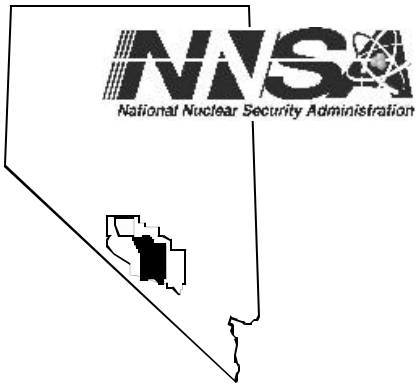
DOE/NV/11718--865

Nevada
Environmental
Restoration
Project



Completion Report for Well ER-7-1

November 2004

Environmental Restoration
Division

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

DISCLAIMER STATEMENT

AVAILABILITY STATEMENT

DOE/NV/11718--865

Completion Report for Well ER-7-1

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

Prepared by:
Bechtel Nevada
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Las Vegas, NV

November 2004

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DOE/NV/11718--865

COMPLETION REPORT FOR WELL ER-7-1

Approved by: William R. Wilborn Date: 12/15/04

William R. Wilborn, Acting Project Manager,
Underground Test Area Project

Approved by: Robert M. Bangerter Jr. Date: 12/15/04

Robert M. Bangerter, Acting Director,
Environmental Restoration Division

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Completion Report for Well ER-7-1
DOE/NV/11718--865

ABSTRACT

Well ER-7-1 was drilled for the U.S. Department of Energy's 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 January and February 2003, as part of a hydrogeologic investigation program in Yucca Flat. A 47.0-centimeter surface hole was drilled and cased off to a depth of 541.0 meters below the surface. The hole diameter was then decreased to 31.8 centimeters for drilling to a total depth of 762.0 meters.

One completion string with one slotted interval was installed in the well, open to the lower carbonate aquifer. A preliminary composite static water level was measured at the depth of 565.1 meters on February 7, 2003, before installation of the completion string. Well ER-7-1 was drilled 91.4 meters deeper than planned because the borehole did not encounter significant groundwater at the original planned total depth of 670.6 meters.

Detailed lithologic descriptions with stratigraphic assignments are included in this report. These are based on composite drill cuttings collected every 3 meters, and 62 sidewall samples taken at various depths below 85.3 meters, supplemented by geophysical log data. Detailed petrographic, chemical, and mineralogical studies were conducted on 22 samples of cuttings. The well was collared in Quaternary surficial deposits and penetrated a thick section of Tertiary-age volcanic deposits before terminating in carbonate rocks of Paleozoic-age.

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List of Acronyms and Abbreviations

BN	Bechtel Nevada
C	centigrade
cm	centimeter(s)
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
E	east
EC	Electrical Conductivity
F	Fahrenheit
FFACO	Federal Facilities Agreement and Consent Order
FMP	Fluid Management Plan
ft	foot (feet)
gal	gallon(s)
gpm	gallons per minute
in.	inch(es)
IT	IT Corporation
LANL	Los Alamos National Laboratory
LCA	lower carbonate aquifer
lpm	liters per minute
LiBr	lithium bromide
m	meter(s)
N	north
NAD	North American Datum
NNSA/NSO	National Nuclear Security Administration Nevada Site Office
NTS	Nevada Test Site
RWP	Radioactive Work Permit
Shaw	Shaw Environmental Inc.
TD	total depth
TFM	thermal flow meter
UGTA	Underground Test Area
UDI	United Drilling, Inc.
USGS	United States Geological Survey
YF-LCU	Yucca Flat lower confining unit

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1.0 Introduction

1.1 Project Description

Well ER-7-1 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-7-1 is the fourth in a series of five wells drilled in Fiscal Year 2003, as part of a hydrogeologic investigation program for the Yucca Flat/Climax Mine Corrective Action Unit Number 97. 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.

The Yucca Flat hydrogeologic investigation well drilling 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 Yucca Flat hydrogeologic investigation well program is also part of the Corrective Action Investigation Plan (DOE/NV, 2000) for the Yucca Flat/Climax Mine Corrective Action Unit. The Corrective Action Investigation Plan is a requirement of the Federal Facility Agreement and Consent Order (FFACO, 1996) agreed to by the DOE, the Nevada Division of Environmental Protection, and the U.S. Department of Defense.

Well ER-7-1 is located in eastern Yucca Flat within the southeastern corner of NTS Area 7 (Figure 1-1). The elevation of the dirt-fill drill pad at the wellhead is 1,294.4 meters (m) (4,246.7 feet [ft]) above mean sea level. The Nevada State (central zone) plane coordinates (North American Datum [NAD] 1983) at the wellhead are North (N) 6,257,968.7 m and East (E) 559,622.5 m. Additional site data are listed in Table 1-1.

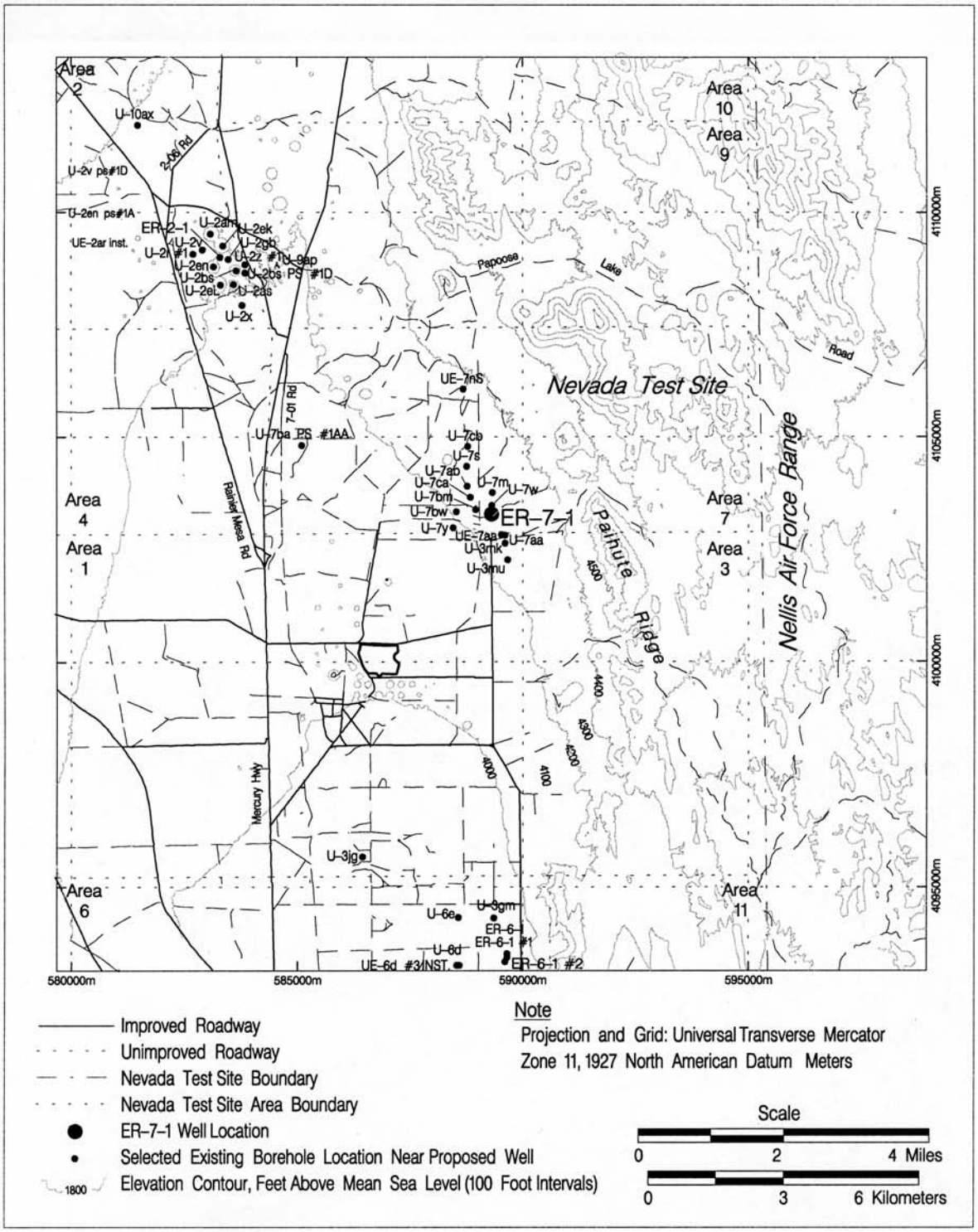

Figure 1-1
Reference Map Showing Location of Well ER-7-1

Table 1-1
Well ER-7-1 Site Data Summary

Well Designation	ER-7-1
Site Coordinates [a]	Nevada State Plane (central zone) (NAD 83): N 6,257,968.7 m (N 20,531,352.4 ft) E 559,622.5 m (E 1,836,028.2 ft) Nevada State Plane (central zone) (NAD 27): N 846,349.7 ft E 695,869.2 ft Universal Transverse Mercator (Zone 11)(NAD 83): N 4,103,471.9 m E 589,235.7 m
Surface Elevation [b]	1,294.4 m (4,246.7 ft)
Drilled Depth	762.0 m (2,500 ft)
Fluid-Level Depth [c]	565.1 m (1,854 ft)
Fluid-Level Elevation	729.2 m (2,392.7 ft)

a Measurement made by BN Survey.
b Measurement made by BN Survey. Elevation at top of construction pad. 1929 National Geodetic Vertical Datum.
c Measured with density neutron log run on February 7, 2003, by Halliburton Energy Services.

Shaw Environmental (Shaw) (formerly IT Corp.; now succeeded by Stoller-Navarro Joint Venture) was the principal environmental contractor for the project, and Shaw 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, 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 the BN Field Activity Work Plan D-001-001.03 (BN, 2002).

The UGTA Technical Working Group, 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 *Yucca Flat Hydrogeologic Investigation Wells, Drilling and Completion Criteria* (IT, 2002) for descriptions of the general plan and goals of the Yucca Flat 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/NV, 2002). Management of solid waste (i.e., cuttings) is addressed in the UGTA Waste Management Plan (DOE/NV, 1996). Estimates of expected production of fluid and drill cuttings for the Yucca Flat holes are given in Appendix F of the drilling and completion criteria document for the Yucca Flat project (IT, 2002), along with sampling requirements and contingency plans for management of any hazardous waste produced. All activities were conducted according to the UGTA Health and Safety Plan (BN, 2001).

This report presents construction data and summarizes scientific data gathered during drilling and installation of the completion string. Some of the information in this report is preliminary and unprocessed, but is being released with the drilling and completion data for convenient reference. A well data report prepared by Shaw (Shaw, 2003) 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 separately.

1.2 Objectives

The primary purpose for constructing Well ER-7-1 was to evaluate the regional carbonate aquifer (lower carbonate aquifer [LCA]) down-gradient from an underground nuclear test conducted close to the LCA. The Well ER-7-1 site located within a cluster of underground nuclear tests, some of which were conducted near (and therefore, potentially connected hydraulically) the LCA. The closest of these tests is the TORRIDO test, which was conducted in Emplacement Hole U-7w. The well site is believed to be down-gradient from TORRIDO, which is located approximately 187.1 m (614 ft) to the north.

Of particular interest is the determination of whether there are permeable, near-vertical pathways (faults) along which radionuclides could migrate from individual underground tests to the underlying regional aquifer. The drilling criteria document (IT, 2002) presents all program objectives, and Appendix C of the document discusses the specific scientific objectives for Well ER-7-1, which include the following:

- Obtain geologic samples and geophysical data that will aid in defining and characterizing hydrostratigraphic units encountered.

- Obtain fracture and other geologic data to aid the overall characterization of the LCA.
- Obtain aqueous geochemistry samples to establish the initial radiochemistry of groundwater within the LCA at this down-gradient position.
- Obtain water level data.

1.3 Project Summary

This section summarizes Well ER-7-1 construction operations; the details are provided in sections 2.0 through 8.0 of this report.

The conductor hole was constructed by augering a 91.4-centimeter- (cm) (36-inch [in.]) diameter hole to a depth of 36.6 m (120 ft) and installing a string of 20-in. casing. Drilling of the surface hole with an 18½-in. rotary bit, using an air-water-foam fluid (with a polymer additive as necessary) in conventional circulation, began on January 27, 2003. A suitable depth to set the surface casing was reached at 541.0 m (1,775 ft). At this point, drilling was suspended for geophysical logging, and then the 13**d**-in. casing string was landed at 535.1 m (1,755.6 ft) on February 1, 2003. Drilling continued with a 12¼-in. bit to a total depth (TD) of 762.0 m (2,500 ft), which was reached on February 6, 2003. The planned TD of Well ER-7-1 was 670.6 m (2,200 ft), but because sufficient water had not been encountered by this depth, the borehole was deepened to accomplish the planned objectives.

Water production was first noted at a depth of approximately 695.3 m (2,281 ft), and reached a maximum of approximately 1,893 liters per minute (lpm) (500 gallons per minute [gpm]) near the bottom of the hole. The fluid level was measured at the depth of 565.1 m (1,854 ft) with the density neutron log on February 7, 2003. No radionuclides above background levels were encountered during drilling of Well ER-7-1.

Composite drill cuttings were collected every 3 m (10 ft) from 36.6 m (120 ft) to TD, and 62 sidewall core samples were taken at various depths below 85.3 m (280 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 providing borehole volume and conditions, and cement location. The well penetrated Quaternary and Tertiary surficial deposits; tuffs of the Timber Mountain Group, Paintbrush Group, Calico Hills Formation, Wahmonie Formation, Crater Flat Group, Belted Range Group, and Tunnel Formation; and carbonate sedimentary rocks of Paleozoic-age.

A single completion string was installed in Well ER-7-1 on February 9, 2003. The string of carbon-steel, 7 **e** -in. production casing was landed at 756.4 m (2,481.7 ft). The bull-nosed string has one slotted interval at 664.1 to 756.4 (2,178.7 to 2,481.7 ft).

No pump was installed at the time of completion, but will be inserted as needed for hydrologic sampling and testing activities, which are beyond the scope of this report.

1.4 Project Manager

Inquiries concerning Well ER-7-1 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

2.1 Introduction

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

The general drilling requirements for all Yucca Flat wells in this series were provided in *Yucca Flat Hydrogeologic Investigation Wells Drilling and Completion Criteria* (IT, 2002). Specific requirements for Well ER-7-1 were outlined in Field Activity Work Plan D-001-001.03 (BN, 2002). Figure 2-1 shows the layout of the drill site. Figure 2-2 is a chart that illustrates the drilling and completion history for Well ER-7-1. Table 2-1 summarizes the drilling statistics for the well. The following information was compiled primarily from daily drilling reports provided by the BN Drilling Department.

2.2 Drilling History

Field operations at Well ER-7-1 began with the augering of a 91.4-cm (36-in.) conductor hole to 36.6 m (120 ft). A string of 20-in. casing was set at the depth of 36.6 m (120 ft). The bottom of the conductor casing was cemented inside to 29.0 m (95 ft), and the annulus was cemented from the bottom of the casing to ground level on November 20, 2002.

The UDI crews rigged up the Wilson Mogul 42B rig on January 23 through 27, 2003, and tagged cement inside the conductor casing at the depth of 29.0 m (95 ft). Drilling resumed through the cement and into the formation with an 18½-in. rotary button bit, using air-foam with a polymer additive. The amounts of polymer and foaming agent in the drilling fluid, and the fluid injection rate, were adjusted as necessary during drilling to maintain superior circulation.

As a precaution against sloughing of the upper sections of unsaturated volcanic rocks, it was decided to install surface casing when a competent formation for supporting the casing was reached. On January 30, 2003, at a depth of 541.0 m (1,775 ft), drilling was halted to set the surface casing. The drillers circulated fluid to clean and condition the hole, pulled the drill string off the bottom, and waited about 30 minutes before tagging bottom again. Fill was encountered at 539.5 m (1,770 ft), then the drillers removed the drill string from the borehole. Drilling activity was suspended for 15 hours during geophysical logging prior to installation of the surface casing.

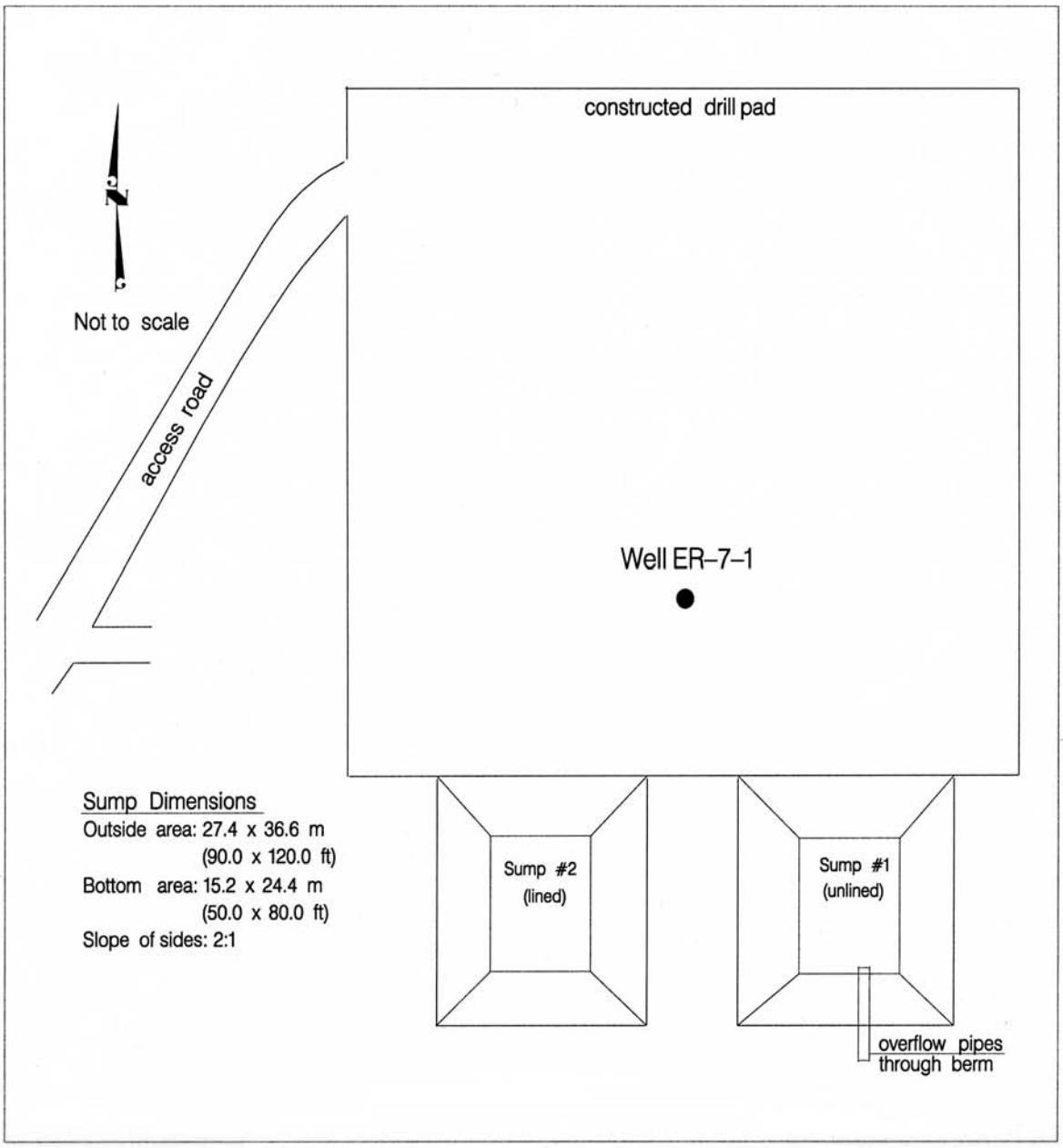

Figure 2-1
Drill Site Configuration for Well ER-7-1

WELL ER–7–1 SUMMARY

Activity	Date
Begin drilling conductor hole:	11/14/2002
Conductor hole completed and 20–in. casing set to 36.6 m (120 ft):	11/19/2002
Begin drilling 18 1/2–in. surface hole:	01/27/2003
Surface hole completed and 13 3/8–in. casing set to 531.1 m (1.755.6 ft):	02/05/2003
Begin drilling 12 1/4–in. intermediate hole:	02/04/2003
Reach total drilled depth of 762 m (2,500 ft):	02/07/2003

LEGEND

BHA	Bottom hole assembly
DRI	Desert Research Institute
ft	foot (feet)
gpm	gallons per minute
in.	inch(es)
lpm	liters per minute
m	meter(s)
TD	Total depth
TIH	Trip into hole
TOC	Top of cement
TOH	Trip out of hole
UDI	United Drillers, Inc.

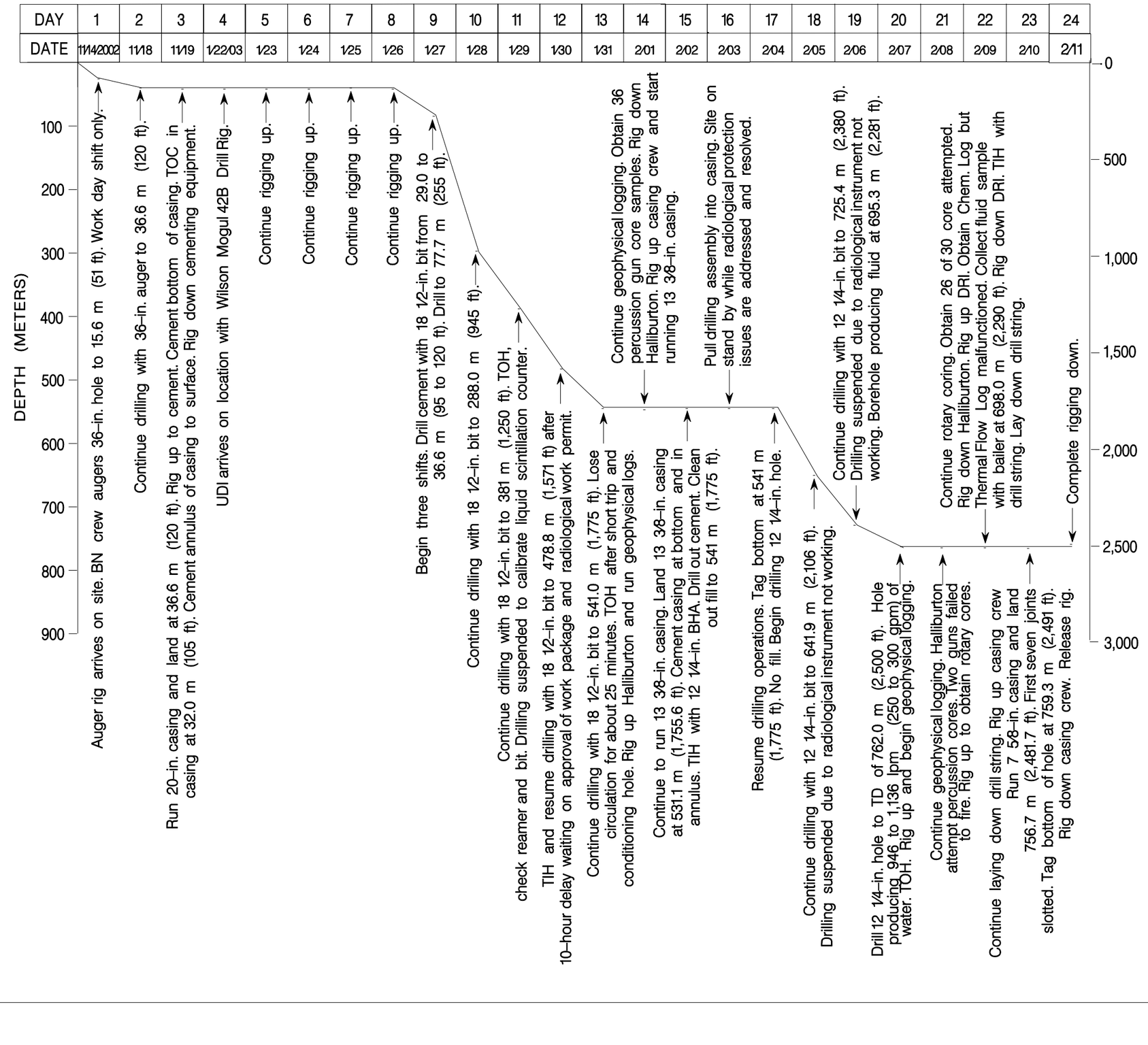

FIGURE 2–2
WELL ER–7–1
DRILLING AND COMPLETION HISTORY
SHEET 1 OF 1

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Table 2-1
Abridged Drill Hole Statistics for Well ER-7-1

LOCATION DATA:			
Coordinates:	Central Nevada State Planar:	NAD83: N6,257,968.7 m	E559,622.5 m
	Universal Transverse Mercator:	NAD27: N846,349.7 ft	E695,869.2 ft
		NAD83: N4,103,471.9 m	E589,235.7 m
Surface Elevation: [a]	1,294.4 m (4,246.7 ft)		
DRILLING DATA:			
Spud Date:	01/26/2003 (main hole drilling with Wilson Mogul 42B rig)		
Total Depth (TD):	762.0 m (2,500 ft)		
Date TD Reached:	02/07/2003		
Date Well Completed: [b]	02/09/2003		
Hole Diameter:	91.4 cm (36 in.) from surface to 36.6 m (120 ft); 47.0 cm (18.5 in.) from 36.6 to 541.0 m (120 to 1,775 ft); 31.1 cm (12.25 in) from 541.0 m (1,775 ft) to TD of 762.0 m (2,500 ft).		
Drilling Techniques:	Dry-hole auger from surface to 36.6 m (120 ft); rotary drill with 18½-in. bit using air-foam/polymer in direct circulation from 36.6 m to 541.0 m (120 to 1,775 ft); rotary drill with 12¼-in. bit and air-foam/polymer to TD of 762.0 m (2,500 ft).		
CASING DATA:	20-in. conductor casing from surface to 36.6 m (120 ft); 13**d**-in. surface casing to 535.1 m (1,775.6 ft).		
WELL COMPLETION DATA:			
The completion string consists of 7 **e**-in. carbon-steel casing. The 19.37-cm (7.625-in.) outside-diameter carbon-steel casing has an inside diameter of 17.701-cm (6.969-in.), is bull-nosed, and has one slotted interval (listed below) that consists of seven consecutive slotted joints. Detailed data for the completion interval are provided in Section 7.0 of this report.			
Total Depth:	756.4 m (2,481.7 ft)		
Depth of Slotted Section:	664.9 to 755.7 (2,181.5 to 2,479.3)		
Depth of Sand Pack:	None used.		
Depth of Gravel Pack:	None used.		
Depth of Pump:	Not installed at time of completion.		
Water Depth: [c]	565.1 m (1,854 ft)		
DRILLING CONTRACTOR:	United Drilling, Inc.		
GEOPHYSICAL LOGS BY:	Halliburton Energy Services		
SURVEYING CONTRACTOR:	Bechtel Nevada		

a Elevation of ground level at collar (1929 National Geodetic Vertical Datum).
b Date completion string as installed.
c Measured by Halliburton Energy Services on February 7, 2003.

A casing subcontractor installed the 13**d**-in. casing. The casing was landed at a depth of 535.1 m (1,755.6 ft) on February 2, 2003, above about 5.8 m (19 ft) of fill that had accumulated in the bottom of the surface hole during geophysical logging.

After the crew drilled out the cement and casing shoe, drilling operations were halted for a total of 39.5 hours on February 2-3, 2003, to address issues with Radioactive Work Permits (RWPs) and bioassays. When drilling resumed, no fill was encountered and the 12¼-in. borehole was advanced past the planned TD of 670.6 m (2,200 ft) because water had not yet been encountered. At approximately 695.3 m (2,281 ft), the hole started producing fluid at an estimated rate of 1,514 lpm (400 gpm) and it was decided to drill to a new TD of 762.0 m (2,500 ft). The final TD was reached on February 6, 2003. Immediately after reaching TD, the drillers circulated fluid to condition the hole before the second phase of geophysical logging, which took place on February 7 through 9, 2003. Installation of the completion string began on February 9, 2003, and demobilization from the Well ER-7-1 site began on February 10, 2003.

The directional survey run inside the 7**e**-in. casing on April 14, 2003, indicates that at the lowest surveyed depth of 754.4 m (2,475 ft) the hole had drifted 5.4 m (17.6 ft) to the southeast of the well collar location. The borehole is relatively straight, with no "dog-legs."

A graphical depiction of drilling parameters, including penetration rate, revolutions per minute, pump pressure, and weight on 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-7-1 are listed in Appendix A-3.

2.3 Drilling Problems

No significant drilling problems were encountered at Well ER-7-1. Fill of generally less than 3 m (10 ft) was encountered only after non-drilling-related delays. Drilling continued 91.4 m (300 ft) past the planned TD because water had not been encountered, but this did not cause a significant delay.

2.4 Fluid Management

Drilling effluent was monitored according to the methods prescribed in the UGTA FMP (DOE/NV, 2002) and the associated site-specific strategy letter (Wycoff, 2003). The air-foam/polymer drill fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional or direct circulation) and then discharged into a sump. Water used to prepare drilling fluids came from Water Well 5B at the Hazardous Materials Spill Center and from the Radioactive Waste Management

Site fill stand. Water from various NTS water wells on the site water well system feeds the fill stand, which may contain a variable mix of waters from Water Well 4 or Water Well 4a. Lithium bromide (LiBr) was added to the drill fluid as a tracer to provide a means of estimating groundwater production. The rate of water inflow was estimated from the dilution of the tracer in the drill fluid returns.

To manage the anticipated water production, two sumps were constructed prior to drilling (Figure 2-1). Although the production of contaminants was considered unlikely, one of the sumps was lined with 40-millimeter, high density polyethylene prior to drilling (Bangerter, 2002). Samples of drilling effluent were tested on site hourly for the presence of tritium, and paint on down-hole tools was tested for lead prior to insertion in the borehole. The onsite monitoring results indicate that tritium remained at background levels (Shaw, 2003).

Before fluids are discharged to the ground surface, the FMP requires that a sample be collected and analyzed by an offsite laboratory to verify onsite monitoring data and demonstrate compliance with the FMP. At Well ER-7-1, the bulk of the fluids were discharged directly to the ground surface; therefore, the ground water characterization sample that was obtained from the depth of 698.0 m (2,290 ft) prior to installation of the completion string was used to demonstrate compliance with the FMP (Wurtz, 2003). The analytical results (Shaw, 2003) showed that discharged fluids were within the parameters of the FMP criteria. Water-quality data for this sample are given in Appendix B.

The results of analyses of samples of drilling fluid collected at Well ER-7-1 during drilling operations indicate that all fluid quality objectives were met, as shown on the fluid management reporting form dated February 11, 2003 (Appendix B). The form lists volumes of solids (drill cuttings) and fluids produced during well-construction operations, Stages I and II (i.e., vadose- and saturated-zone drilling only; 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 volumes of fluids listed on the report are estimates of total fluid production, and do not account for any infiltration or evaporation of fluids from the sumps.

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3.0 Geologic Data Collection

3.1 Introduction

This section describes the sources of geologic data obtained from Well ER-7-1 and the methods of data collection. Improving the understanding of the subsurface structure, stratigraphy, and hydrogeology in an area down-gradient from an underground nuclear test conducted close to the LCA was among the primary objectives of Well ER-7-1. The proper collection of geologic and hydrogeologic data from Well ER-7-1 was considered of prime importance to the completion of the project.

Geologic data collected at Well ER-7-1 consist of drill cuttings, sidewall core samples, and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures.

3.2 Collection of Drill Cuttings

Composite drill cuttings were collected from Well ER-7-1 at 3-m (10-ft) intervals as drilling progressed from the depth of 36.6 m (120 ft) to the TD of the well at 762.0 m (2,500 ft). Triplicate samples were collected from 238 intervals. In addition, the Shaw 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 other set was sent to LANL where it remains. Additionally, a larger composite drill cuttings sample (approximately 3.8 liters [1 gallon] in size) was collected while drilling through the pre-Tertiary carbonate rocks. Selected depths from this collection will be shipped to a commercial laboratory for paleontologic micro-fossil analysis to aid in the stratigraphic assignment of these rocks.

All other samples (i.e., 3 sets of 238 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

Sidewall core samples were collected by Halliburton Energy Services from Well ER-7-1 to verify the stratigraphy and lithology at selected locations. Sample locations were selected by the Shaw field representative on the basis of field lithologic logs (with consideration of borehole conditions determined from caliper logs). A percussion gun tool was used to collect 36 sidewall cores in the upper 561.1 m (1,841 ft) of the borehole on January 31, 2003, prior to installation of the surface casing. Before the completion string was installed, Halliburton collected 25 rotary sidewall cores from the lower part of the borehole. Table 3-1 lists the recovery and stratigraphic assignment for each sample.

3.4 Sample Analysis

Composite samples of drill cuttings from various depths in Well ER-7-1 were submitted to the LANL Earth and Environmental Sciences Division – Geology and Geochemistry laboratories for petrographic, mineralogic, and chemical analysis to aid in stratigraphic identification and for characterization of mineral alteration. The status of these analyses is shown in Table 3-2.

3.5 Geophysical Data

Geophysical logs were run in the Well ER-7-1 borehole to further characterize the lithology, structure, and water content of the rocks encountered. In addition, logs were run to evaluate borehole conditions and to determine the fluid levels during the course of drilling. Geophysical logging was conducted during two stages of drilling and completion: before installation of the surface casing and before installation of the well completion casing. Some logs were run in both the saturated and unsaturated zones of the borehole, while others were run in only the saturated interval. A complete listing of the logs, dates run, depths, and service companies is provided in Table 3-3. The logs are available from BN in Mercury, Nevada, and copies are on file at the office of Stoller-Navarro Joint Venture in Las Vegas, Nevada. Preliminary geophysical data from the logs are reproduced in Appendix D.

The overall quality of the geophysical data collected was good, though the sonic log is considered invalid above the depth of 701.0 m (2,300 ft) due to turbulence in the fluid column. Technical problems that could not be corrected onsite were encountered with some tools.

Table 3-1
Sidewall Samples from Well ER-7-1 (Page 1 of 2)

Core Depth Meters (Feet)	Tool Used [a]	Length Recovered [b] Centimeters (Inches)	Stratigraphic Unit [c]
85.3 (280)	SWC	4.1 (1.6)	Tmr
92.7 (304)	SWC	3.6 (1.4)	Tmr
153.6 (504)	SWC	4.6 (1.8)	Pre-Tmr, post Tw
161.5 (530)	SWC	3.3 (1.3)	Pre-Tmr, post Tw
181.7 (596)	SWC	4.1 (1.6)	Tw
185.6 (609)	SWC	3.6 (1.4)	Tw
201.2 (660)	SWC	4.6 (1.8)	Tw
210.3 (690)	SWC	5.1 (2.0)	Tc
242.0 (794)	SWC	5.1 (2.0)	Tc
248.4 (815)	SWC	3.8 (1.5)	Tc
257.9 (846)	SWC	5.1 (2.0)	Tc
276.2 (906)	SWC	5.1 (2.0)	Tc
285.3 (936)	SWC	3.8 (1.5)	Tc
295.7 (970)	SWC	5.1 (2.0)	Tn4E
309.1 (1,014)	SWC	5.1 (2.0)	Tn4E
317.6 (1,042)	SWC	5.1 (2.0)	Tn4E
358.1 (1,175)	SWC	5.1 (2.0)	Tn3BC
362.4 (1,189)	SWC	5.1 (2.0)	Tn3BC
374.9 (1,230)	SWC	4.6 (1.8)	Tn
382.2 (1,254)	SWC	3.6 (1.4)	Tn
398.7 (1,308)	SWC	4.6 (1.8)	Tn
400.2 (1,313)	SWC	4.6 (1.8)	Tn
412.7 (1,354)	SWC	4.1 (1.6)	Toy
423.4 (1,389)	SWC	4.1 (1.6)	Toy
434.7 (1,426)	SWC	4.1 (1.6)	Toy
447.5 (1,468)	SWC	4.1 (1.6)	Toy
460.9 (1,512)	SWC	4.1 (1.6)	Tn, unit 1
467.6 (1,534)	SWC	4.1 (1.6)	Tn, unit 1
476.7 (1,564)	SWC	4.1 (1.6)	Tn, unit 1
482.5 (1,583)	SWC	4.6 (1.8)	Tn, unit 1
487.7 (1,600)	SWC	2.5 (1.0)	Tn, unit 1
493.5 (1,619)	SWC	3.6 (1.4)	Tn, unit 1
502.9 (1,650)	SWC	4.1 (1.6)	Tn, unit 1

Table 3-1
Sidewall Samples from Well ER-7-1 (Page 2 of 2)

Core Depth Meters (Feet)	Tool Used [a]	Length Recovered [b] Centimeters (Inches)	Stratigraphic Unit [c]
506.6 (1,662)	SWC	4.6 (1.8)	Tn, unit 1
530.1 (1,739)	SWC	5.1 (2.0)	Pz
533.4 (1,750)	SWC	5.1 (2.0)	Pz
561.1 (1,841)	MSCT	4.6 (1.8)	Pz
563.0 (1,847)	MSCT	4.6 (1.8)	Pz
568.2 (1,864)	MSCT	4.1 (1.6)	Pz
577.0 (1,893)	MSCT	4.1 (1.6)	Pz
581.3 (1,907)	MSCT	3.1 (1.2)	Pz
583.1 (1,913)	MSCT	5.0 (2.0)	Pz
590.1 (1,936)	MSCT	4.9 (1.9)	Pz
593.4 (1,947)	MSCT	4.6 (1.8)	Pz
600.5 (1,970)	MSCT	3.8 (1.5)	Pz
603.8 (1,981)	MSCT	3.6 (1.4)	Pz
605.0 (1,985)	MSCT	3.3 (1.3)	Pz
608.4 (1,996)	MSCT	4.8 (1.9)	Pz
613.9 (2,014)	MSCT	3.6 (1.4)	Pz
630.3 (2,068)	MSCT	3.6 (1.4)	Pz
640.1 (2,100)	MSCT	4.6 (1.8)	Pz
672.7 (2,207)	MSCT	2.8 (1.1)	Pz
679.7 (2,230)	MSCT	4.1 (1.6)	Pz
684.9 (2,244)	MSCT	5.1 (2.0)	Pz
700.1 (2,297)	MSCT	4.3 (1.7)	Pz
711.1 (2,333)	MSCT	4.1 (1.6)	Pz
717.8 (2,355)	MSCT	3.8 (1.5)	Pz
734.3 (2,409)	MSCT	4.1 (1.6)	Pz
737.9 (2,421)	MSCT	4.3 (1.7)	Pz
750.7 (2,463)	MSCT	3.6 (1.4)	Pz
754.1 (2,474)	MSCT	4.1 (1.6)	Pz

a **SWC** = Percussion sidewall gun; **MSCT** = Rotary mechanical sidewall coring tool. Both tools operated by Halliburton Energy Services.

b Estimated.

c Preliminary assignments. **Tmr** = Rainier Mesa Tuff; **Pre-Tmr post Tw** = Pre-Rainier, Mesa post-Wahmonie Tuff; **Tw** = Wahmonie Tuff; **Tc** = Crater Flat Tuffs; **Tn4E** = Tunnel 4 member, Bed E (equivalent); **Tn** = Tunnel beds, undifferentiated; **Toy** = Tuff of Yucca Flat; **Tn, unit 1** = Tunnel bed 1; **Pz** = Paleozoic sedimentary rocks, undivided.

Table 3-2
Status of Rock Sample Analyses for Well ER-7-1

Depth [a] meters (feet)	Analyses Performed [b]				
	Petrographic	Mineralogic		Chemical	
	PTS	**MP**	**XRD**	**XRF**	**Fe^{2+}/Fe^{3+}**
57.9 (190)	C	C	N/P	N/P	N/P
91.4 (300)	C	C	C	C	C
149.4 (490)	C	C	C	C	C
189.0 (620)	C	NP	C	C	C
201.2 (660)	C	NP	C	C	C
216.4 (710)	C	NP	C	C	C
237.7 (780)	C	NP	C	C	C
262.1 (860)	C	C	C	C	C
277.4 (910)A	C	NP	C	C	C
277.4 (910)B	C	NP	C	C	C
310.9 (1,020)	C	C	C	C	C
353.6 (1,160)	C	NP	C	C	C
371.9 (1,220)	C	NP	C	C	C
378.0 (1,240)	C	NP	C	C	C
414.5 (1,360)	C	NP	C	C	C
429.8 (1,410)	C	C	C	C	C
463.3 (1,520)	C	C	C	C	C
502.9 (1,650)	C	C	C	C	C
506.0 (1,660)	C	NP	C	C	C
515.1 (1,690)	C	NP	C	C	C
551.7 (1,810)	C	NP	N/P	N/P	N/P
752.9 (2,470)	C	NP	N/P	N/P	N/P

a Depth represents base of 3-m (10-ft) sample interval for drill cuttings. All samples are drill cuttings that represent the lithologic character of the interval.

b Status of analyses: **C** = analysis complete; **P** = analysis pending; **NP** = analysis not planned.
Analysis type: **PTS** = polished thin section; **MP** = electron microprobe; **XRD** = x-ray diffraction; **XRF** = x-ray fluorescence; **Fe^{2+}/Fe^{3+}** = wet chemical analysis for iron.

Table 3-3
Well ER-7-1 Geophysical Log Summary

Geophysical Log Type [a]	Log Purpose	Logging Service [b]	Date Logged	Run Number	Bottom of Logged Interval [c] meters (feet)	Top of Logged Interval [c] meters (feet)
* Natural Gamma Ray Spectroscopy	Stratigraphic correlation, mineralogy, natural and man-made radiation	HES	01/31/2003 02/07/2003	SGR-1/GR-3 SGR-2/GR-7	527.0 (1,729) 746.8 (2,450)	26.2 (86) 579.4 (1,704)
* Gamma Ray / Six Arm Caliper	Stratigraphic correlation, mineralogy, natural and man-made radiation	HES	01/31/2003 02/07/2003	GR-2/CA6-1 GR-6/CA6-2	536.5 (1,760) 756.5 (2,482)	15.2 (50) 487.7 (1,600)
* Epithermal Neutron / Density / Gamma Ray / Caliper	Total water content/borehole conditions	HES	01/31/2003 02/07/2003	DSEN-1/SDL-1/ GR-4 DSEN-2/SDL-2/ GR-8	538.9 (1,768) 759.3 (2,491)	13.7 (45) 518.2 (1,700.0)
* High Resolution Induction	Rock porosity, lithologic determination / stratigraphic correlation	HES	01/31/2003	HRI-1/GR-3	537.4 (1,763)	36.6 (120)
* Dual Laterolog / Gamma Ray / * Spontaneous Potential	Saturated zone: water saturation/ stratigraphic correlation	HES	02/07/2003	DLL-1/GR-7/SP-1	755.3 (2,478)	519.7 (1,705)
Electro MicroImager / Gamma Ray	Saturated zone: lithologic characterization, fracture and void analysis/stratigraphic correlation	HES	02/07/2003	FMI-1/GR-6	756.5 (2,482)	541.3 (1,776)
Temperature / Gamma Ray	Saturated zone: groundwater temperature/stratigraphic correlation	HES	01/31/2003 02/07/2003	TL-1/GR-1 TL-2/GR-5	522.4 (1,714) 743.7 (2,440)	0 426.7 (1,400)
Gamma Ray / Digital Array Sonic A. Wave-form presentations * B. Sonic porosity and travel time computations	Saturated zone: A. Porosity, lithologic determination B. Fracture identification	HES	02/07/2003	GR-9/FWS-1	756.2 (2,481)	518.2 (1,700)
Mechanical Sidewall Coring Tool	Geologic samples	HES	02/07/2003	RSWC-1	754.1 (2,474)	518.2 (1,700)
Percussion Sidewall Coring Gun	Geologic samples	HES	03/31/2003	SWC-1	533.4 (1,750)	85.3 (280)
Thermal Flow Log	Rate and direction of groundwater flow in borehole	DRI	02/09/2003	TFM-2	579.1 (1,900)	579.1 (1,900)
*Chemistry Log	Groundwater chemistry, formation transmissivity	DRI	02/08/2003	CHEM-1 /TL-3	761.4 (2,498)	565.1 (1,854)
Gyroscopic Directional Survey	Borehole deviation	BHI	04/14/2003	DRG-1	754.4 (2,475)	0

a Logs presented in geophysical log summary, Appendix D, are indicated by *.
b **HES** = Halliburton Energy Services; **DRI** = Desert Research Institute; **BHI** = Baker Hughes Inteq
c Depth below ground surface.

4.0 Geology and Hydrogeology

4.1 Introduction

This section summarizes the geology and hydrogeology of Well ER-7-1. The basis for these discussions is the detailed lithologic log presented in Appendix C. The detailed lithologic log was developed using drill cuttings and sidewall core samples, geophysical logs, and drilling parameters. Results from petrographic, mineralogic, and chemical analyses provided by Giday WoldeGabriel of LANL for select lithologic samples (WoldeGabriel, 2003) were incorporated into the lithologic log.

4.2 Geology

This section is subdivided into discussions of the stratigraphic section and structural features interpreted from Well ER-7-1 data, followed by a discussion of alteration noted in samples from the well.

4.2.1 Geologic Setting

Well ER-7-1 is located in south-central Area 7 in eastern Yucca Flat (Figure 4-1). Yucca Flat is a typical basin of the Basin and Range physiographic province, which is characterized by a series of tilted fault blocks resulting in longitudinal mountain ranges and broad intervening basins. In the vicinity of the NTS, the basins and ranges generally trend north-south. Yucca Flat formed as a result of Cenozoic movement and subsequent rotation along mostly normal faults. The basin is currently being filled with alluvial debris eroded from the surrounding mountains. The alluvium has buried a relatively thick sequence of east-dipping Tertiary volcanic rocks whose sources are various calderas in the region. The volcanic rocks are underlain by a thick sequence of Paleozoic miogeosynclinal rocks consisting of mostly carbonates (Gonzales et al., 1998). Figure 4-2 shows the surface geology mapped in the immediate vicinity of Well ER-7-1.

The Yucca Flat geologic quadrangle map (Colton and McKay, 1966) depicts the simple surface geology in this part of Yucca Flat. The sedimentary and volcanic terrains east of the site are illustrated on the Paiute Ridge geologic quadrangle map by Byers and Barnes (1967). Limestone and dolostone of Ordovician and Cambrian age outcrop 1,830 m (6,000 ft) to the east (Slate et al., 1999).

Well ER-7-1 penetrated 65.5 m (215.0 ft) of Quaternary and Tertiary tuffaceous alluvial deposits above 443.5 m (1,455.0 ft) of Tertiary volcanic rocks. Below the Tertiary-age volcanic rocks, the

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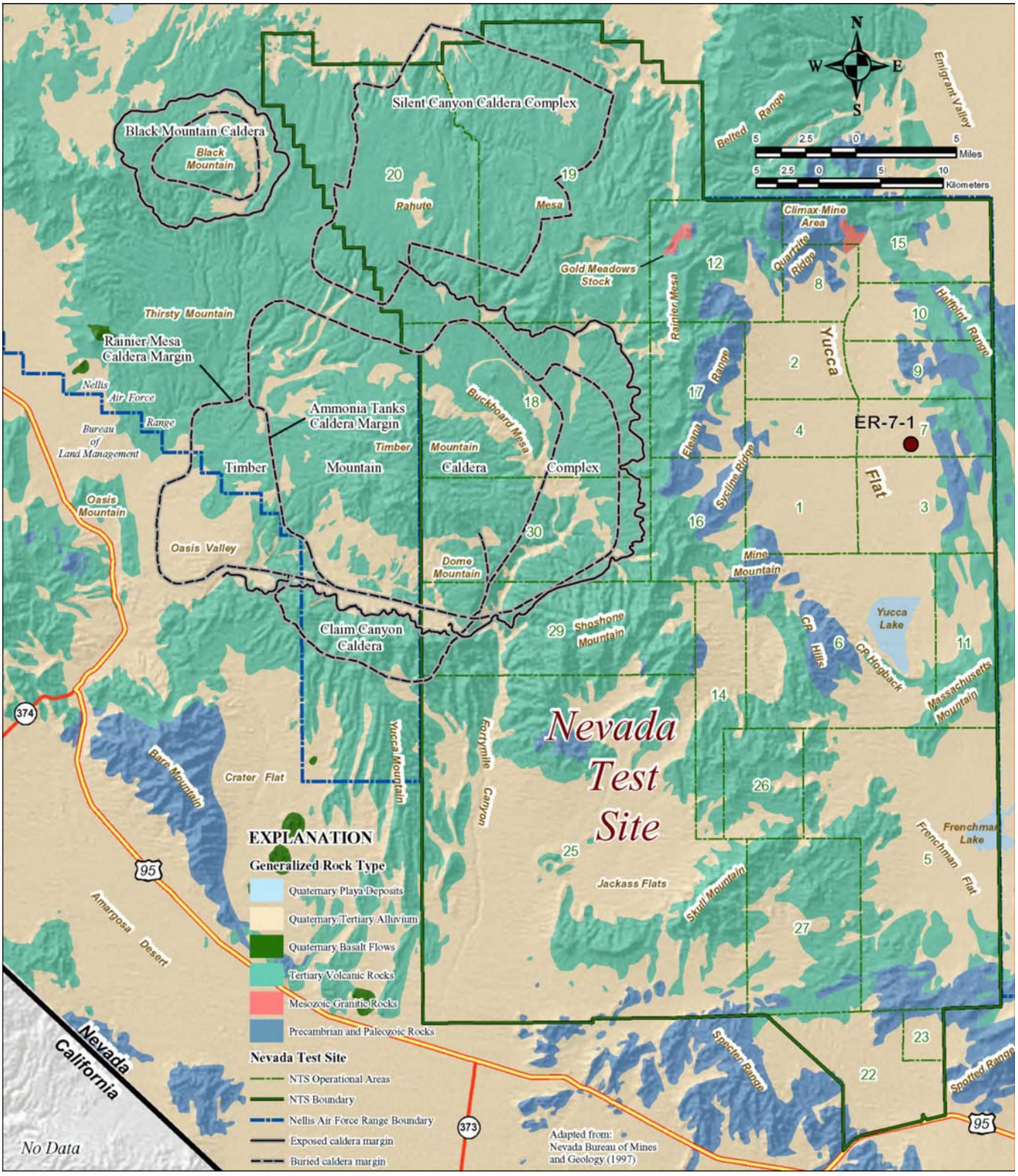

Figure 4-1
Generalized Surface Geologic Map of the Nevada Test Site Area Showing Location of Well ER-7-1

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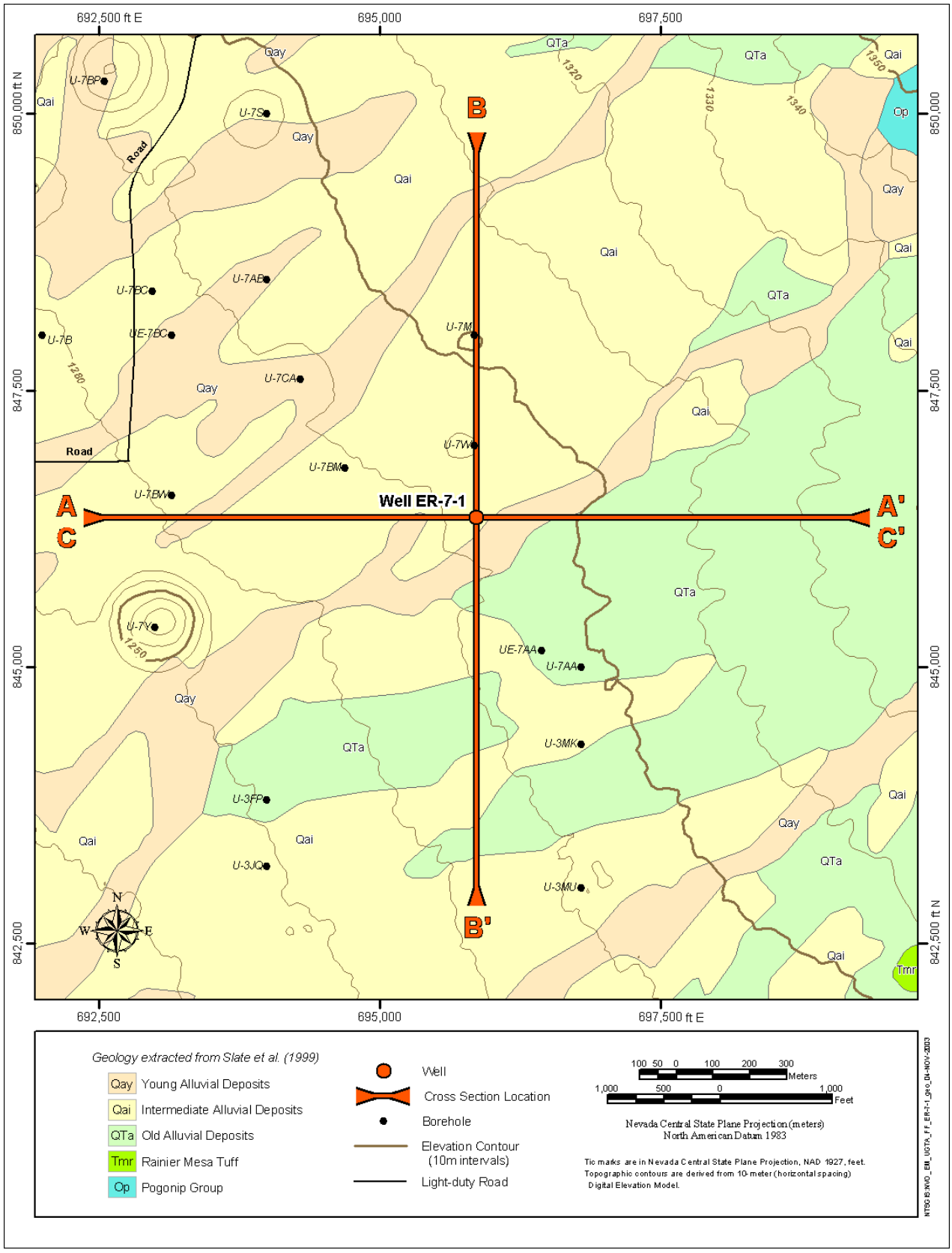

Figure 4-2
Surface Geologic Map of the Well ER-7-1 Site

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borehole penetrated over 244 m (800 ft) of Paleozoic-age sedimentary rocks. The stratigraphy and detailed lithology of the rocks encountered at Well ER-7-1 are very similar to those of nearby Emplacement Hole U-7ca (Drellack et al., 1986) and other nearby holes. The stratigraphy and lithology of Well ER-7-1 are illustrated in Figure 4-3.

4.2.2 Stratigraphy and Structure

Drilling of Well ER-7-1 began in Quaternary and Tertiary tuffaceous alluvial deposits that are 65.5 m (215 ft) thick at the well site. The borehole then penetrated 62.5 m (205 ft) of mostly welded ash-flow tuff assigned to the Rainier Mesa tuff, a unit of the Timber Mountain Group. Below the Timber Mountain Group rocks, the well penetrated 51.8 m (170 ft) of mostly vitric bedded and air-fall tuffs of the pre-Rainier Mesa, post-Wahmonie Canyon Tuffs, in turn underlain by the Wahmonie Tuff and Crater Flat Tuff, that have a combined thickness of 100.6 m (330 ft). Below these units, a thick sequence of bedded and nonwelded tuff units was encountered; these beds are assigned to the Tunnel Formation, older undifferentiated tuffs, and paleocolluvium. These mostly zeolitized units have a combined thickness of 449.7 m (770 ft). Below the Tertiary-age volcanic rocks and the paleocolluvium, the borehole penetrated a thick sequence of limestone of Cambrian age. These limestone units, not yet identified to stratigraphic unit, pending paleontological analysis, have a minimum (drilled) thickness of about 247 m (810 ft). Drilling was terminated in limestone at a depth of 762.0 m (2,500 ft).

The relative position, extent, and thickness of the stratigraphic units near Well ER-7-1 are illustrated on the west-east and north-south cross sections in Figures 4-4 and 4-5, respectively. As shown on the west-east cross section (Figure 4-4), the well is located on a minor structural block bounded by two high-angle, north-south trending faults. The presence of the fault to the west of Well ER-7-1 was geologically inferred from drill-hole data, while the fault to the east was inferred mainly from gravity data (Drellack, 1986). The bedding dip of the Tertiary volcanic units and the upper surface of the underlying Paleozoic section is fairly shallow toward the west, as depicted in the west-east cross section (Figure 4-4). The westerly dip was determined from drill-hole data and by extrapolation from structure contour and isopach maps of the area (Drellack, 1994). Preliminary analysis of the Electric MicroImager® (Enhanced Image, field print) also indicates a westerly dip direction.

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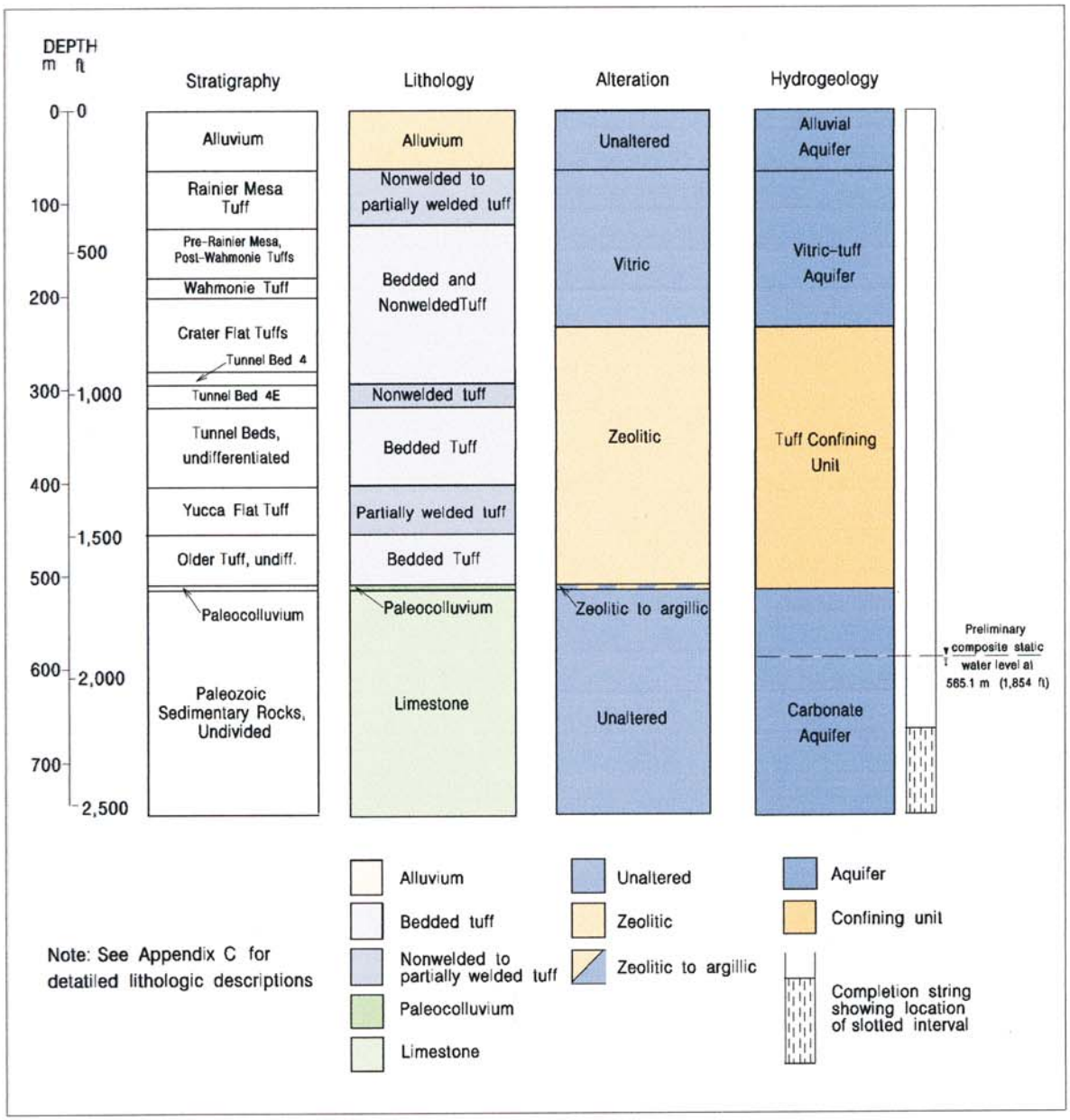

Figure 4-3
Geology and Hydrogeology of Well ER-7-1

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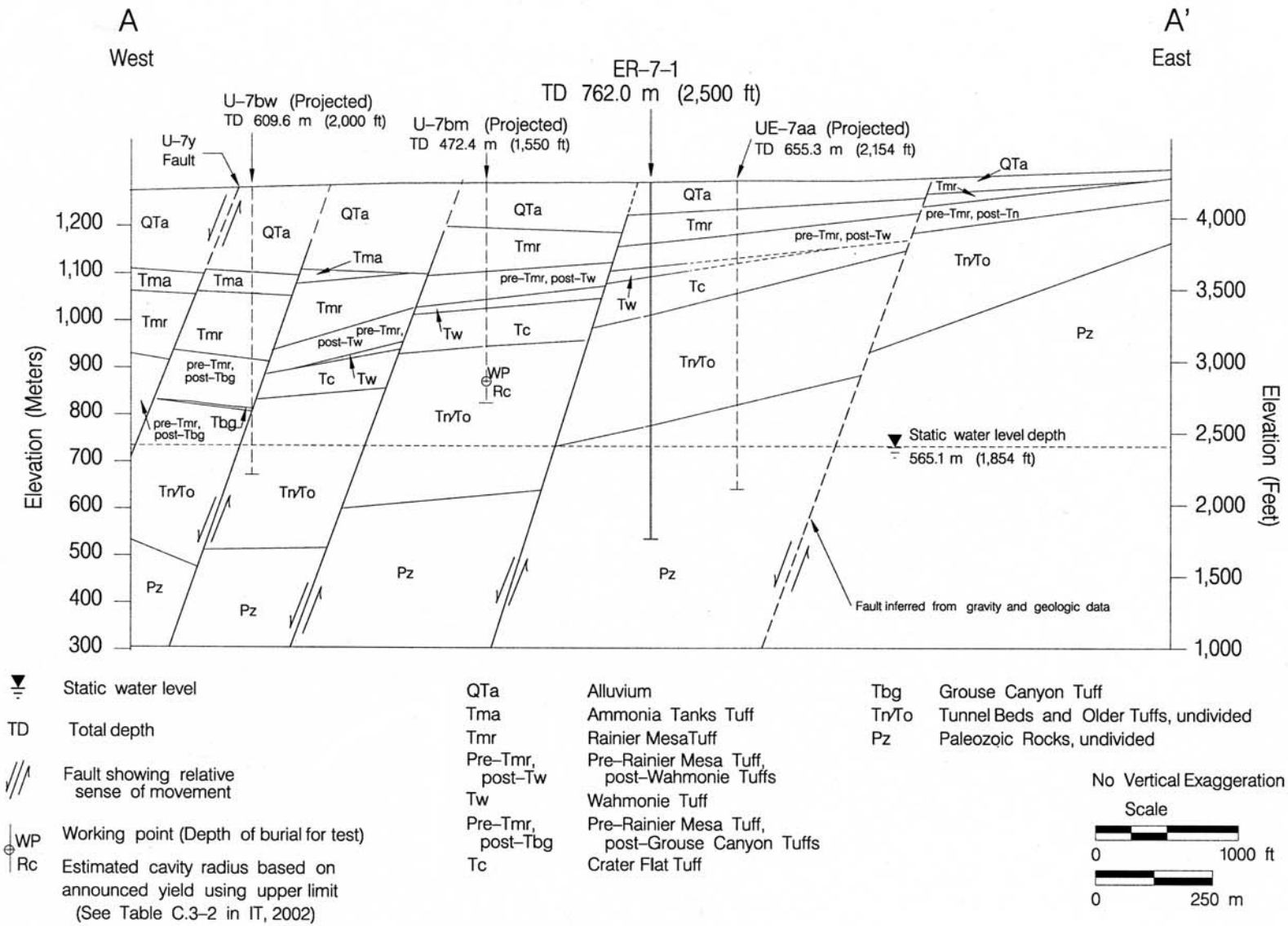

Figure 4-4
West-East Geologic Cross Section A-A' Through Well ER-7-1

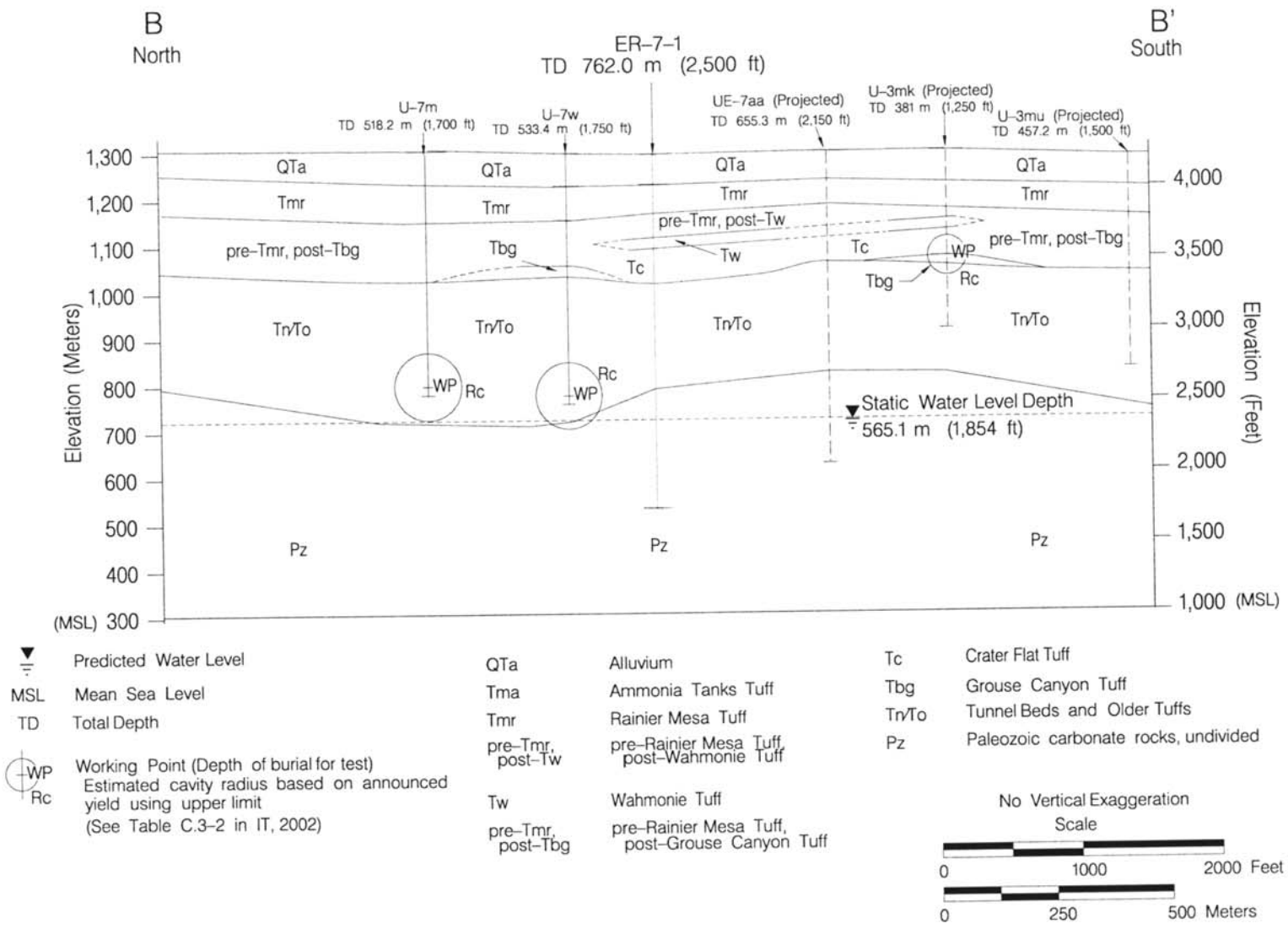

Figure 4-5
North-South Geologic Cross Section B-B' through Well ER-7-1

4.2.3 Alteration

Alteration has a significant effect on both the hydraulic character of volcanic rocks and on how radionuclides migrate through these rocks. The predominant type of mineralogic alteration observed in drill cuttings in each stratigraphic unit encountered in Well ER-7-1 is illustrated in Figure 4-3. The rocks below the 65.5-m (215-ft) thick unaltered alluvium and above the depth of 228.6 m (750 ft) are also mostly unaltered (vitric), with lesser amounts of devitrified, silicic, and zeolitic alteration. Below the depth of 228.5 m (750 ft), the rest of the volcanic section is zeolitic. All rocks below 515.1 m (1,690 ft) are unaltered Paleozoic-age sedimentary rocks consisting mostly of limestone.

4.3 Predicted Versus Actual Geology

The predicted geology for Well ER-7-1 (IT, 2002) was based on knowledge of geologic units that were encountered at nearby holes U-7ca, U-7w, U-7bm, and UE-7aa (Gonzales and Drellack, 1999; Drellack and Thompson, 1990). The depth and detailed lithology of the geologic units encountered in Well ER-7-1 were generally as predicted. A comparison of the predicted and the actual stratigraphy is provided in Figure 4-6.

4.4 Hydrogeology

The rocks of Well ER-7-1 can be subdivided into hydrogeologic units, as illustrated in Figure 4-3. A preliminary interpretation of the distribution of these units is shown in cross section on Figure 4-7.

The dominant saturated hydrogeologic unit in Well ER-7-1 is a carbonate aquifer, consisting mostly of limestone, and accounting for approximately 32 percent of the rocks penetrated by the well. Analysis of water production during drilling indicates that the carbonate aquifer rocks produced water at a rate of about 1,136 lpm (300 gpm) to as much as 1,893 lpm (500 gpm) during drilling below a depth of 695.3 m (2,281 ft).

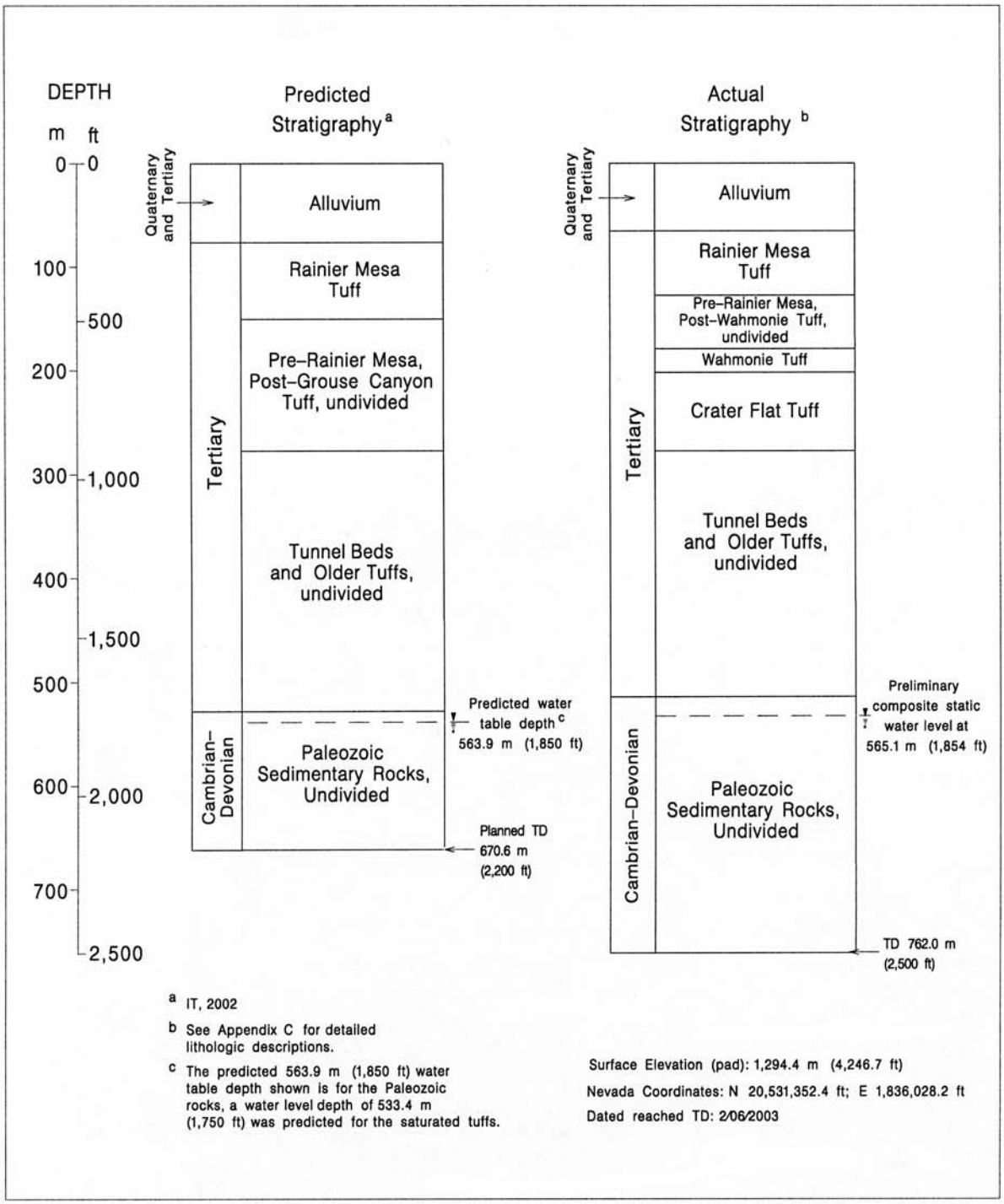

Figure 4-6
Predicted and Actual Stratigraphy at Well ER-7-1

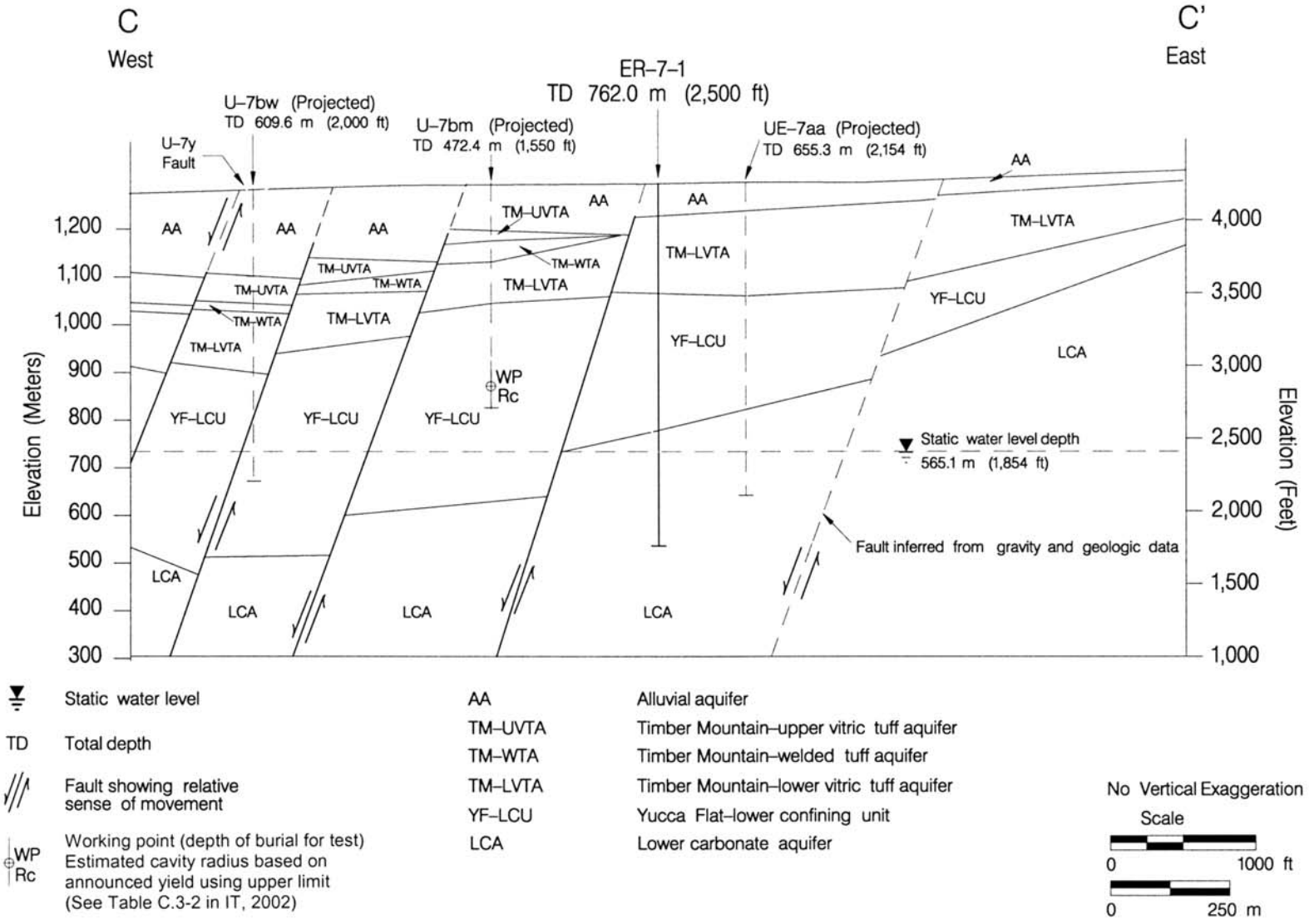

Figure 4-7
West-East Hydrogeologic Cross Section C-C' Through Well ER-7-1

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5.0 Hydrology

5.1 Preliminary Water-Level Information

Well ER-7-1 was drilled to provide additional hydraulic head data for northern Yucca Flat and to provide a well to help evaluate the regional carbonate aquifer down-gradient from an underground nuclear test which was conducted close to the carbonate aquifer. The elevation of the water table at ER-7-1 was projected to be approximately 760.5 m (2,495 ft) in the Tertiary-age volcanic units, and 730.0 m (2,395 ft) in the Paleozoic-age carbonate rocks (IT, 2002). Based on the pre-construction estimate of surface elevation at the site, depth to water was expected at approximately 533.4 m (1,750 ft) (Tertiary-age volcanic units) and 563.9 m (1,850 ft) (Paleozoic-age carbonate rocks). During drilling, water production was first noted at a depth of approximately 695.2 m (2,281 ft), and a fluid depth of 565.1 m (1,854 ft) was obtained from a density neutron log run on February 7, 2003, before the completion string was installed.

5.2 Water Production

Water production was estimated during drilling of Well ER-7-1 on the basis of LiBr dilution data as measured by Shaw field personnel. Water production began at the depth of about 695.2 m (2,281 ft) within the Paleozoic carbonate rocks, and remained fairly steady to the TD of 762.0 m (2,500 ft) at the rate of 1,136 to 1,893 lpm (300 to 500 gpm). Estimated water production rates are presented graphically in Appendix A-1.

5.3 Preliminary Flow Meter Data

Flow meter data, along with temperature, electrical conductivity (EC), and pH measurements, can be used to characterize borehole fluid variability, which may indicate inflow and outflow zones. Desert Research Institute (DRI) personnel tried to make measurements with their thermal flow meter (TFM) tool but, after running two different tools into the hole, only one data point at 579.1 m (1,900 ft) was acquired.

In addition, DRI ran a chemistry log, which included measurements of temperature, EC, and pH in the fluid column, from 565.1 to 761.4 m (1,854 to 2,498 ft). Groundwater temperature gradually increased from the minimum reading of 41.0 degrees Celsius (°C) (105.9 degrees Fahrenheit [°F]) at the top of the fluid column to the depth of approximately 698.0 m (2,290 ft), where the maximum recorded temperature in the borehole was measured at 45.5°C (114°F). Below this depth, which

coincides with the location of maximum water production in the borehole, the fluid temperature decreased slightly. The plot of the chemistry log data is reproduced in Appendix D.

5.4 Preliminary Groundwater Characterization Sample

Following geophysical logging, DRI collected a preliminary groundwater characterization sample at the depth of 698.0 m (2,290 ft) in the open borehole. 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-7-1 consisted of circulating fluid for 30 minutes to clean the borehole and using two compressors to blow water out 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 such as cement, sand, or gravel around the casing, to isolate selected intervals, though in some wells the completion string is left in an open hole. The casing serves as a conduit for insertion of a pump in the well, for inserting devices for measuring fluid level, and for sampling, so that accurate potentiometric and water chemistry data can be collected from known portions of the borehole.

The proposed well completion design for Well ER-7-1, as presented in the Yucca Flat drilling criteria document (IT, 2002) is described in Section 7.2.1. The actual well completion, designed on the basis of the hydrogeology encountered in the borehole, is presented in Section 7.2.2.

Completion activities at Well ER-7-1 took place on February 9 and 10, 2003, after geophysical logging operations were concluded. Figure 7-1 is a schematic of the final completion design for Well ER-7-1, Figure 7-2 depicts 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. Shaw's well data report (Shaw, 2003) was also consulted 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

Well ER-7-1 was designed to provide geologic information and groundwater production data from the LCA, and to serve as a water-level monitoring point within the Yucca Flat lower confining unit (YF-LCU), if the unit were saturated. It was planned to install a production string consisting of slotted, 7 **e** -in. carbon-steel casing, open, through a gravel-pack, to water-producing zones in the LCA. If groundwater were present in the YF-LCU, access to it would be accomplished by installing a 2 **f** -in. piezometer string, slotted within a 15.2-m (50-ft) interval of the YF-LCU. If a surface casing had been installed to stabilize the upper part of the borehole during drilling, the piezometer

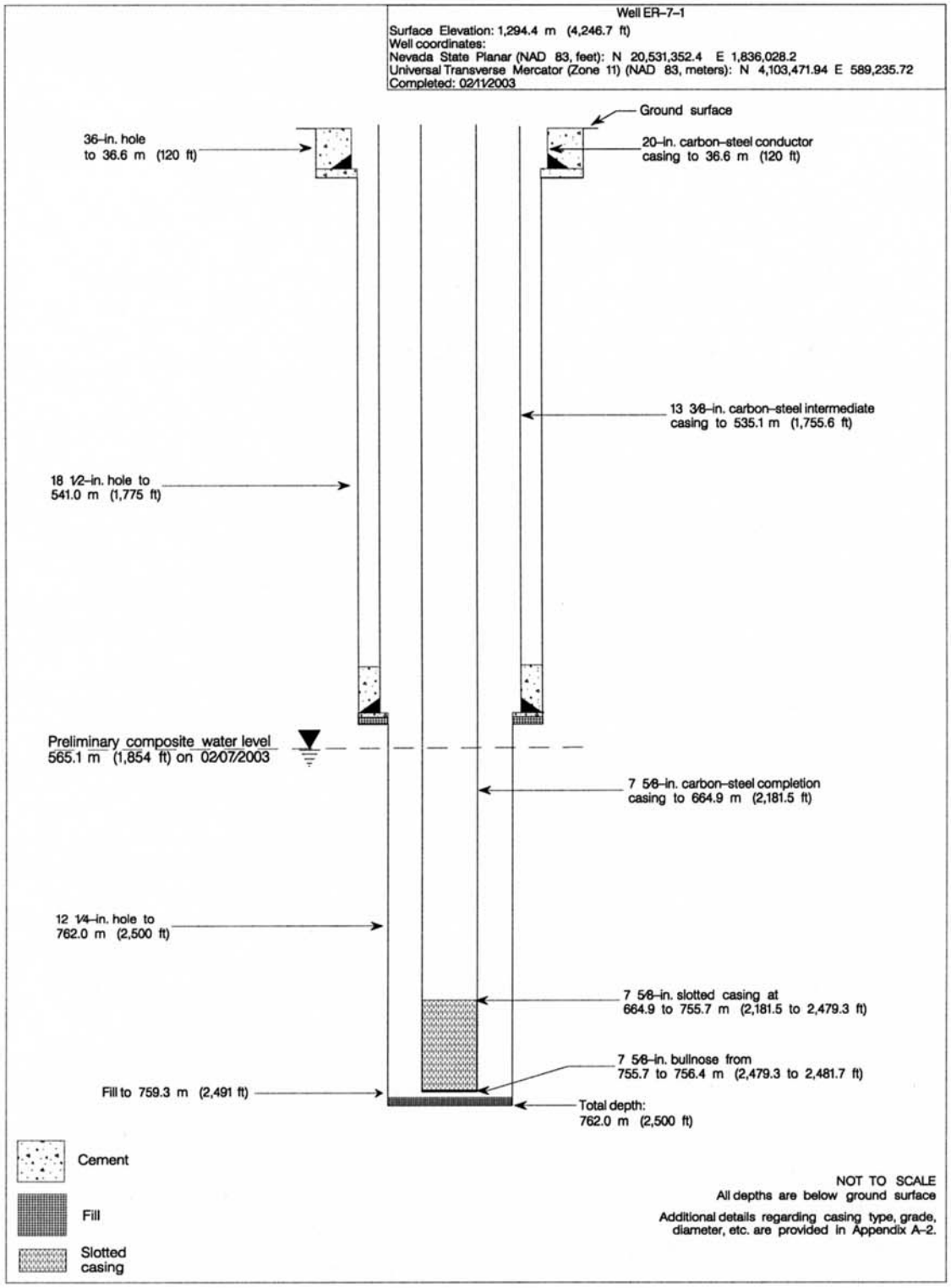
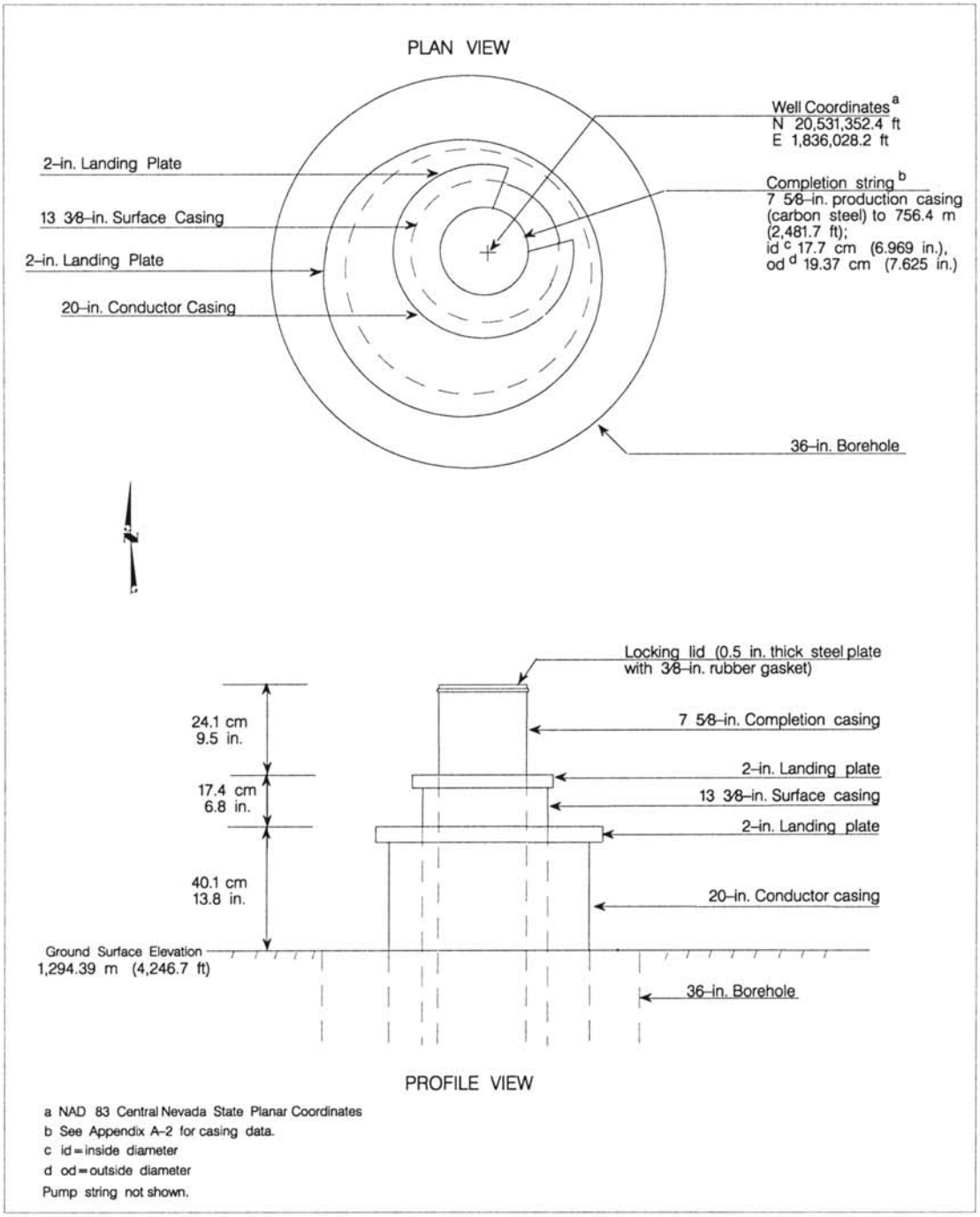


Figure 7-1
As-Built Completion Schematic for Well ER-7-1



a NAD 83 Central Nevada State Planar Coordinates
b See Appendix A–2 for casing data.
c id = inside diameter
d od = outside diameter
Pump string not shown.

Figure 7-2
Wellhead Diagram for Well ER-7-1

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

Casing Type	Configuration meters (feet)		Cement	Sand/Gravel
7 **e** -in. carbon-steel production casing	0 to 664.9 (0 to 2,181.5)	Blank	None	None
	664.9 to 755.7 (2,181.5 to 2,479.3)	7 consecutive slotted joints		
	755.7 to 756.4 (2,479.3 to 2,481.7)	Blank and bull-nosed		

would be installed adjacent to the surface casing, in the borehole annulus, when the surface casing was installed. If the surface casing were not required, the piezometer would be placed in the annulus outside the production casing, and would be gravel-packed and cemented in place at the time the production casing was backfilled.

7.2.2 As-Built Completion Design

The design of the Well ER-7-1 completion was determined through consultation with members of the UGTA Technical Working Group, on the basis of evaluation of data such as lithology and water production, drilling data, and data from various geophysical logs. The as-built completion design provides access to the LCA via a 7 **e** -in. production casing.

The 7 **e** -in. carbon-steel casing was set at 756.4 m (2,481.7 ft), and is slotted in the interval 665.9 to 755.7 m (2,181.5 to 2,479.3 ft). The bottom seven joints are slotted, and the lowest joint is bull-nosed. The openings in each slotted casing joint are 0.15 cm (0.0624 in.) wide and 5.1 cm (2.0 in.) long. The slots are arranged in rows of 18, with rows staggered 10 degrees on 7.62-cm (3-in.) centers. The production casing was installed in the open borehole, and no piezometer string was installed.

7.2.3 Rationale for Differences between Planned and Actual Well Design

The initial planned well design was based on the expectation that groundwater would be present in the YF-LCU and in the LCA. The inability to determine the static water table in the YF-LCU made the establishment of a piezometer in the YF-LCU unnecessary. Likewise, because no other

water-producing zones were to be isolated in Well ER-7-1, and because the slotted interval is well below the water table, gravel-packing and cementing of the production casing were not necessary.

7.3 Well Completion Method

Well completion activities began on February 9, 2003, when the casing crew landed the 7 **e** -in. production casing at 756.4 m (2,481.7 ft). No gravel pack or cement was used with this casing string, which remains open below the 13 **d** -in. intermediate casing, set at the depth of 535.1 m (1,755.6 ft) (Figure 7-1). All well construction materials were inspected according to relevant procedures. Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

The drill rig was released after the 7 **e** -in. production casing was emplaced. 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 original BN cost model developed for Well ER-7-1 was based on drilling to a TD of 670.6 m (2,200 ft). However, when no groundwater had been encountered at the planned TD depth, the decision was made to deepen the borehole, and the baseline model was changed to accommodate the new planned TD. This new cost model is based on the TD of 762.0 m (2,500 ft).

The new drilling program baseline projected that it would require 17 days to accomplish drilling of the surface and main holes, logging, and completion for the well, assuming the conductor hole had already been constructed by BN. The actual time spent to drill the hole and install the completion string in Well ER-7-1 was 16 days. Installation of the production string took one day less time than anticipated. A graphical comparison (by day) of planned and actual well-construction activities is presented in Figure 8-1.

The cost analysis for Well ER-7-1 begins with construction of the conductor hole by BN and the cost of mobilizing the UDI drill rig to the Well ER-7-1 site. The cost of building roads, the drill pad, and sumps is not included, and the cost of well-site support by Shaw is also not included. The total construction cost for Well ER-7-1 includes all drilling costs: charges by the drilling subcontractor; charges by other support subcontractors (including compressor services, drilling fluids, bits, casing services, down-hole tools, and geophysical logging); and charges by BN for mobilization and demobilization of equipment, partial construction of the conductor hole, cementing services, radiation technicians, inspection services, and geotechnical consultation.

The total planned cost for construction Well ER-7-1, based on the new baseline developed due to the deeper than anticipated groundwater, was $1,458,602. The actual cost was $1,372,470, or 5.9 percent less than the planned cost. Figure 8-2 presents a comparison of the planned (new baseline) and actual costs, by day, for drilling and completing Well ER-7-1.

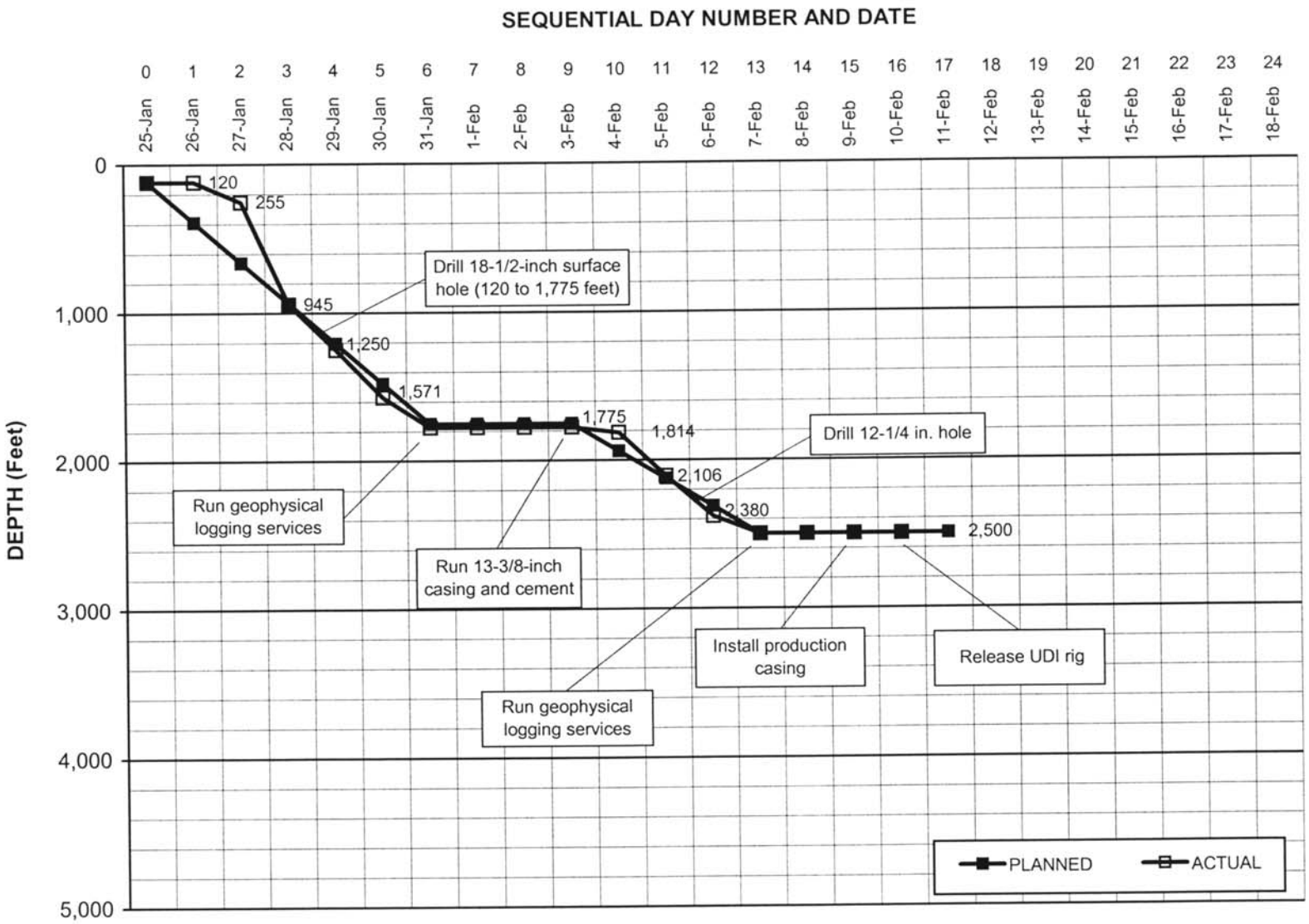

Figure 8-1
Planned versus Actual Construction Progress for Well ER-7-1

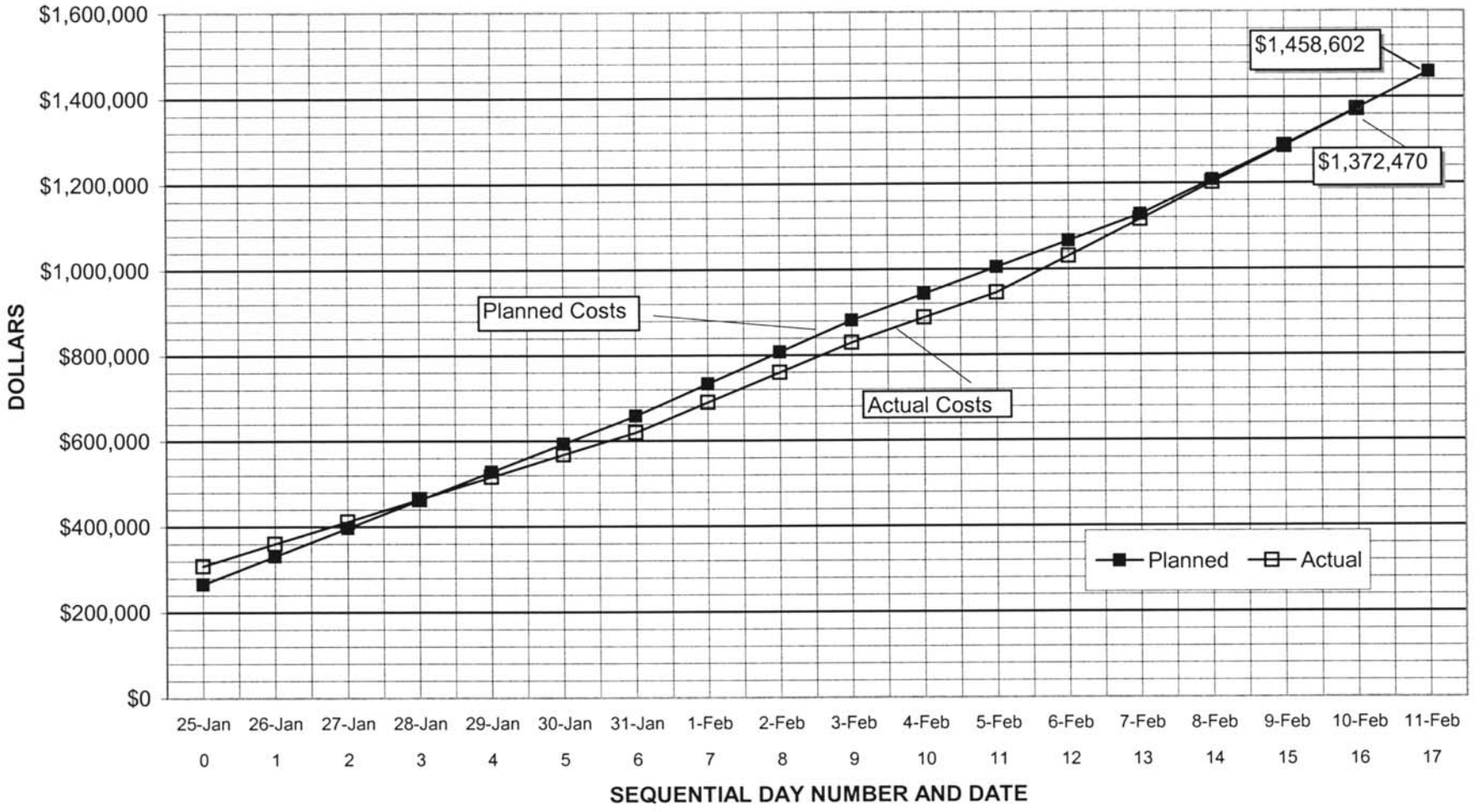

Figure 8-2
Planned versus Actual Cost for Constructing Well ER-7-1

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9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Drilling activities at Well ER-7-1 commenced on January 27, 2003, and concluded on February 7, 2003, when the TD of 762.0 m (2,500 ft) was reached. After geophysical logging, the completion string was installed on February 9, 2003. Crews worked on a 24-hours-per-day, 7-days-per-week schedule for most of the operation. Sixteen working days were expended to drill the surface and main holes, conduct geophysical logging, install the completion string, and rig-down. The only problems encountered during construction of Well ER-7-1 were delays during drilling to address issues with RWPs and monitoring of crew bioassays.

No radionuclides above background were encountered in the groundwater produced from Well ER-7-1. The fluid level within the Paleozoic rocks, based on a neutron density log run on February 7, 2003, was measured at an approximate depth of 565.1 m (1,854.0 ft) below ground surface.

Composite drill cuttings were collected every 3 m (10 ft) from 36.6 m (120 ft) to TD. Sixty-two sidewall samples were collected in the interval 85.3 to 754.1 m (280.0 to 2,474.0 ft). Geophysical logging was conducted in the upper part of the hole before installation of the surface casing, and in the lower part of the hole before installation of the completion string. Some of these logs were used to aid in construction of the well, while others help to verify the geology and determine the hydrologic characteristics of the rocks.

A single completion string with one slotted interval was installed in Well ER-7-1. A string of 7 **e** -in. carbon-steel casing was landed at 756.4 m (2,481.7 ft). No backfill materials were placed around the completion string, and the borehole remains open below the surface casing. The open interval in the 7 **e** -in. casing extends from 664.1 to 746.4 m (2,178.7 to 2,481.7 ft). This interval is open to carbonate sedimentary rocks of Paleozoic age.

9.2 Recommendations

The planned pump installation, well development, groundwater sampling, and hydrologic testing must be conducted at Well ER-7-1 to accomplish the remaining objectives for this well-construction effort.

A complete computer analysis of the Electric Micro Imager® (EMI) log data from Well ER-7-1 is planned to determine dip directions and fracture characteristics.

Twenty-seven of the sidewall core samples taken in Well ER-7-1 were from the limestone of the LCA. It may be possible to obtain valuable data on the fracture filling and other fracture characteristics for the LCA in this area using these samples.

After all the planned Yucca Flat hydrogeologic investigation wells are drilled, geologic and hydrologic data must be evaluated, and interpretations of the area hydrogeology updated for insertion into the UGTA hydrologic model. This process, along with the analysis of the updated model, will enhance the understanding of groundwater flow direction, and velocity in the Yucca Flat region.

9.3 Lessons Learned

On two different occasions, drilling operations were temporarily suspended to address issues with RWPs. In the future, RWP issues should be addressed prior to drilling.

During logging activities, the percussion core tool and the thermal flow tool failed to operate properly. Research to identify and correct the cause of the malfunctioning tools is recommended.

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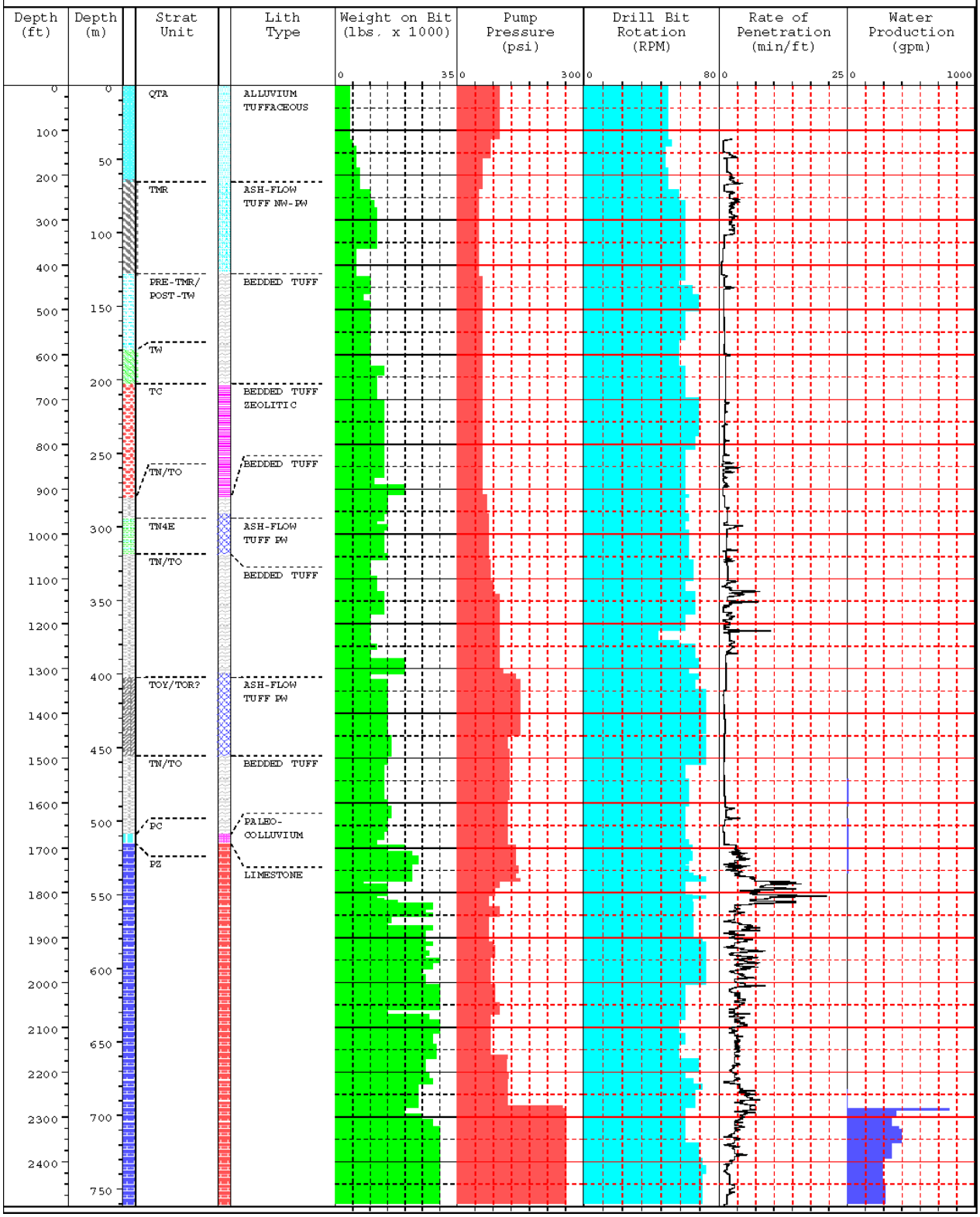
Appendix A
Drilling Data

Appendix A-1
Drilling Parameter Log for Well ER-7-1

Well Name: ER-7-1	Yucca Flat Drilling Program		Northing:4103471.9 m
Date: 08/28/03	Start Date: 01/27/03	Stop Date: 02/09/03	Easting:589235.7 m
Environmental Contractor: UGTA/Shaw		Proj. No. 840223.03030045	Surface Elevation:4246.7 ft
Drilling Contractor: United	Drilling Method: Rotary Air Foam	Geol: J. Wurtz	Depth (ft.): 2500.00



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Appendix A-2
Casing Data for Well ER-7-1

Table A-2
Casing Data for Well ER-7-1

Casing	**Depth Interval** meters (feet)	**Type**	**Grade**	**Outside Diameter** centimeters (inches)	**Inside Diameter** centimeters (inches)	**Wall Thickness** centimeters (inches)	**Weight per foot** (pounds)
Conductor Casing	0 to 36.6 (0 to 120.0)	Carbon steel	N/A	50.5 (20.0)	48.6 (19.124)	1.113 (0.438)	94
Surface Casing	0 to 338.5 (0 to 1,110.5)	Carbon steel	J55	33.97 (13.375)	31.788 (12.515)	1.092 (0.430)	61
Surface Casing	338.5 to 535.1 (1,110.5 to 1,755.6)	Carbon steel	J55	33.97 (13.375)	32.04 (12.615)	0.965 (0.380)	54.5
Completion Casing	0 to 756.4 (0 to 2,481.65)	Carbon steel	N80	19.37 (7.625)	17.701 (6.969)	0.833 (0.328)	26.4

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Appendix A-3
Well ER-7-1 Drilling Fluids and Cement Composition

Table A-3-1
Well ER-7-1 Drilling Fluids

Typical Air-Foam Mix [a]	Typical Air-Foam/Polymer Mix [a]
56.8 liters (15 gallons) Geofoam®[b] per 7,949 liters (50 barrels) water	132.5 liters (35 gallons) Geofoam® and 7.6 liters (2 gallons) LP701®[b] per 7,949 liters (50 barrels) water

a An air-foam ("soap") mix was used as the drilling fluid in Well ER-7-1. Polymer was added to the air-foam mix below 670.6 m (2,200.0 ft).
b Geofoam® foaming agent and LP701® polymer additive are products of Geo Drilling Fluids, Inc.

NOTES:
1. All water used to mix drilling fluids for Well ER-7-1 came from the Radioactive Waste Management Site fill stand (a mix of waters Water Well 4and Water Well 4A) and Water Well 5B.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of 0.7 to 173 milligrams per liter.

Table A-3-2
Well ER-7-1 Cement Composition

Cement Composition	20-inch Conductor Casing	13 d -inch Surface Casing	Completion
Redi-Mix	0 to 36.6 m [a] (0 to 120 ft) [b]	Not used	Not used
Type II neat	Not used	520.6 to 534.9 m (1,708 [c] to 1,755 ft)	Not used

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

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Appendix B
Well ER-7-1 Fluid Management Data

Well ER-7-1 Fluid Disposition Reporting Form

Site Identification: ER-7-1
Site Location: Nevada Test Site
Approximate Site Coordinates: N: 4,103,285 m E: 589,309 m
Well Classification: ER Hydrogeologic Investigation Well
Project Number: 840223.03030045

Report Date: 02/11/2003
NNSA/NSO Project Manager: Bob Bangerter
Shaw Project Manager: Janet Wille
Shaw Site Representative: Jeff Wurtz
Shaw Waste Coordinator: Rob Boehlecke

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	1/27/2003	2/4/2003	5	565.1	739.3	133.9	580.7	0	0	0	NA	Yes
Phase I: Saturated-Zone Drilling	2/4/2003	2/6/2003	3	196.9	95.4	22.4	858.4	0	0	48.8	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:			8	762.0	834.7	156.3	1,439.1	0	0	48.8	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 rock bulking factor of 1.5.
[c]Ground surface discharge and infiltration within the unlined sump.
[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 (at 10 ft fluid level): Sump #1 = 2,029.6 m^3 Sump #2 = 2,029.6 m^3
Infiltration Area (assuming very low/no infiltration) = NA m^3

Remaining Facility Capacity (Approximate) as of 2/11/2003: Sump #1 = 434.2 m^3 (21%) Sump #2 = 2,029.6 m^3 (100%)

Current Average Tritium = (Natural Backround) pCi/L

Shaw Authorizing Signature/Date Janet Wille 5-16-03

Preliminary Analytical Results for Groundwater Characterization Sample from Well ER-7-1

Sample Number	Date Collected	Comment		*Resource Conservation Recovery Act* Metals (mg/L) [a]								Gross Alpha (pCi/L) [b]	Gross Beta (pCi/L)	Tritium (pCi/L)
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury			
ER-7-1-020903-1	02/09/2003	Groundwater Characterization Sample	Total	0.0031 (B) [c]	0.12	0.005 (U) [d]	0.0017 (B)	0.003 (U)	0.005 (U)	0.01 (U)	0.000025 (B)			
			Dissolved	0.0032 (B)	0.069 (B)	0.005 (U)	0.00059 (B)	0.003 (U)	0.005 (U)	0.01 (U)	0.000019 (B)	4.8 (LT) [e] E [f] = 2	9.7 E = 2	0 E = 230
Contract-Required Detection Limit				0.01	0.1	0.005	0.01	0.003	0.005	0.01	0.0002	N/A [g]	N/A	N/A
Nevada Drinking Water Standard (NDWS)				0.05	2.0	0.005	0.1	0.015	0.05	0.1	0.002	15	50	20,000
5 Times NDWS				0.25	10	0.025	0.5	0.075	0.25	0.5	0.01	75	250	100,000

Data provided by Shaw (Shaw, 2003).

All analyses for metals by Paragon Analytics, Inc. Analyses for radionuclides by Bechtel Nevada (filtered prior to analysis).

a mg/L = milligrams per liter
b pCi/L = picocuries per liter
c B = Result less than Contract-Required Detection Limit, but greater than the Instrument Detection Limit
d U = Result less the Instrument Detection Limit or the Minimum Detectable Concentration (MDC)
e LT = Result less than the requested MDC but greater than sample specific MDC
f E = Error
g N/A = Not applicable

Appendix C
Detailed Lithologic Log for Well ER-7-1

Detailed Lithologic Log for Well ER-7-1

Logged by Heather Huckins-Gang, Bechtel Nevada

September 2003

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
0 - 65.5 (0-215)	65.5 (215)	DB1	190	**Alluvium:** Poorly indurated; matrix of alluvium is only rarely preserved in cuttings as small fragments and thin coatings. Where observed, sandy matrix is moderate-brown (5YR4/4) to moderate-yellowish-brown (10YR5/4), calcareous, and tuffaceous. Clasts are approximately 95% volcanic rock fragments (including <1% basalt) and felsic phenocrysts, <5% Paleozoic rock fragments. Most clasts are subangular to subrounded, with few thin calcium carbonate coatings.	Quaternary/ Tertiary alluvium
65.5 - 106.7 (215 -350)	41.2 (135)	DA SWC at 280 304	300	**Nonwelded to Partially Welded Ash-Flow Tuff:** Light-brown (5YR6/4) to moderate-brown (5YR4/4); devitrified. Minor to common grayish-orange-pink (5YR7/2), vitric, fibrous pumice; common felsic phenocrysts, including quartz; minor black biotite; rare lithic fragments.	mafic-poor Rainier Mesa Tuff
106.7 - 128.0 (350-420)	21.3 (70)	DA	none	**Partially Welded Ash-Flow Tuff:** Moderate-brown (5YR4/4); devitrified. Abundant pale-brown (5YR5/2) to grayish-orange-pink (10R8/2) pumice with silky sheen. Toward base of unit about half of the pumice shows vapor phase crystallization, and half remains silky. Common to abundant felsic phenocrysts; minor black biotite; minor sand-sized grayish-brown (5YR 3/2), cherty lithic fragments; minor black glass shards.	
128.0 - 149.4 (420 - 490)	21.4 (70)	DB4 / DA	490	**Bedded Tuff:** Fine-grained ash and lesser tuffaceous sandstone; calcareous in places. Fine-grained ash is white to very-pale-orange (10YR8/2), devitrified. Some beds are aphanitic with a porcelain-like appearance; others contain minor to abundant felsic phenocrysts with minor black biotite and glass shards. Also contains thin silicified beds and chalcedony veins, and minor MnO_2 stains. Sandstone is very-pale-orange (10YR8/2) to moderate-yellowish-brown (10YR4/2), and is made up of rounded white pumice and felsic phenocrysts, with minor black biotite; hornblende noted in sandstone at 140.2-143.3 m (460-470 ft).	pre-Rainier Mesa-post Wahmonie Tuff (or possibly Rainier Mesa Tuff, tuff of Holmes Road?)

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
149.4 - 179.8 (490 to 590)	30.4 (100)	DB4 / DA SWC at 504, 530	none	**Nonwelded Tuff:** Pale-yellowish-brown (10YR6/2) to grayish-orange (10YR7/4), bedded (?) tuff. Abundant dark-yellowish-orange (10YR6/6), zeolitic and very-pale-orange (10YR8/2), devitrified, rounded pumice. Minor tiny mafic minerals; blotchy MnO_2 or iron stains. Abundant vitric, olive-gray (5YR4/1) and white pumice and/or lithic fragments of flow-banded pumiceous lava with lesser obsidian. Includes beds of very light gray (N8) to light brownish-gray (5YR6/1) tuff, seen only in sidewall cores, with abundant to very abundant felsic phenocrysts, including quartz, and minor to very abundant mafic minerals, including clinopyroxene. Contains gray, vitric lithic fragments or pumice at 530 ft).	pre-Rainier Mesa-post Wahmonie Tuff
179.8 - 202.7 (590 - 665)	22.9 (75)	DA SWC at 596 609 660	620 660	**Bedded Tuff:** Yellowish gray (5Y7/2) to pale-greenish-yellow (10Y8/2), vitric. Common to abundant angular, grayish-yellow (5Y8/4) pumice with vapor-phase mineralization. Abundant felsic phenocrysts; abundant mafic minerals including black and bronze biotite; common sand-sized dusky-red lithic fragments. Moderate-brown (5YR4/4) tuffaceous sandstone; made up of mostly fine to very fine sand-sized rounded felsic grains in a muddy matrix with lesser coarse sandy beds. Coarse sandy beds contain common sand-sized lithic fragments, and no apparent pumice. Very abundant, but tiny, black biotite. Also includes beds of and white to very-pale-orange (10YR8/2), vitric bedded tuff. White bedded tuff has patches of dark-yellowish-orange (10YR6/6) staining. White vitric pumice is rare in some beds, abundant in others. All beds have abundant felsic phenocrysts and very abundant black biotite. Some fragments have common chalcedony-lined vugs and rare glassy spherules. Minor sand-sized volcanic lithic fragments.	Wahmonie Tuff

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
202.7 - 246.9 (665 - 810)	44.2 (145)	DB4 / DA SWC at 690 794	710 780	**Bedded Tuff:** Very-light-gray (N8) to light-olive-gray (5Y6/1) tuffaceous sandstone. Common small, white devitrified pumice; abundant felsic phenocrysts; abundant to very abundant mafic minerals, including black biotite; clinopyroxene noted in sidewall core at 210.3 m (690 ft). Minor to common rounded lithic fragments of dark-reddish-brown (10R 3/4) volcanic rocks and lesser medium-gray (N5) pumiceous lava. Grayish-orange (10YR7/2) to moderate-yellowish-brown (10YR5/4). Common to abundant rounded, white to very-pale-orange (10YR8/2), zeolitized pumice, and grayish-yellow (5Y8/4) pumice with quartzofelspathic (?) alteration. Pumice up to 5 mm in size, mostly 1 to 2 mm. Minor to common felsic phenocrysts, including quartz; common to abundant mafic minerals including orthopyroxene (?); reddish, sand-sized lithic fragments. In places, pervasively silicified, moderate-yellowish-brown (10YR5/4), and tends to break into thin flakes Upper level of pervasive zeolitization picked from geophysical logs and x-ray diffraction data at 228.6 m (750 ft).	Crater Flat Tuff
246.9 - 280.4 (810 - 920)	33.5 (110)	DB4 / DA SWC at 815 846 906	860 910	**Nonwelded Ash-Flow (?) Tuff:** Moderate-yellowish-brown (10YR5/4), devitrified; silicified in places. Abundant white, zeolitized pumice commonly 2 to 5 mm, but up to 15 mm, with lesser, small, green and orange, zeolitized pumice. Where silicified, wet rock color is unchanged, but pumice is moderate greenish yellow. Common felsic phenocrysts; abundant to very abundant mafic minerals, predominantly black biotite, clinopyroxene noted. Minor sand-sized lithic fragments;	
280.4 - 294.1 (920 to 965)	13.7 (45)	DB4 / DA	none	**Nonwelded Ash-Flow Tuff:** Moderate-yellowish-brown (10YR5/4) to moderate brown (5YR4/4); partially argillized (?). Minor white to moderate-orange-pink (10YR7/4) and pale-yellowish-orange (10YR8/6), mostly zeolitized pumice; pumice varies from rounded to subangular. Medium light-gray (N6) to light-gray (N7), vitric pumice or lithic fragments containing quartz also noted. Minor felsic phenocrysts; minor mafic minerals, mainly black biotite; minor sand-sized lithic fragments, mainly black vitrophyre; common glass shards and pseudomorphs after glass.	Tunnel Formation, undivided

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
294.1 - 318.5 (965-1,045)	24.8 (80)	DA SWC at 970 1,014 1,042	1,020	**Nonwelded Ash-Flow Tuff:** Grayish-orange (10YR7/4) to very-pale-range (10YR8/2), zeolitic, silicified in places, especially adjacent to lithic fragments; very abundant grayish-yellow (5Y8/4) to moderate-yellow (5Y7/6), zeolitic pumice with remnant fibrous structure. Minor to common felsic phenocrysts including quartz; minor to common mafic minerals, including hornblende, much less biotite and clinopyroxene; mafic minerals increase in abundance with depth. Minor subangular, volcanic lithic fragments, mostly blackish-red (5R2/2) and medium-gray (N5). Lithic fragments increase to common toward base of interval and include pinkish quartzite and black dacite(?).	Tunnel Formation, bed 4E
318.5 - 344.4 (1,045 to 1,130)	25.9 (85)	DA / DB4	none	**Bedded Tuff:** Tuffaceous sandstone with fine-grained, aphanitic interbeds. Grayish-yellow (5Y8/4) with lesser very-pale-orange (10YR8/2), partially zeolitized (?), partially silicified, especially in coarser beds. Abundant rounded, grayish-yellow, silicified (?) pumice. Salt-and-pepper look in coarser (tuffaceous sandstone) beds due to minor small dark lithic fragments, including obsidian, and minor mafic minerals of biotite, and lesser clinopyroxene. Breaks into tabular pieces along indistinct bedding. Types of lithic fragments and phenocryst mineralogy similar to that of overlying tuff. Much of the hornblende looks oxidized. Includes interbeds of more aphanitic tuff, some of which has shard casts.	Tunnel Formation, bed 4JK?
344.4 - 373.4 (1,130 to 1,225)	30.0 (95)	DA / DB4 SWC at 1,189 1,175	1,160 1,220	**Nonwelded Ash-Flow Tuff:** Pale-yellowish-orange (10YR8/6). Minor to common grayish-yellow (5Y8/4) and moderate-orange-pink (5YR8/4), zeolitic pumice; phenocrysts rare; rare to minor lithic fragments; common MnO_2 stains; secondary chalcedony in few fragments; shard casts.	Tunnel Formation, bed 3BC (?)
373.4 - 381.0 (1,225 - 1,250)	7.6 (25)	DA / DB4	1,240	**Bedded Tuff:** Moderate yellowish brown (10YR5/4) to grayish-orange (10YR7/4), zeolitic. Minor white to moderate-reddish-brown (10R4/6), zeolitized and/or argillized pumice. Rare mafic-looking pumice up to 10 mm, partially vitric, fibrous very-dusky-red (10R2) to black, and oxidized to dark-yellowish-orange at margins. Minor felsic phenocrysts including quartz (?); common mafic minerals, including black biotite and lesser hornblende; rare to minor lithic fragments; chalcedony in places.	Tunnel beds, undifferentiated

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
381.0 - 402.3 (1,250 - 1,320)	21.3 (70)	DA	none	**Bedded Tuff:** Moderate-yellow (5YR7/6), zeolitic; fine-grained with interbeds of medium to coarse (1 mm) tuffaceous sandstone. Pumice rare in fine-grained tuff to minor in sandstone; light-brown (5YR5/6) to moderate-reddish-orange (10R6/6), zeolitic; minor felsic phenocrysts; Mafic minerals common to abundant in sandstone, mostly biotite. Lithic fragments very rare in fine-grained ash, small and minor in sandstone.	Tunnel beds, undifferentiated
402.3 - 455.7 (1,320 - 1,495)	53.3 (175)	DA	1,360 1,410	**Nonwelded to Partially Welded Ash-Flow Tuff:** Grayish-orange (10YR7/4) to yellowish-gray (5Y7/2). Common to abundant white to moderate-yellow (5Y7/6) and moderate-reddish-orange (10R6/6), zeolitic pumice. Minor felsic phenocrysts, becoming common and including quartz in lower part of interval; very abundant mafic minerals, mainly black biotite, lesser hornblende; common subangular dark red volcanic lithic fragments.	Tuff of Yucca Flat
455.7 - 509.0 (1,495 - 1,670)	53.3 (175)	DB2 / DA after 1,570 SWC at 1,534 1,564 1,583 1,600 1,619 1,650 1,662	1,520 1,650 1,660	**Bedded Tuff:** Light-brown (5YR5/6) to moderate-reddish-brown (10R4/6), zeolitized. Minor subrounded, zeolitized, pale-greenish-yellow (10Y8/2) pumice; minor felsic phenocrysts, including quartz; abundant mafic minerals, including biotite and lesser hornblende; lithic fragments not observed. Includes beds of pale-greenish-yellow (10Y8/2), dark-yellowish-orange (10YR6/6), pale-yellowish-brown (10YR6/2), grayish-orange (10YR7/4), and grayish-orange-pink (5YR7/2). These beds have varying amounts of zeolitic pumice and felsic phenocrysts; most have abundant to very abundant biotite and rare to minor sand-sized lithic fragments.	Tunnel Formation, bed 1
509.0 - 515.1 (1,670 - 1,690)	(20)	DB4	1,690	**Paleocolluvium:** Contacts picked from geophysical logs. One tuff fragment from mix selected for geochemical analysis.	Paleocolluvium
515.1 - 536.4 (1,690-1,760)	21.3 (70)	DA SWC at 1,739 1,750	none	**Limestone:** Finely crystalline, probably silty or clayey; moderate-yellowish-brown (10YR5/4) with dark-reddish-brown (10R3/4) and pale-yellowish-brown (10YR6/2) bands near top of interval, grayish-brown (5YR3/2) and dark-yellowish-orange (10YR6/6) near base. Fractures coated with dark-reddish-brown (10R3/4) to dark-yellowish-orange (10YR6/6) iron oxides and black MnO_2 stains.	Paleozoic limestone, undifferentiated

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
536.4 - 551.7 (1,760 - 1,810)	15.2 (50)	DA SWC at 1,797	1,810	**Limestone:** Mostly medium crystalline to coarsely crystalline; dusky-brown (5YR2/2) to dark-gray (N3). Includes finely crystalline, moderate-brown (5YR4/4) and grayish-orange (10YR7/4) to brownish-gray (5YR4/1) beds	Paleozoic limestone, undifferentiated
551.7 - 591.3 (1,810 - 1,940)	39.6 (130)	DA SWC at 1,841 1,847 1,864 1,893 1,907 1,913 1,936	none	**Limestone:** Finely crystalline to medium crystalline; moderate-reddish-brown (10R4/6), moderate-brown (5YR4/4), olive-gray (5Y4/1) and moderate-yellowish-brown (10YR5/4). Altered to dark-yellowish-orange (10YR6/6) in some beds and adjacent to fractures. MnO_2 dendrites common on dark-yellowish-orange areas. Includes few interbeds of coarsely crystalline, dark-yellowish-brown limestone near base of interval.	
591.3 - 612.6 (1,940 - 2,010)	21.3 (70)	DA SWC at 1,947 1,970 1,981 1,985 1,996	none	**Limestone:** Medium crystalline to coarsely crystalline; moderate-brown (5YR4/4) to medium-dark-gray (N4), with interbeds of dark-yellowish-brown (10YR4/2). Some fractures coated with dark-yellowish-orange (10YR6/6) and moderate-reddish-brown clay, others coated with crystalline calcite. Sparse, poorly preserved fossil debris and sand grains in some beds.	
612.6 - 707.1 (2,010 - 2,320)	94.5 (310)	DA SWC at 2,014 2,068 2,100 2,207 2,230 2,244 2,297	none	**Limestone:** Coarsely crystalline; dusky-yellowish-brown (10YR2/2). Includes light-brown, finely crystalline beds and intraclasts. Ooliths and intraclasts form up to 80% of rock in some beds below about 609.6 m (2,200 ft).	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Laboratory Analyses** [b]	**Lithologic Description** [c]	**Stratigraphic Unit**
707.1 - 762.0 (2,320 - 2,500)	54.9 (180)	DA SWC at 2,333 2,355 2,409 2,421 2,474 2,463	2,470	**Limestone:** Medium crystalline to coarsely crystalline; dusky-yellowish-brown (10YR2/2). Light-brown (5YR5/6), clayey coatings on some fracture surfaces.	Paleozoic limestone, undifferentiated

a **DA** = drill cuttings that represent lithologic character of interval; **DB1** = drill cuttings enriched in hard components; **DB2** = cuttings from interval different than that drilled; **DB4** = cuttings that are intimate mixtures of units; **SWC** = sidewall core. Sample depths in feet. See Table 3-1 of this report for more information on sidewall core samples.

b Analyses completed to date: x-ray diffraction, x-ray fluoresence, wet chemical analysis for iron. See Table 3-2 of this report for additional information.

c Descriptions are based mainly on visual examination of lithologic samples using a 10x- to 40x-zoom binocular microscope, and incorporating observations from geophysical logs and results of laboratory analyses. 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%.

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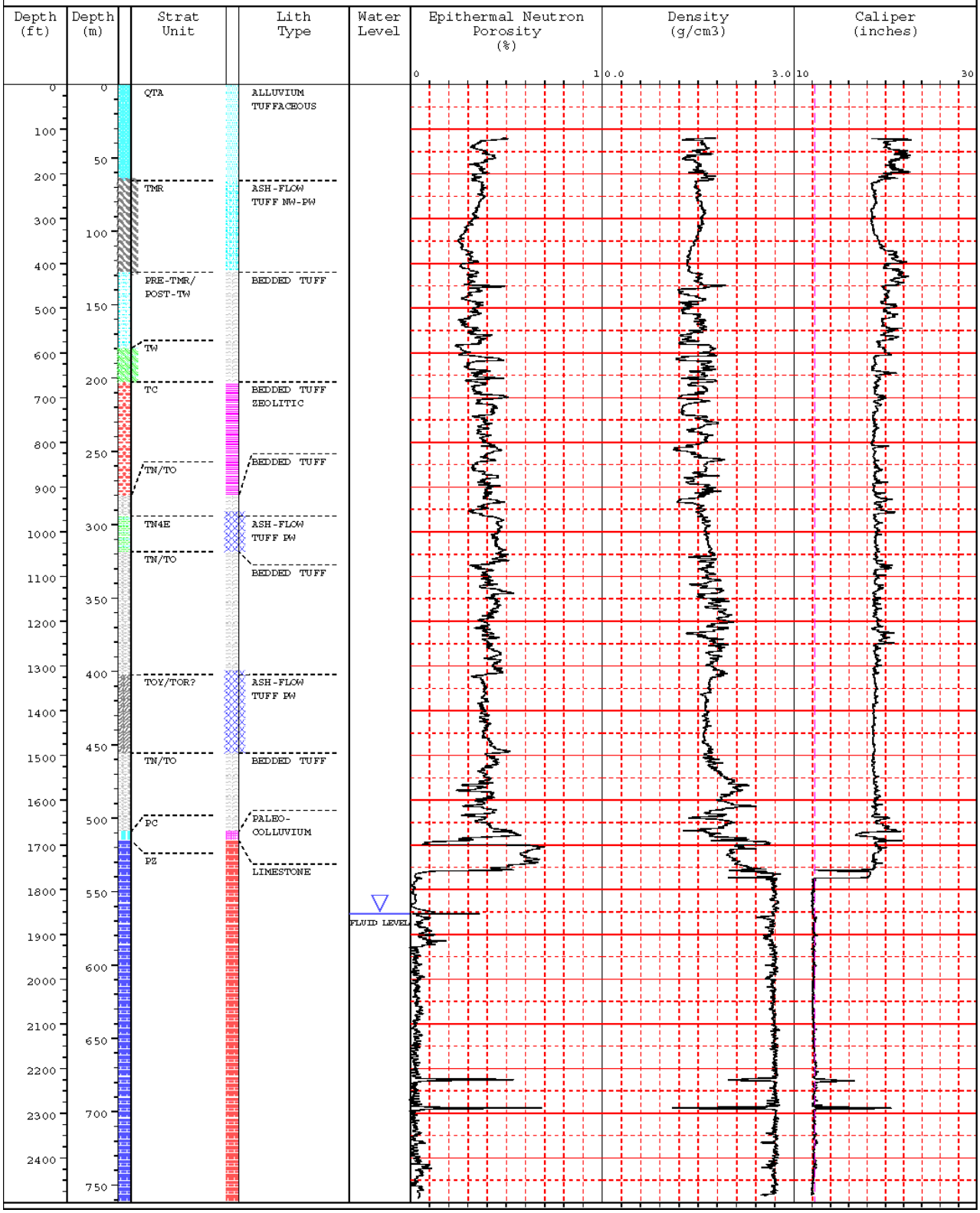
Appendix D
Geophysical Logs Run in Well ER-7-1

Appendix D contains unprocessed data presentations of selected geophysical logs run in Well ER-7-1. Table D-1 summarizes the logs presented. See Table 3-3 for more information.

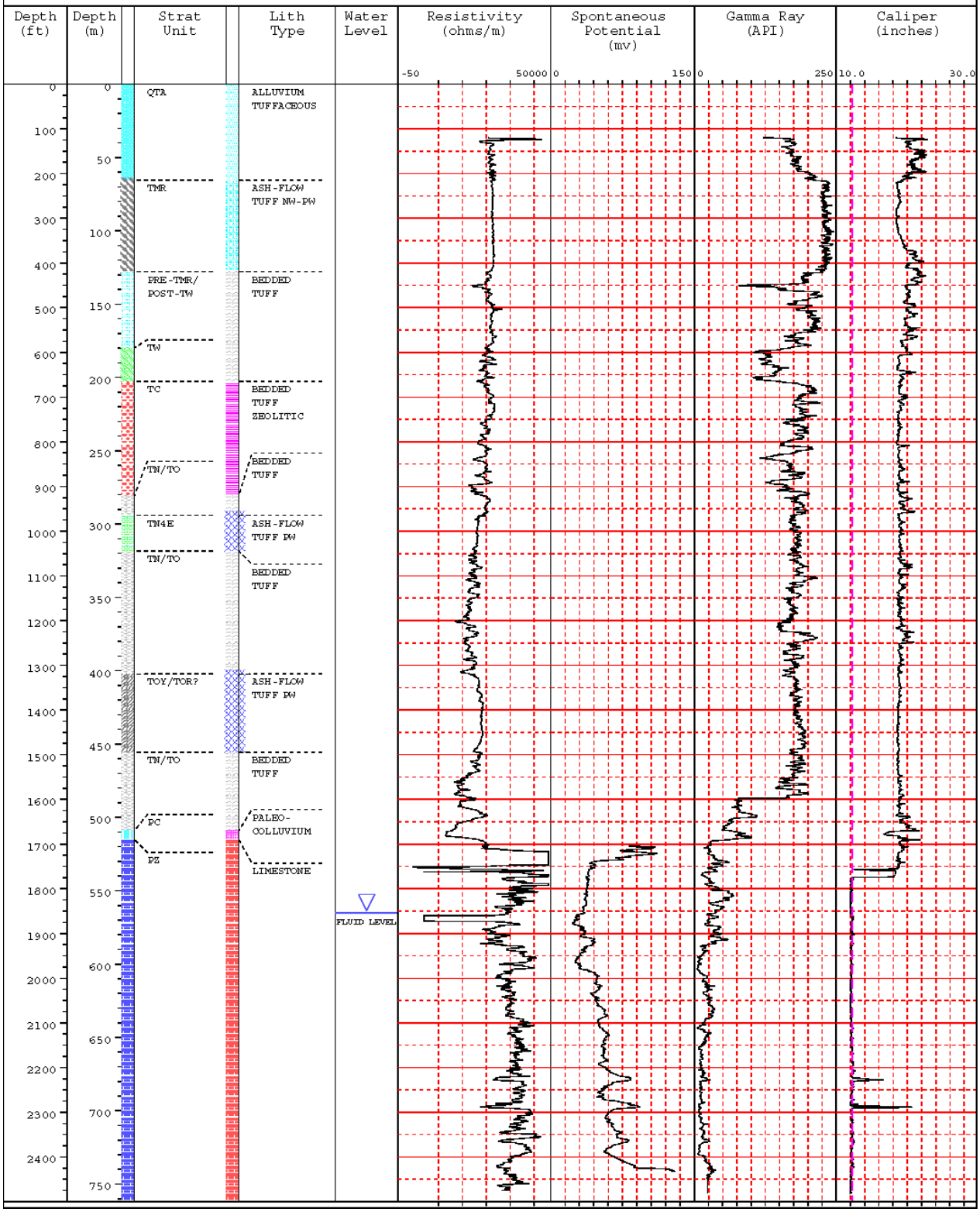
Table D-1
Well ER-7-1 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval meters	Log Interval feet
Caliper	CA6-1 CA6-2	01/30/2003 02/07/2003	15.2 - 536.5 487.7 - 756.5	50 - 1,760 1,600 - 2,482
Epithermal Neutron	DSEN-1 DSEN-2	01/31/2003 02/07/2003	15.2 - 538.9 518.2 - 759.3	50 - 1,768 1,700 - 2,491
Density	SDL-1 SDL-2	01/31/2003 02/07/2003	13.7 - 538.9 518.2 - 759.3	45 - 1,768 1,700 - 2,491
High Resolution Induction	HR1-1	01/31/2003	36.6 - 537.4	120 - 1,763
Induction (resistivity)	DLL-1	02/07/2003	519.7 - 755.3	1,705 - 2,478
Gamma Ray	GR-2 GR-5	01/31/2003 02/07/2003	15.2 - 536.5 487.7 - 756.5	50 - 1,760 1,600 - 2,482
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2	01/31/2003 02/07/2003	26.2 - 527.0 579.4 - 746.8	86 - 1,729 1,704 - 2,450
Spontaneous Potential	SP-1	02/07/2003	519.7 - 755.3	1,705 - 2,478
Digital Array Sonic (delta T and sonic porosity)	FWS-1	02/07/03	518.2 - 756.2	1,700 - 2,481
Chemistry (temperature, pH, electrical conductivity)	1	02/08/03	565.1 - 761.4	1,854 - 2,498

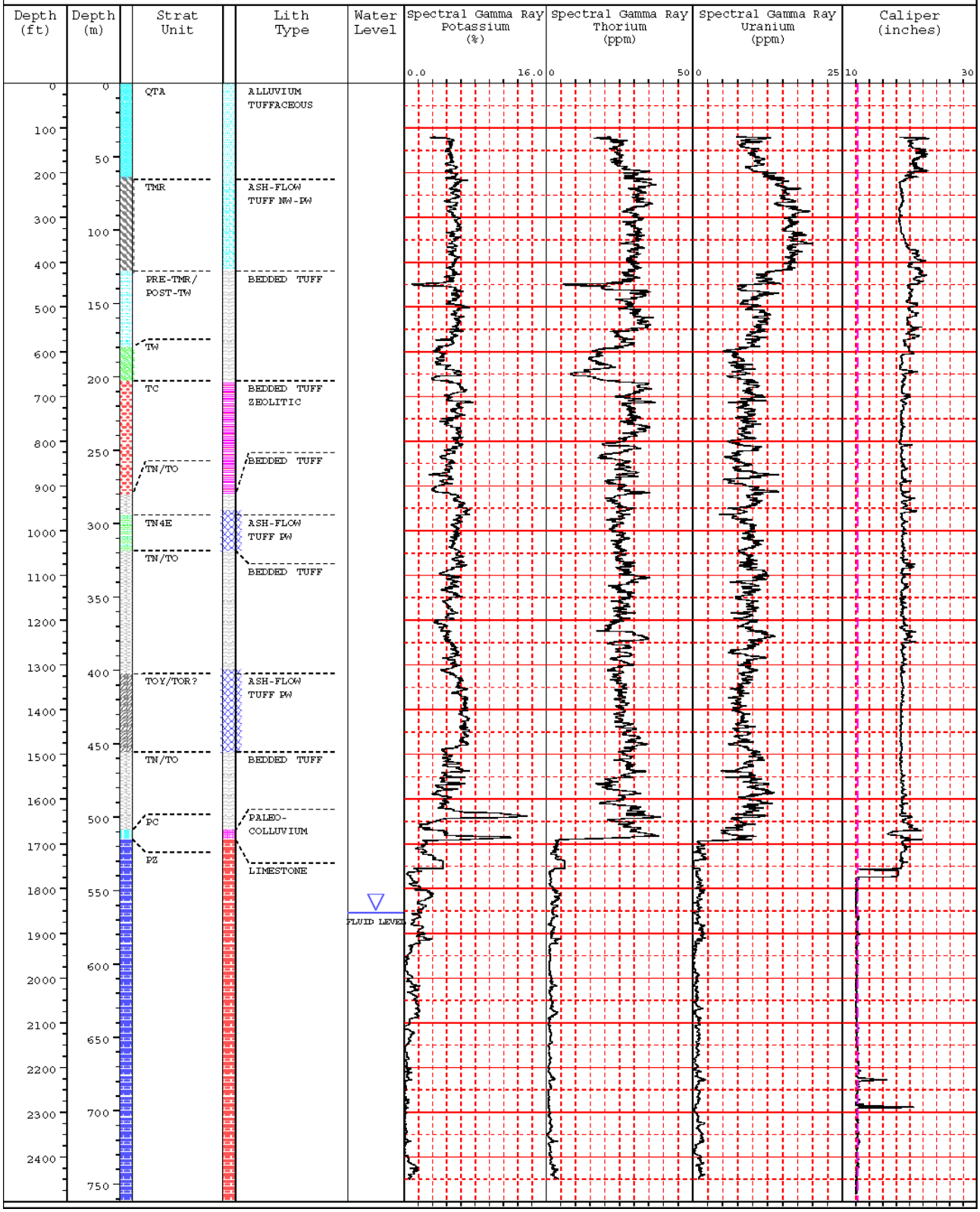
Well Name: ER-7-1	Yucca Flat Drilling Program		Northing:4103471.9 m
Date: 08/29/03	Start Date: 01/27/03	Stop Date: 02/09/03	Easting:589235.7 m
Environmental Contractor: UGTA/Shaw		Proj No. 840223.03030045	Surface Elevation:4246.7 ft
Drilling Contractor: United	Drilling Method: Rotary Air Foam	Geol: J. Wurtz	Depth (Ft.): 2500.00



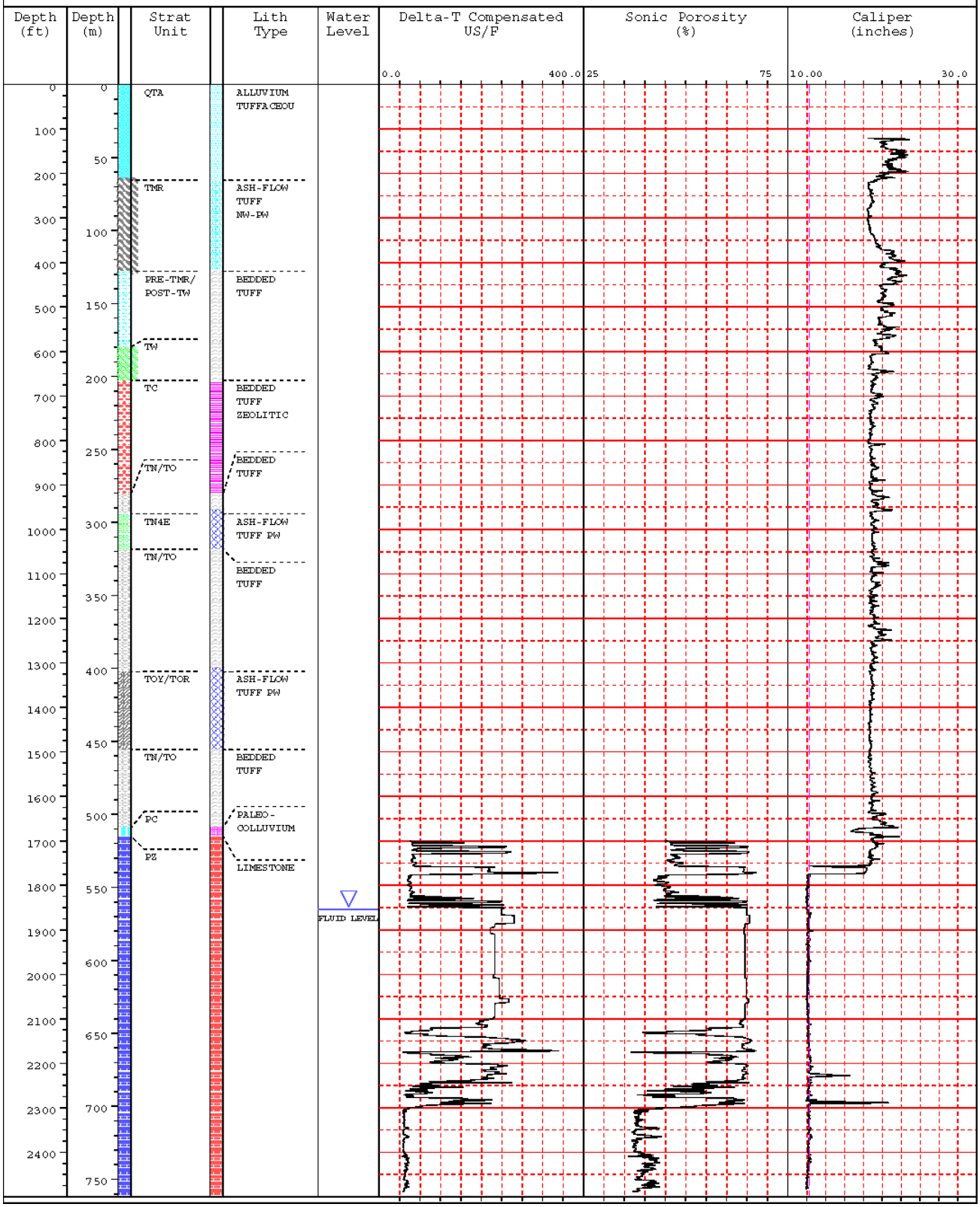
Well Name: ER-7-1	Yucca Flat Drilling Program		Northing:4103471.9 m
Date: 08/29/03	Start Date: 01/27/03	Stop Date: 02/09/03	Easting:589235.7 m
Environmental Contractor: UGTA/Shaw		Proj. No. 840223.03030045	Surface Elevation:4246.7 ft
Drilling Contractor: United	Drilling Method: Rotary Air Foam	Geol: J. Wurtz	Depth (Ft.): 2500.00



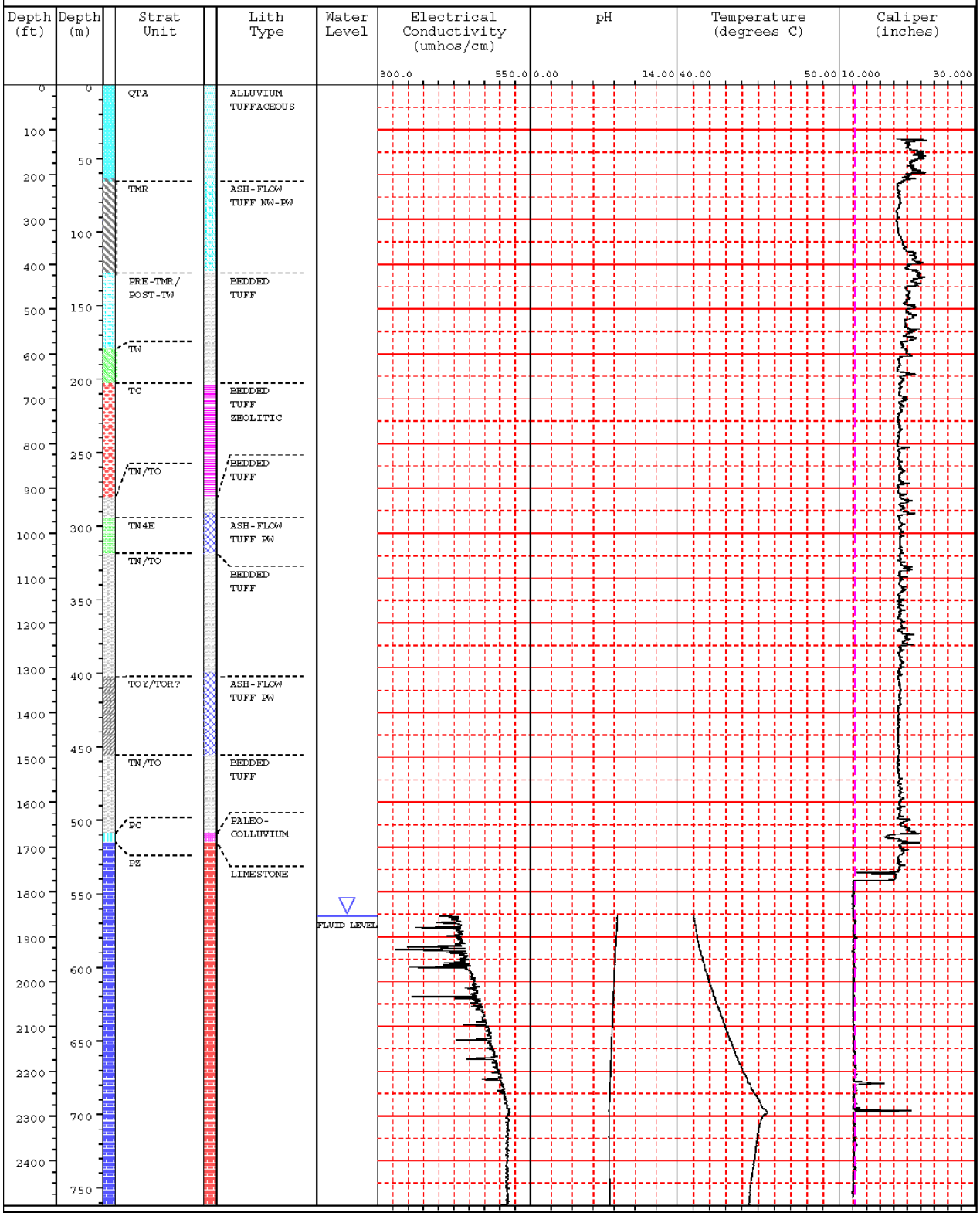
Well Name: ER-7-1	Yucca Flat Drilling Program		Northing:4103471.9 m
Date: 08/29/03	Start Date: 01/27/03	Stop Date: 02/09/03	Easting:589235.7 m
Environmental Contractor: UGTA/Shaw		Proj. No. 840223.03030045	Surface Elevation:4246.7 ft
Drilling Contractor: United	Drilling Method: Rotary Air Foam	Geol: J. Wurtz	Depth (ft.): 2500.00



Well Name: ER-7-1	Yucca Flat Drilling Program		Northing: 4103471.9 m
Date: 08/28/03	Start Date: 01/27/03	Stop Date: 02/09/03	Easting: 589235.7 m
Environmental Contractor: UGTA/Shaw		Proj No. 840223.03030045	Surface Elevation:4246.7 ft
Drilling Contractor: United	Drilling Method: Rotary Air Foam	Geol: J. Wurtz	Depth (Ft.): 2500.00



Well Name: ER-7-1	Yucca Flat Drilling Program		Northing: 4103471.9 m
Date: 08/28/03	Start Date: 01/27/03	Stop Date: 02/09/03	Easting: 589235.7 m
Environmental Contractor: UGTA/Shaw		Proj. No. 840223.03030045	Surface Elevation:4246.7 ft
Drilling Contractor: United	Drill Method:Rotary Air Foam	Geol: J. Wurtz	Depth: 1386 ft



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