

**Nevada
Environmental
Restoration
Project**

DOE/NV--1270



Completion Report for the Well ER-6-2 Site

Corrective Action Unit 97: Yucca Flat - Climax Mine

March 2008

Environmental Restoration Project



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

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Prepared for:

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

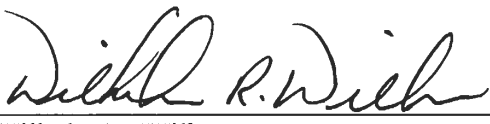
Prepared by:


National Security Technologies, LLC
Environmental Management
Under Contract Number DE-AC52-06NA25946

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COMPLETION REPORT FOR THE WELL ER-6-2 SITE

**CORRECTIVE ACTION UNIT 97:
YUCCA FLAT - CLIMAX MINE**

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Abstract

Well ER-6-2 and its satellite hole, Well ER-6-2#1, were 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. Well ER-6-2 was drilled in two stages in 1993 and 1994; the satellite hole, Well ER-6-2#1 was drilled nearby in 1993 but was abandoned. The wells were drilled as part of a hydrogeologic investigation program for the Yucca Flat-Climax Mine Corrective Action Unit Number 97, in the northeastern portion of the Nevada Test Site. The wells are located in Yucca Flat, within Area 6 of the Nevada Test Site. The wells provided information regarding the radiological and hydrogeological environment in a potentially down-gradient position from tests conducted in northern and central Yucca Flat.

Construction of Well ER-6-2 began with a 1.2-meter-diameter surface conductor hole, which was drilled and cased off to a depth of 30.8 meters below the surface. A 50.8-centimeter-diameter surface hole was then rotary drilled to the depth of 578.5 meters and cased off to the depth of 530.4 meters. The hole diameter was then reduced to 27.0 centimeters, and the borehole was advanced to a temporary depth of 611.4 meters. The borehole was conventionally cored to a total depth of 1,045 meters with a diameter of 14.0 centimeters. Borehole sloughing required cementing and re-drilling of several zones. The open-hole completion accesses the lower carbonate aquifer, the CP thrust fault, and the upper clastic confining unit. A fluid level depth of 543.2 meters was most recently measured in the open borehole in September 2007. No radionuclides were encountered during drilling.

The satellite hole Well ER-6-2#1 was drilled approximately 15.2 meters north of Well ER-6-2 on the same drill pad. This was planned to be used as an observation well during future hydrologic testing at Well ER-6-2; however, the satellite hole was abandoned at the depth of 399 meters due to stuck drill pipe, and was subsequently cemented to the surface.

Detailed lithologic descriptions with stratigraphic assignments in this report are based on composite drill cuttings samples collected every 3 meters, cores taken between the depths of 619.3 and 1,042.4 meters, and geophysical log data. Stratigraphic assignments within the Paleozoic section are based on paleontological analyses. The well was collared in alluvium and at 30.8 meters penetrated Paleozoic carbonate rocks. These consisted of dolostone with minor shale and limestone of the Bonanza King Formation, and limestone with minor quartzite, sandstone, and dolostone assigned to the Guilmette Formation. The borehole reached total depth in a shale unit assigned to the Chainman Shale. The units below the Bonanza King Formation are overturned due to faulting and folding and, therefore, are stratigraphically upside-down.

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List of Acronyms and Abbreviations

AA	alluvial aquifer
AWS	Atlas Wireline Services
BHA	bottom-hole assembly
BHI	Baker Hughes INTEQ
BN	Bechtel Nevada
BWS	Barbour Well Surveying
CA	carbonate aquifer
CCU	clastic confining unit
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
FMP	Fluid Management Plan
ft	foot (feet)
in.	inch(es)
IT	IT Corporation
LCA	lower carbonate aquifer
m	meter(s)
N	north
NAD	North American Datum
NARA	National Archives and Records Administration
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NSTec	National Security Technologies, LLC
NTS	Nevada Test Site
od	outside diameter
REECo	Reynolds Electrical and Engineering Company
RSN	Raytheon Services Nevada
RVC	Record of Verbal Communication
SNJV	Stoller-Navarro Joint Venture
SWL	static water level
TD	total depth
TFM	thermal flow meter
TIH	trip into hole
TOH	trip out of hole
UGTA	Underground Test Area
USGS	U.S. Geological Survey
Welenco	Welenco, Inc.

PREFACE

This report was originally prepared under the same title in 1997 by Bechtel Nevada and IT Corporation as an Underground Test Area informal report, sometimes referred to as a draft report. As part of the current scope of National Security Technologies, LLC (NSTec), this report has been updated and submitted for approval for public release so it will be accessible for public review and for citation in future documents.

This report has been updated by revising it to conform with current editorial standards of NSTec and of the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. Also included now for completeness is a brief description of hydraulic testing operations and installation of a pump, both conducted in 2004 (details published elsewhere). The original construction and hydrogeological data are unchanged.

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1.0 Introduction

1.1 Project Description

Well ER-6-2 was drilled for the U.S. Department of Energy, Nevada Operations Office (DOE/NV; now the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office [NNSA/NSO]) in support of the Nevada Environmental Restoration Project at the Nevada Test Site (NTS), Nye County, Nevada. This drilling project was part of the U.S. Department of Energy's Underground Test Area (UGTA) sub-project at the NTS. The goals of the UGTA sub-project include evaluating the nature and extent of contamination in groundwater due to underground nuclear testing and establishing a long-term groundwater monitoring well network. As part of the UGTA sub-project, scientists are developing computer models to predict groundwater flow and contaminant migration within and near the NTS. To build and test these models, it is necessary to collect geologic, geophysical, and hydrologic data from new and existing wells to define groundwater quality, migration pathways, and migration rates. Data from these wells will allow for more accurate modeling of groundwater flow and radionuclide migration in the region. Some of the wells may also function as long-term monitoring wells.

Well ER-6-2 is located in the southwestern portion of Yucca Flat in the central part of the NTS Area 6 (Figure 1-1). This location was selected to investigate geologic and hydrologic conditions of the Paleozoic lower carbonate aquifer (LCA) in southern Yucca Flat (Hudson and Hokett, 1992). The site is located in a potentially down-gradient position from underground nuclear test sites in northern and central Yucca Flat. Well ER-6-2 is located 2,087 meters (m) (6,846 feet [ft]) southwest of Emplacement Hole U-6a, in which the nearest underground nuclear test (RUSSET) was conducted in 1968 (Figure 1-2).

Well ER-6-2 and its satellite hole, Well ER-6-2#1, were drilled on the same pad approximately 15.2 m (50 ft) apart (Figure 1-3). Well ER-6-2#1 was planned to be used as an observation well in conjunction with future hydrologic testing at Well ER-6-2; however, it was abandoned at the depth of 399 m (1,309 ft) due to stuck drill pipe (some of which was left in the borehole) and subsequently was cemented to the surface.

The Nevada State Planar coordinates, ground elevation of the well collars, and other site data are provided in Table 1-1.

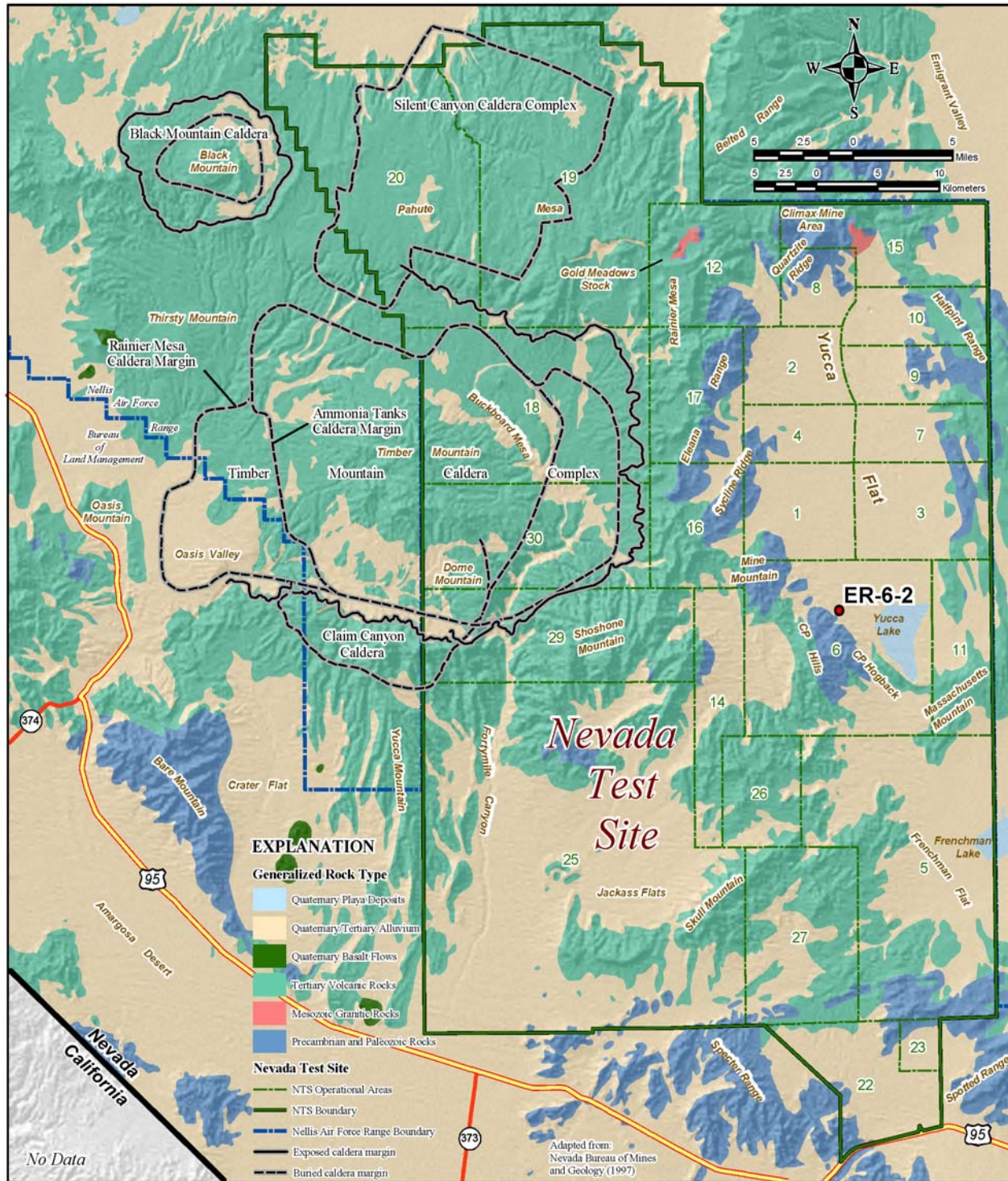


Figure 1-1
Reference Map Showing Location of Well ER-6-2

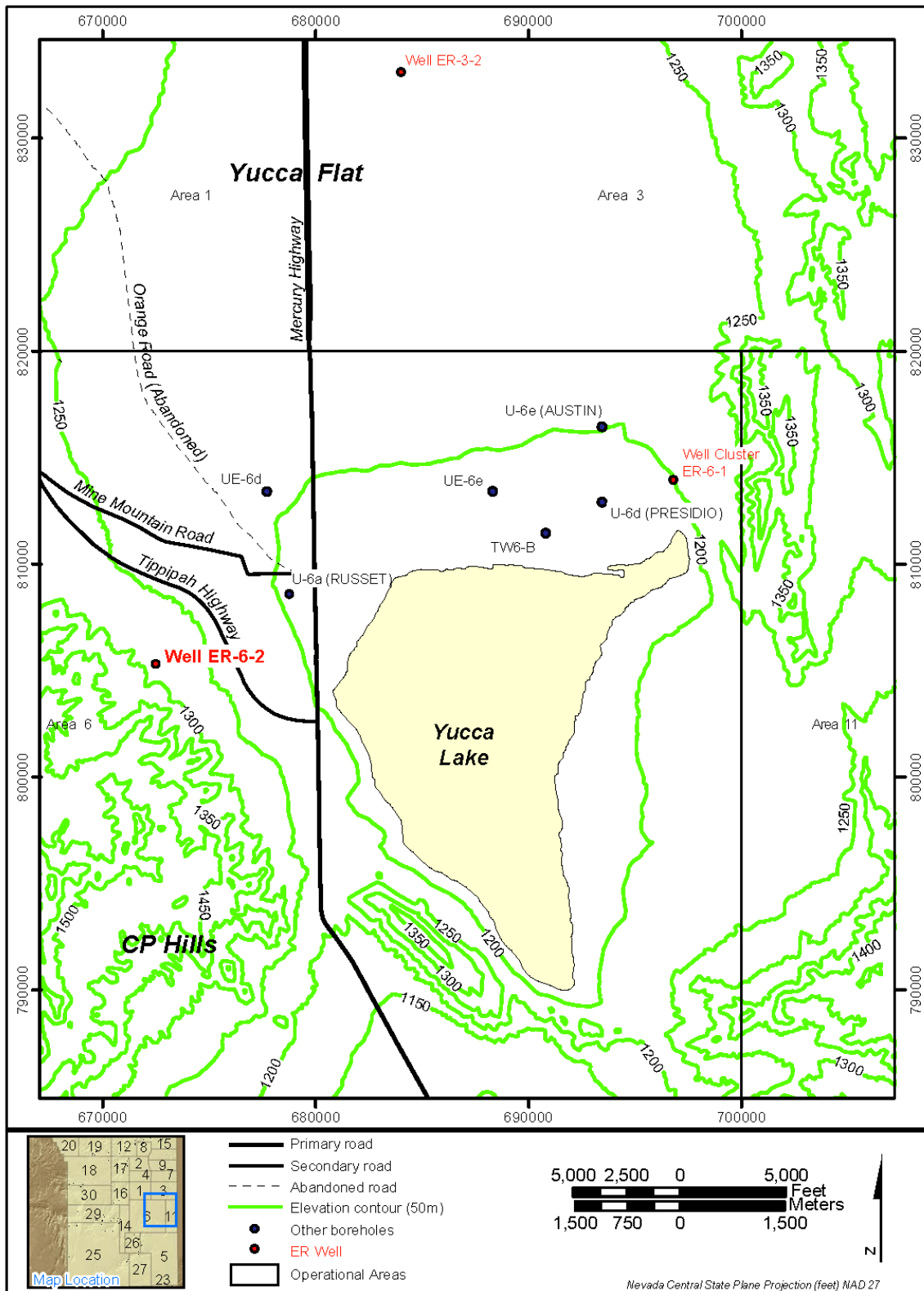


Figure 1-2
Location Map for Well ER-6-2

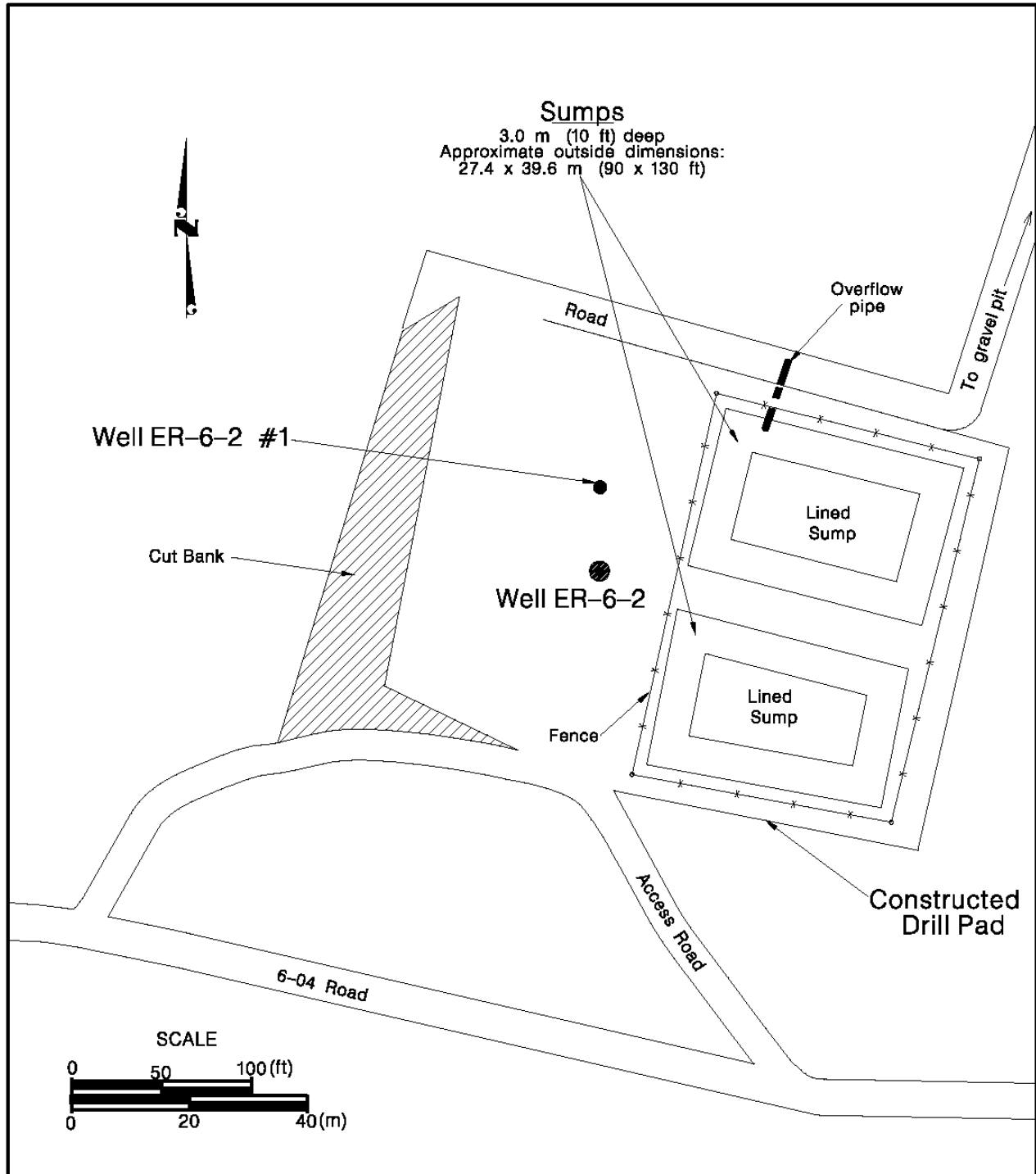


Figure 1-3
Drill Site Configuration for Well ER-6-2

Table 1-1
Well ER-6-2 Site Data Summary

Well Designation		Well ER-6-2	Well ER-6-2#1 ^c
Site Coordinates ^a	Nevada State Plane (Central Zone) (NAD 83) meters	N 6,245,460.6 E 552,497.5	N 6,245,474.7 E 552,497.0
	Nevada State Plane (Central Zone) NAD 83) feet	N 20,490,315.2 E 1,812,625.5	N 20,490,362 E 1,812,650
	Nevada State Plane (Central Zone) (NAD 27) feet	N 805,313.5 E 672,494.0	N 805,360 E 672,492
	Universal Transverse Mercator (Zone 11) (NAD 27) meters	N 4,090,745.0 E 582,235.8	N 4,090,759.1 E 582,235.1
	Universal Transverse Mercator (Zone 11) (NAD 83) meters	N 4,090,942.0 E 582,156.4	N 4,090,956.2 E 582,155.7
Surface Elevation		1,289.5 m ^b (4,230.8 ft)	1,289.6 m (4,231 ft)
Drilled Depth		1,045.5 m (3,430 ft)	399.0 m (1,309 ft)
Fluid-Level Depth (open borehole) ^d		543.2 m (1,782.3 ft)	Not applicable
Fluid-Level Elevation		746.3 m (2,448.5 ft)	Not applicable

a Measurement made by Raytheon Services Nevada Survey Department. NAD = North American Datum (National Archives and Records Administration [NARA], 1989; U.S. Coast and Geodetic Survey, 1927)

b Measurement made by Raytheon Services Nevada Survey. Elevation at top of construction pad. National Geodetic Vertical Datum, 1929 (NARA, 1973).

c Coordinates and elevation approximate: not surveyed.

d Measured by U.S. Geological Survey, September 11, 2007.

IT Corporation (IT) was the principal environmental contractor for the project. Reynolds Electrical and Engineering Company (REECo) served as the as the drilling contractor and also provided field support. The coring subcontractor was Tonto Drilling, Inc. Engineering, inspection, and geotechnical services were provided by Raytheon Services Nevada (RSN). The roles and responsibilities of these and other contractors involved in the UGTA project are described in RSN Drilling Programs D-011-002 and D-007-003 (RSN, 1992; 1993a).

This report presents well construction data and summarizes scientific data gathered during the drilling, coring, and well installation for both Wells ER-6-2 and ER-6-2#1. Additional information related to water levels, aquifer testing, and groundwater sampling were reported by Stoller-Navarro Joint Venture (SNJV, 2004; 2005). Updated geologic interpretations for this area were compiled in the data documentation package for the Yucca Flat-Climax Mine hydrostratigraphic framework model (Bechtel Nevada [BN], 2006); however, the lithologic and stratigraphic logs for these holes are provided in final form in this document.

1.2 Objectives

The primary purpose of constructing the two wells at the Well ER-6-2 site was to assess geologic and hydrologic conditions of Paleozoic sedimentary rocks in a potentially down-gradient position from underground nuclear test sites in northern and central Yucca Flat (Hudson and Hokett, 1992). In addition, data from these wells, in combination with that from Well ER-6-1 (NNSA/NSO, 2004), Test Well B (TW6-B), and other nearby boreholes (Figure 1-2), were expected to provide data to improve the hydrogeologic interpretation for southern Yucca Flat. Individual objectives, as discussed in the drilling criteria document (IT, 1992) and the coring and completion plan (IT, 1994), included the following:

- a. Obtain subsurface geologic information to support development of hydrogeologic models of the regional hydrostratigraphic units, LCA and upper clastic confining unit.
- b. Obtain hydraulic head data in a structurally complex hydrogeologic environment.
- c. Obtain rock core samples that may be used to perform lithologic, paleontologic, petrophysical, and hydrologic laboratory tests that will yield information to be used in local and regional groundwater flow and contaminant transport models.
- d. Obtain rock core samples that will be used to calibrate geophysical tools and logging data.
- e. Obtain data that can be used to interpret the frequency, orientation, and hydraulic properties of fractures.
- f. Obtain water samples for analysis of groundwater chemistry in the LCA.
- g. Construct a potential long-term monitoring point for the detection of possible migration of testing-related radionuclides.

All of these objectives were met, except that core samples obtained were not tested to aid in calibration of geophysical logging tools due to changes in programmatic priorities. Some

objectives were met through additional work conducted (outside the scope of this report) in 2004, when a pump was installed and hydraulic testing conducted (SNJV, 2004; 2005). Geology and hydrology data from this and other wells in the Yucca Flat area were used in the development of a hydrostratigraphic framework model for Yucca Flat (BN, 2006).

1.3 Project Summary

This section summarizes Well ER-6-2 construction operations; the details are provided in Sections 2.0 through 7.0 of this report.

Wells ER-6-2 and ER-6-2#1 were drilled on the same pad approximately 15.2 m (50 ft) apart, to accommodate planned hydrologic testing. Well ER-6-2 was drilled in two stages. In the first, a borehole was rotary-drilled to a depth of 611.4 m (2,006 ft). In the second stage, the borehole was cored to the total depth (TD) of 1,045.5 m (3,430 ft). Well ER-6-2#1 was drilled to a depth of 399.0 m (1,309 ft) but was abandoned due to borehole instability problems.

For both holes, composite drill cuttings were collected every 3 m (10 ft) from the ground surface to TD; core was obtained in the lower portion of Well ER-6-2. Open-hole geophysical logging in Well ER-6-2 was conducted to help verify the geology and characterize the hydrologic properties of the rocks; some logs also aided in the construction of the well by indicating borehole volume and condition. Well ER-6-2 penetrated 30.8 m (101 ft) of alluvium and 1,014.7 m (3,329 ft) of Paleozoic dolostone, limestone, shale, and quartzite.

1.3.1 Well ER-6-2 Rotary-Drilled Interval

Commencing on November 20, 1992, a 121.9-centimeter (cm) (48-inch [in.]) diameter conductor hole was drilled with an auger bit, and a 24-in. surface casing was set at 30.8 m (101 ft). Drilling of the main hole began on December 3, 1992. The borehole was advanced using a 20-in. down-hole hammer bit, alternating with a 20-in. rotary bit with air-foam drilling fluid in conventional circulation. A suitable location for setting casing was reached at 578.5 m (1,898 ft). After the casing string (11³/₄-in. buttress casing below 13³/₈-in. casing) was set and cemented at 530.4 m (1,740 ft), rotary drilling with a 10⁵/₈-in. bit and air-foam continued. The temporary TD of 611.4 m (2,006 ft) was reached on January 26, 1993. The static, open-hole fluid level was measured at the depth of 534.2 m (1,782 ft) on January 28, 1993. No tritium above background levels was encountered in the fluid returns.

1.3.2 Well ER-6-2 Cored Interval

Coring operations at Well ER-6-2, in which the borehole was advanced from 611.4 m (2,006 ft) to the TD of 1,045.5 m (3,430 ft), took place between June 8 and July 21, 1994. A total of 188 cores, 8.5 cm (3.345 in.) in diameter, were taken. The static, open-hole fluid-level depth was measured at 544.4 m (1,786 ft) on July 22, 1994. No tritium above background levels was encountered in the fluid returns.

1.3.3 Well ER-6-2#1

The 47.0-cm (18.5-in.) surface hole for Well ER-6-2#1 was drilled using mud in conventional circulation, then a 13³/₈-in. surface casing was set at the depth of 32.3 m (106 ft), and its annulus cemented to the surface. Rotary drilling with a 9⁷/₈-in. bit and a Dyna-Drill down-hole motor, using a air-foam drilling fluid with a polymer additive, began on August 5, 1993. The borehole was advanced to the depth of 399.0 m (1,309 ft), where the borehole wall began to slough and circulation was lost. An attempt to regain circulation was made by adding a polymer/soap mix and high viscosity mud, but it was not successful. After numerous attempts to clean out fill and to free the stuck drill pipe, the bottom-hole assembly (BHA) twisted off. The hole was subsequently abandoned and cemented to the surface in September 1993. Tritium sampling and analysis activities were limited to vadose-zone drilling operations because the water table was not reached. The results showed no tritium levels above background.

1.3.4 Recent Activities

No additional well construction or completion has been performed at Well ER-6-2, but the well was developed, hydraulically tested, and sampled in 2004 (SNJV, 2004; 2005). Following this activity, a low-volume pump for obtaining periodic water characterization samples was installed and remains in the well as of this writing. The U.S. Geological Survey (USGS) has been monitoring the water level in the well since 1994. The most recent measurement, in September 2007, tagged the water level at the depth of 543.2 m (1,782.3 ft) (USGS, 2007).

1.4 Project Director

Inquiries concerning Well ER-6-2 should be directed to the UGTA Federal Project Director at:

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

2.0 Drilling Summary for Well ER-6-2

2.1 Introduction

This section contains detailed descriptions of the drilling process and fluid management activities for Well ER-6-2. The general drilling requirements were outlined in the RSN Drilling Program D-011-002 (RSN, 1992). Changes to these criteria were documented in RSN Records of Verbal Communication (Appendix A-1). Figure 1-3 shows the layout of the drill site. Completion of Well ER-6-2 is described in Section 7.0

2.2 Drilling History for Well ER-6-2

Figure 2-1 is a chart of the drilling history for the original rotary-drilled borehole and the deepening of the borehole by coring. A summary of drilling statistics for the well is given in Table 2-1. The following information was compiled primarily from RSN daily drilling reports and the RSN drill hole history (RSN, 1993b). A plot of drilling parameters is not available for this borehole. See Appendix A-2 for a listing of casing materials. Drilling fluids and cements used in Well ER-6-2 are listed in Appendix A-3.

2.2.1 Drilling History for the Original Borehole

Field operations at Well ER-6-2 began on November 19, 1992, with the mobilization of a Class VIII auger rig to the site to construct the surface hole. A 1.22-m (48-in.) diameter hole was dry-augered by REEC Co drillers to the depth of 30.9 m (101.5 ft) in four stages, starting with a 36-in. bit. A string of 24-in. casing was set at the depth of 30.8 m (101 ft) on November 30, 1992, and its annulus was cemented to the ground surface.

An International Petroleum Services/Cardwell 500 drill rig was mobilized to the site and rotary drilling began on December 3, 1992, with air-foam drilling fluid used in direct circulation. A 52.1-cm (20.5-in.) hole was drilled to the depth of 57.0 m (187 ft), and then work on the hole was suspended until December 7, 1992. Drilling resumed with a 20-in. hammer bit and down-hole hammer using air-foam as the drilling fluid. After drilling to the depth of 187.2 m (614 ft) borehole sloughing problems necessitated cementing off the zone from 29.0 to 120.4 m (98 to 395 ft) on December 10, 1992. Caliper and annulus investigation logs were run in the borehole to help determine borehole conditions. Drilling resumed the next day, but unstable borehole conditions persisted, and two more intervals (29.9 to 73.5 m [98 to 124 ft] and 76.8 to 111.9 m

Table 2-1
Abridged Drill Hole Statistics for Well ER-6-2

LOCATION DATA:	
Coordinates:	Nevada State Plane (central zone): NAD 27: N 805,313.5 ft E 672,494.0 ft
Universal Transverse Mercator:	NAD 27: N 4,090,745.0 m E 582,235.8 m NAD 83: N 4,090,942.0 m E 582,156.4 m
Surface Elevation ^a :	1,289.5 m (4,230.8 ft)
DRILLING DATA:	
Spud Date:	11/20/1992 (auger rig); 12/02/1992 (main hole drilling with Cardwell 500 rig)
Total Depth (TD):	1,045.5 m (3,430 ft)
Date TD Reached:	07/21/1994
Date Well Completed:	07/21/1994 (open-hole completion)
Hole Diameter:	1.22 m (48 in.) from surface to 30.9 m (101.5 ft); 52.1 cm (20.5 in.) to 57.0 m (187 ft); 50.8 cm (20 in.) to 578.5 m (1,898 ft); 27 cm (10.625 in.) to 611.4 m (2,006 ft); 14.0 cm (5.5 in.) to TD at 1,045.5 m (3,430 ft).
Drilling Techniques:	Dry-hole auger from surface to 30.9 m (101.5 ft.). Rotary drilling with air-foam in direct circulation from 30.9 m (101.5 ft) to 57.0 m (187 ft) using a 20½-in. bit. Alternated between air-foam, direct-circulation rotary and air hammer drilling, using a 20-in. tri-cone pilot bit or hammer bit from 57.0 to 578.5 m (187 to 1,898 ft). After fishing and cementing operations, a 10⅝-in. tri-cone bit and air-foam were used to drill out cement from 517.6 to 532.2 m (1,698 to 1,746 ft) and deepen hole to 611.4 m (2,006 ft). Conventional wireline coring from 611.4 to 1,045.5 m (2,006 to 3,430 ft) using an 8.5-cm (3.345-in.) inside diameter by 13.4-cm (5.276-in.) outside diameter diamond bit with a 14.0-cm (5.5-in.) outside diameter reaming shell.
CASING DATA: ^b	24-in. conductor casing to 30.8 m (101 ft). Intermediate casing set at 530.4 m (1,740 ft), consists of 492.7 m (1,616 ft) of 11¾-in. buttress casing hanging from 37.8 m (124 ft) of 13⅝-in. casing, with a crossover sub at 37.8 m (124 ft).
WELL COMPLETION DATA:	
A low volume sampling pump was installed in the open borehole at Well ER-6-2 in August 2004, following hydrologic testing and sampling. The intake is positioned at the depth of 580.4 m (1,904.2 ft).	
Water Depth ^c :	The composite fluid level of 543.2 m (1,782.3 ft) was last measured inside the open borehole, September 11, 2007.
DRILLING CONTRACTOR:	Reynolds Electrical and Engineering Co., Inc.
CORING CONTRACTOR:	Tonto Drilling, Inc.
GEOPHYSICAL LOGS BY:	Atlas Wireline Services, Desert Research Institute, Barbour Well Surveying, Baker Hughes INTEQ, Welenco, Inc.
SURVEYING CONTRACTOR:	Raytheon Services Nevada

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

b See Appendix A-2 for more information on casing materials.

c Fluid level tag by USGS (USGS, 2007).

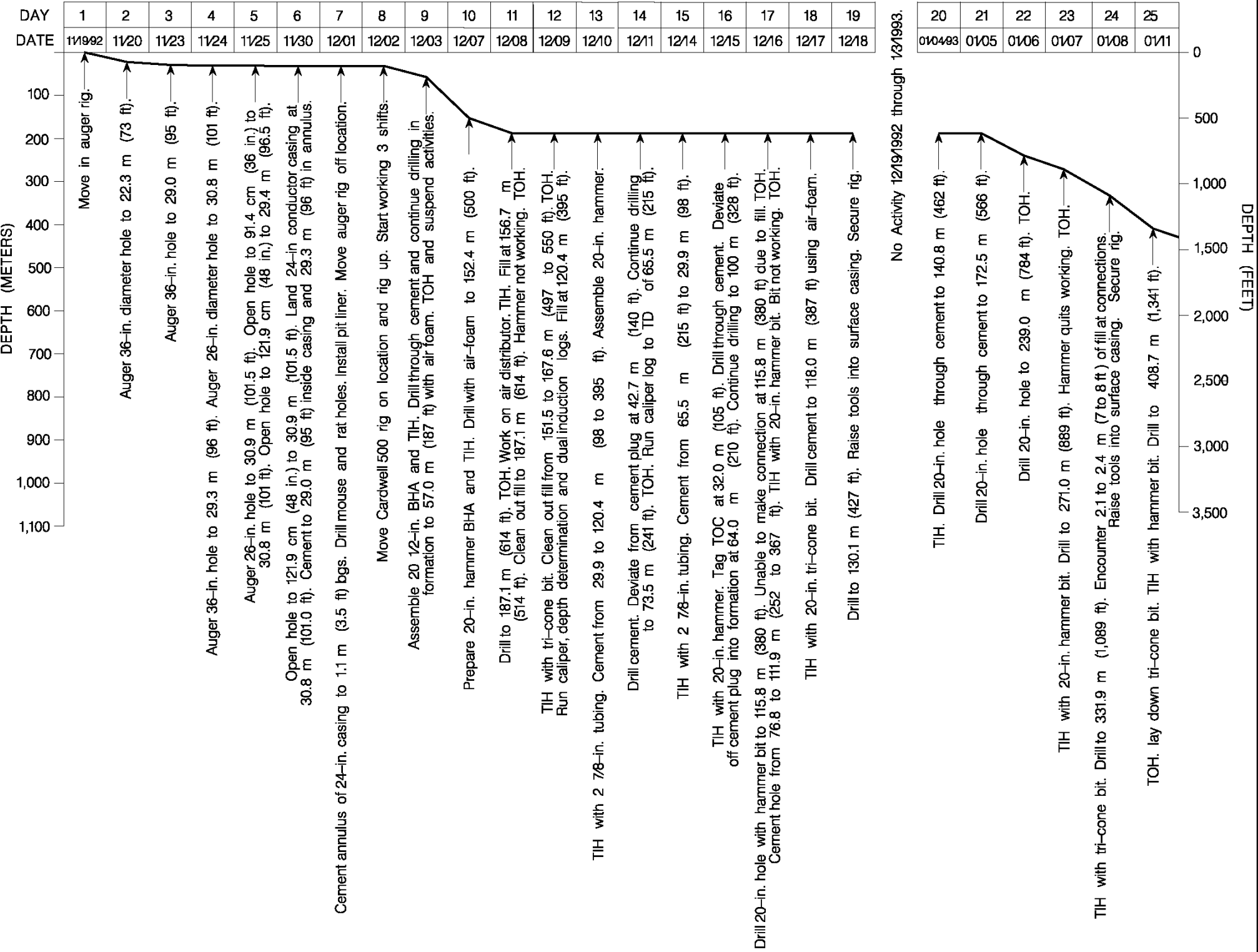
WELL ER-6-2 SUMMARY

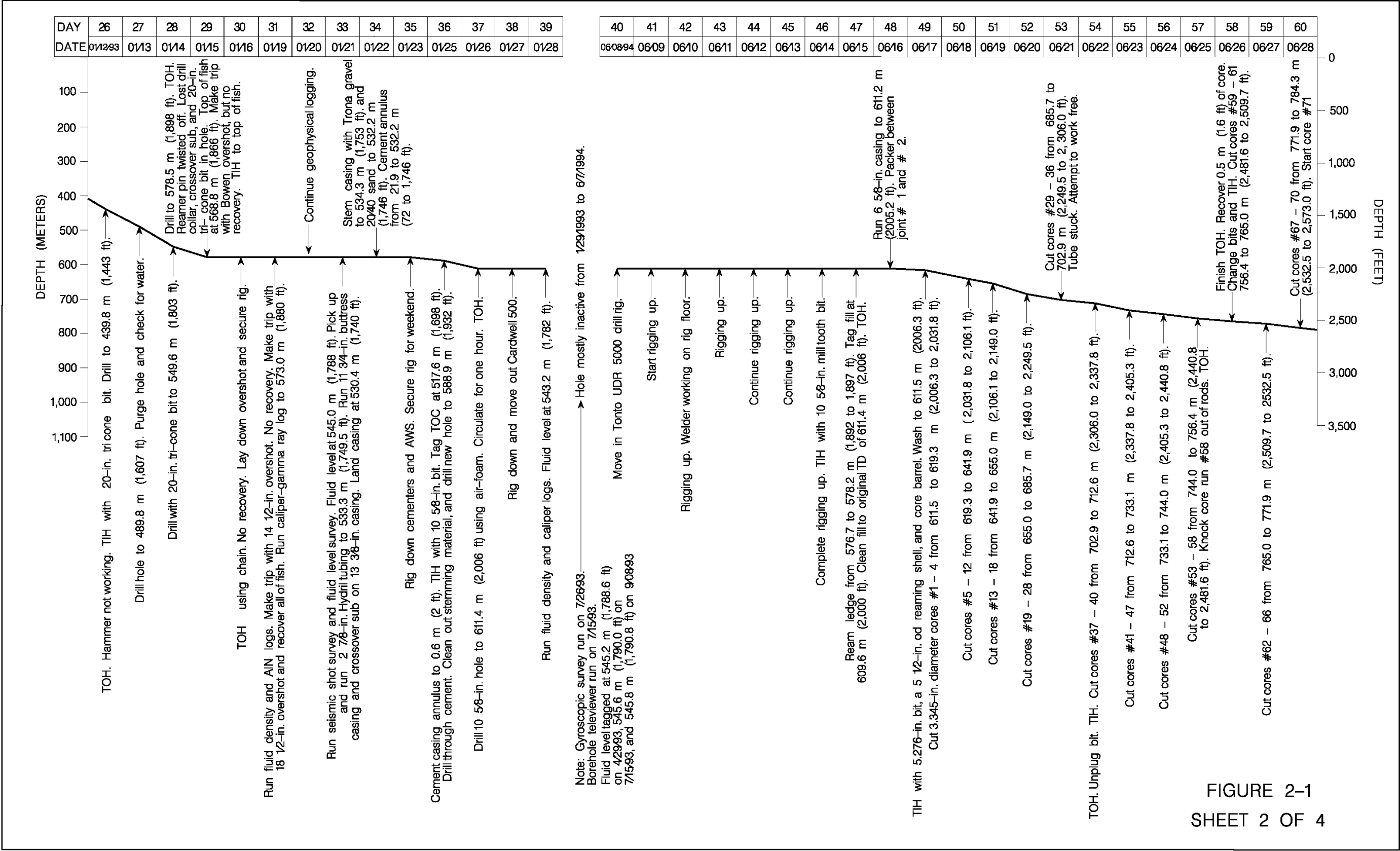
Activity	Date
Hole Spudded	11/20/1992
Conductor hole completed and 24-in. casing set at 30.8 m (101 ft)	12/01/1992
Begin drilling 20 12-in. hole	12/03/1992
Begin drilling 20-in. hole	12/07/1992
Intermediate casing set to depth of 530.4 m (1,740 ft)	01/22/1993
Begin drilling 10 58-in. hole	01/25/1993
TD 10 58-in. hole at 611.4 m (2,006 ft)	01/26/1993
Drilling suspended	01/28/1993 through 06/08/1994
Move in core rig	06/08/1994
Begin coring at 611.5 m (2006.3 ft)	06/17/1994
Reach TD of 1,045.5 m (3,430 ft)	07/21/1994
Rig down and suspend activities	07/28/1994
Dedicated pump installed	08/31/2004

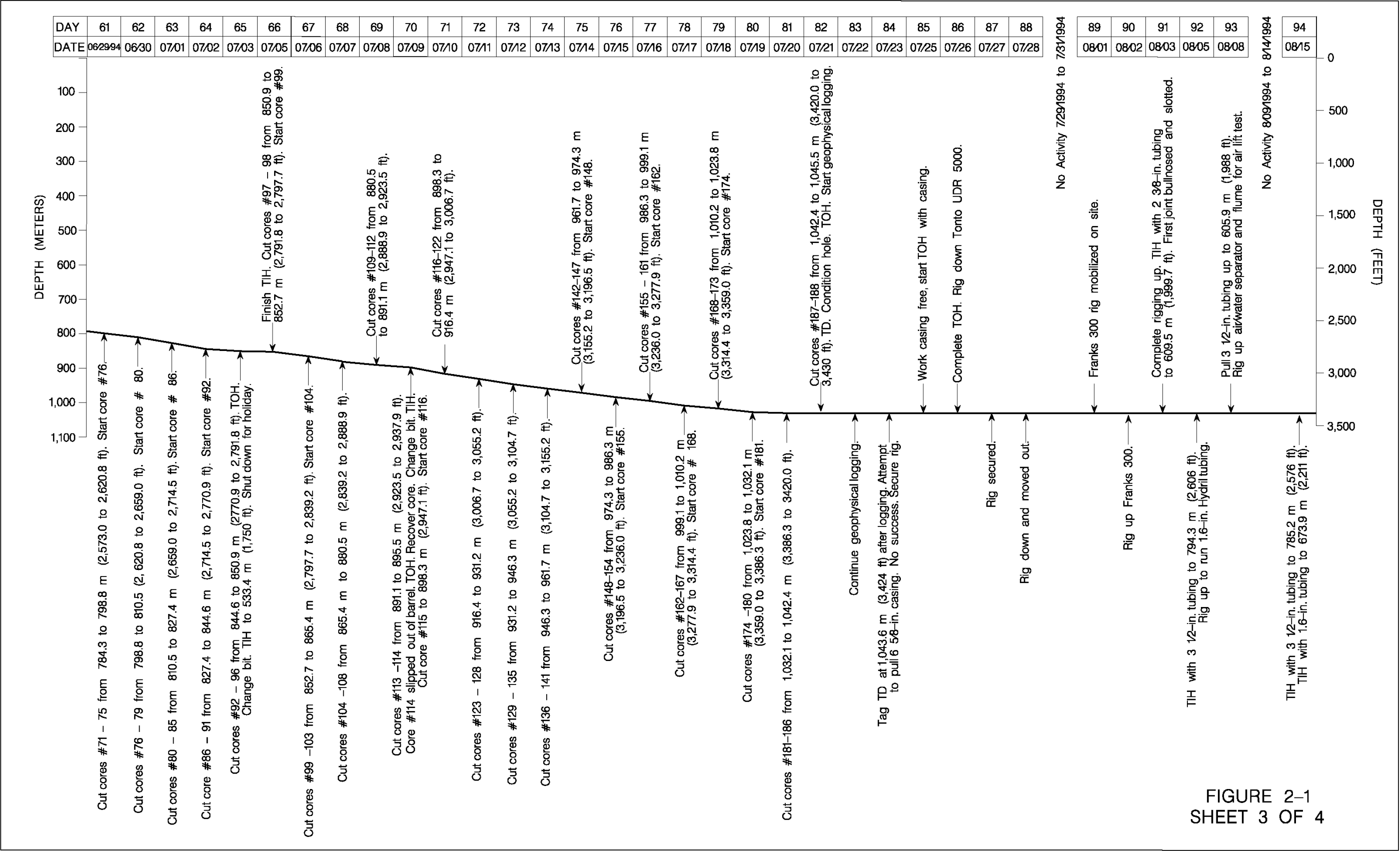
LEGEND

AIN	annulus inspection
AWS	Atlas Wireline Service
BHA	bottom hole assembly
bgs	below ground surface
DRI	Desert Research Institute
ft	foot (feet)
in.	inch(es)
m	meter(s)
od	outer diameter
SLM	steel line measurement
SNJV	Stoller Navarro Joint Venture
ss	stainless steel
TD	total depth
TIH	trip into hole
TOC	top of cement
TOH	trip out of hole

FIGURE 2-1
WELL ER-6-2
DRILLING AND COMPLETION
HISTORY
SHEET 1 OF 4







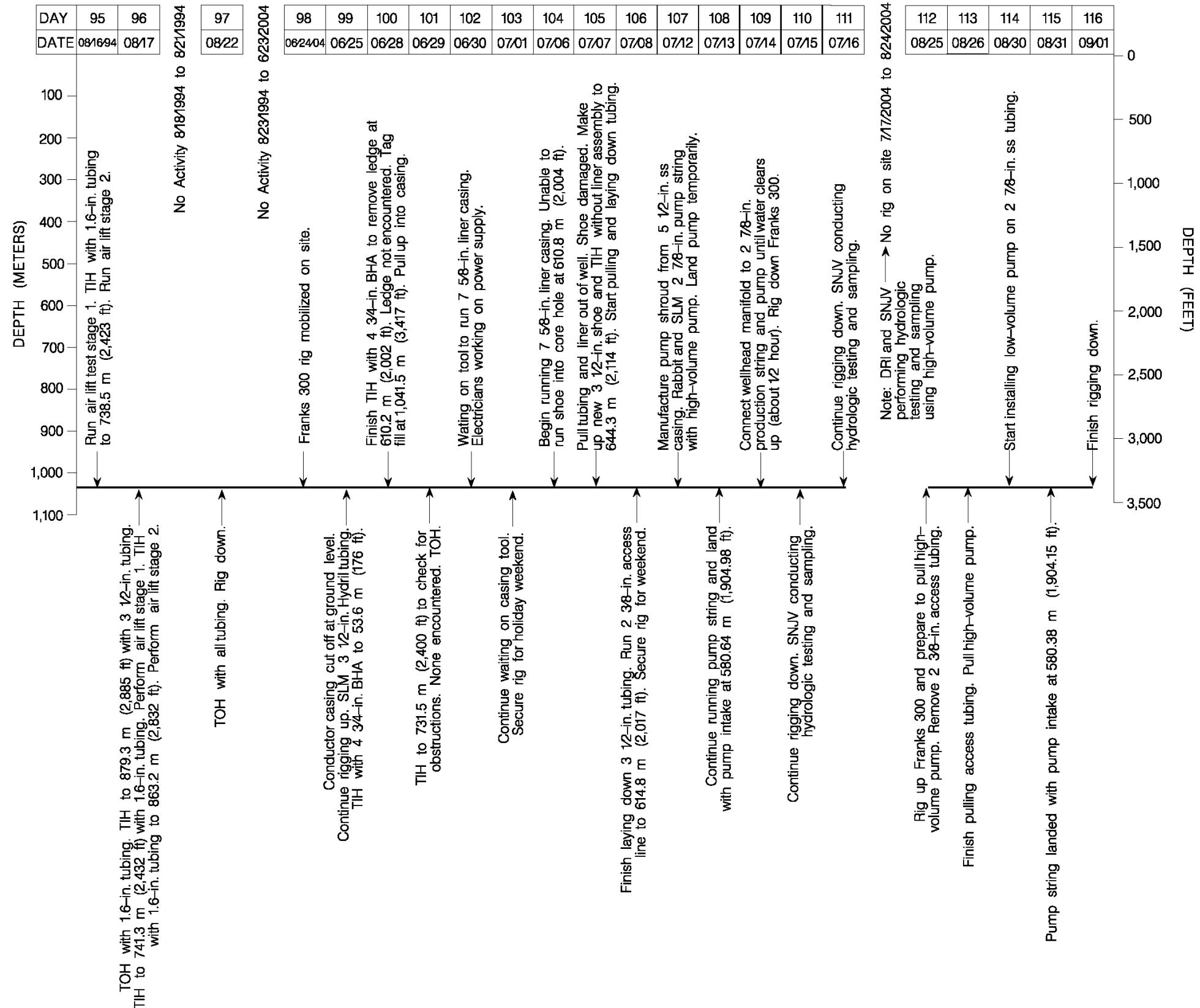


FIGURE 2-1
SHEET 4 OF 4

[252 to 367 ft]) were alternately cemented and re-drilled with a rotary tri-cone bit. After the depth of 130.1 m (427 ft) was reached on December 18, 1992, drilling operations were suspended for the holidays.

On January 4, 1993, drilling resumed with a 20-in. tri-cone bit. At a depth of 239.0 m (784 ft) the drill string was removed from the hole to change to the hammer-bit assembly. The borehole was deepened to 271.0 m (889 ft), where the hammer quit working, so the drill string was again removed to change back to the tri-cone bit, and drilling then continued to the depth of 331.9 m (1,089 ft).

The rig was secured for the weekend, and on January 11, 1993, the crew pulled the drill string from the hole again to change back to the hammer-bit assembly. At the depth of 408.7 m (1,341 ft) the hammer foot valve became inoperative, so the assembly was removed to again change back to the tri-cone bit. Drilling then proceeded to the depth of 578.5 m (1,898 ft).

On January 15, 1993, as the crew was pulling the drill string from the hole, a reamer pin twisted off, leaving a drill collar, the crossover sub, and the tri-cone bit in the hole. The top of the lost drilling assembly was at the depth of 568.8 m (1,866 ft). Two attempts to fish the equipment from the borehole were unsuccessful, so the rig was secured. When operations resumed on January 19, 1993, all of the BHA was recovered using an overshot assembly. Geophysical logging then took place January 19–21, 1993. The fluid level was measured at the depth of 545.0 m (1,788 ft) on January 19, 1993.

After logging was complete the drill crew set an intermediate casing string at the depth of 530.4 m (1,740 ft) which consisted of 492.7 m (1,616 ft) of 11¾-in. casing hanging from 37.8 m (124 ft) of 13⅜-in. casing. The 11¾-in. casing was beveled, with centralizers positioned 0.9 and 12.1 m (3.0 and 39.8 ft) from the bottom of the string. To prevent cementing the lowermost section of open hole, gravel was dumped down the casing, stemming the borehole to the depth of 534.3 m (1,753 ft). A section of 20/40 sand was placed on top of the gravel to the depth of 532.2 m (1,746 ft). Finally the annulus of the casing was cemented in four stages through 2⅞-in. Hydril tubing.

On January 26, 1993, a 10⅝-in. bit and air-foam drilling fluid were used to drill out the cement and stemming material. The borehole was then deepened to a TD of 611.4 m (2,006 ft) and drilling operations were suspended. The Cardwell 500 drill rig was removed from the location. The fluid level in the hole was measured at the depth of 543.2 m (1,782 ft) on January 28, 1993.

2.2.2 Drilling History for the Core Hole

Operations at Well ER-6-2 recommenced on June 8, 1994, when a Tonto drill rig was mobilized to the site and rigged up. After the borehole was cleaned out using a 10⁵/₈-in. mill-tooth bit, a string of 6⁵/₈-in. casing was run into the hole and landed at the depth of 611.2 m (2,005.2 ft). The crew then began coring with a 13.4-cm (5.276-in.) outside-diameter (od) diamond bit and core barrel with a 13.97-cm (5.5-in.) od reaming shell. On June 17, 1994, the first of 188, 8.5-cm (3.345-in.) diameter cores was cut. A total of 434.0 m (1,424 ft) of borehole were cored with no major problems. The final TD of 1,045.5 m (3,430 ft) was reached on July 21, 1994.

The drillers conditioned the hole with a polymer mix and then flushed the borehole with 150 barrels of water tagged with lithium bromide as a tracer. The coring assembly was then removed from the hole in preparation for geophysical logging. After the 6⁵/₈-in. casing was pulled from the hole, the crew rigged down and the Tonto drill rig was moved out.

2.2.3 Post-Construction Activities

Initial development of the cored portion of Well ER-6-2 was accomplished in August 1994 using the dipstick method, as described in Section 6.3. A Franks 300 rig was used by the REEC Co drill crew to facilitate insertion and removal of tubing strings during two stages of air-lift testing.

Work was also conducted in the borehole in the summer of 2004 in preparation for planned hydraulic testing. A BN drill crew cut the conductor casing off at ground level to facilitate access to the borehole. It was suspected that a ledge or other obstruction was present at the transition between the rotary-drilled and cored portions of the hole near the depth of 610.2 m (2,002 ft). Thus, on June 28, 2004, the drillers used a 4³/₄-in. BHA with a mill-tooth bit to clear the obstruction. However, no ledge or obstruction was encountered to the depth of 1,041.5 m (3,417 ft), and the BHA was removed. On July 6, 2004, the crew tried to insert a 7⁵/₈-in. liner casing into the hole but were unable to pass the depth of 610.8 m (2,004 ft). They pulled the casing and inserted a 3¹/₂-in. guide shoe; they were able to run it to the depth of 644.3 m (2,114 ft) but damaged the shoe in doing so. The project team finally decided to use a 2³/₈-in. access line and to run the required pump on 2⁷/₈-in. tubing. See Section 7.3.2 of this report. Detailed information about the hydraulic testing is provided in SNJV (2004; 2005).

2.2.4 Borehole Deviation

A gyroscopic survey run in the borehole indicates that at the lowest surveyed depth of 1,043.3 m (3,423 ft), the hole had drifted 55.7 m (182.6 ft) to the south-southwest of the collar location (Figure 2-2). No severe “doglegs” are visible on the vertical profile of the deviation data. The

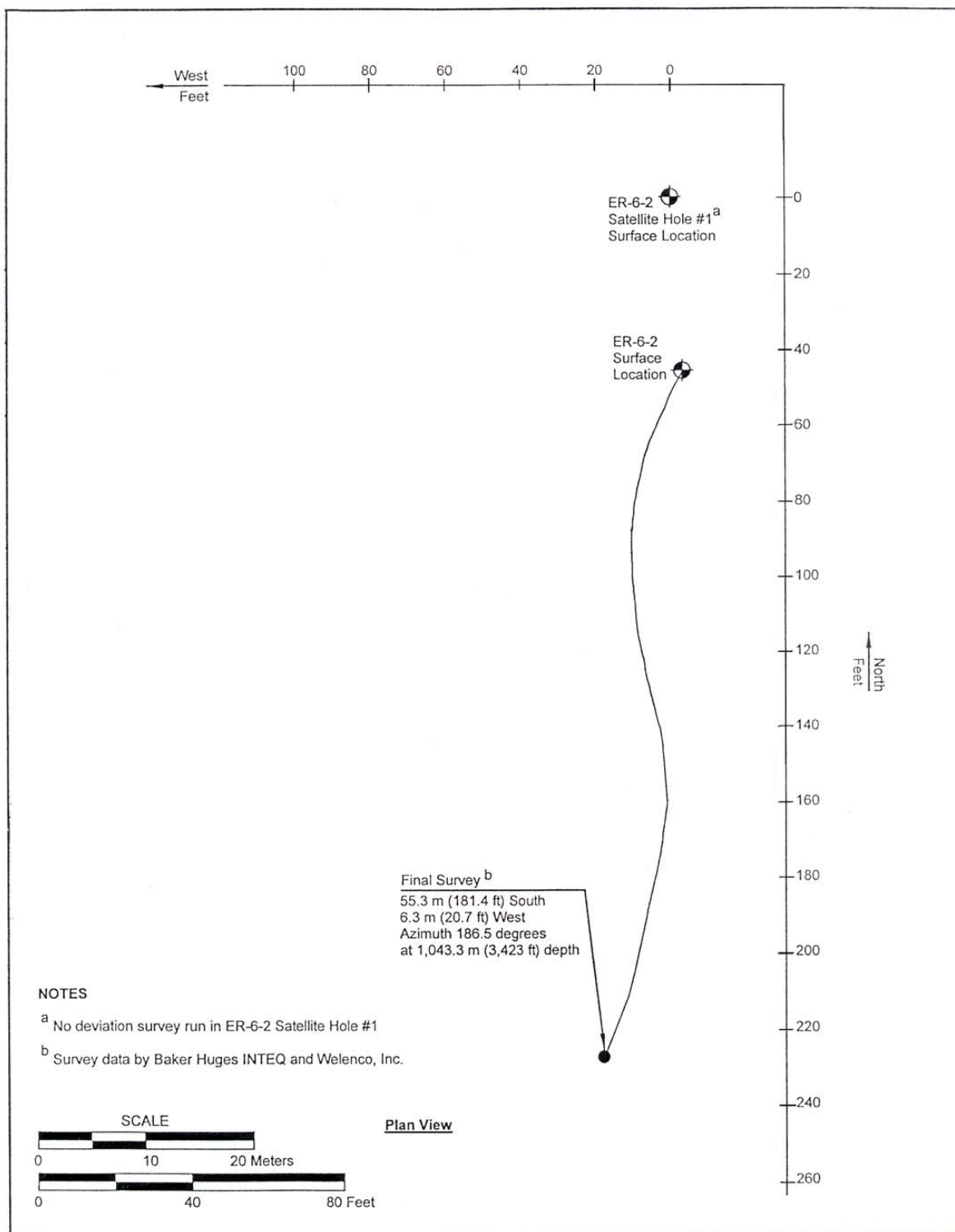


Figure 2-2
Map View of Wells ER-6-2 and ER-6-2#1 Showing Collar Locations and Measured Borehole Deviation of Well ER-6-2

gradual lateral deviation was not expected to cause any installation problems for future completions at this well.

2.3 Drilling Problems

Borehole sloughing was the primary problem encountered during drilling of Well ER-6-2. The sloughing was controlled by cementing off and re-drilling the following intervals:

- 29.9 to 73.5 m (98 to 241 ft)
- 29.9 to 120.4 m (98 to 395 ft)
- 76.8 to 111.9 m (252 to 367 ft)

The intermediate casing set at 530.4 m (1,740 ft) also helped control the sloughing problems and allowed the planned TD to be reached.

2.4 Fluid Management

Well ER-6-2 was drilled to the depth of 611.4 m (2,006 ft) using air-foam as the drilling fluid. The remainder of the hole was cored using a polymer fluid. To manage the anticipated water production, two lined sumps were constructed prior to drilling (Figure 1-3).

The drilling effluent was monitored according to the Draft Fluid Management Plan (FMP) in effect at the time the well was drilled (DOE/NV, 1993). *The Drilling Criteria for Well ER-6-2, Revision No. 1* (IT, 1992) and the *Coring, Testing, Sampling, and Completion Plan for the Underground Test Area Operable Unit Investigation Well ER-6-2* (IT, 1994) also provided guidance.

The results of analyses on samples of drilling fluid collected indicate that all fluid quality objectives were met, as shown on the fluid management reporting form (Appendix B) dated March 16, 2005, prepared after final well development and aquifer testing (see Section 6.4). The form lists volumes of solids (drill cuttings) and fluids produced during all phases of well construction, well development, and aquifer testing. (Final well development and aquifer testing were conducted several years after the well was constructed and is only summarized in this report; see SNJV [2004; 2005] for details.) 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; borehole sloughing and re-drilling of cemented intervals are also taken into account. The volumes of fluids listed on the report are estimates of total fluid production, calculated from water-truck delivery tickets and measurements of fluids in the sumps, but do not account for any evaporation of fluids from the sumps.

3.0 Drilling Summary for Well ER-6-2#1

3.1 Introduction

Well ER-6-2#1 was drilled as a “satellite” to Well ER-6-2, on the same drill pad, soon after the first phase of drilling of Well ER-6-2 was completed. The drilling requirements for Well ER-6-2#1 were outlined in the RSN Drilling Program D-007-003 (RSN, 1993a). Changes to the program were documented in RSN Records of Verbal Communication (Appendix A-1). This section describes the construction of Well ER-6-2#1.

3.2 Construction of Well ER-6-2#1

Figure 3-1 is a chart of the drilling and completion history for Well ER-6-2#1. A summary of drilling statistics for the well is given in Table 3-1. The following information was compiled primarily from RSN daily drilling reports, field notes prepared by the IT Field Representatives, and the RSN Well ER-6-2#1 well history (RSN, 1993c). A plot of drilling parameters is not available for this borehole. See Appendix A-2 for a listing of casing materials. Drilling fluids and cements used in Well ER-6-2#1 are listed in Appendix A-3. See Figure 1-3 for a depiction of the site layout.

Field operations at Well ER-6-2#1 began on July 30, 1993, with the mobilization of a “CP 750” rotary drill rig to drill the surface hole. A REEC Co crew drilled a 47.0-cm (18.5-in.) diameter hole using drilling mud in conventional circulation to the depth of 36.6 m (120 ft). Drilling was completed on August 3, 1993, but some sloughing occurred and the final tagged depth on top of fill was 35.7 m (117 ft).

An International Petroleum Services/Cardwell 500 drill rig was mobilized to the site on August 4, 1993. The crew set a string of 13³/₈-in. casing to the depth of 32.3 m (106 ft) and cemented the annulus to the ground surface with 7.1 cubic meters (250 cubic feet) of cement. The cement was emplaced down the casing string and displaced with a rubber plug followed by water.

Rotary drilling began on August 5, 1993. The crew used a 9⁷/₈-in. bit and a down-hole Dyna-Drill motor, with a drill fluid consisting of air-foam with a polymer additive. A 25.1-cm (9.875-in.) diameter hole was drilled to 300.8 m (987 ft) in two days, and the rig was secured for the weekend.

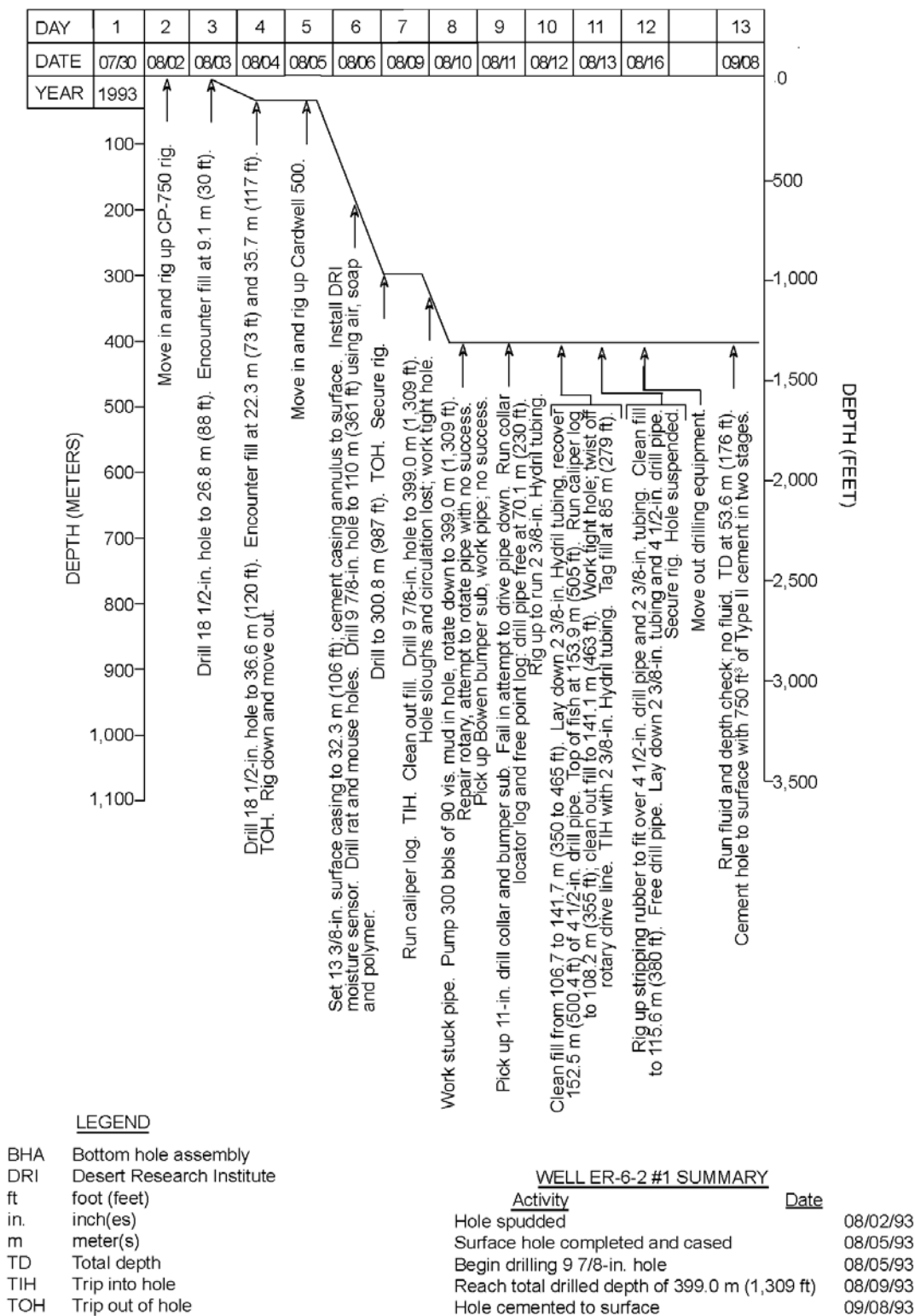


Figure 3-1
Drilling History for Well ER-6-2#1

Table 3-1
Abridged Drill Hole Statistics for Well ER-6-2#1

LOCATION DATA:	
Coordinates ^a :	Nevada State Plane (central zone): NAD 27: N 805,360 ft E 672,492 ft
	Universal Transverse Mercator: NAD 27: N 4,090,759.1 m E 582,235.1 m NAD 83: N 4,090,956.2 m E 582,155.7 m
Surface Elevation ^b :	1,289.6 m (4,231 ft), estimated
DRILLING DATA:	
Spud Date:	07/30/1993 (auger rig); 08/02/1993 (main hole drilling)
Total Depth (TD):	399.0 m (1,309 ft)
Date TD Reached:	08/09/1993
Date Well Completed:	Not completed. Well abandoned and cemented to surface 09/08/1993.
Original Hole Diameter:	47 cm (18.5 in.) from surface to 36.6 m (120 ft); 25.1 cm (9.875 in.) to TD at 399.0 m (1,309 ft).
Drilling Techniques:	Rotary drilling using an 18½-in. button bit and mud in conventional circulation to 36.6 m (120 ft). Rotary drilling with a 9⅞-in. button bit and Dyna-Drill through cement in casing at 27.7 to 32.6 m (91 to 107 ft) with conventional circulation using air-foam and polymer. Rotary drilling with 9⅞-in. button bit and Dyna-Drill to TD at 399.0 m (1,309 ft). Bit stuck at 399.0 m (1,309 ft) due to severe hole sloughing. Fishing operations recover 152.5 m (500.4 ft) of drill pipe, leaving the bottom-hole assembly and drill pipe in hole. Top of equipment at 153.9 m (505 ft). Fill tagged at 53.6 m (176 ft). Upper part of hole cemented to ground level.
CASING DATA: ^c	13⅝-in. surface conductor to 32.3 m (106 ft). No intermediate casing.
WELL COMPLETION DATA:	Hole abandoned; no completion strings installed.
Depth of Slotted Section:	None
Depth of Gravel Pack:	None
Depth of Pump:	None
Water Depth:	Fluid level not reached.
DRILLING CONTRACTOR:	Reynolds Electrical and Engineering Co., Inc.
GEOPHYSICAL LOGS BY:	Atlas Wireline Services
SURVEYING CONTRACTOR:	Not applicable

a Estimated location coordinates: well collar not surveyed.

b Elevation of ground level at wellhead. National Geodetic Vertical Datum, 1929 (NARA, 1973).

c See Appendix A-2 for more information on casing materials.

When operations resumed on August 9, 1993, a caliper log was run to a depth of 298.1 m (978 ft), where fill was encountered. The crew cleaned out the fill and drilled with the 9⁷/₈-in. bit to 399.0 m (1,309 ft). At that point, the borehole walls sloughed and circulation was lost. The drillers worked tight spots in the borehole and pumped 460 barrels of polymer, soap mix, and mud into the hole, with no returns. On August 10, 1993, the bit was finally worked back down to the depth of 399.0 m (1,309 ft), and the drillers then stopped to repair a broken rotary drive line. After repairs, the drillers attempted to work the pipe and rotate the bit, without success. The crew then picked up a Bowen lubricated bumper sub and worked the pipe, without success.

The next day an attempt to drive the drill pipe down with an 11-in. drill collar and bumper sub failed. On August 12, 1993, collar-locator and free-point logs were run and the pipe was found to be free at the depth of 70.1 m (230 ft). The drillers then ran 2³/₈-in. Hydril tubing down the annulus of the drill pipe and cleaned fill from 106.7 to 141.7 m (350 to 465 ft). They removed the tubing and were able to recover 152.5 m (500.4 ft) of drill pipe. It was discovered that the bottom joint of pipe was twisted off at the pin shoulder. The equipment left in the hole (the “fish”) consists of the BHA (82.7 m [271.5 ft] long) and 17 joints of 4¹/₂-in. drill pipe (162.3 m [532.5 ft] long). The top of the fish was at the depth of 153.9 m (505 ft).

A caliper log was run to a depth of 108.2 m (355 ft), and the decision was made to resume fishing efforts. The drillers inserted drill pipe with a 9⁷/₈-in. bit into the borehole and cleaned out and conditioned the hole to the depth of 141.1 m (463 ft). The pipe became stuck at the depth of 125.0 m (410 ft), so 100 barrels of high viscosity mud was pumped down the hole. The rotary drive line twisted off while the drillers worked the pipe, so the crew inserted 2³/₈-in. Hydril tubing to the top of fill at 85 m (279 ft). The next day the drillers cleaned out fill from 85.0 to 115.8 m (279 to 380 ft) and the drill pipe came free. The tubing and 4¹/₂-in. drill pipe were removed, and work on the hole was suspended.

On September 8, 1993, checks on the borehole depth and fluid level determined that the top of fill was at 53.6 m (176 ft) and there was no fluid in the hole. The hole was then cemented to the surface, and Well ER-6-2#1 was considered abandoned. Figure 3-2 shows the final configuration of the borehole, and Figure 3-3 shows the wellhead diagram. See Table 3-2 for a list of equipment left in the borehole. It is possible that portions of the borehole below the tagged fill depth of 53.6 m (176 ft) may contain voids due to bridging, and open areas around or within the drill pipe.

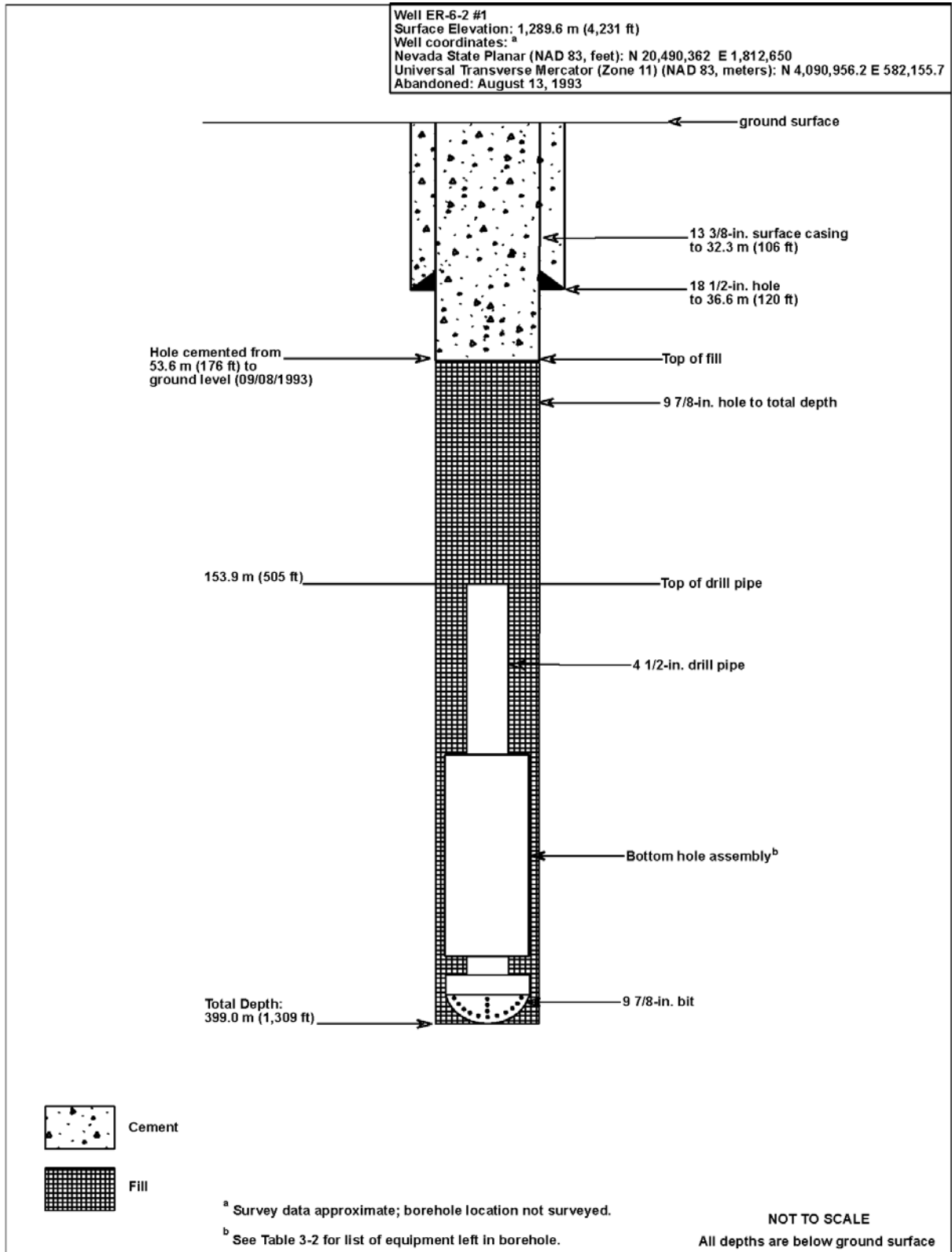


Figure 3-2
As-built Completion Schematic for Well ER-6-2#1

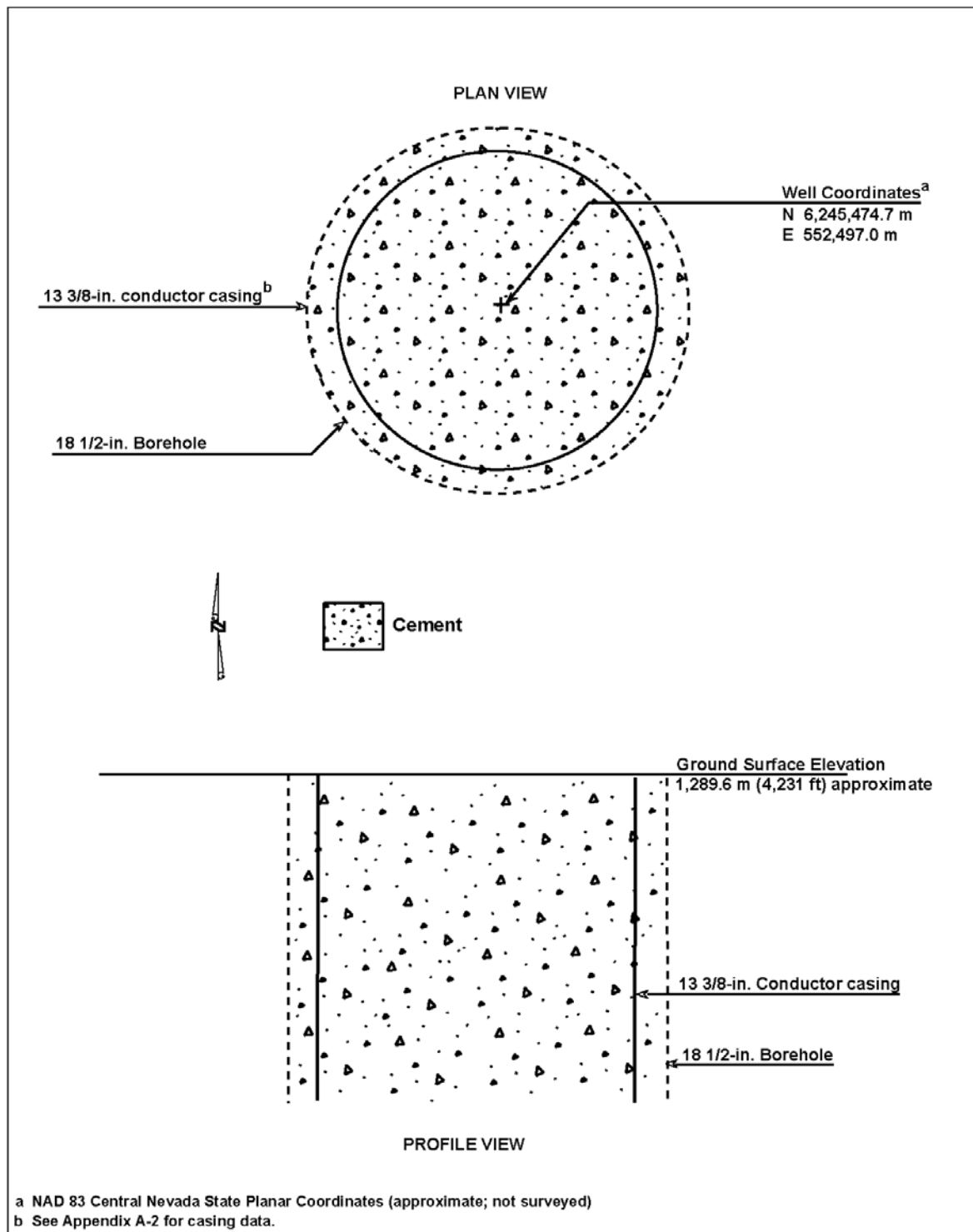


Figure 3-3
Wellhead Diagram for Well ER-6-2#1

Table 3-2
Equipment Left in the Well ER-6-2#1 Borehole

Components Left in the Borehole		Length
Drill Pipe	4½-inch drill pipe	162.3 meters (532.5 feet)
Bottom-Hole Assembly	6½-inch drill collars (7) String stabilizer 6½-inch drill collar (1) String stabilizer Crossover sub Dyna-Drill 9⅞-inch bit	82.7 meters (271.5 feet)
Total		245.1 meters (804.0 feet)

3.3 Drilling Problems

Hole sloughing problems began in the upper part of the borehole but were controlled by the surface casing set at 32.3 m (106 ft). No other drilling problems were encountered until drilling reached the depth of 399.0 m (1,309 ft). Circulation was lost at this point, and the hole sloughed and was eventually lost. Most of the fill material consisted of dolostone fragments.

The caliper log indicates the presence of large washed-out areas in the intervals 32.3 to 53.6 m (106 to 176 ft) and 79.2 to 85.3 m (260 to 280 ft), and a ragged section of hole from 105.5 to 109.7 m (346 to 360 ft).

3.4 Fluid Management

Bentonite drilling mud was used to drill Well ER-6-2#1 to the depth of 36.6 m (120 ft). The remainder of the borehole was drilled using air-foam, with applications of polymer and bentonite mud as needed to condition the hole. The drilling effluent was stored in the south sump (lined sump #2; see Figure 1-3).

The drilling effluent was monitored according to methods prescribed in the FMP (DOE/NV, 1993) and the RSN drilling program (RSN, 1993a). The results of analyses on samples of drilling fluid collected indicate that all the fluid quality objectives established for this well were met, as shown on the fluid management reporting form dated February 28, 1994 (Appendix B). The form lists volumes of solids (drill cuttings) and fluids produced during well-construction operations. 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, calculated from water-truck delivery tickets and measurements of fluids in the sumps, but do not account for any evaporation of fluids from the sumps.

4.0 Geologic Data Collection

4.1 Introduction

This section describes the sources of geologic data obtained from Wells ER-6-2 and ER-6-2#1 and the methods of data collection. Improving the understanding of the subsurface structure, stratigraphy, and hydrogeology in southern Yucca Flat was among the primary objectives of this drilling project, so the proper collection of geologic and hydrogeologic data from the borehole was considered fundamental to successful completion of the project.

Geologic data collected at the Well ER-6-2 site consist of drill cuttings, conventional cores, and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures, as described in Drellack (1992a), McCall (1993), and IT (1993; 1994).

4.2 Well ER-6-2

Information about drill cuttings, cores, and geophysical logs is presented in the following paragraphs.

4.2.1 Drill Cuttings Samples

REECO drilling personnel collected composite drill cuttings samples, each consisting of approximately 550 cubic centimeters of material, during drilling of Well ER-6-2. The samples were collected at 3-m (10-ft) intervals as drilling progressed from the ground surface to the TD of the rotary-drilled portion of the borehole at 611.4 m (2,006 ft), for a total of 196 sample intervals. Two samples were collected from each interval during auger-drilling from the ground surface to the depth of 30.3 m (100 ft), and triplicate samples were collected from 30.3 m (100 ft) to TD of the rotary-drilled section. No samples were collected at the depths of 79.2 and 237.7 m (260 and 780 ft). In addition, thirty-four 3.8-liter (1-gallon) samples were collected for paleontologic analysis at 15.2-m (50-ft) intervals from throughout most of the drilled section. No cuttings were collected during coring operations.

All samples were checked at the rig by RSN geologists, who then delivered the samples to the USGS Geologic Data Center and Core Library under chain of custody. Samples not sent for analysis are stored at the USGS Geologic Data Center and Core Library in Mercury, Nevada, under environmentally controlled, secure conditions. One of each triplicate sample set was sealed with custody tape at the rig site and remains sealed as an archive sample, one set was left unsealed in the original sample containers, and the third set was washed and stored according to

standard USGS Core Library procedures. The washed set was used by RSN geologists to construct the detailed lithologic log presented in Appendix C.

Drill cuttings from Well ER-6-2 were generally of good quality; however, some samples between the depths of 306.6 and 356.6 m (1,006 and 1,160 ft) were found to contain abundant material sloughed from up-hole.

4.2.2 Core Samples

Continuous core samples were cut from the interval 611.4 to 1,045.5 m (2,006 to 3,430 ft). All 188 cores are stored at the USGS Geologic Data Center and Core Library in Mercury, Nevada. Table 4-1 summarizes core sample depths and recovery. Core recovery was excellent, at 99.8 percent.

Table 4-1
Summary of Wireline Cores Taken from Well ER-6-2

Core Number	Cored Interval meters (feet)	Core Cut meters (feet)	Core Recovered meters (feet)	Stratigraphic Unit	Hydrostratigraphic Unit^a
1 to 45	611.5–727.0 (2,006.3–2,385.3)	115.5 (379.0)	115.3 (378.3)	Banded Mountain Member, Bonanza King Formation	Lower carbonate aquifer
46 to 107	727.0–877.5 (2,385.3–2,879.0)	150.5 (493.7)	150.3 (493.0)	Guilmette Formation	Lower carbonate aquifer
108 to 188	877.5–1,045.5 (2,879.0–3,430.0)	168.0 (551.0)	167.5 (549.4)	Chainman Shale	Upper clastic confining unit

a Modified from Winograd and Thordarson (1975)

4.2.3 Geophysical Log Data

Geophysical logs were run at various stages in drilling of the borehole to evaluate borehole conditions and to further characterize the lithology, structure, and hydrologic properties of the rocks encountered. Geophysical logging was conducted in three stages: during problems with borehole sloughing, after the TD of the rotary-drilled portion of the hole was reached at 611.4 m (2,006 ft), and after completion of coring to the final TD of 1,045.5 m (3,430 ft). A complete listing of the logs, dates run, depths, and service companies is provided in Table 4-2. The logs are available from NSTec in Mercury, Nevada, and copies are on file at the office of SNJV in Las Vegas, Nevada, and at the USGS Geologic Data Center and Core Library in Mercury, Nevada. Geophysical data from selected logs are reproduced in Appendix D.

4.2.4 Additional Data

Thirteen paleontology samples consisting of bulk fractions of cuttings from the Paleozoic section in Well ER-6-2 were analyzed by Micro-Strat, Inc., of Houston, Texas. The results of these analyses are reported in the document *High Resolution Palynomorph Biostratigraphy of Thirteen Well Samples* (Micro-Strat, Inc., 1993). Eight samples of limestone from the cored section of Well ER-6-2 were processed and analyzed for conodont fossils by the USGS. The results are reported in the document *Stratigraphic and Structural Interpretations of Paleontologic Studies and Core Logging, ER-6-1 and ER-6-2 Wells, Nevada Test Site* (Cole and Harris, 1996). A detailed analysis of the borehole image log for the rotary-drilled portion of Well ER-6-2 was prepared by CER Corporation of Las Vegas, Nevada, and reported in the document, *CBIL Image Analysis of Well ER-6-2, Nevada Test Site* (CER Corporation, 1994).

4.3 Well ER-6-2#1

Drill cuttings samples and geophysical logs obtained from Well ER-6-2#1 are described in the following paragraphs.

4.3.1 Drill Cuttings Samples

IT personnel collected triplicate composite drill cuttings samples, each consisting of approximately 550 cubic centimeters of material, during drilling of Well ER-6-2#1. The samples were collected at 3-m (10-ft) intervals as drilling progressed from 36.6 to 396.2 m (120 to 1,300 ft), for a total of 119 sample intervals. The quality of the drill cuttings was degraded due to borehole sloughing and circulation problems during drilling.

Table 4-2
Well ER-6-2 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)
Annulus Investigation Log (AIN)	Omnidirectional density (check for cement location and/or fluid location)	AWS	12/10/1992	AIN-1	118.3 (388)	102.7 (337)
			12/10/1992	AIN-2	118.3 (388)	41.8 (137)
			12/10/1992	AIN-3	118.3 (388)	81.7 (268)
			12/10/1992	AIN-4	110.3 (362)	84.4 (277)
			12/10/1992	AIN-5	110.0 (361)	77.1 (253)
			12/10/1992	AIN-6	103.6 (340)	84.4 (277)
			12/10/1992	AIN-7-11	98.2 (322)	22.3 (73)
			12/14/1992	AIN-12	35.4 (116)	18.9 (62)
			12/16/1992	AIN-13	78.0 (256)	59.1 (194)
Borehole Seismic Analysis (airgun)	Lithologic determination/ formation velocities	AWS	01/20/1993	SGG-1	563.9 (1,850)	45.7 (150)
Borehole Televiewer/Gamma Ray	Borehole examination for fractures, structure, and lithology/ stratigraphic correlation	AWS	07/15/1993	BHTV-1 / GR-9	609.0 (1,998)	547.7 (1,797)
		Welenco	07/22/1994	BHTV-2	1,043.4 (3,423)	609.3 (1,999)
* Caliper/Gamma Ray	Borehole conditions/ stratigraphic correlation	AWS	12/09/1992	CA6-1 / GR-1	118.3 (388)	14.9 (49)
			12/11/1992	CA6-2 / GR-3	64.3 (211)	13.4 (44)
			01/19/1993	CA6-3 / GR-4	570.3 (1,871)	13.7 (45)
			01/28/1993	CA6-4 / GR-8	607.2 (1,992)	513.6 (1,685)
			07/22/1994	CA6-5 / GR-10	1,040 (3,415)	594.4 (1,950)
Cement Top Locator	Cement location	AWS	01/22/1993	CTN-1, -2	516.9 (1,696)	11.6 (38)
* Compensated Density/Gamma Ray	Lithology/stratigraphic correlation	AWS	01/20/1993	CDL-1 / GR-6	573.0 (1,880)	21.3 (70)
* Compensated Density/ Compensated Neutron/Gamma Ray	Lithology/stratigraphic correlation	AWS	07/22/1994	CDL-2 / CN-1 / GR-11	1,043.3 (3,423)	591.9 (1,942)
Directional Gyroscope	Borehole deviation	BHI	07/23/1994	DRG-1	609.0 (1,198)	0
		Welenco	07/22/1994	DR-2	1,043.3 (3,423)	617.2 (2,025)
Downhole Video	Borehole examination for fractures, structure, and lithology	BWS	01/20/1993	TV-1	554.7 (1,787)	0

Table 4-2
Well ER-6-2 Geophysical Log Summary (continued)

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)
* Dual Induction/Gamma Ray	Rock porosity/lithology	AWS	12/09/1992 01/19/1993	DIFL-1 / GR-2 DIFL-2 / GR-5	115.2 (378) 571.2 (1,874)	14.3 (47) 19.5 (64)
* Dual Laterolog/Gamma Ray	Lithology/stratigraphic correlation	AWS	07/22/1994	DLL-1 / GR-12	1,043.6 (3,424)	606.6 (1,990)
* Epithermal Neutron/Gamma Ray	Rock porosity/stratigraphic correlation	AWS	01/20/1993	ENP-1 / GR-7	527.1 (1,877)	11.9 (39)
Fluid Density	Depth to water	AWS	01/19/1993	DF-1	561.1 (1,841)	535.8 (1,758)
			01/19/1993	DF-2	573.6 (1,882)	522.4 (1,714)
			01/21/1993	DF-3	548.8 (1,800)	516.9 (1,696)
			01/22/1993	DF-4	531.9 (1,745)	510.8 (1,676)
			01/28/1993	DF-5	554.1 (1,818)	530.4 (1,740)
			07/21/1994	DF-6	553.2 (1,815)	535.5 (1,757)
			07/22/1994	DF-7	552.3 (1,812)	533.4 (1,750)
* Thermal Flow Log with Electrical Conductivity and Temperature	Determine rate/direction of groundwater flow within the borehole	DRI	12/14/1994	HPFLOW-1	1,039.7 (3,411)	547.1 (1,795)

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

b AWS = Atlas Wireline Services; Welenco - Welenco Inc.; BWS = Barbour Well Surveying; BHI - Baker Hughes INTEQ; DRI = Desert Research Institute.

c Depth below ground surface.

All samples are stored under environmentally controlled, secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada. One of each triplicate sample set was sealed with custody tape at the rig site and remains sealed as an archive sample, one set was left unsealed in the original sample containers, and the third set was washed and stored according to standard USGS Core Library procedures.

4.3.2 Geophysical Logging Data

The only geophysical logs run in Well ER-6-2#1 were two caliper logs, a collar-locator log, and a free-point log. These logs were run during fishing operations to determine the borehole condition and to locate fill surrounding the stuck drill pipe. All logs run in Well ER-6-2#1 are listed in Table 4-3. The logs are available from NSTec in Mercury, Nevada, and copies are on file at the office of SNJV in Las Vegas, Nevada, and at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

**Table 4-3
Well ER-6-2#1 Geophysical Log Summary**

Geophysical Log Type ^a	Log Purpose	Date Logged	Run Number	Bottom of Logged Interval ^b meters (feet)	Top of Logged Interval ^b meters (feet)
6-Arm Caliper	Borehole conditions	08/09/1993 08/12/1993	CA6-1 CA6-2	295.7 (970) 105.5 (346)	15.2 (50) 15.2 (50)
Casing Collar Locator	Drill pipe and casing conditions	08/11/1993	CCL-1	166.4 (546)	0
Free-Point (Pipe)	Locate fill in annulus around drill pipe	08/11/1993	FPP-1	147.8 (485)	12.2 (485)

a All logs run by Atlas Wireline Services.

b Depth below ground surface.

5.0 Geology and Hydrogeology

5.1 Introduction

This section describes the geology and hydrogeology of the Well ER-6-2 site. The basis for the discussions here is the detailed lithologic and stratigraphic logs of Well ER-6-2 presented in Appendix C. These logs were developed by BN geologists through examination of drill cuttings, conventional cores, geophysical logs, and drilling parameters. Information from paleontologic analyses by Micro-Strat, Inc. (1993) and the USGS (Cole and Harris, 1996) was incorporated into the detailed lithologic log.

Stratigraphic and lithologic logs were not prepared for Well ER-6-2#1 because of the lack of quality drill cuttings due to borehole sloughing and circulation problems during drilling. However, examination of the cuttings from the hole indicated that the stratigraphy and lithologies penetrated by the borehole are similar to those of Well ER-6-2, as would be expected for two holes drilled within approximately 15.2 m (50 ft) of each other.

5.2 Geology

Well ER-6-2 is located at the base of the CP Hills on the southwestern edge of Yucca Flat (Figure 5-1). Yucca Flat is a closed hydrologic basin that is bounded by highlands of intensely folded and faulted Paleozoic and Precambrian-age sedimentary rocks that are overlain in places by less deformed Tertiary-age volcanic rocks. The Yucca Flat basin has been filled with Tertiary-age volcanic rocks and Quaternary and Tertiary alluvium consisting of debris eroded from the adjacent highlands. Regional groundwater flow beneath Yucca Flat is generally to the south and southwest within the LCA, which consists mainly of fractured Paleozoic carbonate rocks (Laczniak et al., 1996). Lower Paleozoic and upper Precambrian clastic rocks form a regional confining unit known as the lower clastic confining unit. Upper Paleozoic (mostly Mississippian age) clastic rocks form the locally present upper clastic confining unit (Winograd and Thordarson, 1975). Because these units are intensely folded and faulted they do not constitute an easily modeled hydrogeologic system. A list of stratigraphic units of southern Yucca Flat is given in Table 5-1.

The remainder of this section is divided into three discussions relating to the geology of Well ER-6-2. Section 5.2.1 describes the predicted versus actual geology encountered. The stratigraphic and lithologic units penetrated at the well are discussed in Section 5.2.2, and structural features are discussed in Section 5.2.3. More detailed descriptions of the

Table 5-1
Stratigraphic, Lithologic, and Hydrologic Units in the Vicinity of Well ER-6-2

Stratigraphic Group	Stratigraphic Unit ^a	Symbol	Typical Lithology	Hydrostratigraphic Unit ^b
Quaternary/Tertiary Sediments				
Quaternary/Tertiary Sediments		QTa	Gravelly, sandy alluvium	Alluvial Aquifer
Tertiary Volcanic Rocks ^c				
Pre-Tertiary Units				
Paleozoic Section	Bird Spring Formation	Pb	Limestone	Upper Carbonate Aquifer
	Chainman Shale	MDc	Shale	Upper Clastic Confining Unit
	Guilmette Formation	Dg	Limestone	Lower Carbonate Aquifer
	Simonson Dolomite	Ds	Dolostone	
	Sevy Dolomite	DSs	Dolostone	
	Laketown Dolomite	Sl	Dolostone	
	Ely Spring Dolomite	Oes	Dolostone	
	Eureka Quartzite	Oe	Quartzite	
	Pogonip Group	Op	Limestone	
	Nopah Formation	Cn	Limestone	
	Bonanza King Formation	Cb	Limestone and dolostone	
	Carrara Formation	Cc	Limestone (upper part) and siltstone/quartzite	Lower Clastic Confining Unit
	Zabriskie Quartzite	Cz	Quartzite	
Precambrian Section	Precambrian units undifferentiated	Z	Predominantly quartzite with minor siltstone and limestone	

a Slate et al., 1999

b Modified from Winograd and Thordarson (1975), Lacznia et al. (1996), and BN, (2006).

c The Tertiary volcanic section has been eroded away in the vicinity of Well ER-6-2. See BN (2006) for a detailed description of the stratigraphy of Yucca Flat.

stratigraphy, lithology, and alteration of the rocks encountered are provided in the detailed lithologic log presented in Appendix C.

5.2.1 Predicted Versus Actual Geology

In general, the geology encountered at Well ER-6-2 is similar to that exposed just to the west and south in the CP Hills, where Paleozoic sedimentary rocks are complexly deformed. This complexity, along with the lack of any nearby drill hole data, made detailed pre-drill predictions of the subsurface geologic conditions impossible. However, the geology encountered at Well ER-6-2 is very similar to the general subsurface geologic predictions made prior to drilling (Hudson and Hokett, 1992; Drellack, 1992b; Allen, 1993) (Figure 5-2).

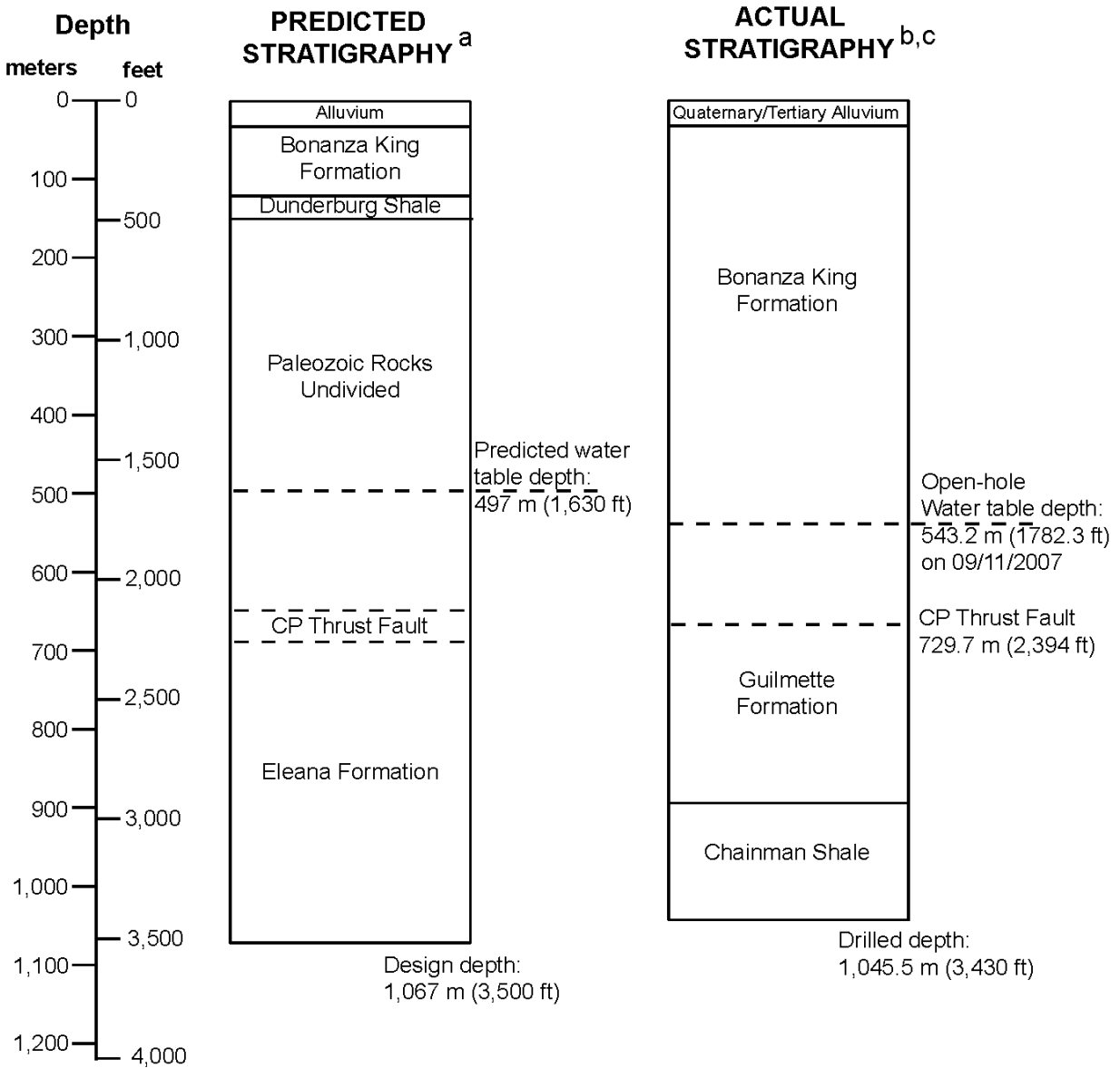
5.2.2 Stratigraphy and Lithology

The rocks encountered above the static water level at Well ER-6-2 consist mainly of alluvium and dolostone. Alluvium, consisting of sandy gravel, is present from the surface to the depth of 30.5 m (101 ft), and beneath the alluvium the borehole encountered dolostone of the Bonanza King Formation. A sequence of shale and limestone was encountered from 267.0 to 375.5 m (876 to 1,232 ft) within the unsaturated dolostone section.

Saturated rocks encountered consist of a continuation of the dolostone of the Bonanza King Formation to the depth of 729.7 m (2,394 ft). At this depth, a major fault, which is probably the CP thrust fault, was encountered. Units penetrated below the fault are overturned. The Guilmette Formation was encountered from 729.7 to 878.7 m (2,394 to 2,883 ft) and consists predominantly of limestone with minor quartzite, sandstone, and dolostone. The stratigraphic contact between the Guilmette Formation and the younger Chainman Shale was encountered at the depth of 878.7 m (2,883 ft). The Chainman Shale consists predominantly of black shale. The geology and hydrogeology of Well ER-6-2 is illustrated in Figure 5-3.

5.2.3 Structural Geology

As mentioned previously, rocks exposed in the CP Hills near Well ER-6-2 have been complexly deformed (Cole, 1997; Cole and Cashman, 1999). Structural features mapped in the CP Hills include overturned folds, thrust faults, and low- and high-angle dip-slip faults (McKeown et al., 1976). Due to the location of Well ER-6-2 at the base of the CP Hills, it is reasonable to assume that these same types of structural features were probably penetrated by the borehole. Unfortunately, it is usually difficult to identify complex structural features and determine their relationships using drill hole data alone. However, data from Well ER-6-2 indicate that a major



^a Hudson and Hokett, 1992; Drellack, 1992; Allen, 1993

^b Cole and Harris, 1996

^c See Appendix C for lithology and stratigraphy

Figure 5-2
Predicted and Actual Stratigraphy at Well ER-6-2

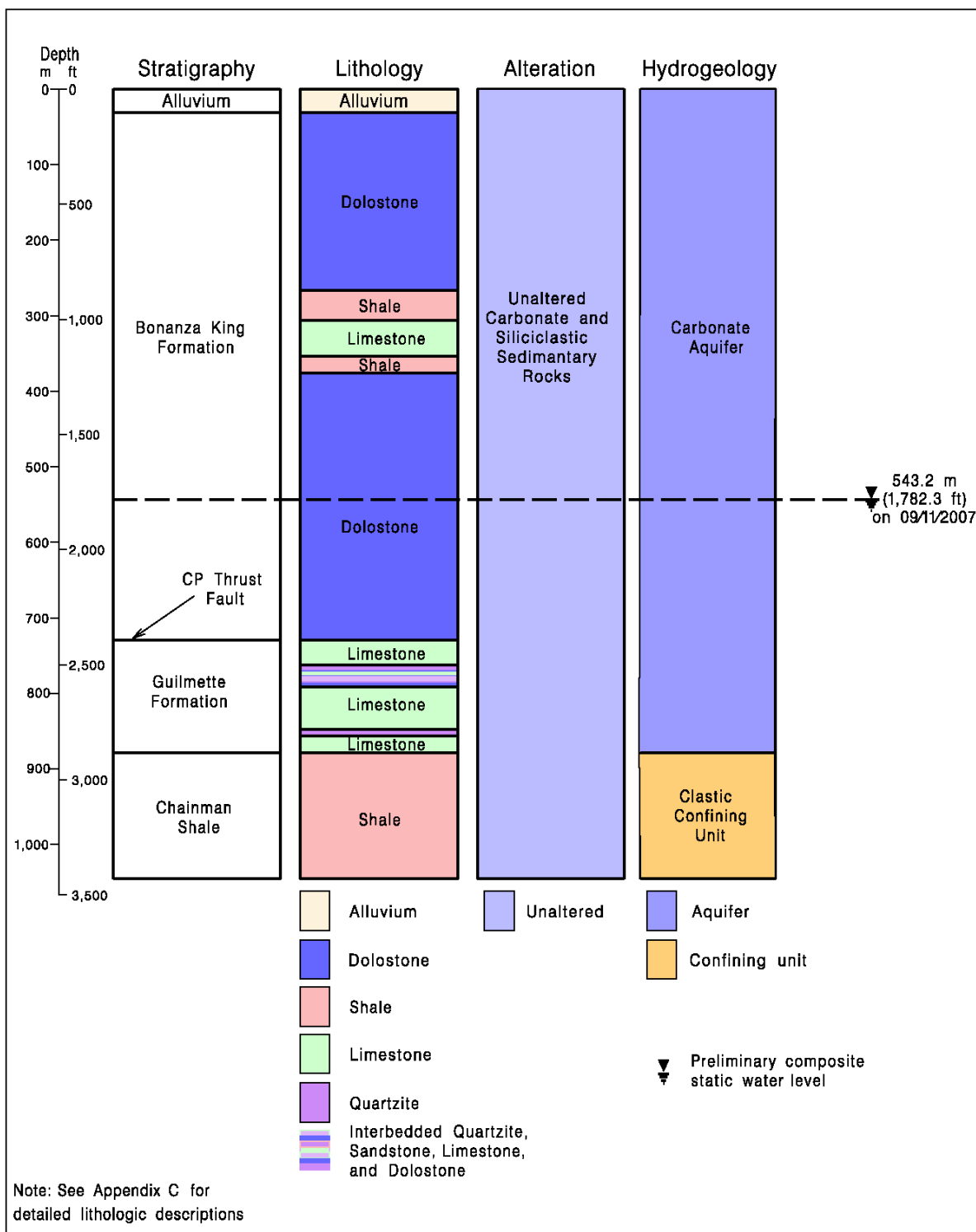


Figure 5-3
Geology and Hydrogeology of Well ER-6-2

fault, probably the west-vergent CP thrust fault (Caskey, 1991), was penetrated at the depth of 729.7 m (2,394 ft) and the stratigraphy below the fault is overturned. The fault has placed Cambrian-age dolostone of the Bonanza King Formation over younger Devonian-age limestone of the Guilmette Formation. An interval of breccia that is probably the result of movement along the fault was encountered from 720.9 to 729.7 m (2,365 to 2,394 ft). The rocks below the fault are interpreted to be overturned because the contact between the overlying Guilmette Formation and younger Chainman Shale is a stratigraphic contact, and not a structural (i.e., fault) contact.

A natural-source magnetotelluric survey was conducted in the Yucca Flat area in 2003 by the USGS. The results of the survey supported the structural interpretation described briefly above for the western portion of the basin (Rodriguez, 2004a; 2004b).

The borehole image log for the rotary-drilled portion of Well ER-6-2 (0 to 611.4 m [2,006 ft]) indicates that fractures strike generally northeast to east-northeast (CER Corporation, 1994). Analysis and comparison of the Well ER-6-2 core and the borehole image log for the cored portion of the hole (611.4 to 1,045.5 m [2,006 to 3,430 ft]) identified a set of open extensional fractures within the carbonate rocks. These fractures have a mean strike azimuth of 77 degrees and dips of 75 to 85 degrees. A set of closed (or filled) shear fractures was also identified within the carbonate section. These fractures have variable strikes, and dips of 10 to 50 degrees. A set of bedding plane slip fractures was identified within the shale section below the depth of 878.7 m (2,883 ft). These fractures have a mean strike azimuth of north-south and dip approximately 45 degrees to the west (IT, 1995a). Borehole image logs from Well ER-6-2 also indicate that the rocks dip west to northwest. See Cole and Harris (1996) for a discussion of the implications of observed bedding dips in this area.

Figure 5-4 is a west-east cross section through the CP Hills and Well ER-6-2, which shows the major geologic and hydrogeologic features in the area as well as those encountered in Well ER-6-2. However, due to the complexity and associated uncertainty of the structural relationships in the area, the cross section is schematic and highly simplified.

5.3 Hydrogeology

The hydrogeology of Well ER-6-2 appears rather straightforward, with rocks of the LCA encountered to the depth of 878.7 m (2,883 ft) and rocks of the upper clastic confining unit encountered below the LCA to TD (Figure 5-3). However, the complex structural relationships of these units probably result in rather complex hydrogeologic relationships as well (Figure 5-4).

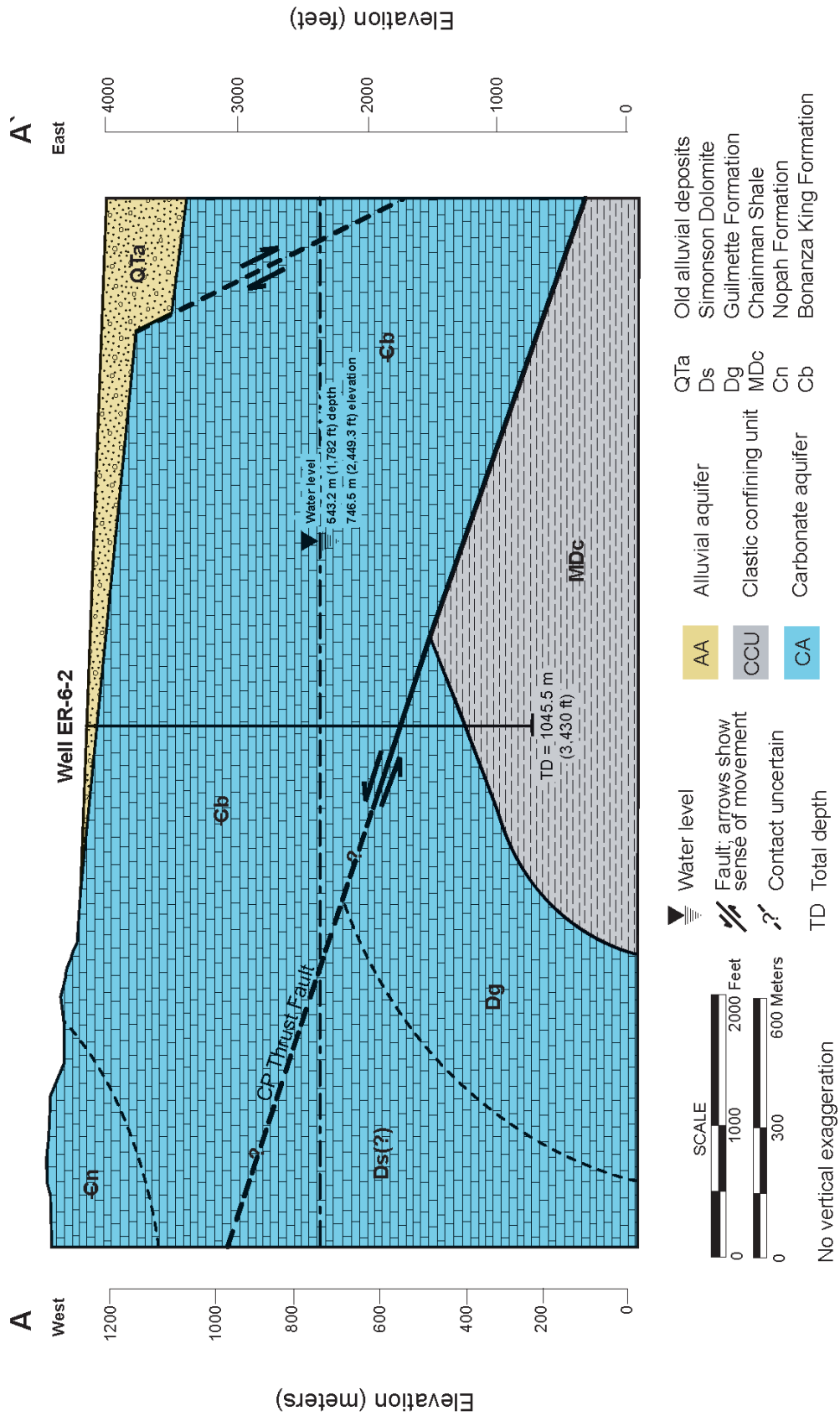


Figure 5-4
West-East Hydrogeologic Cross Section A-A' through Well ER-6-2

Comparisons of fracture data with temperature, chemistry, and flow logs (see Section 6.2) indicate three fractured intervals where groundwater is moving between the borehole and the formation (IT, 1995a). The three intervals, all in carbonate rocks, are listed below:

- 625.5 to 634.6 m (2,052 to 2,082 ft)
- 706.2 to 729.7 m (2,317 to 2,394 ft)
- 826.6 to 834.2 m (2,712 to 2,737 ft)

The two lower intervals contain zones of breccia that are probably related to movements along faults. This indicates that, at least in the vicinity of the Well ER-6-2 borehole, faults were acting as conduits for groundwater flow at the time the measurements were made.

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6.0 Hydrology

6.1 Preliminary Water-Level Information

Prior to drilling, the depth to the regional water level at Well ER-6-2 was estimated to be 558 m (1,830 ft) (Hudson and Hokett, 1992) based on the Yucca Flat water table map by Doty and Thordarson (1983). Observations made during drilling of Well ER-6-2 indicated a static, open-hole water level at the depth of approximately 545 m (1,788 ft). Measurements made by the Desert Research Institute (DRI) on December 13, 1994, indicated the fluid level to be at the depth of 545.4 m (1,789.4 ft). The most recent open-hole fluid tag was made by the USGS on September 11, 2007, at the depth of 543.2 m (1,782.3 ft) (USGS, 2007).

On July 29, 1993, IT personnel installed a transducer and monitoring equipment in Well ER-6-2. The water level was monitored in the main hole during drilling of Well ER-6-2#1 from late July to early September 1993. The water levels were observed to fluctuate diurnally with an amplitude of approximately 0.15 m (0.5 ft) (IT, 1994). Well ER-6-2#1 was abandoned before reaching the static water level.

6.2 Preliminary Flow Meter Data

Thermal flow meter (TFM) data, along with temperature, electrical conductivity, and pH measurements, are typically used in UGTA wells to characterize borehole fluid variability, which may indicate inflow and outflow zones. In December 1994, DRI personnel ran temperature, electrical conductivity, and pH logs, and made TFM measurements at nine locations between the depths of 617.2 and 899.1 m (2,025 and 2,950 ft) in Well ER-6-2. These data indicated that inflow was occurring at two locations: between the depths of 724 and 765 m (2,375 and 2,510 ft) and between 832 and 860 m (2,730 and 2,822 ft). Outflow was occurring above 617 m (2,024 ft) and at the fault gouge zone between 826 and 832 m (2,710 and 2,730 ft). Little or no flow was occurring below the depth of 899 m (2,950 ft) (Lyles and Gillespie, 1994). These preliminary flow data were correlated with fracture data by IT (1995a), as described in Section 5.3.

6.3 Precompletion and Open-Hole Development

The first precompletion development conducted in Well ER-6-2 consisted of circulating fluid for about one hour after geophysical logging operations were completed at the temporary TD of 611.3 m (2,006 ft). Initial development of the cored portion of Well ER-6-2 was accomplished in August 1994, using the dipstick method. Two stages of air-lifting were attempted at two

depth intervals, 785.2 and 879.3 m (2,576 and 2,885 ft), with approximately 13,000 liters (3,450 gallons) of fluid pumped.

No precompletion or open-hole development was conducted at Well ER-6-2#1.

6.4 *Final Development and Aquifer Testing*

During the period July 15–25, 2004, SNJV and BN conducted well development by pumping and surging the well, conducting a step-rate test, and monitoring the water quality. From July 26 through August 4, 2004, SNJV conducted a constant-rate test and collected groundwater characterization samples. After post-test water-level monitoring was completed, the pump and tubing were removed from the well and replaced with a low-volume pump on stainless-steel tubing. Information about the hydraulic testing and sampling of Well ER-6-2 is given in SNJV (2004; 2005).

7.0 Well Completion

7.1 Introduction

Well completion refers to the installation in a borehole of a string of tubing or casing that is slotted or screened at one or more locations along its length. The completion process also typically includes emplacement of backfill materials around the casing, with coarse (porous) fill such as gravel adjacent to the open intervals and impervious materials such as cement placed between or above the open intervals to isolate them. The string may serve as a conduit for insertion of a pump in the well, for inserting devices for measuring fluid level, or for sampling so that accurate potentiometric and water chemistry data can be collected from known portions of the borehole. An alternative method is open-hole completion in which no backfill materials or completion strings are installed.

The proposed well completion design for Well ER-6-2, as presented in *Coring, Testing, Sampling, and Completion Plan for the Underground Test Area Operable Unit Investigation Well ER-6-2* (IT, 1994), is described in Section 7.2. Because Well ER-6-2#1 was abandoned and cemented to the surface, it was not completed; thus, this section addresses only Well ER-6-2. Section 7.3 summarizes additional work conducted after construction of the well. Figure 7-1 is a schematic diagram of the final well-completion for Well ER-6-2, and Figure 7-2 shows a plan view and profile of the wellhead surface completion.

7.2 Proposed Well Completion Design

The original completion design (presented by IT [1994]) was based on the assumption that Well ER-6-2 would penetrate rocks of only the LCA. The well was planned to be completed with two piezometer strings, each of which would be slotted near the bottom. A Moyno[®] pump stator was to be installed in each piezometer string. However, the geologic and hydrogeologic conditions were more complex than anticipated, and an open-hole completion was used; that is, no completion string or backfill materials were installed in the borehole immediately after drilling.

7.3 Actual Completion Design

Completion activities were conducted at Well ER-6-2 in a few stages over a period of approximately ten years after drilling, as summarized in the following sections.

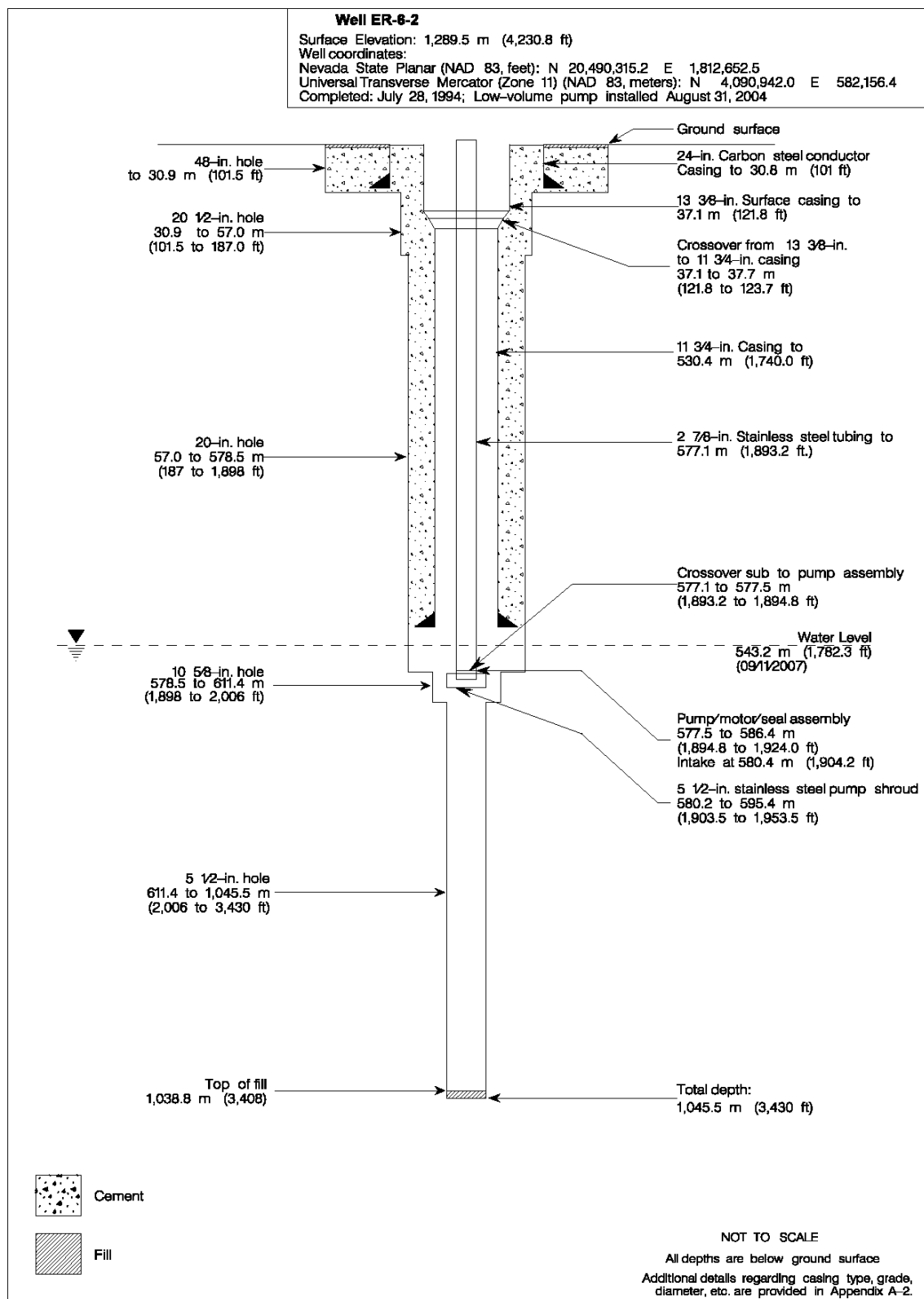


Figure 7-1
As-Built Completion Schematic for Well ER-6-2

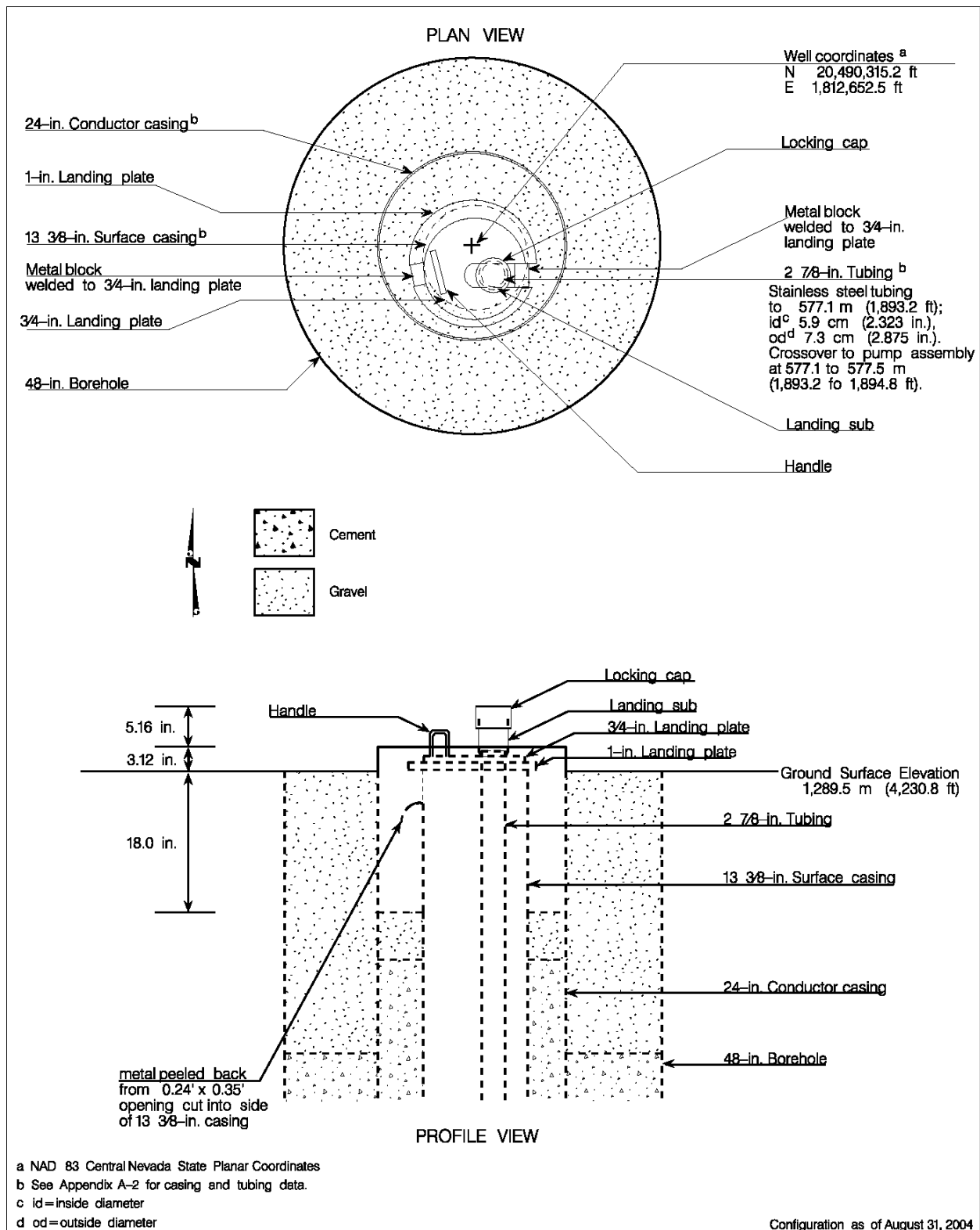


Figure 7-2
Wellhead Diagram for Well ER-6-2

7.3.1 Attempt to Install Bridge Plugs

During the summer of 1995, several attempts were made to install temporary bridge plugs in Well ER-6-2 to restrict cross-flow in the borehole (IT, 1995b). However, an obstruction in the borehole at the depth of 610.2 m (2,002 ft) prevented installation of these bridge plugs. No additional work was performed at the well until 2004.

7.3.2 Development and Testing in 2004

Well ER-6-2 was developed, hydraulically tested, and sampled in 2004. Installations of tubing and pumps for these activities are summarized in this section. See SNJV (2004; 2005) for more information.

On July 14, 2004, an electrical submersible pump was run on 2⁷/₈-in. tubing and landed with the bottom of the pump assembly at the depth of 594.9 m (1,951.8 ft). The pump intake was located at 580.6 m (1,905.0 ft). A string of 2³/₈-in. tubing was also inserted to serve as an access line for use in making water level measurements. This tubing was landed at the depth of 614.8 m (2,017.2 ft).

During the period July 15–25, 2004, SNJV and BN conducted well development by pumping and surging the well, conducting a step-rate test, and monitoring the water quality. From July 26 through August 4, 2004, SNJV conducted a constant-rate test and collected groundwater characterization samples. After post-test water-level monitoring was completed, the pump and tubing were removed from the well.

On August 30, 2004, BN and SNJV personnel installed a low-volume sampling pump (for obtaining periodic water characterization samples) and conducted a function test. This pump remains in the well as of this writing (Figure 7-1). Information about the hydraulic testing and sampling of Well ER-6-2 is provided in SNJV (2004; 2005).

8.0 *Planned and Actual Costs*

The costs for the original construction of Wells ER-6-2 and ER-6-2#1 are presented in the following paragraphs. The costs associated with support of the hydraulic testing conducted in 2004 are not included.

8.1 *Well ER-6-2*

The cost of drilling Well ER-6-2 can be broken down into charges by the NTS drilling and support contractor, REEC Co, who drilled the main hole, and charges by the coring subcontractor in 1994. The cost of the geophysical logging subcontractor are included with the REEC Co costs.

Work order estimates were prepared for the drilling and original completion of the main hole; the cost of coring activities were estimated from the subcontract. Drilling and completion costs for Well ER-6-2 were tracked by RSN on a weekly and monthly basis. The total planned cost of constructing Well ER-6-2 was \$2,016,200. The actual cost of the well was \$2,032,881, or 0.8 percent more than the planned cost. Table 8-1 presents the planned and actual costs for the drilling, coring, and initial completion of Well ER-6-2.

8.2 *Well ER-6-2#1*

Planned costs for drilling and geophysical logging of Well ER-6-2#1 were determined from RSN work order estimates and tracked by RSN on a weekly and monthly basis. The total planned cost of drilling Well ER-6-2#1 was \$405,566. The actual cost of the hole was \$360,297, or 11.2 percent less than the planned cost. Table 8-2 presents the planned and actual costs for the drilling Well ER-6-2#1.

Table 8-1
Well ER-6-2 Actual Versus Planned Costs

Activity	Planned Cost	Actual Cost	Percent Difference Actual versus Planned
Main hole drilling and geophysical logging	970,200 ^a	1,120,318 ^b	15.5
Core hole drilling			
Coring subcontractor	494,800 ^c	593,967	20.0
NTS support	216,000	152,296	-29.5
<i>Subtotal</i>	<i>710,800</i>	<i>746,263</i> ^d	<i>5.0</i>
Well completion (through initial completion and efforts to install bridge plug in 1995)	335,200 ^e	166,300 ^f	-50.4
Total	2,016,200	2,032,881	0.8

a Source: RSN work order estimate, March 1993.

b Source: RSN monthly cost summary for May 1993.

c Source: Subcontract No. 950-CUC-01(4), Schedule A.

d Source: RSN monthly cost summary for April 1995.

e Source: RSN work order estimate, July 1994

f Source: RSN monthly cost summaries for September and December 1995.

Table 8-2
Well ER-6-2#1 Actual Versus Planned Costs

Activity	Planned Cost ^a	Actual Cost ^b	Percent Difference Actual versus Planned
Drilling and geophysical logging	405,566	360,297	-11.2
Well completion	not applicable	not applicable	not applicable
Total	405,566	360,297	-11.2

a Source: RSN work order estimate, July 1993

b Source: RSN monthly summary for August 1993.

9.0 Summary and Lessons Learned

This section provides summaries, recommendations, and lessons learned from both Wells ER-6-2 and ER-6-2#1.

9.1 Summary

9.1.1 Well ER-6-2

The first phase of drilling commenced at Well ER-6-2 on November 20, 1992, and concluded on January 16, 1993. A 50.8-cm (20-in.) diameter borehole was advanced to a depth of 578.5 m (1,898 ft), and a string of 11¾-in. casing was installed at a depth of 650.3 m (1,740 ft). Then a 27.0-cm (10.6-in.) diameter borehole was drilled to the depth of 611.4 m (2,006 ft).

The second phase of work at Well ER-6-2 began on June 8, 1994, and concluded on July 26, 1994. A 14.0-cm (5.5-in.) diameter core hole was advanced to the final TD of 1,045.5 m (3,430 ft).

During the rotary drilling of the main hole, crews worked on a five-days-per-week, 24-hours-per-day schedule, except during drilling of the surface hole, when the crew was on an 8-hour-shift schedule. Crews worked on a seven-days-per-week, 24-hours-per-day schedule on the cored portion of the hole.

Well ER-6-2 was developed, hydraulically tested, and sampled in 2004. At this writing, a low-volume sampling pump remains installed in the well. The fluid level was last measured at the depth of 543.2 m (1,782.3 ft) on September 11, 2007.

9.1.2 Well ER-6-2#1

Drilling commenced at Well ER-6-2#1 on August 2, 1993, and concluded on September 8, 1993. A 13¾-in. conductor casing was set at the depth of 32.3 m (106 ft). A 25.1-cm (9.9-in.) diameter borehole was drilled to the depth of 399.0 m (1,309 ft). Due to unstable hole conditions, the drilling equipment became irretrievably stuck in the hole. The borehole was cemented to the surface and abandoned.

9.2 *Lessons Learned*

Sloughing hole conditions encountered in Well ER-6-2#1 resulted in two lessons learned:

- Setting of a surface casing to the depth of at least 120 m (400 ft), based on the caliper log from Well ER-6-2, may have prevented excessive sloughing of up-hole material in Well ER-6-2#1.
- Down-hole Dyna-Drill motors may not be the best equipment to use in boreholes where sloughing is a problem.

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Appendix A

Drilling Data

- A-1 Records of Verbal Communication for Wells ER-6-2 and ER-6-2#1**
- A-2 Tubing and Casing Data for Wells ER-6-2 and ER-6-2#1**
- A-3 Drilling Fluids and Cement Composition for
 Wells ER-6-2 and ER-6-2#1**

Appendix A-1

Records of Verbal Communication for Wells ER-6-2 and ER-6-2#1

Table A-1-1
Records of Verbal Communication (RVC) Applicable to Well ER-6-2 Drilling

RVC#	Date	Subject
RVC-0249	11/30/1992	Revision to drilling program for GCP Well ER-6-2: Surface hole
RVC-0251	12/03/1992	Revision to drilling program for GCP Well ER-6-2: Tri-cone bit size
RVC-0253	12/07/1992	Revision to drilling program for GCP Well ER-6-2: Tritium sampling
T-92-171	12/08/1992	Logging program for ER-6-2
RVC-0254	12/10/1992	Revision to drilling program for GCP Well ER-6-2: Drilling fluid
RVC-0255	12/14/1992	Revision to drilling program for GCP Well ER-6-2: Cement-back #2
RVC-0256	12/15/1992	Revision to drilling program for GCP Well ER-6-2: Cement additive
RVC-0257	12/16/1992	Revision to RVC-0256 for GCP Well ER-6-2: Cement change
RVC-0260	01/11/1993	Revision to drilling program for GCP Well ER-6-2: Disposal record
RVC-0261	01/13/1993	Revision to drilling program for GCP Well ER-6-2: Drilling/casing change
RVC-0262	01/14/1993	Revision to drilling program for GCP Well ER-6-2: Casing changes
RVC-0263	[12/14/1993]*	Revision to drilling program for GCP Well ER-6-2: Cement backs
T-93-003	01/19/1993	Logging program for ER-6-2
RVC-0264	01/22/1993	Revision to drilling program for GCP Well ER-6-2: Cementing
RVC-0266	01/25/1993	Revision to drilling program for GCP Well ER-6-2: Rig change
T-93-004	01/26/1993	Logging on ER-6-2
L-93-035	07/13/1993	BHTV and directional surveys
L-93-036	07/20/1993	Logging at ER-6-1, ER-6-1 Satellite#1, ER-6-2, and ER-19-1
L-93-048	11/29/1993	Bolt lost in ER-6-2
L-94-058	02/15/1994	Analysis of borehole televiewer logs
RVC-0392	07/18/1994	Completion of coring at UGTA OU Well ER-6-2
RVC-0395	07/25/1994	UGTA OU well development planning schedule
RVC-0396	07/26/1994	UGTA OU workover rig anchor holes
RVC-0398	07/28/1994	UGTA OU Well ER-6-2 development
RVC-0399	08/01/1994	UGTA OU Well ER-6-2 access line
L-95-005	05/25/1995	ER-6-1 and ER-6-2 flow logging and bridge plug setting

* Signed 01/20/1993.

GCP: Groundwater Characterization Project

UGTA OU: Underground Test Area Operative Unit

Table A-1-2
Records of Verbal Communication (RVC) Applicable to Well ER-6-2#1 Drilling

RVC#	Date	Subject
RVC-0327	07/12/1993	Temporary suspension of operations at GCP Well ER-6-2#1
RVC-0325	08/05/1993	Revise Program D-007-003, GCP Well ER-6-2#1: Equipment & methods
L-93-038	08/11/1993	Stuck pipe operations in ER-6-2#1
RVC-0328	08/12/1993	Revision to drilling program for GCP Well ER-6-2#1: Fishing

GCP: Groundwater Characterization Project

Appendix A-2

Tubing and Casing Data for Wells ER-6-2 and ER-6-2#1

Table A-2-1
Casing and Tubing Data for Well ER-6-2

Casing and Tubing	Depth Interval meters (feet)	Type	Grade	Outside Diameter centimeters (inches)	Inside Diameter centimeters (inches)	Wall Thickness centimeters (inches)	Weight per foot (pounds)
Conductor Casing	0 to 30.8 (0 to 101)	Carbon Steel	K-55	76.20 (24)	59.06 (23.250)	0.953 (0.375)	94
Surface Casing	0 to 37.8 (0 to 124)	Carbon Steel	K-55	33.97 (13.375)	32.042 (12.615)	0.965 (0.380)	54.5
Intermediate Casing	37.8 to 530.4 (124 to 1,740)	Carbon Steel	K-55	29.85 (11.750)	27.361 (10.772)	1.242 (0.489)	60
Pump Tubing (including crossover to pump assembly)	0 to 577.5 (0 to 1,894.8)	Stainless Steel	SS-304	7.30 (2.875)	6.20 (2.441)	0.55 (0.217)	7.66

Table A-2-2
Casing Data for Well ER-6-2#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 32.3 (0 to 106)	Carbon Steel	J-55	33.97 (13.375)	32.042 (12.615)	0.965 (0.380)	54.5

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Appendix A-3

Drilling Fluids and Cement Composition for Wells ER-6-2 and ER-6-2#1

Table A-3-1
Drilling Fluids Used in Well ER-6-2

Typical Air-Foam Mix ^{a, b}
159 liters (42 gallons) detergent 907 kilograms (2,000 pounds) bentonite 45.4 kilograms (100 pounds) soda ash 22.7 kilograms (50 pounds) guar gum per 14,309 liters (120 barrels) water

- a Air-foam was used to drill from 30.8 to 611.4 meters (m) (101 to 2,006 feet [ft]).
- b Various proportions of EZ-Mud DP[®] polymer (a product of Baroid Drilling Fluids, Inc.) were added to air-foam mix to suit conditions during coring operations, 611.4 to 1,045.5 m (2,006 to 3,430 ft) ("Air-foam/polymer").

NOTES:

1. All water used to mix drilling fluids for Well ER-6-2 came from Water Wells C and C-1.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of approximately 20 to 30 milligrams per liter.

Table A-3-2
Well ER-6-2 Cement Composition

Cement Composition	24-inch Conductor Casing	13 $\frac{3}{8}$ -inch Surface Casing	Hole Plugs ^f
Type II plus 2% CaCl ₂ ^a	Lower 1.8 m ^b (6 ft ^c)	In annulus: 85.0 m ^{3 d} (3,000 ft ^{3 e}) at 21.9 to 532.2 m (72 to 1,746 ft) and Lower 14.6 m (48 ft)	70.6 m ³ (2,500 ft ³) at 29.9 to 120.4 m (98 to 395 ft) and 7.1 m ³ (250 ft ³) at 29.9 to 73.5 m (98 to 241 ft)
Type II plus 3% CaCl ₂	Not used	Not used	1.4 m ³ (50 ft ³) at 29.9 to 73.5 m (98 to 241 ft)
90% W-60 plus 10% Type II	Not used	Not used	7.1 m ³ (250 ft ³) at 76.8 to 111.9 m (252 to 367 ft)
75% neat plus 25% gypsum	In annulus: 1.1 to 29.0 m (3.5 to 95 ft)	Not used	Not used
90% neat plus 10% gypsum	Not used	In annulus: 4.2 m ³ (150 ft ³) at 0.6 to 21.9 m (2 to 72 ft)	Not used

a calcium chloride; b meter (s); c feet; d cubic meters; e cubic feet

f Used to control sloughing. Borehole was re-drilled at these intervals.

Note: Hole below surface casing was stemmed to 532.2 m (1,746 ft) with 15,876 kilograms (35,000 pounds) of Trona gravel and 453.5 kilograms (1,000 pounds) of 20/40 sand, but was later redrilled and cleaned out prior to coring.

Table A-3-3
Drilling Fluids Used in Well ER-6-2#1

#1 Air-Foam ^a	Mud ^b
159 liters (42 gallons) detergent 907 kilograms (2,000 pounds) bentonite 45.4 kilograms (100 pounds) soda ash 22.7 kilograms (50 pounds) guar gum per 14,309 liters (120 barrels) water	1,964 kilograms (4,330 pounds) bentonite per 14,309 liters (120 barrels) water

- a Various proportions of EZ-Mud DP[®] polymer (a product of Baroid Drilling Fluids, Inc.) were added to air-foam mix to suit conditions during air-foam drilling ("Air-foam/polymer").
- b High viscosity mud used to attempt to control borehole sloughing.

NOTES:

1. All water used to mix drilling fluids for Well ER-6-2#1 came from Water Wells C and C-1.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of approximately 17 to 270 milligrams per liter.

Table A-3-4
Well ER-6-2#1 Cement Composition

Cement Composition	Conductor Casing	Plug
Type II plus 2% CaCl ₂ ^a	In annulus: 7.1 m ³ ^b (250 ft ³ ^c) at 0 to 32.3 m ^d (0 to 106 ft ^e) and Lower 4.6 m (15 ft)	Not used
Type II	Not used	21.2 m ³ (750 ft ³) at 0 to 53.6 m (0 to 176 ft)

- a calcium chloride; b cubic meter (s); c cubic feet; d meters; e feet

Appendix B

Fluid Management Status Reports for Wells ER-6-2 and ER-6-2#1

Table B-1
Fluid Management Fluid Reporting Form for Well ER-6-2

Site Identification: ER-6-2

Site Location: Nevada Test Site

Site Coordinates: N 4,090,745.00 m E 582,235.73 m

Well Classification: ER Hydrogeologic Investigation Well

Project Number: UG04-530

Report Date: 3/1/2005

NNSA Project Manager: Bob Bangerter

Stoller-Navarro Project Manager: John McCord

Stoller-Navarro Site Representative: Jeff Wurtz

Stoller-Navarro Waste Coordinator: David Schrock

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			
Phase I: Vadose-Zone Drilling	11/20/1992	1/21/1993	NA*	578.5	20	224	NA*	NA	NA	NA*	NA	Yes
Phase I: Saturated-Zone Drilling	1/26/1993	7/21/1994	NA*	1,045.5	3,800	3	NA*	NA	NA	NA*	NA	Yes
Phase II: Initial Well Development	8/16/1994	8/18/1994	3	1,045.5	NA	NA	13	NA	NA	NA*	NA	Yes
Phase II: Final Development	7/14/2004	7/21/2004	8	1,045.5	NA	NA	2,376	NA	1,292	1,145	NA	Yes
Phase II: Aquifer Testing	7/26/2004	8/4/2004	10	1,045.5	NA	NA	0	NA	668	7,794	NA	Yes
Cumulative Production Totals to Date:			18	1,045.5	3,820	227	2,389	NA	1,960	8,939	NA	Yes

* Data not recorded during operations.

^aOperational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift.

^bSolids volume estimates include rock bulking factor of 1.5

^cGround surface discharge

^dOther 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 m³ - Cubic Meters

Total Facility Capacities (at 10 ft fluid level): Sump #1 = 2,029.6 m³

Sump #2 = 2,029.6 m³

Infiltration Area (assuming very low/no infiltration) = NA m³

Remaining Facility Capacity (Approximate) as of 8/4/2004: Sump #1 = 0 m³ (0%) Sump #2 = 0 m³ (0%)

Current Average Tritium = 482 pCi/L

Stoller-Navarro Authorizing Signature/Date

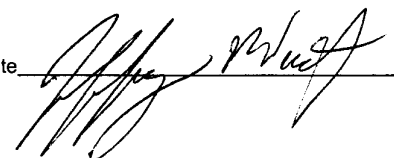
 3-16-05

Table B-2
Fluid Management Reporting Form for Well ER-6-2#1

Site Identification: ER-6-2 Satellite Hole #1
Site Location: Area 6 - NTS
Site Coordinates: N 805,312/E 672,493
Well Classification: Water Level Observation Hole
IT Project No: 301957.116.XX

Report Date: 02/28/94
DOE/NV Project Manager: S. Lawrence
IT Project Manager: J. Eberlin
IT Site Representative: F. Baird
IT Waste Coordinator: L. Cardenas

Well Construction Activity	Activity Duration		#Ops. Days (A)	Well Depth (m)	Import Fluid (m³)	(NORTH) Lined Sump #1 (m³)		(SOUTH) Lined Sump #2 (m³)		Infiltration Area (m³)	Other (C)	Fluid Quality Objectives Met?
	From	To				Solids (B)	Liquids	Solids	Liquids			
Stage I: Vadose-Zone Drilling	08/05/93 08/10/93	08/09/93 08/12/93	4 3 (D)	399 399	707 223 (D)	-0-	-0-	26	707 112 (E)	-0-	-0-	YES
Stage II: Saturated-Zone Drilling	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stage III: Initial Well Development	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stage IV: Aquifer Testing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stage V: Well Completion/Final Development	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cumulative Production Totals to Date:			7	399	930	-0-	-0-	26	819	-0-	-0-	YES

(A) Operational days refer to the number of days that the drill rig or, during aquifer testing, that the pump was in operation during at least part of one shift.
 (B) Solids refer to the drill volume estimates include added volume attributed to interstitial spaces.
 (C) "Other" refers to fluid conveyance to other locations or facilities away from the well site, such as vacuum truck transport to another location.
 (D) Additional operating days and fluid deliveries were required to recover stuck drill pipe after vadose-zone drilling operations were complete.
 (E) Approximately 111 m³ of fluid were lost to the formation during drill pipe recovery operations.
 m = Meters; m³ = cubic meters; NA = Not Appropriate
Total Sump Capacity: Lined Sump #1 = 1800 m³ Lined Sump #2 = 1800 m³
Remaining Sump Capacity (Approximate) as of 08/09/93: Sump #1 = 1800 m³ (100%) Sump #2 = 981 m³ (55%)

IT Authorizing Signature/Date:

John Eberlin

Appendix C
Detailed Lithologic Log for Well ER-6-2

Table C-1
Lithologic Log for Well ER-6-2

Logged by Lance Prothro, Bechtel Nevada, September 19, 1996

Lithologic descriptions for the interval 0 to 611.4 meters (m) (2,006 feet [ft]) are revisions by L. B. Prothro of an unpublished lithologic log produced by R. L. McCall, Raytheon Services Nevada, March 1993. These descriptions are from drill cutting samples at 3.0-m (10-ft) intervals. Descriptions below 611.4 m (2,006 ft) are from IT Corporation (1995) and were compiled by L. B. Prothro. These descriptions are from 8.4-centimeter (3.3-inch) conventional core. The lithologic descriptions follow Bechtel Nevada Department Procedures NTS-GEO-003. Stratigraphic contacts and lithologic divisions are tied to geophysical logs whenever possible. All depths from the cored interval (611.4 to 1,045.5 m [2,006 to 3,430 ft]) are from geophysical logs which are approximately 0.9 m (3 ft) higher than the depths marked on the core. Stratigraphic nomenclature is generally from Ferguson and others, 1994. Stratigraphic assignments for the drilled interval (0 to 611.4 m [2,006 ft]) are based on paleontological analysis of drill cuttings by Micro-Strat Inc., July 1993. Stratigraphic assignments for the cored interval (611.4 to 1,045.5 m [2,006 to 3,430 ft]) are based on lithology and stratigraphic position. Paleontological analysis by J. C. Cole and A. G. Harris of the U.S. Geological Survey confirm these stratigraphic assignments.

Depth Interval ^a meters (feet)	Thickness meters (feet)	Sample Type ^b	Depth of Analytical Samples ^c meters (feet)	Lithologic Description ^d	Stratigraphic Unit
0–30.8 (0–101)	30.8 (101)	DA	None	Sandy Gravel: Samples consist of loose, poorly sorted, sand- to pebble-sized clasts of Tertiary volcanic rocks and Pre-Tertiary sedimentary rocks. Clasts are subangular to subrounded and have moderate-yellowish-brown, calcareous, silty coatings.	Alluvium
30.8–54.9 (101–180)	24.1 (79)	DA	45.7 (150)	Dolostone: Brownish-black; finely crystalline; moderate-red (5R 4/6) staining throughout interval but particularly abundant in upper portion; scarce dolomite filled fractures generally less than 1 mm in width.	Bonanza King Formation
54.9–82.3 (180–270)	27.4 (90)	DA	None	Dolostone: Samples consist of a mixture of mostly finely crystalline dolostone fragments ranging in color from light-brownish-gray to grayish-red (10 R 4/2) to brownish-black. Abundant moderate-red (5R 4/6) and dark yellowish-orange staining on many fragments. Numerous fragments are cut by veinlets of white dolostone generally less than 1–2 mm in width. Some fragments are highly fractured and/or brecciated.	

Table C-1
Lithologic Log for Well ER-6-2 (continued)

Depth Interval ^a meters (feet)	Thickness meters (feet)	Sample Type ^b	Depth of Analytical Samples ^c meters (feet)	Lithologic Description ^d	Stratigraphic Unit
82.3–122.8 (270–403)	40.5 (133)	DA	91.4 (300)	Dolostone: Grayish-black; medium to coarsely crystalline; highly fractured with numerous dolomite-filled fractures cutting most fragments; common fragments of white coarsely crystalline recrystallized dolomite; trace of slickensides and vuggy porosity; minor moderate-red (5R 4/6) and dark yellowish-orange staining.	Bonanza King Formation
122.8–164.6 (403–540)	41.8 (137)	DA	137.2 (450)	Dolostone: Light-medium-gray and medium-gray to brownish-gray; finely crystalline in upper part, becoming mostly medium crystalline near base of interval. Fragments of white, finely granular, moderately indurated, dolomitic fault gouge with moderate-red (5R 4/6) and pale-yellowish-orange staining are common throughout interval. Trace of slickensides.	
164.6–267.0 (540–876)	102.4 (336)	DA	182.9 (600) 259.1 (850)	Dolostone: Medium-dark-gray to dark-gray, becoming medium-gray below approximately 253.0 m (830 ft); coarsely crystalline. Moderate-red (5R 4/6) staining and minor fragments of white, very coarsely crystalline recrystallized dolomite occur below approximately 253.0 m (830 ft).	
267.0–306.6 (876–1,006)	39.6 (130)	DA	289.6 (950)	Shale: Dark-gray, becoming dark-yellowish-orange near base of interval; moderately indurated, becoming poorly indurated and fissile near base of interval; weakly to moderately calcareous; trace of pyrite; weak schistose sheen on partings; common veinlets of white calcite.	
306.6–318.2 (1,006–1,044)	11.6 (38)	DB4	None	Limestone: Light-red to dusky-red; finely crystalline; silty and argillaceous; abundant veinlets of white calcite; pervasive light-red to dusky-red staining. Samples contain abundant fragments of lithologies caved from up-hole.	

Table C-1
Lithologic Log for Well ER-6-2 (continued)

Depth Interval ^a meters (feet)	Thickness meters (feet)	Sample Type ^b	Depth of Analytical Samples ^c meters (feet)	Lithologic Description ^d	Stratigraphic Unit
318.2–353.6 (1,044–1,160)	35.4 (116)	DB4	335.3 (1,100)	Limestone: Various shades of red, gray, and brown; finely to medium crystalline; silty and argillaceous; common coarsely crystalline recrystallized calcite; conspicuous moderate-red (R5 4/6) iron-oxide staining. Samples contain a considerable amount of material from up-hole.	Bonanza King Formation
353.6–375.5 (1,160–1,232)	21.9 (72)	DA	365.8 (1,200)	Shale: Dark-gray; moderately to well indurated, trace of pyrite; weakly fissile; weak schistose sheen on some partings; common veinlets of white calcite.	
375.5–445.0 (1,232–1,460)	69.5 (228)	DA	411.5 (1,350)	Dolostone: Dark-gray, light-brownish-gray, and very light-gray, mottled, with a grayish-pink tint below approximately 432.8 m (1,420 ft); medium to coarsely crystalline; moderate-red (5R 4/6) staining throughout interval but particularly apparent below approximately 432.8 m (1,420 ft). Many of the drill cuttings have a brecciated appearance.	
445.0–466.3 (1,460–1,530)	21.3 (70)	DA	457.2 (1,500)	Dolostone: Very-light-brownish-gray to white; medium to coarsely crystalline; pervasive moderate-red (5R 4/6) staining in upper part.	
466.3–582.2 (1,530–1,910)	115.8 (380)	DA	502.9 (1,650) 579.1 (1,900)	Dolostone: Various shades of gray; mostly medium crystalline; intensely brecciated at top of interval; common veinlets mostly white calcite. A yellowish-gray (5Y 7/2), finely crystalline, silty, laminated limestone occurs from approximately 524.3 to 530.4 m (1,720 to 1,740 ft). Dusky-yellow-green to dusky-yellowish-green granite (?) drill cuttings make up about 10% of the samples below 576.1 m (1890 ft). The granite (?) is subrounded (probably from drilling process) and fine- to very coarse grained with colorless quartz, moderate-orange-pink to very-pale-orange feldspar, and green mica (chlorite?).	
582.2–611.4 (1,910–2,006) Temporary TD (drill hole)	29.2 (96)	DA	594.4 (1,950)	Dolostone: Light-brownish-gray; medium crystalline; minor moderate-red (5R 4/6) and dark-yellowish-orange staining. Samples below 603.5 m (1,980 ft) contain scarce fragments of granite (?) very similar to overlying interval.	

Table C-1
Lithologic Log for Well ER-6-2 (continued)

Depth Interval ^a meters (feet)	Thickness meters (feet)	Sample Type ^b	Depth of Analytical Samples ^c meters (feet)	Lithologic Description ^d	Stratigraphic Unit
611.4–729.7 (2,006–2,394)	118.3 (388)	C	None	<p>Dolostone: Mostly medium-gray to medium-dark-gray, lesser medium-light-gray and dark-gray; cryptocrystalline to finely crystalline, lesser medium crystalline; scarce, finely disseminated pyrite; dark-gray intervals have strong fetid odor when struck with hammer; common stylolites of white dolomite and dark-gray to black clay. Interval is intensely brecciated below 720.9 m (2,365 ft) consisting of medium-gray to dark-gray angular dolostone fragments up to 15 cm (6 in.) size in a white, very crystalline calcite matrix having red, orange, and yellow iron-oxide staining and conspicuous vuggy openings lined with euhedral calcite crystals up to 2 cm (0.8 in.) in size. This brecciation is probably the result of movement along a fault (possibly the CP thrust fault) which forms the lower contact of the interval.</p> <p>Note: Units below 729.7 m (2,394 ft) are overturned and therefore, stratigraphically up-side-down.</p>	Bonanza King Formation
729.7–736.6 (2,394–2,417)	7.0 (23)	C	732.7–733.7 (2,404–2,407)	<p>Limestone: Medium-gray and light-brownish-gray, becoming light-olive-gray and dark-yellowish-orange with conspicuous grayish-red (5R 4/2) banding below 734.0 m (2,408 ft); medium to finely crystalline; becomes sandy below 731.8 m (2,401 ft) with approximately 25% very fine, subrounded sand and silt; common stylolites of dark-gray and dark-yellowish-orange clay above 731.8 m (2,401 ft). Dark-gray to medium-light-gray, coarsely to medium crystalline dolostone occurs at base of interval from 734.6 to 736.7 m (2,410 to 2,417 ft). The dolostone is intensely brecciated from 734.6 to 736.1 m (2,410 to 2,415 ft) consisting of dark-gray angular dolostone fragments up to 15 cm (6 in.) in size in a white, very coarsely crystalline calcite matrix having less than 5% vuggy porosity. This dolostone unit appears similar to the dolostone from 611.4 to 729.7 m (2,006 to 2,394 ft) (Bonanza King Formation) and may have been emplaced within the Guilmette Formation by faulting.</p>	Guilmette Formation

Table C-1
Lithologic Log for Well ER-6-2 (continued)

Depth Interval ^a meters (feet)	Thickness meters (feet)	Sample Type ^b	Depth of Analytical Samples ^c meters (feet)	Lithologic Description ^d	Stratigraphic Unit
736.6–762.6 (2,417–2,502)	25.9 (85)	C	762.0–763.8 (2,500–2,506)	Limestone: Mostly medium-dark-gray to dark-gray, lesser medium-light-gray to medium-gray; finely crystalline; becomes sandy in part below 753.8 m (2,473 ft) with up to 50% fine-grained, well sorted, subrounded quartz sand; weak fetid odor when struck with hammer. Brecciated in part above 746.8 m (2,450 ft) consisting of angular limestone fragments up to 5 cm (2 in.) in size in a white, very coarsely crystalline calcite matrix.	Guilmette Formation
762.6–770.5 (2,502–2,528)	7.9 (26)	C	None	Interbedded Quartzite, Sandstone and Limestone: Quartzite and sandstone are very light-brownish-gray to dark-gray; well indurated; >75% fine- to medium-grained, well to very well sorted, subrounded to rounded, quartz sand; <25% silica and calcite cement; common dark-gray to grayish-black laminae; individual beds up to 1.8 m (6 ft) thick. Limestone is very light-brownish-gray to dark-gray; crypto-crystalline to finely crystalline; sandy in part, with thin interbeds and lenses containing up to 50% fine-grained, subangular to subrounded, well sorted, quartz sand; abundant fossils resembling stromatoporoid <i>Amphipora</i> at 768.7 m (2,522 ft); laminated in part; fetid odor when struck with hammer. A thin (<30 cm [1 ft]) dark-yellowish-orange, laminated, calcareous siltstone occurs at 766.0 m (2,513 ft).	
770.5–791.2 (2,528–2,596)	20.7 (68)	C	None	Interbedded Dolostone and Limestone: Dolostone is medium-light-gray to medium-gray and coarsely crystalline, becoming mostly dark-gray and finely to medium crystalline towards base of interval. Limestone is light gray to dark-gray; mostly crypto-crystalline; common laminae and stylolites of dark-gray and grayish-black clay; common fossils resembling stromatoporoid <i>Amphipora</i> at 780.9 m (2,562 ft).	

Table C-1
Lithologic Log for Well ER-6-2 (continued)

Depth Interval ^a meters (feet)	Thickness meters (feet)	Sample Type ^b	Depth of Analytical Samples ^c meters (feet)	Lithologic Description ^d	Stratigraphic Unit
791.2–847.0 (2,596–2,779)	55.8 (183)	C	793.1–794.0 (2,602–2,605) 823.3–823.9 (2,701–2,703)	Limestone: Light-gray to dark-gray, lesser very-light-brownish-gray; crypto-crystalline to finely crystalline; common wavy laminae and stylolites of dark-gray to grayish-black clay, particularly conspicuous at base of interval, and much less grayish-orange clay; in places having a weak fetid odor when struck with hammer. Interval from 828.4 to 829.7 m (2,718 to 2,722 ft) appears to be a fault zone and consists of breccia and very coarsely crystalline calcite with large vuggy openings containing dark-yellow-orange euhedral calcite crystals up to 2.5 cm (1 in.) in size.	Guilmette Formation
847.0–855.8 (2,779–2,808)	8.8 (29)	C	None	Quartzite: Light-gray to medium-light-gray; well indurated; >75% fine- to medium-grained, well sorted, rounded, quartz sand; <25% silica cement; laminated in part; conspicuous grayish-black dendrites emanating from laminae and hairline fractures; pale-reddish-brown and grayish-orange staining around some hairline fractures.	
855.8–878.7 (2,808–2,883)	22.9 (75)	C	None	Limestone: Medium-gray to dark-gray; medium crystalline at top of interval, becoming crypto-crystalline below; sandy in part below 875.4 m (2,872 ft) consisting of lenses and thin beds of up to 50% fine- to medium-grained, well sorted, subrounded to rounded quartz sand with scarce, finely disseminated pyrite; wavy laminae and stylolites of grayish-black clay and pyrite common in lower part of interval; common fossils resembling stromatoporoid <i>Amphipora</i> from 860.1–861.7 m (2,822–2,827 ft).	

Table C-1
Lithologic Log for Well ER-6-2 (continued)

Depth Interval ^a meters (feet)	Thickness meters (feet)	Sample Type ^b	Depth of Analytical Samples ^c meters (feet)	Lithologic Description ^d	Stratigraphic Unit
878.7–1,045.5 (2,883–3,430) Final TD (core hole)	166.8 (547)	C	879.0–879.7 (2,884–2,886) 1,004.3–1,005.5 (3,2295–3,299) 1,010.4–1,011.0 (3,315–3,317) 1,023.5–1,024.2 (3,358–3,360)	Shale: Grayish-black to black; laminated; breaks parallel to laminae; silty; pyritic with pyrite occurring as lenses, laminae, and as finely disseminated crystals; non-calcareous to very weakly calcareous. Minor beds of medium-gray and dark-gray calcareous, fossiliferous siltstone up to 1.8 m (6 ft) thick occur throughout interval. A 1.5-m (5-ft) thick sandstone occurs at top of interval. Sandstone is dark-gray; well indurated; consisting predominately of medium- to coarse-grained, well sorted, rounded quartz sand with minor chert; silica cemented.	Chainman Shale

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

b **DA** = drill cuttings that represent lithologic character of interval; **DB4** = drill cuttings that are intimate mixtures of units (generally less than 50 percent of drill cuttings represent lithologic character of interval); **C** = conventional core.

c Depth of lithologic samples sent for laboratory analysis. All samples above the depth of 611.4 m (2,006 ft) analyzed by Micro-Strat, Inc., 1993. All samples below the depth of 611.4 m (2,006 ft) analyzed by Cole and Harris, 1996 (uncorrected core depths listed to nearest foot).

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

References:

Cole, J. C., and A. G. Harris, 1996. "Stratigraphic and Structural Interpretations of Paleontologic Studies and Core Logging ER-6-1 and ER-6-2 Wells, Nevada Test Site." U.S. Geological Survey Assessment Task WBS 1.4.1.2.1.02.01.06. Las Vegas, NV.

Ferguson, J. F., A. H. Cogbill, and R. G. Warren, 1994. "A Geophysical-Geological Transect of the Silent Canyon Caldera Complex, Pahute Mesa, Nevada." *Journal of Geophysical Research*, v. 99, n. B3, pp 4,323–4,339.

Micro-Strat, Inc., 1993. *High Resolution Palynomorph Biostratigraphy of Thirteen Well Samples, Nevada*. Micro-Strat, Inc., Report MSI 93-22. Houston, TX.

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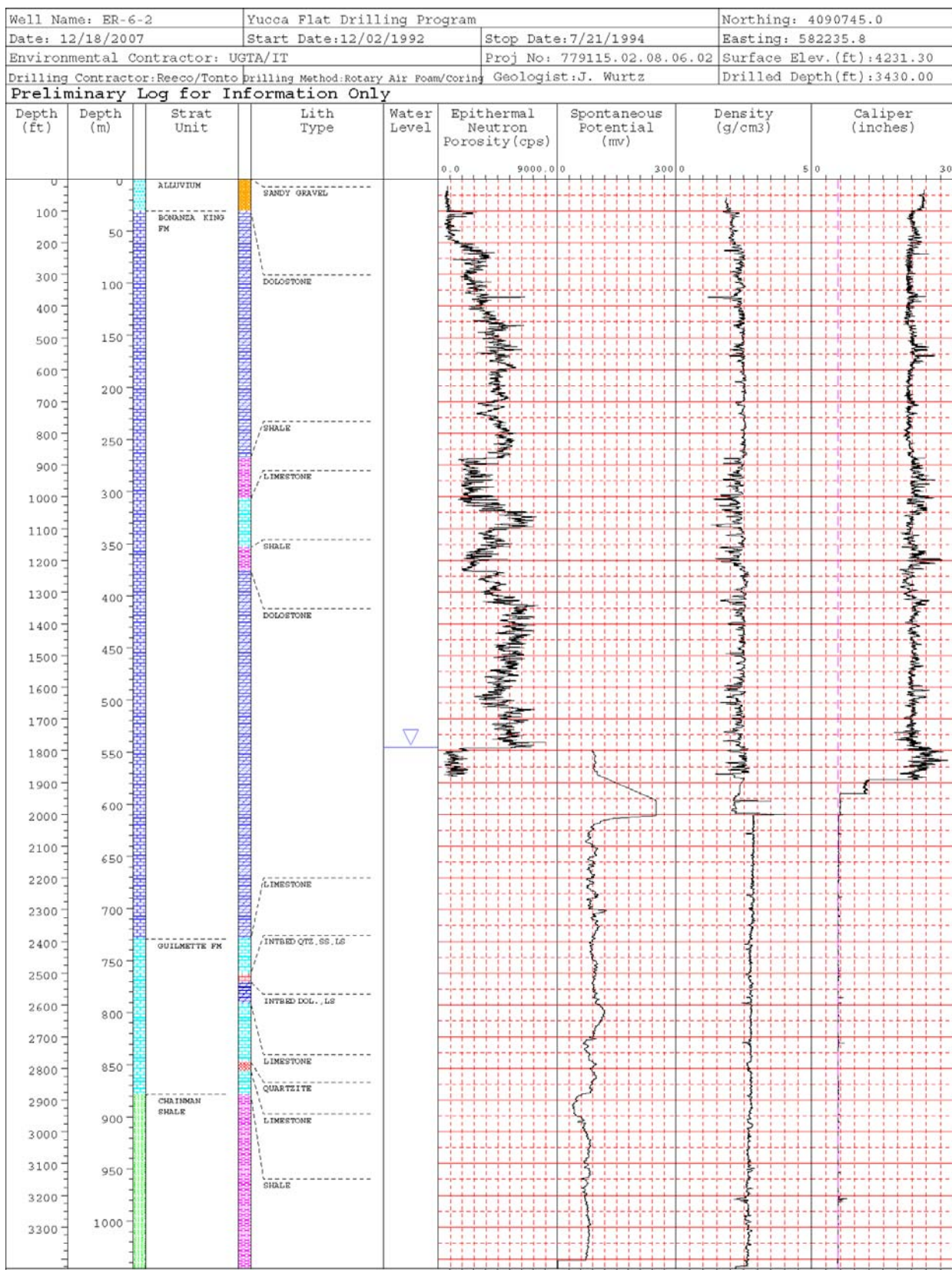
Appendix D
Geophysical Logs Run in Well ER-6-2

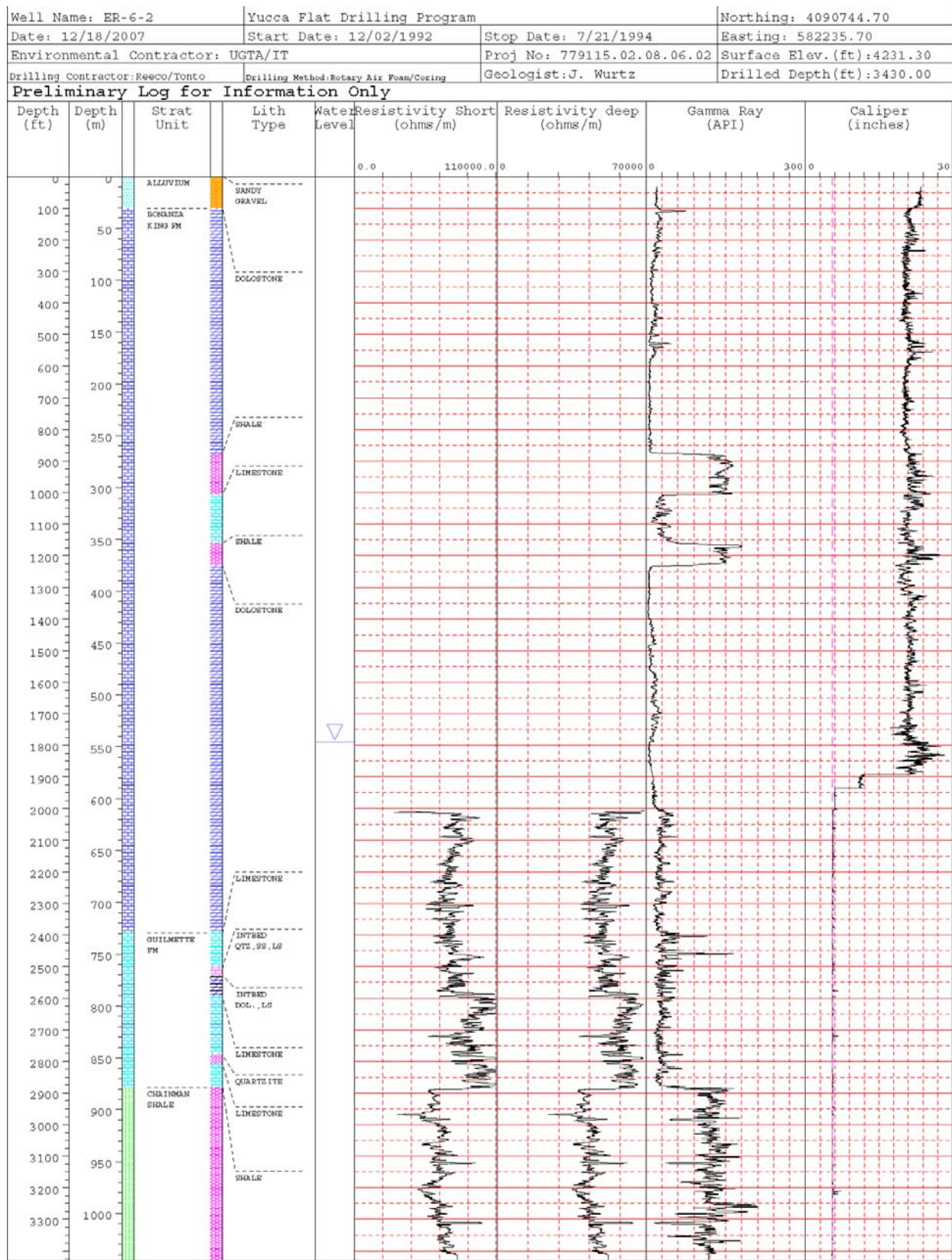
Appendix D contains presentations of selected geophysical logs run in Well ER-6-2. Table D-1 summarizes the logs presented on pages D-2 through D-5. Some of the log plots were created by merging more than one log run, and some data gaps and overlaps may be “smoothed” for presentation. See Table 4-2 for information about other logs run.

Table D-1
Well ER-6-2 Geophysical Logs Presented in Appendix D

Log Type		Run Number	Date	Log Interval	
				meters	feet
Caliper		CA6-3	01/19/1993	13.7–570.3	45–1,871
		CA6-4	01/28/1993	513.6–607.2	1,685–1,992
		CA6-5	07/22/1994	583.7–1,040.0	1,915–3,415
Epithermal Neutron (porosity)		ENP-1	01/20/1993	11.9–527.1	39–1,877
Compensated Density		CDL-1	01/20/1993	21.3–573.0	70–1,880
		CDL-2	07/22/1994	591.9–1,043.3	1,942–3,423
Resistivity	Dual Induction	DIFL-1	12/19/1992	14.3–115.2	47–378
		DIFL-2	01/19/1993	19.5–571.2	64–1,874
	* Dual Laterolog	DLL-1	07/22/1994	606.6–1,043.6	1,990–3,424
Gamma Ray		GR-4	01/19/1993	13.7–570.3	45–1,871
		GR-8	01/28/1993	513.6–607.2	1,685–1,992
		GR-10	07/22/1994	594.4–1,040.0	1,950–3,415
Chemistry/Temperature		HPFLOW-1	12/14/1994	547.1–1,039.7	1,795–3,411

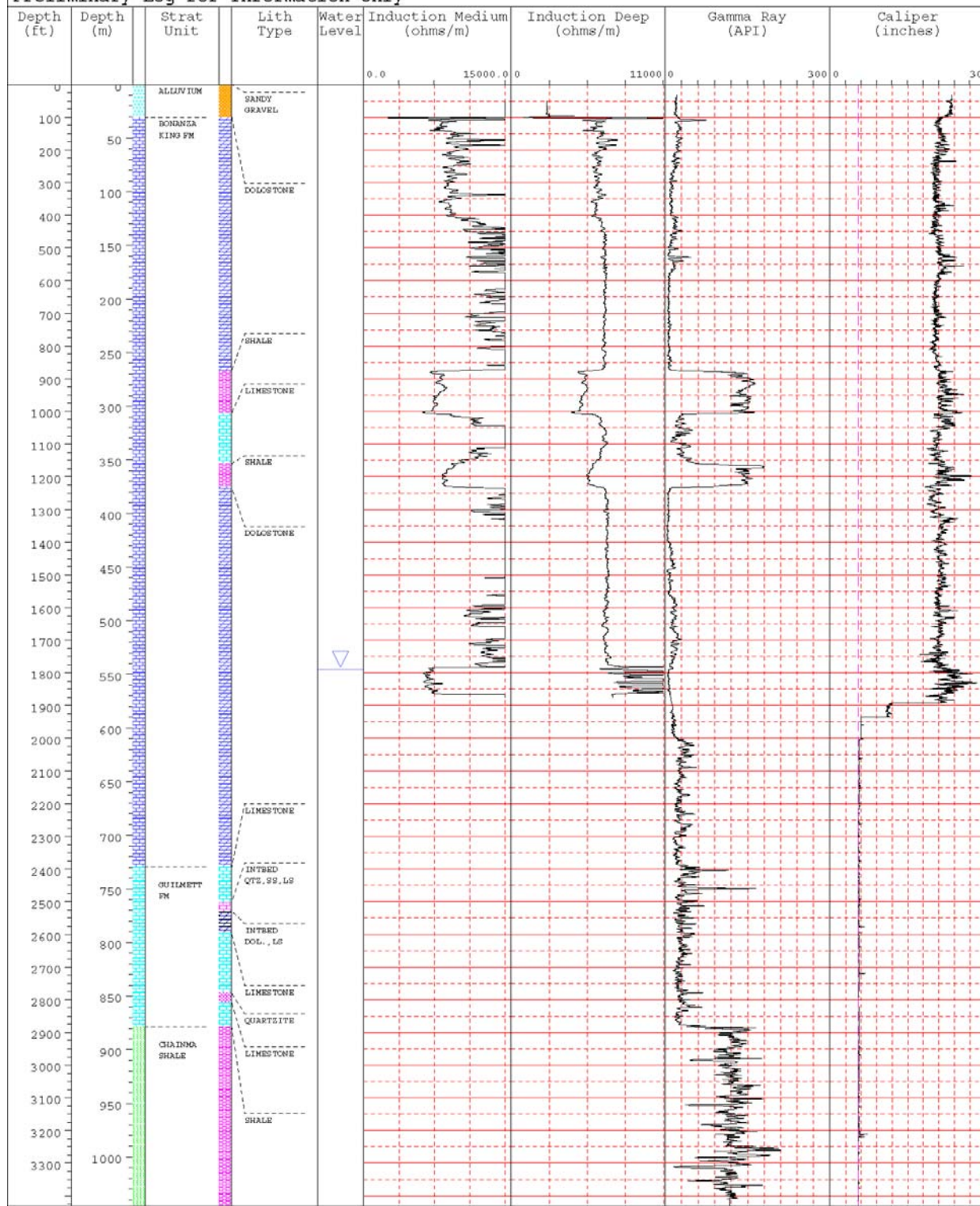
* Spontaneous Potential log rerun and merged with Dual Laterolog; presented on page D-2 as Spontaneous Potential.

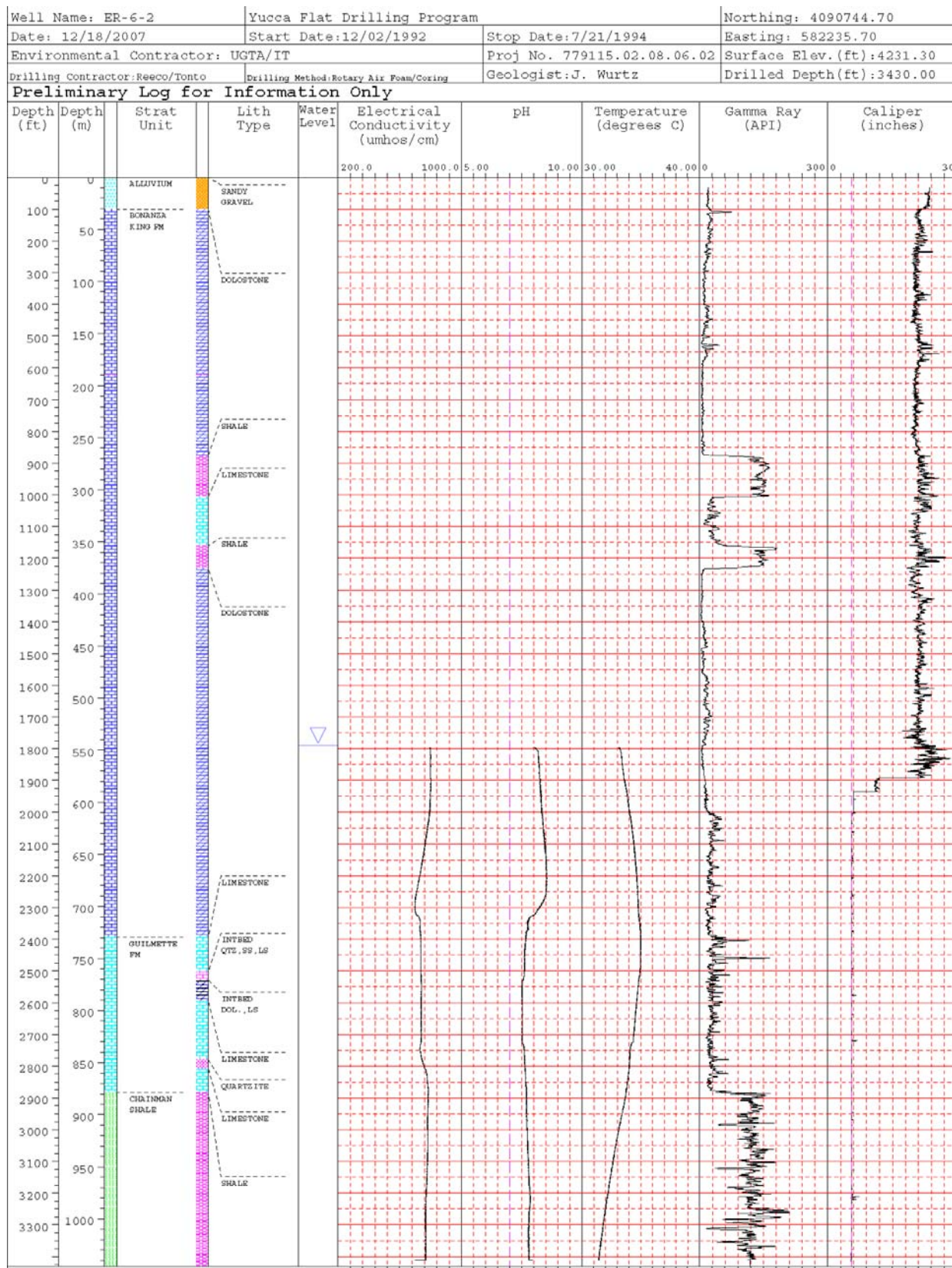




Well Name: ER-6-2	Yucca Flat Drilling Program	Northing: 4090744.70
Date: 12/18/2007	Start Date: 12/02/1992	Stop Date: 7/21/1994
Environmental Contractor: UGTA/IT	Proj No: 779115.02.08.06.02	Easting: 582235.70
Drilling Contractor: Reeco/Tonto	Drilling Method: Rotary Air Foam/Coring	Surface Elev. (ft): 4231.30
	Geologist: J. Wurtz	Drilled Depth (ft): 3430.00

Preliminary Log for Information Only





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