor Casing	13 d -inch Surface Casing	Completion
Type II plus 25 percent sand	0 to 21.8 m [a] (0 to 71.5 ft [b])	Above cement baskets 0 to 20.4 m (0 to 67.0 ft)	Not used
Type II	Not used	225.9 [c] to 346.3m (741 [c] to 1,136.0 ft)	219.5 to 336.8 m (720 to 1,105 ft) 345.6 to 356.3 m (1,134 to 1,169ft) 440.1 to 467.0 m (1,444 to 1,532 ft) 534.9 to 559.3 m (1,755 to 1,835 ft) 654.1 to 668.7 m (2,146 to 2,194 ft)

a meter(s) b foot (feet) c estimated

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Appendix B
Well ER-EC-5 Fluid Management Data

Fluid Disposition Reporting Forms for ER-EC-5

Site Identification: ER-EC-5

Site Location: Nellis Air Force Range

Site Coordinates (UTM Zone 11, NAD 83, meters):
N: 4,104,137 m E: 538,702 m

Well Classification: ER Hydrogeologic Investigation Well

Project Number: 779115.02.08.08.02

Report Date: 11/23/1999

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	6/24/99	6/28/99	5	346.5	537.4	67.8	280.9	0	0	NA	NA	YES
Phase I: Saturated-Zone Drilling	6/30/99	7/4//99	5	415.5	702.7	47.8	1,057.0	12.5	1,247.1	7,655.0	NA	YES
Phase II: Initial Well Development	Pending	Pending	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	Pending	Pending	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	Pending	Pending	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			10	762.0	992.1	115.6	1,337.9	12.5	1,247.1	7,555.0	NA	YES

[a]Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift.
[b]Solids volume estimates include calculated added volume attributed to rock bulking factor.
[c]Ground surface discharge and infiltration within the unlined sumps.
[d]Other refers to fluid conveyance to other fluid management locations or facilities away from the well site, such as vacuum truck transport to another well site.

NA = Not applicable m = meters m^3 = cubic meters

Total Facility Capacities: Sump #1 = 1,539.52 m^3 Sump #2 = 1,489.78 m^3
Infiltration Area (assuming very low/no infiltration) = NA m^3

Remaining Facility Capacity (Approximate) as of 07/04/99: Sump #1 = 255.51 m^3 (17%) Sump #2 = 230.23 m^3 (15%)
Current Average Tritium = (Natural Background) pCi/L

IT Authorizing Signature/Date: 11-23-99

Preliminary Analytical Results for Fluid Management Samples at Well ER-EC-5

Sample Number	Date & Time Collected	Comment		RCRA Metals (milligrams per liter)								Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury			
EC-5-06299-1	04/29/1999 11:30	Sample collected from sump #1	Total [a]	0.0232	0.315	U 0.0002	0.029	0.0443	0.0088	U 0.0005	B 0.00056	N/Anl	N/Anl	N/Anl
			Dissolved [b]	0.0129	B 0.0153	U 0.0002	B 0.0054	0.0247	0.0133	B 0.00054	0.0002	21.68	8.08	128
EC-5-06299-2	06/29/1999 11:40	Sample collected from sump #1	Total	0.0312	0.475	U 0.0002	0.040	0.0565	0.0055	U 0.0005	B 0.00062	N/Anl	N/Anl	N/Anl
			Dissolved	B 0.0042	B 0.0295	B 0.0002	B 0.0075	0.0318	B 0.0071	0.0438	0.0002	20.34	5.96	70
EC-5-07099-1	07/09/1999 08:30	Sample collected from sump #1	Total	B 0.0077	B 0.039	U 0.0002	B 0.0032	B 0.0015	U 0.0029	U 0.0007	U 0.00002	N/Anl	N/Anl	N/Anl
			Dissolved	B 0.0057	B 0.0031	U 0.0002	B 0.003	U 0.0013	U 0.0029	U 0.0007	U 0.00002	11.50	3.66	-239
EC-5-07099-2	07/09/1999 08:45	Sample collected from sump #2	Total	B 0.007	B 0.0816	U 0.0002	B 0.0015	B 0.0021	U 0.0029	U 0.0007	U 0.00002	N/Anl	N/Anl	N/Anl
			Dissolved	B 0.0054	B 0.0041	U 0.0002	U 0.0005	U 0.0013	U 0.0029	U 0.0007	U 0.00002	8.11	3.56	314
Contract-Required Detection Limit (CRDL)				0.01	0.1	0.005	0.01	0.003	0.005	0.01	0.0002	NA	NA	NA
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

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

Data provided by IT, 1999.

RCRA = Resource Conservation and Recovery Act of 1976
N/Anl = not analyzed
NA = not applicable
pCi/L = picocuries per liter
B = result less than the CRDL but greater than the instrument detection limit
U = result less than the instrument detection limit

Appendix C
Detailed Lithologic Log for Well ER-EC-5

Detailed Lithologic Log for ER-EC-5

Logged by Heather Noto and Lance Prothro, Bechtel Nevada

February 7, 2000

Depth Interval meters/(feet)	**Thickness** meters/ (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
0 - 28.7 (0 - 94)	28.7 (94)	DA No samples above 21.3 m (70 ft)	None	**Partially Welded Ash-Flow Tuff:** Grayish-red (10R 4/2); devitrified with vapor-phase mineralization; minor light-gray (N7) and grayish-red (10R 4/2) pumice; minor felsic phenocrysts of feldspar, including chatoyant sanidine; minor mafic minerals of clinopyroxene and olivine; minor very-dusky-red (10R 2/2) and grayish-brown (5YR 3/2) lithic fragments.	Pahute Mesa Tuff (Ttp)
28.7 - 32.3 (94 - 106)	3.7 (12)	DA	None	**Moderately Welded Ash-Flow Tuff:** Grayish-brown (5YR 3/2); devitrified; minor pumice; minor felsic phenocrysts of feldspar, including chatoyant sanidine; rare mafic minerals of clinopyroxene and olivine; rare very-dusky-red (10R 2/2) and dusky-reddish-brown (10R 3/4) lithic fragments.	
32.3 - 37.5 (106 - 123)	5.2 (17)	DA	None	**Nonwelded Ash-Flow Tuff:** Moderate-brown (5YR 4/4); vitric; abundant light-brown (5YR 5/6) and moderate-brown (5YR 4/4) pumice; minor felsic phenocrysts of feldspar; minor mafic minerals of clinopyroxene and olivine; minor lithic fragments.	
37.5 - 64.9 (123 - 213)	27.4 (90)	DA, DB1	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Ash-Flow Tuff:** Moderate yellowish-brown (10YR 5/4), grayish-brown (5YR 3/2), and moderate-brown (5YR 4/4); devitrified with vapor-phase mineralization; very abundant light-brown (5YR 5/6) remnant glass shards; common light-brown (5YR 5/6) pumice; common felsic phenocrysts of feldspar; minor to common mafic minerals of clinopyroxene and olivine; minor lithic fragments. Several samples in this interval are a concentration of loose felsic crystals.	Rocket Wash Tuff (Ttr)

Depth Interval meters/(feet)	**Thickness** meters/ (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
64.9 - 81.7 (213 - 268)	16.8 (55)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Reworked Tuff:** Moderate-yellowish-brown (10YR 5/4); zeolitic, some fragments weakly calcareous; common grayish-yellow (5Y 8/4) to white (N9) pumice; minor frosted felsic phenocrysts of feldspar and lesser quartz; minor biotite and lesser hornblende; altered sphene observed; common lithic fragments.	Caldera moat-filling sedimentary deposits (Tgc)
81.7 - 89.0 (268 - 292)	7.3 (24)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded and Reworked Tuff:** Grayish-yellow (5Y 8/4) and moderate-yellow (5Y 7/6); zeolitic and silicic, moderately calcareous; common grayish-yellow (5Y 8/4) pumice; minor to common felsic phenocrysts of feldspar and quartz; minor to common biotite, trace hornblende; common lithic fragments.	
89.0 - 121.3 (292 - 398)	32.3 (106)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Reworked Tuff:** Moderate-yellowish-brown (10YR 5/4), light-brown (5YR 5/6), and moderate-reddish-brown (10R 4/6); zeolitic and argillic; common white (N9) pumice; rare to minor felsic phenocrysts of feldspar and quartz; minor biotite; minor to common lithic fragments.	
121.3 - 158.5 (398 - 520)	37.2 (122)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Tuff:** Grayish-orange-pink (5YR 7/2), pale-brown (5YR 5/2), and light-brown (5YR 6/4); zeolitic, partially silicic with increasing silicification below approximately 155.4 m (510 ft); common to abundant grayish-orange-pink (5YR 7/2) to pale-greenish-yellow (10Y 8/2) pumice; common felsic phenocrysts of feldspar; minor biotite; pseudomorphs after sphene are present; common brownish-black (5YR 2/1), grayish-brown (5YR 3/2), and moderate-brown (5YR 3/4) lithic fragments.	rhyolite of Beatty Wash (Tfbw)
158.5 - 187.5 (520 - 615)	29.0 (95)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Tuff:** Moderate-reddish-brown (10R 4/6) at top, becoming very-pale-orange (10YR 8/2), and grayish-orange (10YR 7/4) lower; zeolitic, weakly silicic; common white (N9) to very-pale-orange (10YR 8/2) pumice; minor felsic phenocrysts of feldspar; minor to common biotite; pseudomorphs after sphene are present; common grayish-brown (5YR 3/2) and brownish-gray (5YR 4/1) lithic fragments.	

Depth Interval meters/(feet)	**Thickness** meters/ (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
187.5 - 246.9 (615 - 810)	59.4 (195)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Nonwelded Tuff:** Dusky-yellow (5Y 6/4), grayish-orange-pink (5YR 7/2), and grayish-orange (10YR 7/4); zeolitic and silicic, with silicification increasing below 240.8 m (790 ft); common pumice; common felsic phenocrysts of feldspar; minor to common biotite; pseudomorphs after sphene are present; common lithic fragments, possibly becoming more lithic-rich below 240.8 m (790 ft).	Tfbw
246.9 - 253.6 (810 - 832)	6.7 (22)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Landslide Breccia:** Angular clasts of moderate-brown (5YR 3/4), quartzo-feldspathic, densely welded ash-flow tuff resembling mafic-poor Ammonia Tanks Tuff in a scarce, coarse-grained, granular, tuffaceous matrix.	Timber Mountain landslide breccia (Tmx) [d]
253.6 - 263.3 (832 - 864)	9.8 (32)	DA, DB1	None	**Tuffaceous Gravel:** Very abundant, subangular to subrounded clasts of grayish-brown (5YR 3/2), quartzo-feldspathic, moderately welded ash-flow tuff resembling mafic-poor Ammonia Tanks Tuff in a scarce, very-pale-orange (10YR 8/2), fine-grained, zeolitic matrix.	
263.3 - 268.2 (864 - 880)	4.9 (16)	DA	None	**Landslide Breccia:** Very similar to interval 246.9 - 253.6 m (810 - 832 ft) with angular clasts of moderate-brown (5YR 3/4), quartzo-feldspathic, densely welded ash-flow tuff resembling mafic-poor Ammonia Tanks Tuff in a scarce, coarse-grained, granular, tuffaceous matrix.	
268.2 - 277.4 (880 - 910)	9.1 (30)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Bedded Tuff:** Samples consist of various tuffaceous lithologies primarily nonwelded and reworked tuff. The nonwelded tuff is moderate-reddish-orange (10R 6/6), zeolitic, with common pale-greenish-yellow (10Y 8/2) pumice, minor felsic phenocrysts of quartz and feldspar, minor biotite, and minor lithic fragments. The reworked tuff is mostly pale-brown (5YR 5/2), and lesser moderate-brown (5YR 4/4) and moderate-reddish-brown (10R 4/6), consisting of mostly fine to medium sand, with lesser coarse to very coarse sand in a very-fine-grained, zeolitic, tuffaceous matrix; grains are moderately sorted and subangular and consist of frosted quartz and feldspar crystals, biotite, pumice, and various volcanic fragments.	

Depth Interval meters/(feet)	**Thickness** meters/ (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
277.4 - 305.4 (910 - 1,002)	28.0 (92)	DA	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Landslide Breccia:** Similar to intervals 246.9 - 253.6 m (810 - 832 ft) and 263.3 - 268.2 m (864 - 880 ft) with angular clasts of moderate-brown (5YR 3/4), quartzo-feldspathic, densely welded ash-flow tuff resembling mafic-poor Ammonia Tanks Tuff in a scarce, coarse-grained, granular, tuffaceous matrix.	Tmx
305.4 - 321.9 (1,002 - 1,056)	16.5 (54)	DA, DB1	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Reworked Tuff:** Light-brown (5YR 6/4), pale-brown (5YR 5/2), and moderate-reddish-orange (10R 6/6); zeolitic and lesser argillic, moderately calcareous; common felsic phenocrysts of frosted feldspar and quartz; common to abundant biotite and trace sphene; very abundant grayish-brown (5YR 3/2), brownish-black (5YR 2/1), and dark-gray (N3) subangular to subrounded lithic fragments of densely welded tuff resembling mafic-poor Ammonia Tanks Tuff.	
321.9 - 335.0 (1,056 - 1,099)	13.1 (43)	DA	None	**Densely Welded to Vitrophyric Ash-Flow Tuff:** Mostly moderate-brown (5YR 4/4), lesser light-brown (5YR 5/6) and grayish-black (N2); mostly devitrified, lesser vitric, weakly calcareous; remnant perlitic texture in some cuttings fragments; minor pumice; abundant felsic phenocrysts of feldspar and lesser quartz; very abundant biotite and lesser clinopyroxene; minor dark-reddish-brown (10R 3/4) lithic fragments. Induction log indicates vitrophyre from 328.0 to 333.1 m (1,076 to 1,093 ft).	mafic-rich Ammonia Tanks Tuff (Tmar)
335.0 - 434.0 (1,099 - 1,424)	99.1 (325)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately Welded Ash-Flow Tuff:** Pale-brown (5YR 5/2) and moderate-brown (5YR 4/4); quartzo-feldspathic, minor zeolitic and/or argillic alteration from 408.4 to 429.8 m (1,340 to 1,410 ft); rare to minor pumice; abundant felsic phenocrysts of partially altered feldspar and lesser quartz; very abundant unaltered biotite; common lithic fragments. Calcite occurs as coatings on fragments and as vein fillings.	

Depth Interval meters/(feet)	**Thickness** meters/ (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
434.0 - 462.1 (1,424 - 1,516)	28.0 (92)	DA, SC	None	**Moderately Welded Ash-Flow Tuff:** Moderate-brown (5YR 3/4), moderate-brown (5YR 4/4), and grayish-red (5R 4/2); quartzo-feldspathic, minor argillic and/or zeolitic alteration, and moderately calcareous; minor pumice; abundant felsic phenocrysts of quartz and feldspar, including partially altered feldspar and pseudomorphs after feldspar; abundant unaltered biotite; minor lithic fragments.	Tmar
462.1 - 513.0 (1,516 - 1,683)	50.9 (167)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately Welded Ash-Flow Tuff:** Moderate-brown (5YR 4/4) and moderate-brown (5YR 3/4); quartzo-feldspathic with minor zeolitic and/or argillic alteration; common felsic phenocrysts of quartz and feldspar, including chatoyant sanidine and partially altered feldspar and pseudomorphs after feldspar; abundant unaltered biotite; minor lithic fragments.	
513.0 - 678.2 (1,683 - 2,225)	165.2 (542)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately Welded Ash-Flow Tuff:** Moderate-brown (5YR 3/4), grayish-brown (5YR 3/2), dark-reddish-brown (10R 3/4), and moderate-brown (5YR 4/4); quartzo-feldspathic alteration with substantial silicification, weakly to moderately calcareous; abundant felsic phenocrysts of feldspar, including partially altered feldspar and pseudomorphs after feldspar, and lesser quartz; abundant unaltered biotite.	
678.2 - 680.6 (2,225 - 2,233)	2.4 (8)	DA	None	**Moderately Welded Ash-Flow Tuff:** Moderate-reddish-brown (10R 4/6), light-brown (5YR 5/6), and moderate-brown (5YR 4/4); quartzo-feldspathic with substantial silicification; common to abundant felsic phenocrysts of feldspar, including partially altered feldspar and pseudomorphs after feldspar, and lesser quartz; minor to common unaltered biotite.	mafic-poor Ammonia Tanks Tuff (Tmap)
680.6 - 682.8 (2,233 - 2,240)	2.1 (7)	DA	None	**Vitrophyric Ash-Flow Tuff:** Grayish-black (N2) and brownish-black (5YR 2/1); mostly vitric, lesser devitrified and silicic; common felsic phenocrysts of feldspar and quartz; minor biotite.	

Depth Interval meters/(feet)	**Thickness** meters/ (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
682.8 - 744.9 (2,240 - 2,444)	62.2 (204)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Moderately to Densely Welded Ash-Flow Tuff:** Pale-brown (5YR 5/2), moderate-brown (5YR 3/4), and light-brown (5YR 5/6); quartzo-feldspathic alteration, with substantial silicification in some intervals; common felsic phenocrysts of quartz and feldspar, including partially altered feldspar; minor unaltered biotite; minor lithic fragments.	Tmap
744.9 - 762.0 (2,444 - 2,500)	17.1 (56)	DA, SC	PTS, XRD, XRF, Fe^{2+}/Fe^{3+}	**Densely Welded Ash-Flow Tuff:** Grayish-brown (5YR 3/2); intense quartzo-feldspathic alteration, including substantial silicification; common to abundant felsic phenocrysts of quartz and pseudomorphs after feldspar; minor biotite and pseudomorphs after biotite.	

a **DA** = drill cuttings that represent lithologic character of interval; **DB1** = drill 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. See Table 3-2 of this report for additional information.

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

d See discussion in Section 4-1 of this report for origin of rocks assigned as Tmx in Well ER-EC-5.

Appendix D
Well ER-EC-5 Geophysical Logs

Appendix D contains unprocessed data presentations of selected geophysical logs run in Well ER-EC-5. Table D-1 summarizes the header information for logs presented. See Table 3-3 for information about other logs run in Well ER-EC-5.

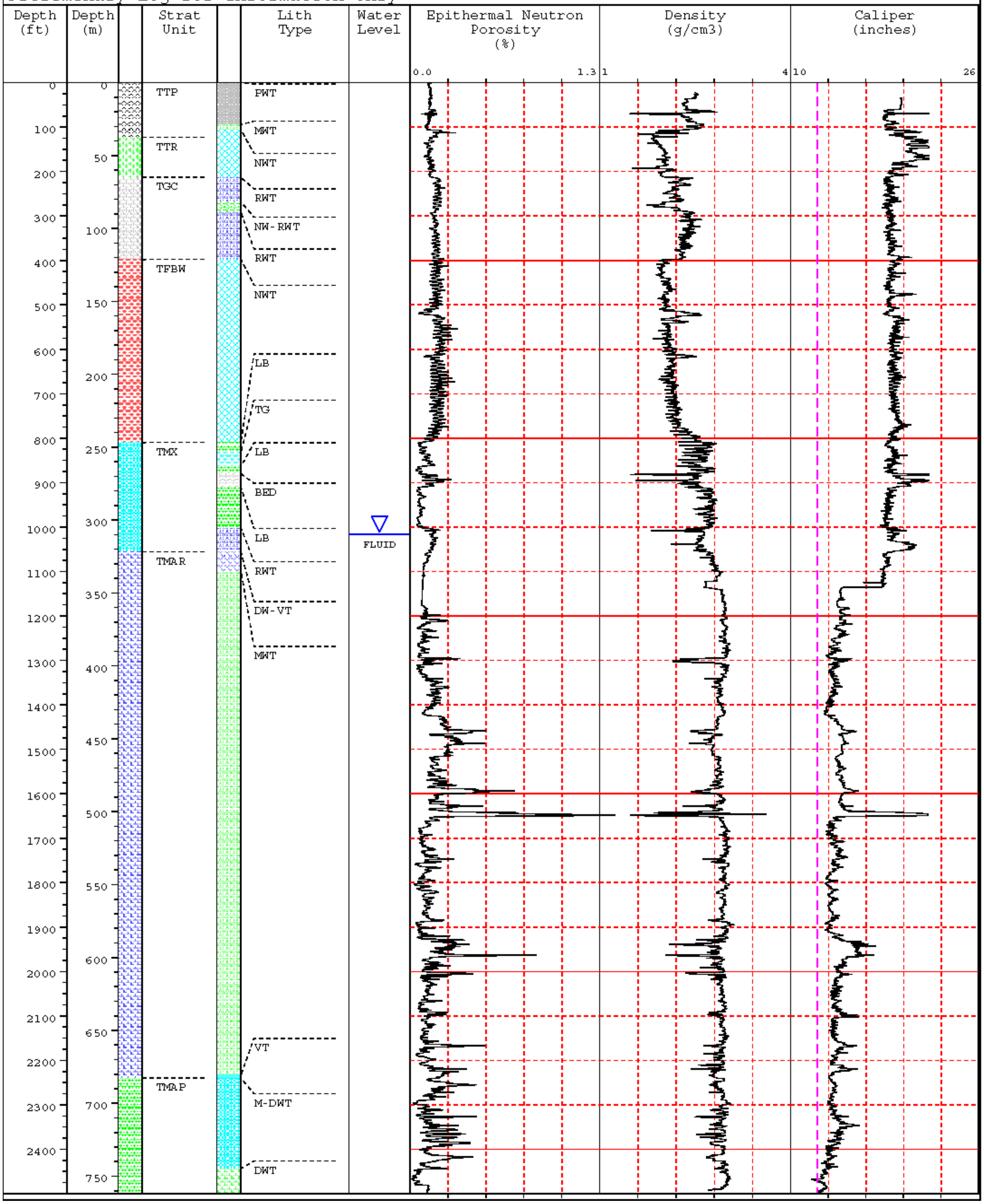
Table D-1
Well ER-EC-5 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval meters	Log Interval feet
Epithermal Neutron	ENP-1 ENP-2	06/28/1999 07/05/1999	21.3 -338.3 173.1 - 761.4	70 - 1,110 568 - 2,498
Density	CDL-1 CDL-2	06/28/1999 07/05/1999	21.3 -338.3 173.1 - 761.4	70 - 1,110 568 - 2,498
Array Induction and Dual Laterolog (resistivity)	IND-1 DLL-1	06/28/1999 07/05/1999	21.3. - 340.2 342.6 - 757.4	70 - 1,116 1,124 - 2,485
Gamma Ray	SGR-1 GR-2	06/28/1999 07/05/1999	21.3 - 329.8 342.6 - 761.7	70 - 1,082 1,124 - 2,499
Digital Array Sonic (delta T and sonic porosity)	AC-1	07/07/1999	304.8 - 753.8	1,000 - 2,473
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2	06/28/1999 07/06/1999	21.3 - 329.8 310.9 - 752.6	70 - 1,082 1,020 - 2,469
Thermal Flow	1	07/07/1999	310.6 - 755.9	1,019 - 2,480 [a]
Chemistry (temperature, pH, electrical conductivity)	1	07/07/1999	310.6 - 755.9	1,019 - 2,480

a Logging interval recorded on print of log. Discrete measurements were made at seven locations between the depths of 387.1 and 749.2 m (1,270 and 2,458 ft).

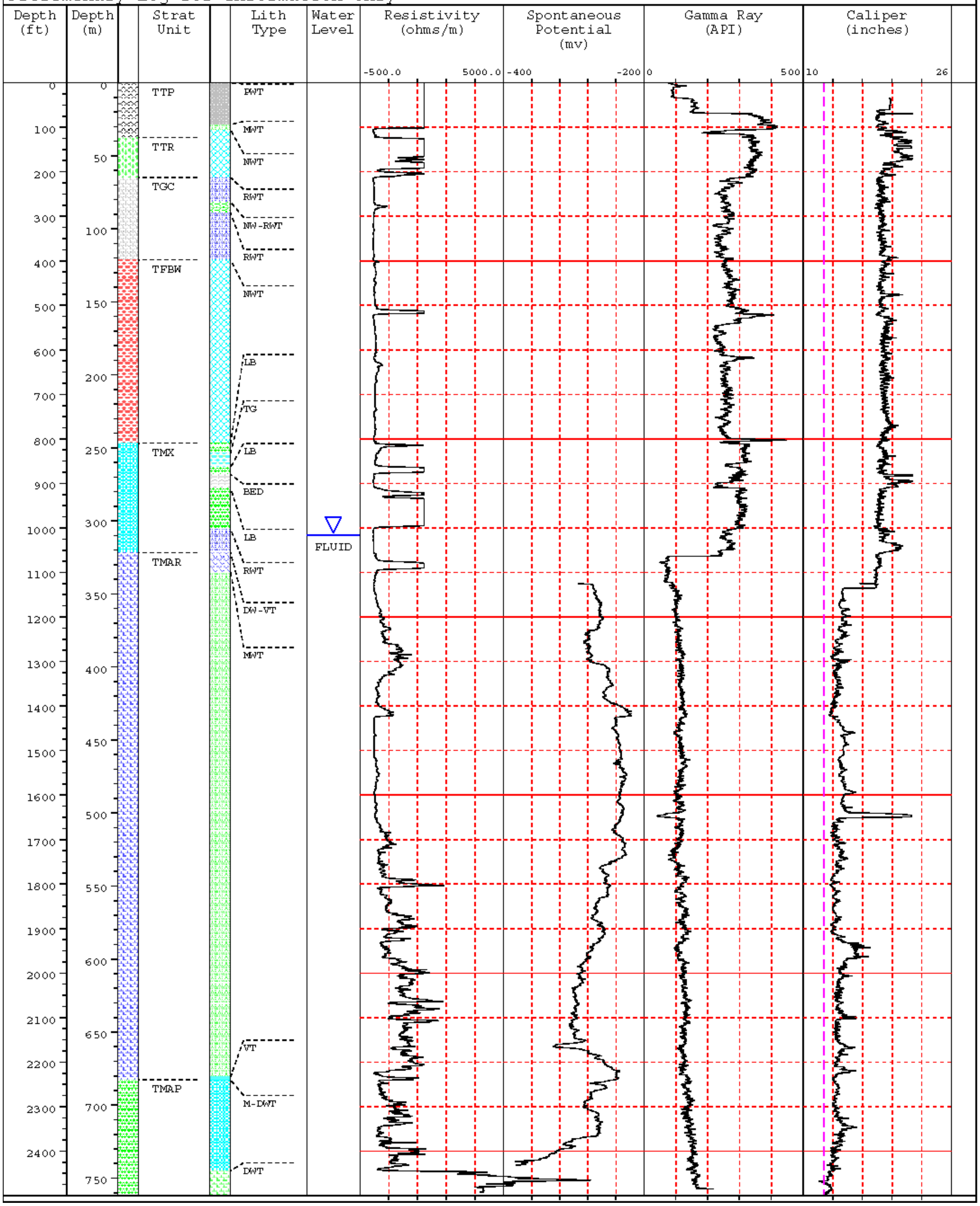
Well Name: ER-EC-5	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4104333.9 m
Date: 12/20/99	Start Date: 6/24/99	Stop Date: 7/11/99	Easting: 538621.6 m
Environmental Contractor: UGTA/IT		Proj No: 779115.02.08.08.02	Surface Elevation:5077.0 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft

Preliminary Log for Information Only



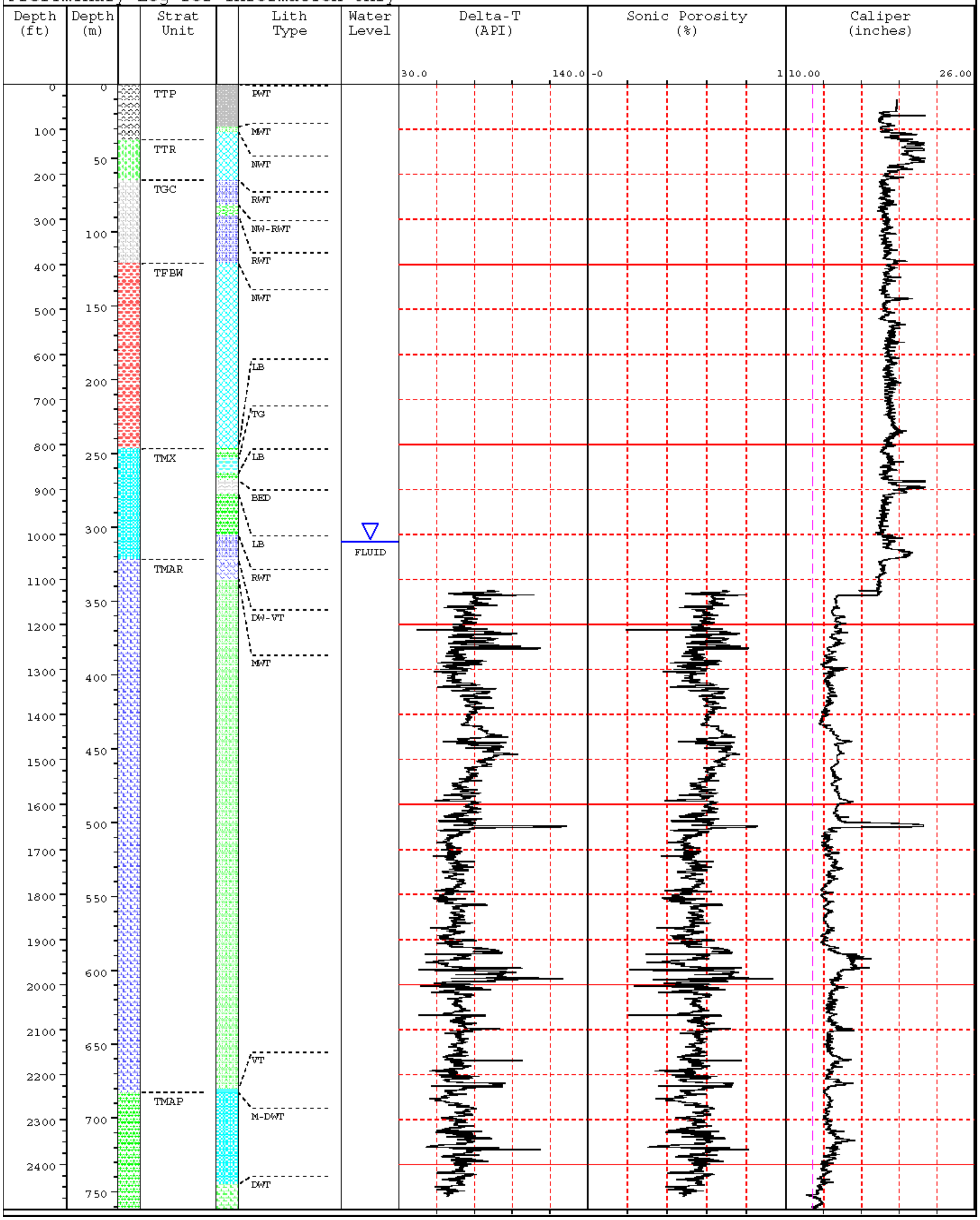
Well Name: ER-EC-5	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4104333.9 m
Date: 12/20/99	Start Date: 6/24/99	Stop Date: 7/11/99	Easting: 538621.6 m
Environmental Contractor: UGTA/IT		Proj No: 779115.02.08.08.02	Surface Elevation:5077.0 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft

Preliminary Log for Information Only



Well Name: ER-EC-5	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4104333.9 m
Date: 12/20/99	Start Date: 6/24/99	Stop Date: 7/11/99	Easting: 538621.6 m
Environmental Contractor: UGTA/IT		Proj No: 779115.02.08.08.02	Surface Elevation:5077.0 ft
Drilling Contractor: United	Drilling Method: Air Foam	Geol: J. Wurtz	Depth: 2500 ft

Preliminary Log for Information Only



Well Name: ER-EC-5	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4104333.9 m
Date: 12/20/99	Start Date: 6/24/99	Stop Date: 7/11/99	Easting: 538621.6 m
Environmental Contractor: UGTA/IT		Proj No: 779115.02.08.08.02	Surface Elevation:5077.0 ft
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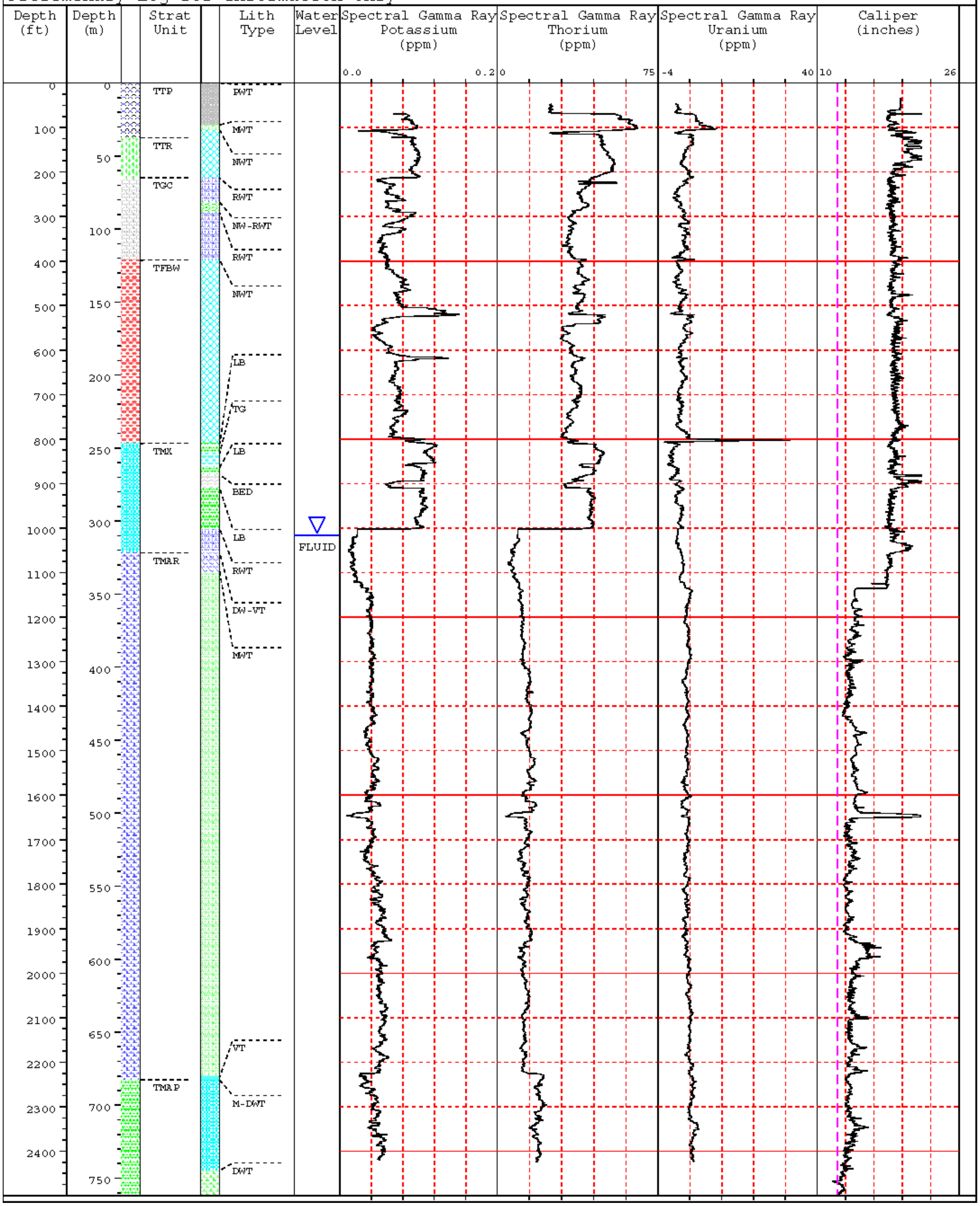
Preliminary Log for Information Only



Well Name: ER-EC-5	Western Pahute Mesa - Oasis Valley Drilling Program		Northing: 4104333.9 m
Date: 12/20/99	Start Date: 6/24/99	Stop Date: 7/11/99	Easting: 538621.6 m
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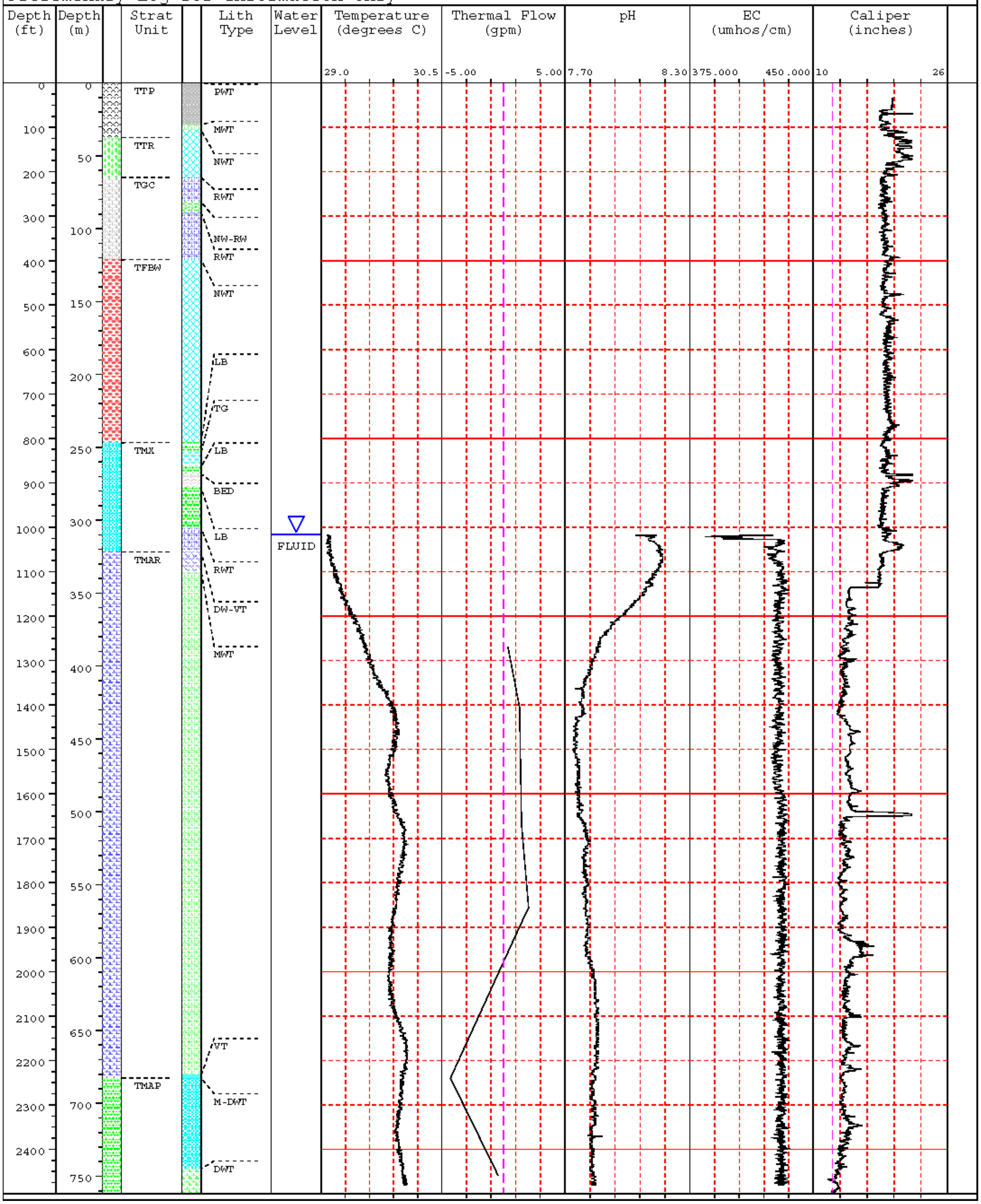
Preliminary Log for Information Only



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