DOE/NV--408
UC-700

Nevada
Environmental
Restoration
Project

Completion Report for Well ER-3-2

December 1995

Environmental Restoration
Division

U.S. Department of Energy
Nevada Operations Office

DOE/NV--408
UC-700

COMPLETION REPORT FOR WELL ER-3-2

Prepared for

DOE Nevada Operations Office
Las Vegas, Nevada

Prepared by

IT CORPORATION
4330 South Valley View Boulevard. Suite 114
Las Vegas. Nevada 89103

December 1995

COMPLETION REPORT
FOR WELL ER-3-2

Approved: Robert M. Bangerter Jr. Date: 12-19-95

Robert M. Bangerter, Jr.
General Engineer
Environmental Restoration Division

Approved: Steven J. Lawrence Date: 12-19-95

Steven J. Lawrence
Subproject Manager
Environmental Restoration Division

Approved: Stephen A. Mellington Date: 12-19-95

Stephen A. Mellington
Project Manager
Environmental Restoration Division

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

AWS	Atlas Wireline Services
bbl	barrel
cm	centimeter
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
ft	foot
id	inside diameter
in.	inch
IT	IT Corporation
LiBr	lithium bromide
m	meter
m^3	cubic meter
NV ERP	Nevada Environmental Restoration Project
od	outside diameter
REECo	Reynolds Electrical & Engineering Co., Inc.
RSN	Raytheon Services Nevada
TD	total depth
TDR	time domain reflectometry
UGTA	Underground Test Area
USGS	U.S. Geological Survey
WW-A	Water Well A

1.0 Introduction

1.1 Project Description

Well ER-3-2 was drilled for the U.S. Department of Energy, Nevada Operations Office (DOE/NV), in support of the Nevada Environmental Restoration Project (NV ERP) at the Nevada Test Site. IT Corporation (IT) was the principal environmental contractor for the project. The roles and responsibilities of IT and other contractors involved in the project are described in the Raytheon Services Nevada (RSN) Drilling Program (1994a) and the *Underground Test Area Operable Unit Project Management Plan* (DOE, 1994). The well will become part of the Underground Test Area (UGTA) monitoring well network.

The site is located in the west central portion of Area 3 in Yucca Flat (Figure 1-1), in an area where underground nuclear tests have been conducted above and below the water table. This location was selected to obtain data on the thickness of the alluvial section and information on a postulated hydraulic sink in the area (Winograd and Thordarson, 1975). Well ER-3-2 is located approximately 1.4 kilometers from the closest drill hole (UE-3c) that penetrated the full thickness of the alluvial section and is approximately 34 meters (m) (110 feet [ft]) north of Water Well A (WW-A) (Figure 1-2).

The Central Nevada State Planar Coordinates for the well are N833,111.6 ft and E684,014.8 ft. The ground surface elevation at the wellhead is 1,221.6 m (4,007.9 ft) above mean sea level. Additional site summary and survey information is given in Table 1-1.

This report presents construction information and limited scientific data gathered during the drilling and well-installation phase of the investigation. Most of the information in this report is preliminary and unprocessed, compiled to summarize the drilling history, geophysical data, and well-installation design. However, the lithologic log is provided in final form. Information on well development, water levels, aquifer testing, and groundwater analytical sampling will be presented in a future hydrologic data report(s). Additional information on the results of geologic, geophysical, and hydrologic investigations will be presented in one or more analysis and interpretation reports.

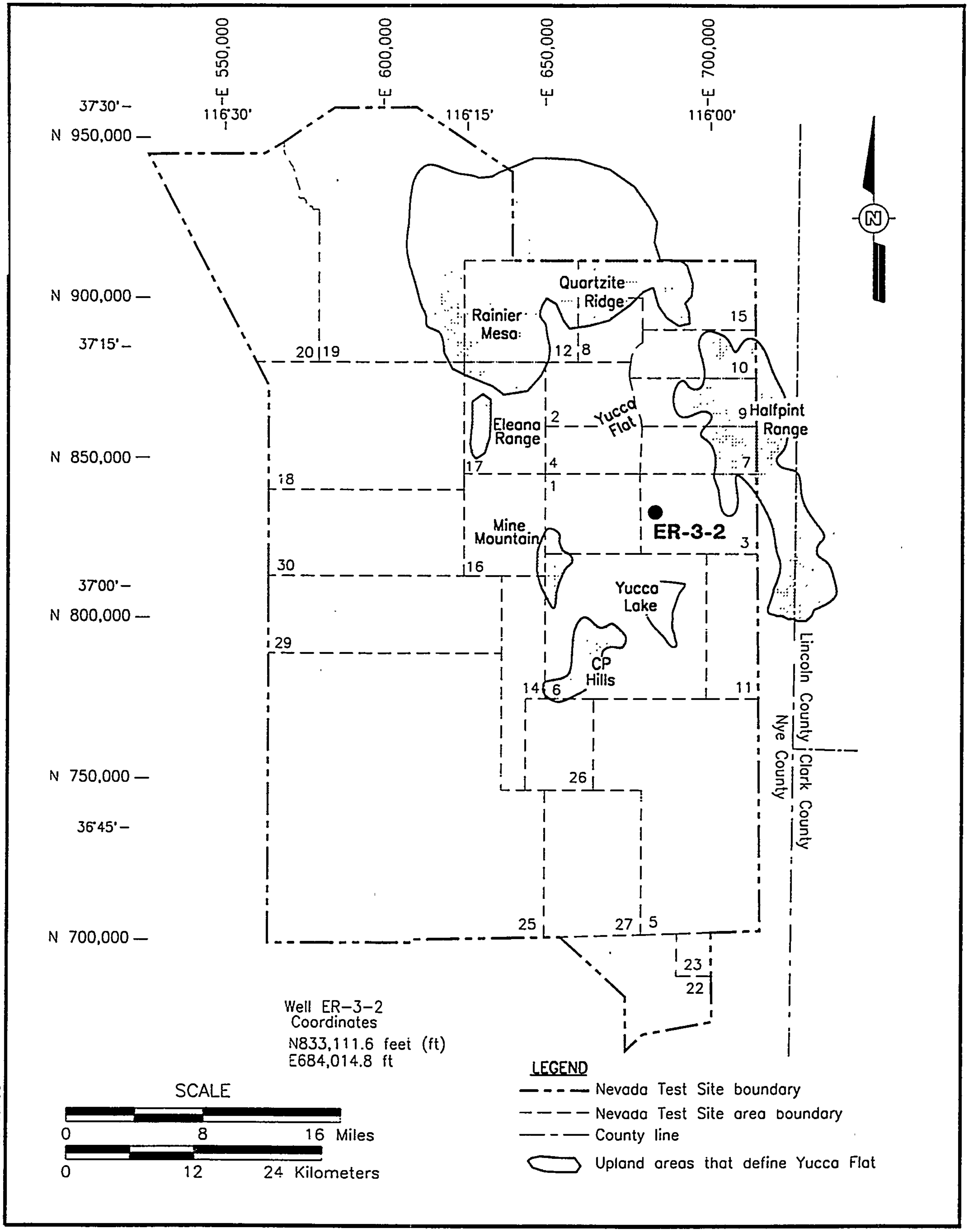


Figure 1-1
Location of Well ER-3-2

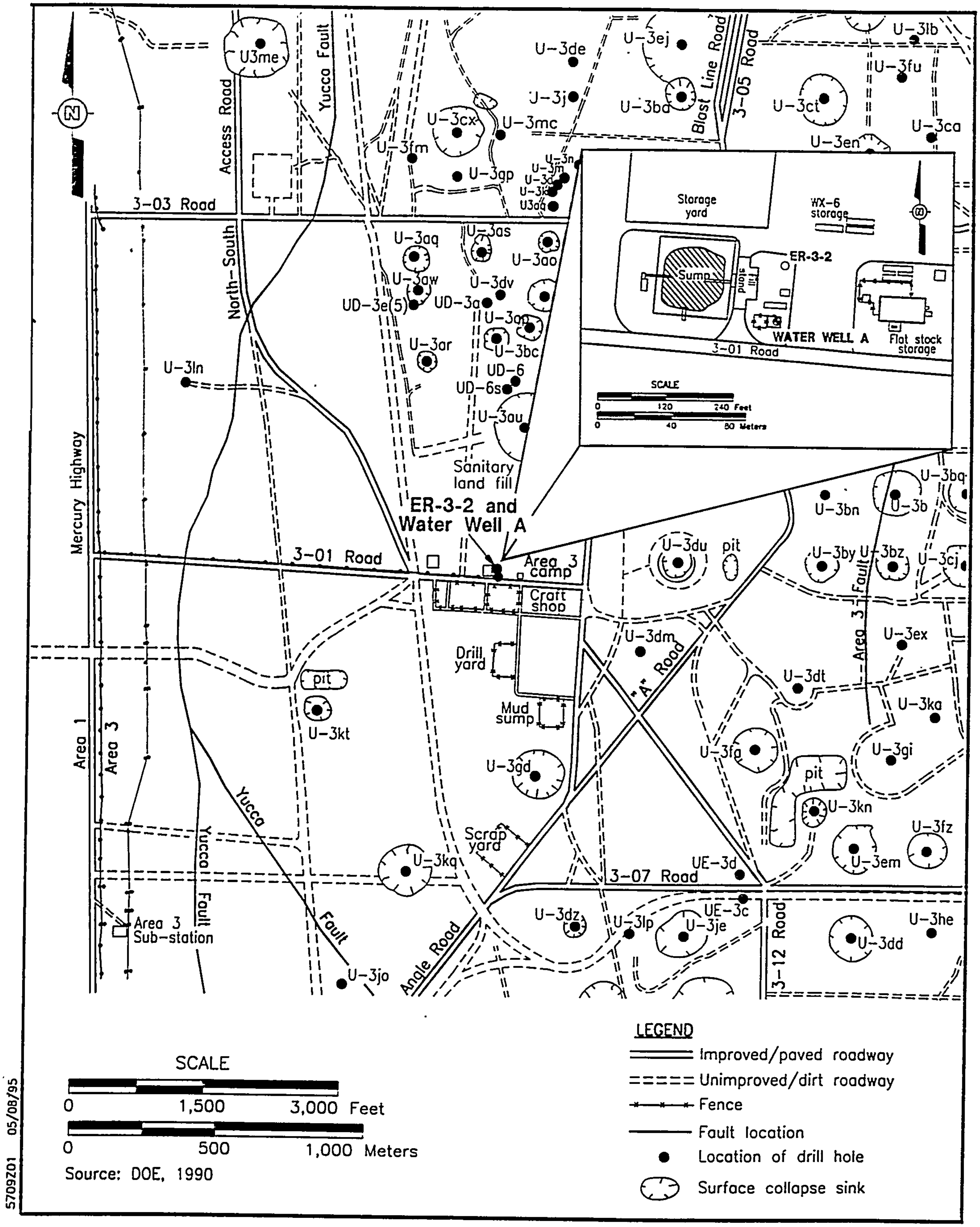


Figure 1-2
Locations of Well ER-3-2 and Water Well A

Table 1-1
Well ER-3-2 Site Summary

Hole Designation	ER-3-2
Site Coordinates[a]	Central Nevada State Planar: N833,111.6, E684,014.8 feet (ft) Universal Transverse Mercator: (Zone 11) N4,099,228.0, E585,716.8 meters (m)
Surface Elevation[b]	1,221.6 m (4,007.9 ft)
Drilled Depth	914.4 m (3,000 ft)
Completed Depth	914.4 m (3,000 ft)
Fluid-Level Depth	490 m (1,607 ft)
Fluid-Level Elevation	732 m (2,401 ft)

[a]1927 North American Datum. Measurement made by RSN Survey.
[b]1929 North American Vertical Datum. Measurement made by RSN Survey.

1.2 Objectives

The primary scientific purpose for drilling Well ER-3-2 was to obtain vertical permeability and water-level data from the saturated volcanic rocks that make up the welded-tuff aquifer underlying the alluvium in south-central Yucca Flat. Other objectives, as discussed in the Drilling and Completion Criteria Report (IT, 1993) and the Drilling Program (RSN, 1994a), include the following:

- Establish a monitoring well to obtain information on vertical and lateral permeability of the valley-fill and welded-tuff aquifers (when tested in conjunction with Water Well A)
- Determine the distribution of potentiometric levels between the valley-fill and welded-tuff aquifers
- Obtain samples for determination of natural chemistry and radiochemistry of local groundwater
- Determine the thickness of the alluvium at this location.

Interpretation of these data is expected to further the understanding of the hydraulic sink in this portion of Yucca Flat first postulated by Winograd and Thordarson (1975).

1.3 Project Summary

Well ER-3-2 was drilled with conventional rotary drilling techniques, using a direct circulation system, to a total depth of 914.4 m (3,000 ft) between December 14, 1993, and February 8, 1994.

Most of the hole was drilled using bentonite air foam and polymer air foam, but high-viscosity bentonite and sepiolite mud was required to drill the last 310 m (1,017 ft) because of problems with sloughing of saturated alluvium into the borehole. Beyond the depth of 623.6 m (2,046 ft), no drill fluid was recovered, resulting in the loss of approximately 2,703 cubic meters (m^3) (17,000 barrels [bbl]) of high-viscosity bentonite and sepiolite mud to the formation.

Composite drill cuttings were obtained every 3 m to the depth of 623.6 m (2,046 ft) for lithologic descriptions. When no cuttings were returned during drilling, percussion-gun sidewall core samples were collected. Geophysical logs were run periodically during drilling with no returns and after drilling was completed to aid in verification of the geology. The hole penetrated 801.9 m (2,631 ft) of Quaternary/Tertiary-age alluvium and reached total depth in Tertiary-age volcanic tuff.

No open-hole precompletion development was attempted in Well ER-3-2 because of hole instability problems. Three completion strings were installed in the well: one in the welded-tuff aquifer and two in the valley-fill aquifer. The lowest piezometer, String #1, was landed off at 895.5 m (2,938 ft) and has a 6.1-m (20-ft) slotted section located between 883.1 and 889.2 m (2,897 to 2,917 ft). The middle piezometer, String #2, was landed off at 809.3 m (2,655 ft) and also has a 6.1-m slotted section, located at the contact of the valley-fill aquifer with the underlying tuff, between 796.9 and 803.0 m (2,614 to 2,634 ft). Moyno® pump stators were installed in both lower piezometer strings. Piezometer String #3 was landed at 542.4 m (1,779 ft), at the top of the valley-fill aquifer, just below the static water level (490 m [1,607 ft]). String #3, consisting entirely of Hydril® tubing, contains two slotted intervals at 523.2 to 533.2 m (1,716 to 1,749 ft) and 496.8 to 505.9 m (1,630 to 1,660 ft). The third piezometer was installed for use in conjunction with hydrologic testing planned for nearby WW-A.

1.4 Project Manager

Inquiries regarding Well ER-3-2 should be directed to Mr. Steven J. Lawrence, UGTA, Project Manager at:

Environmental Restoration Division
DOE/Nevada Operations Office
Post Office Box 98518
Las Vegas, Nevada 89193-8518

2.0 Drilling Summary

2.1 Introduction

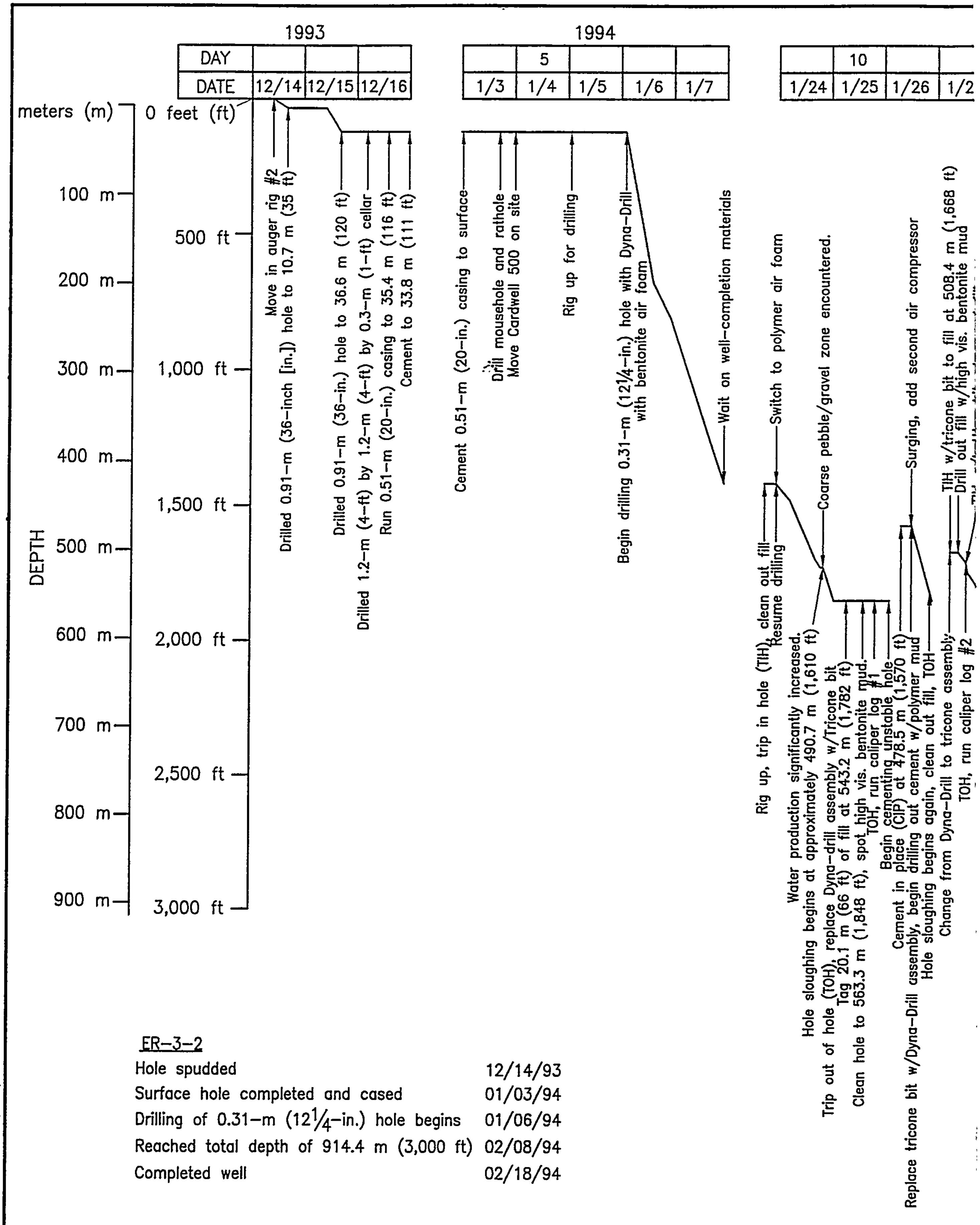
This summary was compiled from field notes prepared by the IT Field Representative and from the RSN ER-3-2 Hole History (RSN, 1995), in which complete details of drilling activities can be found. Figure 2-1 is a chart of the drilling and completion history for Well ER-3-2. A summary of drilling statistics for Well ER-3-2 is given in Table 2-1.

2.2 Drilling History

Mobilization for drilling of Well ER-3-2 began on December 14, 1993. A 0.91-m (36-inch [in.]) diameter borehole was dry-augered from the surface to 36.6 m (120 ft) on December 15, 1993, using a Reynolds Electrical & Engineering Co., Inc. (REECo) auger rig. A 0.51-m (20-in.) outside diameter (od) casing was set at a depth of 35.4 m (116 ft) and the bottom of the casing was cemented on December 16, 1993; final cement was in place on January 3, 1995. Operations were suspended until a REECo Cardwell 500 drill rig was mobilized to the site on January 3, 1994, and bentonite-based air foam was used in direct circulation to drill a 0.31-m (12¼-in.) diameter hole. Drilling operations were temporarily suspended at a depth of 431.0 m (1,414 ft) on January 7, 1994, and the hole was left open until well-completion materials became available.

When drilling operations at Well ER-3-2 resumed on January 24, 1994, a polymer air foam mixture was substituted for the bentonite-based air foam. Drilling continued to a depth of 563.3 m (1,848 ft) where it became necessary to address hole sloughing problems. Attempts to clean out the hole were unsuccessful, and in accordance with contingency plans described in the Drilling Program, the hole was cemented back to 478.5 m (1,570 ft) on the morning of January 26, 1994. The cement was drilled out to the original depth of 563.3 m (1,848 ft) with polymer air foam late on January 26, but hole sloughing continued to hamper drilling efforts. The drilling fluid was changed to high-viscosity bentonite drilling mud (in accordance with contingency plans), and the hole was successfully cleaned out to 559.3 m (1,835 ft) on January 28, 1994. The hole was stabilized for the weekend by filling it with high-viscosity bentonite drilling mud to a depth of 179.8 m (590 ft).

Drilling resumed on January 31, 1994, with bentonite-based air foam, after pumping out the bentonite mud. Drilling efforts were again hampered by sloughing at a depth of 604.4 m



ER-3-2

Hole spudded	12/14/93
Surface hole completed and cased	01/03/94
Drilling of 0.31-m (12¼-in.) hole begins	01/06/94
Reached total depth of 914.4 m (3,000 ft)	02/08/94
Completed well	02/18/94

5709L01 09/12/95

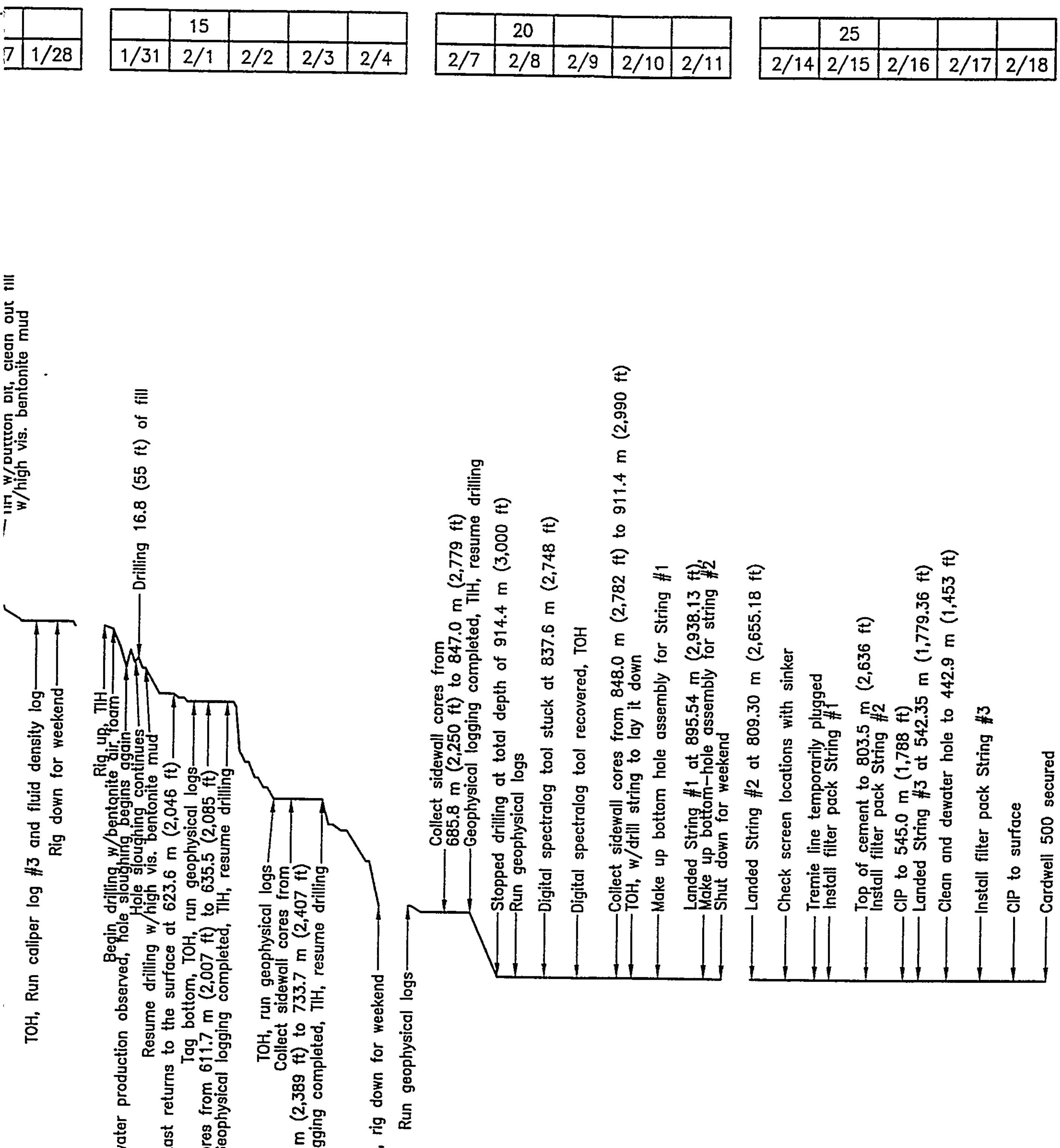


FIGURE 2-1
WELL ER-3-2
DRILLING/COMPLETION HISTORY

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

LOCATION DATA: Coordinates — Central Nevada State Planar: N833,111.6, E684,014.8 feet (ft)
Universal Transverse Mercator: N4,099,228.0, E585,716.8 meters (m)

Surface Elevation — 1,221.6 m (4,007.9 ft)

DRILLING DATA:

Spud Date:	12/14/93 (auger rig); 01/06/94 (Cardwell 500)
Total Depth (TD):	914.4 m (3,000 ft)
Date TD Reached:	02/08/94
Date Well Completed:	02/18/94
Original Hole Diameter:	91 centimeters (cm) (36 inches [in.]) from surface to 36.6 m (120 ft); 31 cm (12¼ in.) from 36.6 m (120 ft) to 914.4 m (3,000 ft)
Drilling Techniques:	Dry hole auger from surface to 36.6 m (120 ft). Air-foam rotary drilling from 36.6 m (120 ft) to 604.4 m (1,983 ft) using a 31-cm (12¼-in.) tricone bit with conventional circulation. Rotary drilling with high-viscosity bentonite and sepiolite muds from 604.4 m (1,983 ft) to 914.4 m (3,000 ft) using a 31-cm (12¼-in.) tricone bit with conventional circulation.

CASING DATA: 51-cm (20-in.) outside diameter (od) casing from surface to 35.4 m (116 ft).
No intermediate casing set in hole.

WELL COMPLETION DATA:

Lower two piezometer strings consist of 2⅞-in. od tubing, carbon steel in the unsaturated zone, stainless steel within and extending approximately 33 m (108 ft) above the saturated zone. Upper piezometer string consists of 1.9-in. Hydril® tubing.

	Lower Piezometer (#1)	Middle Piezometer (#2)	Upper Piezometer (#3)
Total Depth:	895.5 m (2,938 ft)	809.3 m (2,655 ft)	542.4 m (1,779 ft)
Depth of Slotted Section:	883.1-889.2 (2,897-2,917 ft)	796.9-803.0 m (2,614-2,634 ft)	523.2-533.2 m (1,716-1,749 ft) 496.8-505.9 m (1,630-1,660 ft)
Depth of Sand Pack:	871.7-914.4 m (2,860-3,000 ft)	788.8-803.5 m (2,588-2,636 ft)	472.4-496.5 m (1,550-1,629 ft)
Depth of Gravel Pack:	NA	NA	496.5-576.1 m (1,629-1,890 ft)
Depth of Moyno® Stator:	859.9-864.6 m (2,821-2,837 ft)	773.7-778.4 m (2,538-2,554 ft)	NA
Fluid Depth[a]:	490.3 m (1,608.7 ft)	437.3 m (1,434.8 ft)	438.6 m (1,439.1 ft)

DRILLING CONTRACTOR: Reynolds Electrical & Engineering Co., Inc.

GEOPHYSICAL LOGS BY: Atlas Wireline Services (AWS), Haliburton Logging Service, Baker Hughes INTEQ

SURVEYING CONTRACTOR: Raytheon Services Nevada

[a]Preliminary fluid level measured by IT on February 23, 1994. Probably reflects presence of residual drilling fluid in tube.

(1,983 ft). At this point, the Drilling Program contingency plan called for the use of high-viscosity bentonite mud, which was used to drill the rest of the hole. Drilling continued without further sloughing problems to the total depth, but no drilling-fluid returns were obtained beyond a depth of 623.6 m (2,046 ft). A total depth of 914.4 m (3,000 ft) was reached on February 8, 1994. Approximately 2,703 m^3 (17,000 bbls) of high-viscosity bentonite and sepiolite drilling mud were lost to the formation while drilling without returns. See Figure 2-2 for an illustration of fluid use during drilling of Well ER-3-2 and Appendix A-4 for additional data on fluids used down hole.

A graphical depiction of drilling parameters including penetration rate, revolutions per minute, pump pressure, and weight on the bit is presented in Appendix A-2. Geophysical logs were run several times during drilling to assess borehole geology, and the final suite of logs was completed on February 10, 1994.

The Desert Research Institute (DRI) installed time domain reflectometry (TDR) instrumentation in the fluid discharge line at the rig on Well ER-3-2 to determine the effectiveness of TDR in detecting the presence of free water in the fluid discharge line of the drill rig. The TDR system and the results of this test are discussed in Section 5.0.

Completion activities were begun on February 11, 1994, and finished on February 18, 1994, (see Section 7.0).

2.3 Drilling Problems

The primary problems encountered during drilling of Well ER-3-2 were the result of sloughing of alluvium into the borehole. It had been recognized that sloughing could occur in the lower saturated alluvium, and the Drilling Program specified procedures to mitigate the various possible degrees of sloughing severity. The following is a list of the primary consequences of sloughing and mitigation procedures at Well ER-3-2:

- Additional rig time was required for cementing and redrilling unstable sections of the hole (see Section 8.0).
- High-viscosity bentonite mud required to stabilize the hole could compromise one or more of the scientific objectives of the hole (because of the potentials for wall-cake formation, for fluid invasion, and for channeling during completion [see Section 7.0]).
- The presence of high-viscosity mud prevented proper operation of the acoustic televiewer log, and thus no data were obtained on fractures in the borehole.

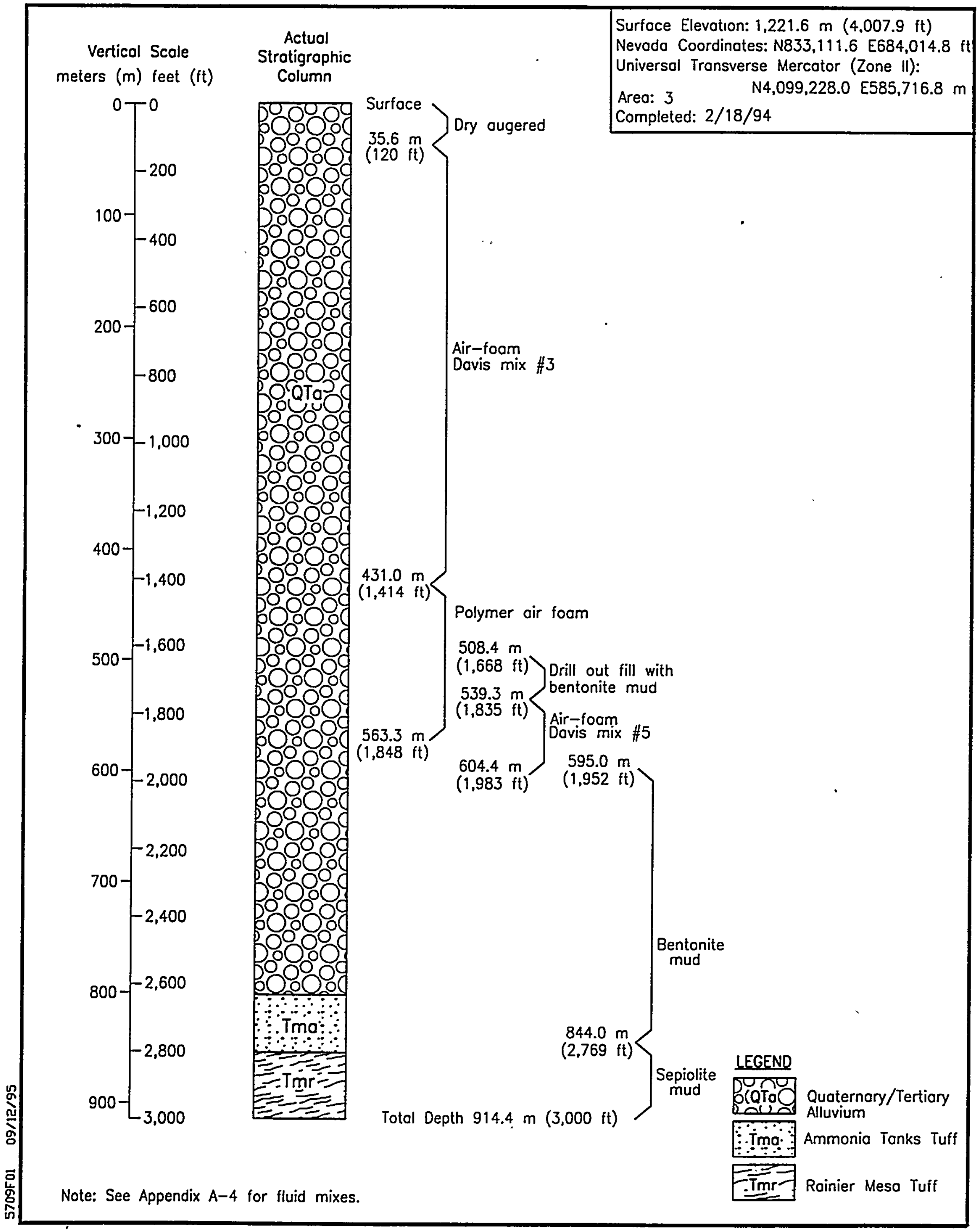


Figure 2-2
Drilling-Fluid Use Diagram

The lack of fluid returns from the depth of 604.4 m (1,983 ft) to total depth caused additional problems:

- Lack of drill cuttings prevented assessment of the lithology and stratigraphy during drilling, making "real-time" identification of the target formation and completion zones impossible.
- Drilling of Well ER-3-2 was frequently interrupted in this interval to run geophysical logs. This added both rig time costs and logging costs to the project (see Section 8.0).

Minor incidents of lost time also occurred, including the following:

- After several failed attempts to acquire acoustic televiewer data, it was discovered that the presence of high-viscosity drilling mud in the borehole severely limited the tool's performance.
- A logging tool became stuck in the hole, possibly due in part to the presence of liquid mud, and proper fishing tools were unavailable.

2.4 Fluid Management

Bentonite air-foam, polymer air-foam, high-viscosity bentonite, and sepiolite muds were used during drilling of Well ER-3-2. All air-foam mixtures were modified to eliminate soda ash (sodium carbonate [Na_2CO_3]) from the mixture except for the first 114.6 m^3 (720 bbls) mixed on January 5, 1994, and used while drilling to the depth of 431.0 m (1,414 ft).

Drilling-fluid effluent was monitored in accordance with the Draft Fluid Management Plan for NV ERP Well Construction Activities (DOE, 1993) in effect at the time the well was drilled. The results of analyses on samples of drilling fluid collected at Well ER-3-2 during drilling operations indicate that all fluid quality objectives were met.

Appendix B of this report contains a fluid disposition reporting form and final analytical results. The fluid disposition form lists volumes and data for well-construction operations, Stages I through III. The volumes of fluids imported to and produced at Well ER-3-2 were calculated from vacuum-truck delivery tickets and measurements of fluids in the lined sump. The solids produced were calculated using the diameter of the borehole and the depth drilled and take into account hole sloughing, redrill of cemented intervals, and lost circulation.

3.0 Geologic Data Collection

3.1 Introduction

This section describes the sources of geologic data obtained from Well ER-3-2 and methods of data collection. Obtaining geologic data was one of the primary objectives of Well ER-3-2 because of the need for information on the welded-tuff aquifer that underlies the alluvium in this part of Yucca Flat. Few nearby holes penetrate the entire alluvium section, so the depth of the tuff aquifer had been estimated from indirect sources. Thus, the proper collection of geologic data from Well ER-3-2 was considered fundamental to successful completion of the project. Geologic data collection and sampling at Well ER-3-2 consisted of drill cuttings, sidewall core samples, and geophysical logs.

Geologic data collection, sampling, transfer, and documentation activities were performed in accordance with applicable RSN, REECo, and IT procedures.

3.2 Collection of Drill Cuttings

Drill cuttings were collected continuously from Well ER-3-2 at 3.05-m (10-ft) intervals as drilling progressed from 36.6 m (120 ft) to 603.5 m (1,980 ft). Below 603.5 m (1,980 ft), poor-quality cuttings were returned at 612.6 m (2,010 ft) and at 623.6 m (2,046 ft), but no cuttings reached the surface from any deeper in the hole due to lost circulation conditions. The IT Field Geologist collected a grab sample from each of the cuttings samples before relinquishing custody to the U.S. Geological Survey (USGS) Core Library via RSN. These samples were examined at the drill site, and the field lithologic descriptions were used to prepare the lithologic log for Well ER-3-2 given in Appendix C.

3.3 Sidewall Core Sampling

Drilling was stopped three times after fluid returns were lost to collect sidewall core samples to verify geology. In particular, the cores were taken to obtain material for detailed lithologic descriptions and to identify the geologic contact between the alluvium and the underlying tuff.

Depth intervals for the core runs and the individual core sample depths were determined by the IT Field Representative and the IT Field Manager in consultation with RSN geologists and logging engineers. Samples were taken where lithologic data were needed after analysis of penetration-rate changes, geophysical logs (to identify lithologic boundaries), and caliper logs (for successful operation of the sidewall tool).

The 611.7- to 635.5-m (2,007- to 2,085-ft) interval was sampled every 0.6 m to 1.5 m (2 to 5 ft) on February 1, 1994. The 728.2- to 733.7-m (2,389- to 2,407-ft) interval was sampled every 0.6 to 1.2 m (2 to 4 ft) on February 3, 1994. Two intervals were sampled on February 7, 1994; 4 samples were taken in the interval 685.8 to 726.9 m (2,250 to 2,385 ft), and 17 samples were taken in the interval 746.8 to 847.0 m (2,450 to 2,779 ft). A final set of cores was taken after total depth was reached in the 848.0- to 911.4-m (2,782- to 2,990-ft) interval at 0.9- to 28.3-m (3- to 93-ft) spacings.

Sixty-six 20-millimeter (0.8-in.) diameter sidewall cores were obtained out of the 71 attempted. Five samples (and the core barrels) were not recovered. The percussion-gun sidewall cores were collected by Atlas Wireline Services (AWS) personnel and transferred to the USGS Core Library in Mercury. Table 3-1 summarizes sidewall-core depths and dates.

3.4 Geophysical Data

Geophysical logs were run at various stages of drilling and well-completion to further characterize the lithology, structure, and water content of the formations encountered. Geophysical logs were also run to check hole conditions and to determine the extent of caving, the depth to water prior to cementing, fluid levels during the course of drilling, and to monitor completion activities. All logs run are listed in Table 3-2. Geophysical logs used in geologic interpretation are presented as a composite log in Appendix D.

Geophysical logs from Well ER-3-2 are available from RSN in Mercury, Nevada, or the Well ER-3-2 project files maintained by IT.

Table 3-1
Well ER-3-2 Sidewall Core Data

Depth meters (feet)	Date	Core Run Number	Depth meters (feet)	Date	Core Run Number
611.7 (2,007)	02-01-94 2030 hours	SGUN-1	732.4 (2,403)	02-03-94 (cont.)	SGUN-2
613.3 (2,012)			733.0 (2,405), NR		
614.8 (2,017)			733.7 (2,407)		
616.3 (2,022)			746.8 (2,450)	02-07-94 1300 hours	SGUN-3
617.8 (2,027)			762.0 (2,500)		
619.4 (2,032)			779.1 (2,556)		
620.9 (2,037)			788.2 (2,586)		
622.4 (2,042)			791.3 (2,596)		
623.9 (2,047)			795.5 (2,610)		
625.4 (2,052)			800.4 (2,626)		
627.0 (2,057)			800.4 (2,626)		
627.6 (2,059)			802.8 (2,634)		
628.2 (2,061)			804.7 (2,640)		
628.8 (2,063)			811.4 (2,662)		
629.4 (2,065)			818.7 (2,686)		
630.0 (2,067)			824.2 (2,704)		
630.6 (2,069)			835.8 (2,742)		
631.2 (2,071), NR[a]			844.3 (2,770)		
631.9 (2,073)			845.8 (2,775)		
632.5 (2,075)			847.0 (2,779)		
633.1 (2,077)			848.0 (2,782)	02-10-94 1000 hours	SGUN-4
633.7 (2,079)			848.6 (2,784), NR		
634.3 (2,081)			854.0 (2,802)		
634.9 (2,083)			855.6 (2,807)		
635.5 (2,085)			868.7 (2,850), NR		
685.8 (2,250)	02-07-94 1300 hours	SGUN-3	883.9 (2,900)		
701.0 (2,300)			887.0 (2,910)		
726.9 (2,385)			887.0 (2,910)		
726.9 (2,385)			890.0 (2,920)		
728.2 (2,389)	02-03-94 0530 hours	SGUN-2	902.2 (2,960)		
728.8 (2,391)			905.3 (2,970)		
729.4 (2,393)			908.3 (2,980)		
730.0 (2,395)			909.8 (2,985)		
730.6 (2,397)			911.4 (2,990)		
731.2 (2,399), NR			911.4 (2,990)		
731.8 (2,401)					

Sidewall Core Type - Percussion-Gun: Series 1812 CM Corgun
Operator - Atlas Wireline Services

[a]No Recovery; core barrels also lost.

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

Geophysical Log Name	Log Purpose	Logging Service	Date Logged	Run Number	Bottom of Logged Interval meters (feet)	Top of Logged Interval meters (feet)
Acoustic Televiewer	Fracture density, character, and orientation	HLS[a]	02/8/94	BHTV-1	912.9 (2,995) NOTE: No reliable readings due to heavy mud.	844.3 (2,770)
Caliper/Gamma Ray	Hole conditions, cement volumes/stratigraphic correlation	AWS[b]	01/25/94 01/27/94 01/28/94 01/28/94 02/03/94 02/07/94 02/08/94	CA6-1/GR-1 CA6-2/GR-2 CA6-3/GR-3 CA6-4/GR-4 CA6-5/GR-7 CA6-6/GR-12 CA6-7/GR-13[c]	551.1 (1,808) 516.9 (1,696) 555.0 (1,821) 432.8 (1,420) 730.9 (2.398) 852.2 (2,796) 881.5 (2,892)	20.1 (66) 14.9 (49) 394.1 (1,293) 14.9 (49) 14.9 (49) 696.5 (2,285) 21.9 (72)
Casing Collar Locator	Locate casing collar	AWS	02/14/94 02/14/94 02/14/94	CCL-1 CCL-2 CCL-3	490.1 (1,608) 490.4 (1,609) 909.5 (2,984)	418.2 (1,372) 431.9 (1,417) 825.4 (2,708)
Compensated Density/ Gamma Ray	Lithologic identification, degree of welding, porosity	AWS	02/01/94 02/03/94 02/04/94 02/08/94	CDL-1/GR-6[c] CDL-2/GR-9[c] CDL-3/GR-10[c] CDL-4/GR-14[c]	637.0 (2,090) 731.8 (2,401) 847.6 (2,781) 911.0 (2,989)	15 8 (52) 543.2 (1,782) 698.9 (2,293) 788.8 (2,588)
Percussion-Gun Sidewall Core	Geologic samples, geophysical log calibration	AWS	02/01/94 02/03/94 02/07/94 02/10/94	SGUN-1 SGUN-2 SGUN-3 SGUN-4	635.5 (2,085) 733.7 (2,407) 847.0 (2,779) 911.4 (2,990)	611.6 (2,007) 728.2 (2,389) 685.8 (2,250) 848.0 (2,782)
Dual Lateralog/ Gamma Ray	Water saturation (sat. zone)/ stratigraphic correlation	AWS	02/01/94 02/03/94 02/07/94 02/08/94	DLL-1/GR-5[c] DLL-2/GR-8 DLL-3/GR-11 DLL-4/GR-15[c]	636.4 (2,088) 734.6 (2,410) 847.3 (2,780) 911.7 (2,991)	106.7 (350) 545.9 (1,791) 696.5 (2,285) 482.5 (1,583)
Fluid Density	Depth to water in borehole	AWS	01/25/94 02/17/94 02/17/94	DF-1 DF-2 DF-3	520.0 (1,706) 413.3 (1,356) 368.8 (1,210)	454.2 (1,490) 387.7 (1,272) 343.8 (1,128)
Gyroscopic Survey	Borehole deviation	BHI[d]	03/02/94	DRG-1	846.5 (2,810)	0

Refer to footnotes on next page.

Table 3-2
Well ER-3-2 Geophysical Log Summary
(Page 2 of 2)

Geophysical Log Name	Log Purpose	Logging Service	Date Logged	Run Number	Bottom of Logged Interval meters (feet)	Top of Logged Interval meters (feet)
Photon Annulus Investigation (nuclear)	Omnidirectional density (check for cement and/or fluid location)	AWS	01/26/94	AIN-1	527.9 (1,732)	502.3 (1,648)
			01/26/94	AIN 2	502.3 (1,648)	474.9 (1,558)
			01/26/94	AIN-3	481.6 (1,580)	455.1 (1,493)
			01/27/94	AIN 4	504.1 (1,654)	433.4 (1,422)
			01/28/94	AIN-5	216.1 (709)	160.9 (528)
			01/28/94	AIN 6	214.9 (705)	181 4 (595)
			02/14/94	AIN-7	292.3 (959)	266.1 (873)
			02/14/94	AIN-8	155.1 (509)	139.6 (458)
			02/15/94	AIN-9	876.0 (2,874)	836.4 (2,744)
			02/15/94	AIN-10	874.5 (2,869)	812.3 (2,665)
			02/15/94	AIN-11	871.4 (2,859)	842.8 (2,765)
			02/15/94	AIN-12	857.7 (2,814)	699.2 (2,294)
			02/15/94	AIN-13	837.6 (2,748)	701.6 (2,302)
			02/15/94	AIN-14	826.0 (2,710)	777.2 (2,550)
			02/16/94	AIN-15	824.8 (2,706)	749.2 (2,458)
			02/16/94	AIN-16	807.4 (2,649)	560.8 (1,840)
Spectral Gamma Ray	Stratigraphic correlation, mineralogy, natural radiation	AWS	02/07/94	SGR-1[c]	847.3 (2,780)	684.3 (2,245)
			02/08-09/94	SGR-2[c]	912.0 (2,992)	838.2 (2,750)

[a]Halliburton Logging Service
[b]Atlas Wireline Services
[c]Logs used in composite, Appendix D
[d]Baker Hughes INTEQ

4.0 Geology

The formations encountered in Well ER-3-2 are Quaternary/Tertiary alluvium and Tertiary-age volcanic tuffs, which include Ammonia Tanks Tuff and Rainier Mesa Tuff, both of the Timber Mountain Group. IT personnel prepared field lithologic descriptions of the cuttings and sidewall cores, and selected samples were sent to Los Alamos National Laboratory for petrographic and mineralogical analysis (Warren, 1994). Using these data and incorporating analysis of geophysical data, RSN geologists prepared the final lithologic and stratigraphic logs presented in Appendix C.

The drill hole penetrated approximately 801.9 m (2,631 ft) of alluvium, 44.2 m (145 ft) of nonwelded to partially welded ash flow and 5.8 m (19 ft) bedded tuff of the Ammonia Tanks Tuff, and approximately 62.5 m (205 ft) of nonwelded to moderately welded ash flow of the Rainier Mesa Tuff. Real-time evaluation of the formations encountered during drilling were complicated by the lack of cutting samples below the depth of 623.6 m (2,046 ft). The field call of the alluvium/tuff contact at 802.8 m (2,634 ft) was used to design the placement of piezometers. However, based on an analysis of more complete data available later, the alluvium/tuff contact is placed at 801.9 m (2,631 ft).

The contact of the alluvium with volcanic tuff was encountered 222.8 m (731 ft) below the predicted depth of 579.1 m (1,900 ft). The contacts are shown compared with the predicted stratigraphy on Figure 4-1 (IT, 1993). Detailed analysis and interpretation of the geologic data will be submitted in a separate report.

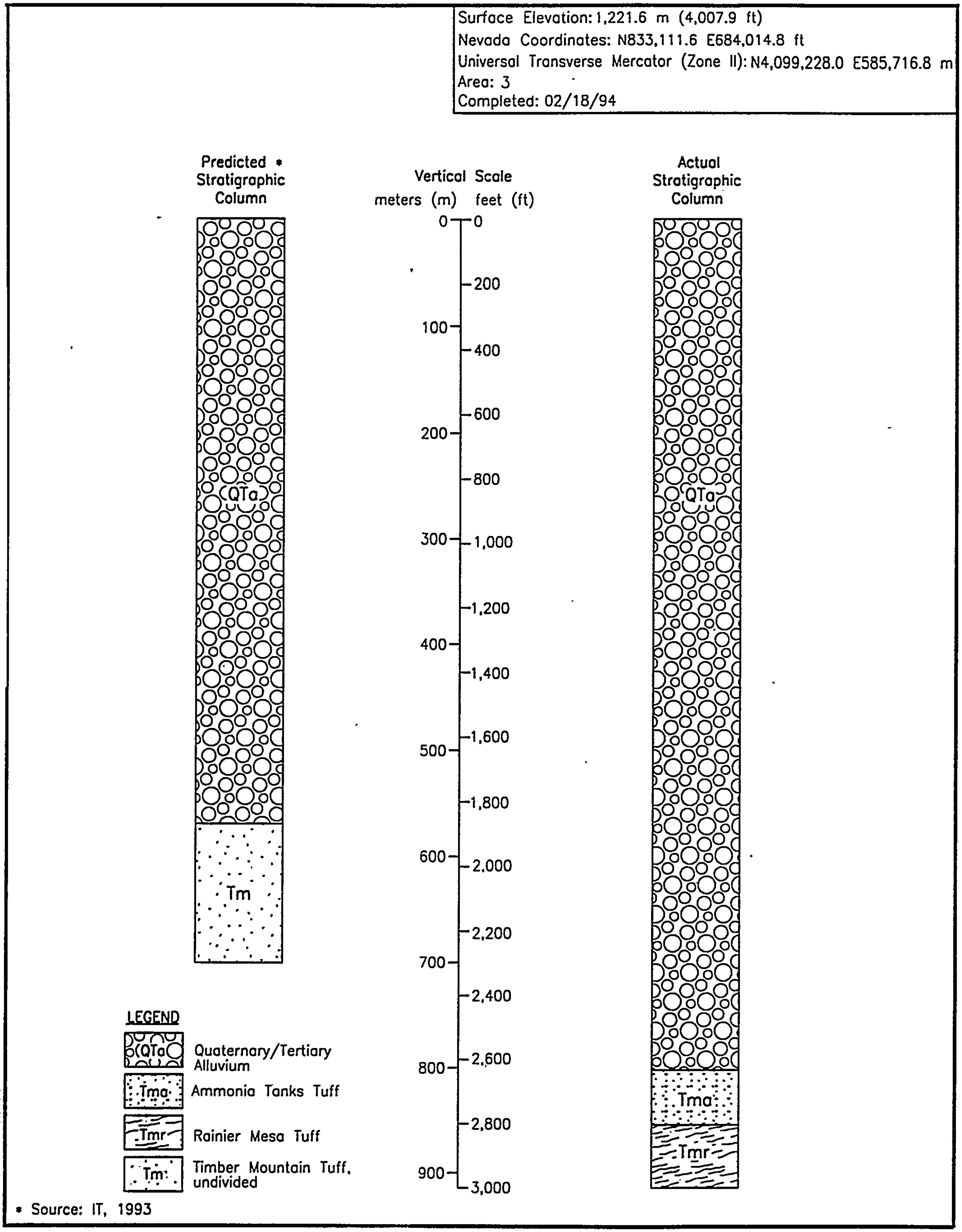


Figure 4-1
Well ER-3-2 Predicted versus Actual Stratigraphy

5.0 Hydrology

5.1 Water-Level Information

The depth to water projected for Well ER-3-2 was approximately 494 ± 6 m (1,620 ± 20 ft) (IT, 1993), based on water-level measurements made in WW-A located approximately 34 m (110 ft) south of Well ER-3-2. However, the last depth-to-water measurement in WW-A was in 1971, and the well is no longer accessible for water-level measurements. Thus, it is not known what effect groundwater pumping in WW-A (1960 to 1988) and any subsequent recovery may have had on the local groundwater level.

Observations made during drilling of Well ER-3-2 indicated a static, open-hole water level at the depth of approximately 490 m (1,607 ft) and an elevation of approximately 732 m (2,401 ft).

5.2 Time Domain Reflectometry Test

Time domain reflectometry instrumentation to detect the presence of water in the drilling effluent was tested by DRI during drilling of Well ER-3-2. The sensor was a modified two-wire TDR probe designed to fit within the drill rig's fluid discharge line. Time domain reflectometry monitoring began after dry-augering at 36.6 m (120 ft) and continued to a depth of 530 m (1,739 ft) when visual inspection of the drilling fluids indicated that the water table had been penetrated. The TDR response showed a pronounced shift toward drier readings between 470 m (1,542 ft) and 490 m (1,608 ft). However, the addition of instrumentation to measure pump strokes (that add moisture to the drilling fluid) and compressor pressure was required to provide data on the effect of drill-fluid pump rate on the TDR response. Additional analysis incorporating these data indicated a water-level depth of 490 m (1,608 ft). Desert Research Institute concluded that without the pump-stroke measurements, TDR data alone were not a useful indicator of water-table penetration (Hokett et al., 1994).

6.0 Precompletion and Open-Hole Development

Precompletion open-hole development was not attempted in Well ER-3-2 due to unstable hole conditions encountered in the lower saturated alluvium section.

7.0 Well Completion

7.1 Introduction

The objective of well completion is to hydraulically isolate specific water-producing zones within a single borehole in order to collect potentiometric and water-chemistry data from the desired producing zones. Completion of Well ER-3-2 began on February 10, 1994, and was concluded on February 18, 1994. Figure 7-1 is a schematic of the final well-completion design for Well ER-3-2, Table 7-1 is a construction summary for the well, and Figure 7-2 shows a plan view and profile of the wellhead surface completion.

The as-built completion of Well ER-3-2 differed significantly from the planned completion design, as described in this section: three piezometers were installed in the borehole instead of two to maximize data acquisition in a hydrogeologic setting with a thicker than expected valley-fill alluvium section. The lowest completion string (String #1) is located in a moderately welded tuff aquifer about 79.2 m (260 ft) below the alluvium/tuff contact, in an interval believed (based on degree of welding) to have a high fracture permeability. The original plan for an upper completion string in volcanic rock was changed to place String #2 at the base of the saturated valley-fill aquifer, spanning the alluvium/tuff contact. This will allow potentiometric head measurements at the boundary of the valley-fill and welded-tuff aquifers and the monitoring of drawdown during pumping of String #1. The added string (String #3) is located near the top of the valley-fill aquifer, just below the static water level, with the screened interval placed in a coarse-gravel zone expected to have a high permeability.

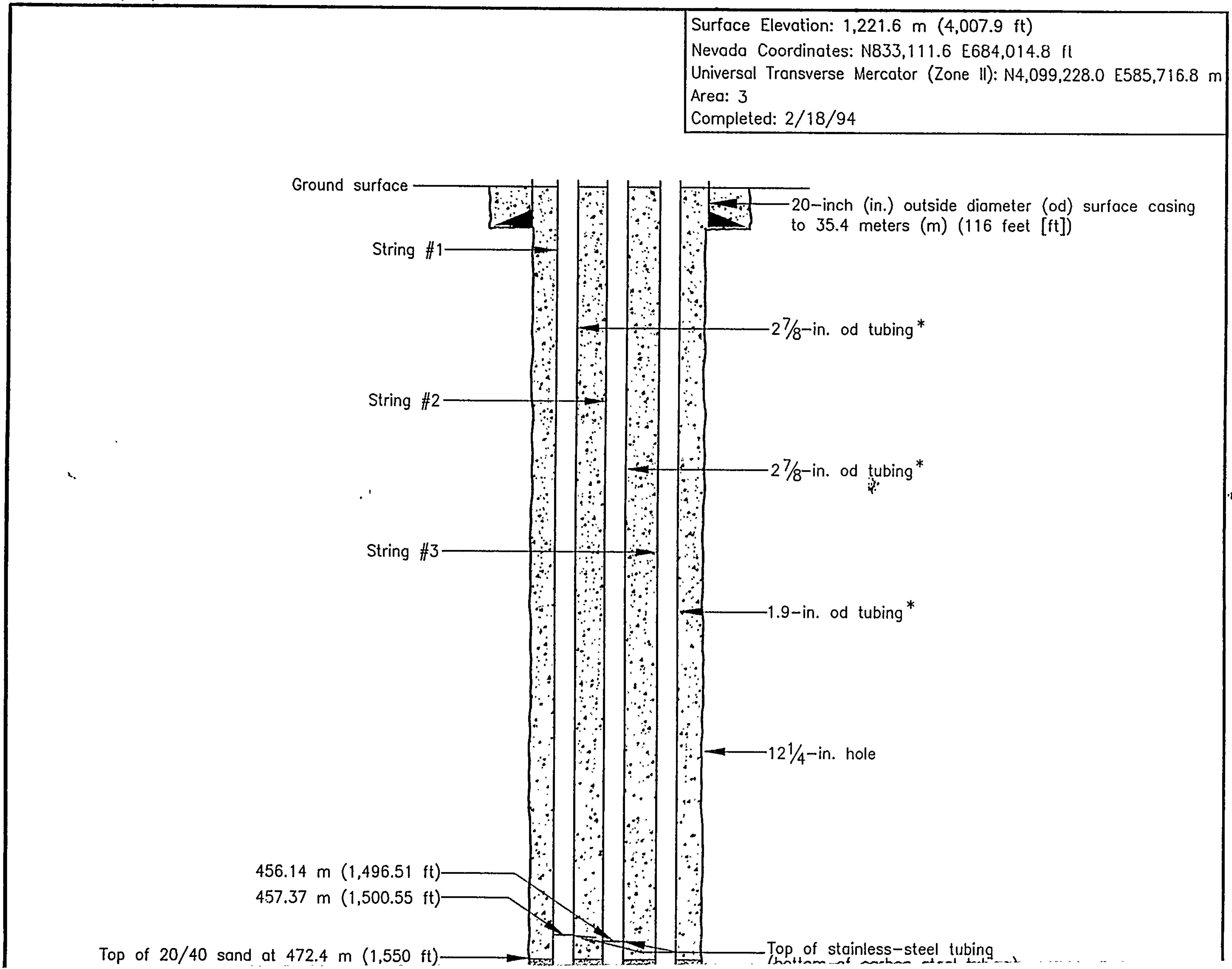
Development of Well ER-3-2 as completed is expected to provide data on the vertical permeability between the valley-fill and tuff aquifers if the process is not hindered by the presence of excessive high-viscosity bentonite mud. Information on lateral permeability in the valley-fill alluvium aquifer can be gained in conjunction with recompletion and testing in nearby WW-A.

7.2 Well Completion Design

7.2.1 As-Built Completion Design: Strings #1 and #2

Strings #1 and #2 are composed of stainless steel, including one slotted section in each piezometer, from the bottom of the string to just above the water level, and then flush-joint carbon-steel casing to the surface. Detailed diagrams of the completion zones for Strings #1

5709C01 09/12/95



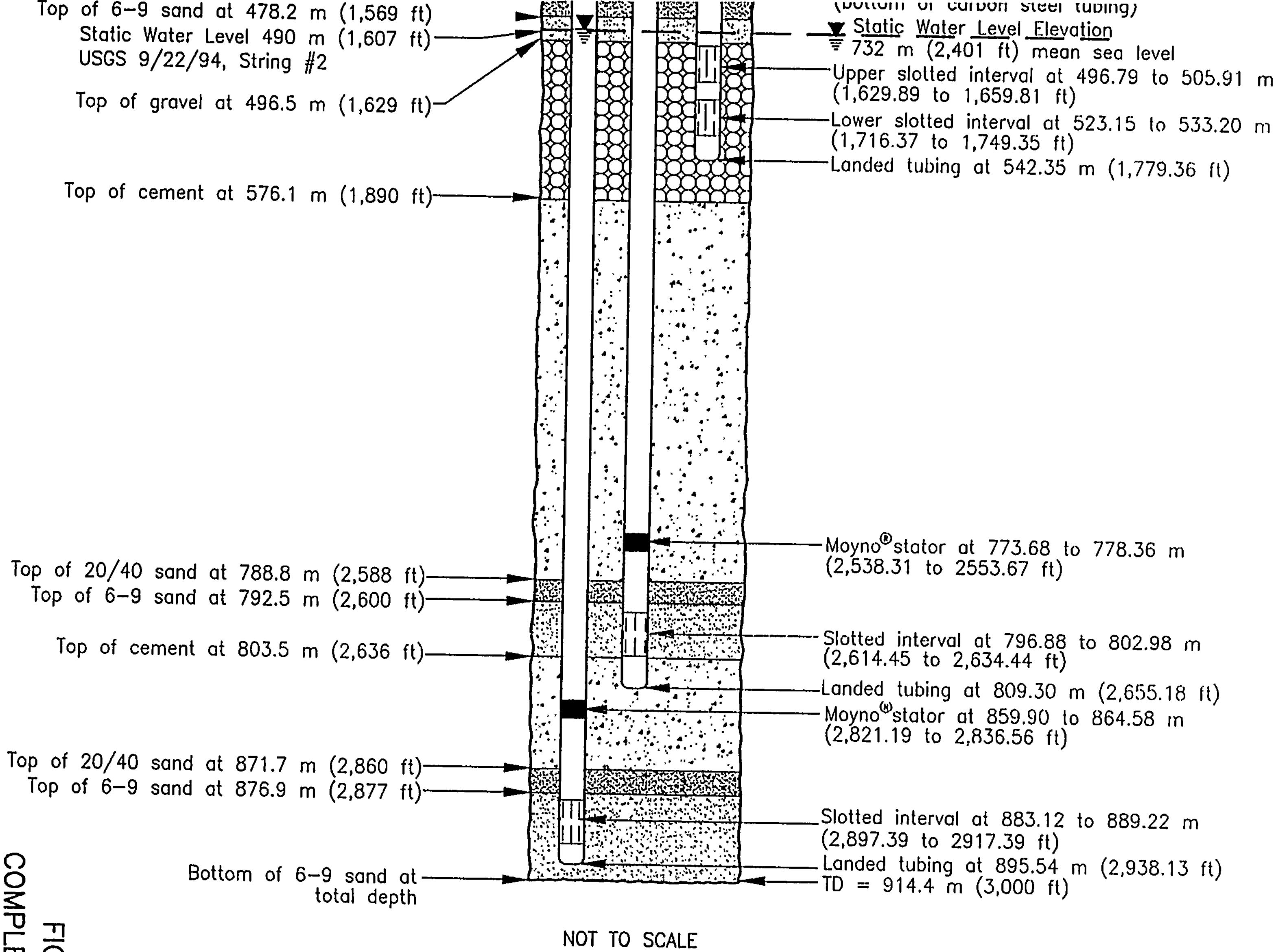


FIGURE 7–1
COMPLETION DIAGRAM
FOR WELL ER–3–2

* Additional details regarding tubing type, grade, diameter, etc. are provided in Appendix A–3.

Table 7-1
Well ER-3-2 Construction Summary
(Page 1 of 2)

String	Tubing[a]			Cement	Sand/Gravel	Depth to Fluid[b]
	Carbon Steel	Stainless Steel				
#1	Ground Surface to 457.37 m (1,500.55 ft)	457.37 to 895.54 m (1,500.55 to 2,938.13 ft)	Blank 457.37 meters (m) to 859.90 m (1,500.55 to 2,821.19 feet [ft])	Type II + 2% $CaCl_2$ 803.5 to 871.7 m (2,636 to 2,860 ft)	20/40 Sand 871.7 to 876.9 m (2,860 to 2,877 ft)	Date 02/23/94
			Moyno® Stator[c] 859.90 to 864.58 m (2,821.19 to 2,836.56 ft)		6-9 Sand 876.9 to 914.4 m (TD) (2,877 to 3,000 ft)	Fluid Level 490.3 m (1,608.7 ft)
			Blank 864.58 to 883.12 m (2,836.56 to 2,897.39 ft)			
			Slotted 883 12 to 889 22 m (2,897.39 to 2,917.39 ft)			
			Bull-Nosed Tailpipe 889.22 to 895.54 m (2,917.39 to 2,938.13 ft)			
#2	Ground Surface to 856.47 m (1,496.51 ft)	456.14 to 809 30 m (1,496.51 to 2,655.18 ft)	Blank 456.47 to 773.68 m (1,496.51 to 2,538.31 ft)	Type II + 2% $CaCl_2$ 576.1 to 788.8 m (1,890 to 2,588 ft)	20/40 Sand 788.8 to 792.5 m (2,588 to 2,600 ft)	Date 09/22/94
			Moyno® Stator[c] 773.68 to 778.36 m (2,538.31 to 2,553.67 ft)		6-9 Sand 792.5 to 803.5 m (2,600 to 2,636 ft)	Fluid Level 489.8 m (1,607 ft)
			Blank 778.36 to 796 88 m (2,553.67 to 2,614.45 ft)			
			Slotted 796 88 to 802.98 m (2,614.45 to 2,634.44 ft)			
			Bull-Nosed Tailpipe 802.98 to 809.30 m (2,634.44 to 2,655.18 ft)			

Refer to footnotes at end of table

Table 7-1
Well ER-3-2 Construction Summary
(Page 2 of 2)

String	Carbon Steel		Cement	Sand/Gravel	Depth to Fluid[b]
#3	Ground Surface to 542.35 m (1,779.36 ft)	Blank Surface to 496.79 m (0.0 to 1,629.89 ft)	Type II + 2% $CaCl_2$ Ground Surface to 472.4 m (1,550 ft)	20/40 Sand 472.4 to 478.2 m (1,550 to 1,569 ft)	Date 02/23/94
		Slotted 496.79 to 505.91 m (1,629.89 to 1,659.81 ft)		6-9 Sand 478.2 to 496.5 m (1,569 to 1,629 ft)	Fluid Level 438.6 m (1,439.1 ft)
		Blank 505.91 to 523.15 m (1,659.81 to 1,716.37 ft)			
		Slotted 523.15 to 533.20 m (1,716.37 to 1,749.35 ft)		Chevreaux and Trona Gravel 496.5 to 576.1 m (1,629 to 1,890 ft)	
		Bull-Nosed Tailpipe 533.20 to 542.35 m (1,749.35 to 1,779.36 ft)			

[a]Additional details regarding casing and tubing are provided in Appendix A-3

[b]Fluid levels after completion. Levels shown here probably reflect residue drilling mud in the tubing. Data on actual static water levels measured during postcompletion activities will be provided in a future report.

[c]Moyno® stators are composed of carbon steel.

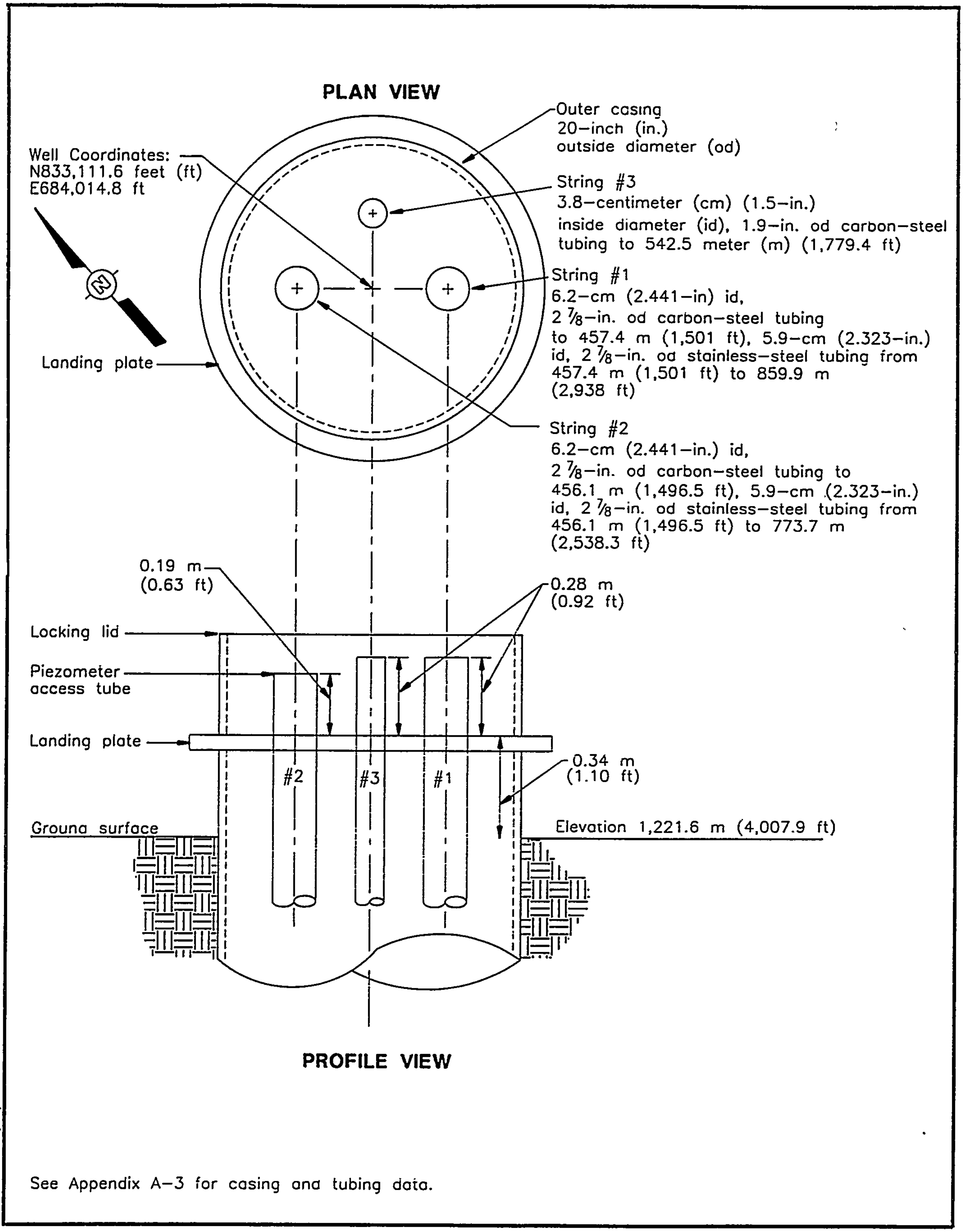


Figure 7-2
Well ER-3-2 Wellhead Diagram

and #2 are shown in Figures 7-3 and 7-4, respectively, and the string compositions summarized here are listed in Table 7-1.

The lower section of both strings is 2⅞-in. od, Type 304 stainless steel to approximately 33 m (108 ft) above static water level (based on a static water level in the hole of approximately 490 m [1,607 ft]). Each bottom assembly is composed of a 6.1-m (20-ft), Schedule 40, stainless-steel, bull-nosed tailpipe as a sediment trap, followed by a 6.1-m (20-ft), Schedule 40, stainless-steel, slotted section.

The slotted section of each piezometer contains eight rows of saw-cut slots, 7.62 cm long by 0.10 cm wide (3 in. by 0.038 in.), staggered on 30.5-centimeter (cm) (12-in.) centers. Above each slotted section are three solid, 6.1-m (20-ft) joints, followed by a 4.6-m (15-ft) carbon-steel Moyno® pump stator. The slotted section and the stator were separated by three solid joints so that the stator could be encased in cement to reduce contact of its carbon-steel case with groundwater.

Above the slotted section of both strings, the rest of the casing is composed of solid 6.1-m stainless-steel joints to approximately 33 m (108 ft) above the static water level, followed by 9.6 m (31.5 ft) long, 2⅞-in. od carbon-steel joints to the surface.

7.2.2 As-Built Completion Design: String #3

String #3 is composed entirely of 1.9-in. od, Grade L-80, Hydril® tubing, with two slotted sections. The bottom assembly is composed of a 9.1-m (30-ft), bull-nosed tailpipe as a sediment trap, followed by a 10.1-m (33-ft) slotted section. Above the slotted section are two 8.5-m (28-ft) solid sections followed by another 9.1-m (30-ft) slotted section. Both slotted sections contain eight rows of saw-cut slots, 7.62 cm long by 0.32 cm wide (3 in. by 0.125 in.), staggered on 30.5-cm (12-in.) centers. Figure 7-5 is a detailed diagram of the completion zone for String #3.

7.2.3 Rationale for Differences between Actual and Proposed Well Design

The differences between the as-built and proposed well-completion designs (as specified in the Completion Criteria [IT, 1993] and the Drilling Program [RSN, 1994a]) are summarized below.

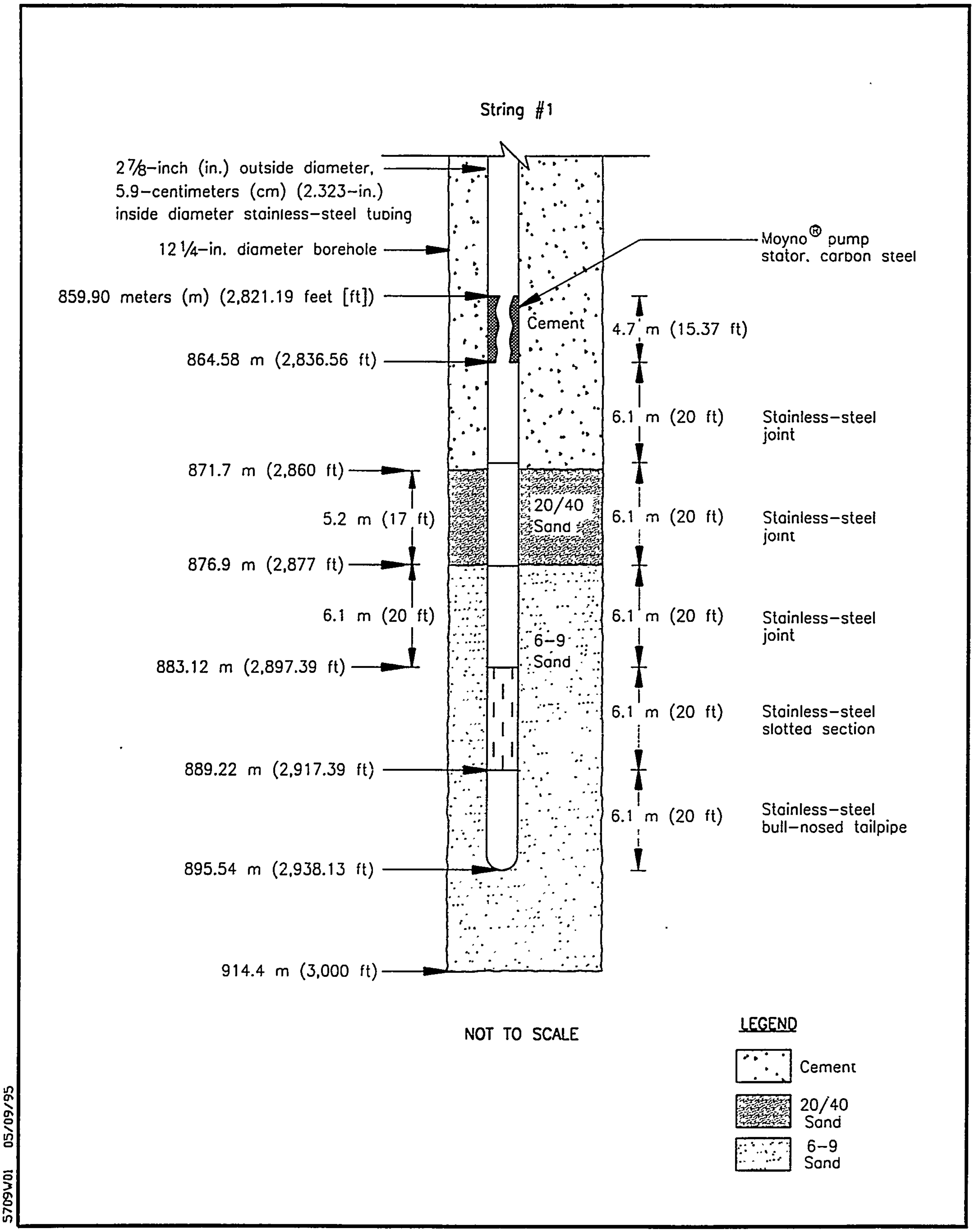


Figure 7-3
Completion Configuration for Well ER-3-2
Lower Completion Zone (String #1)

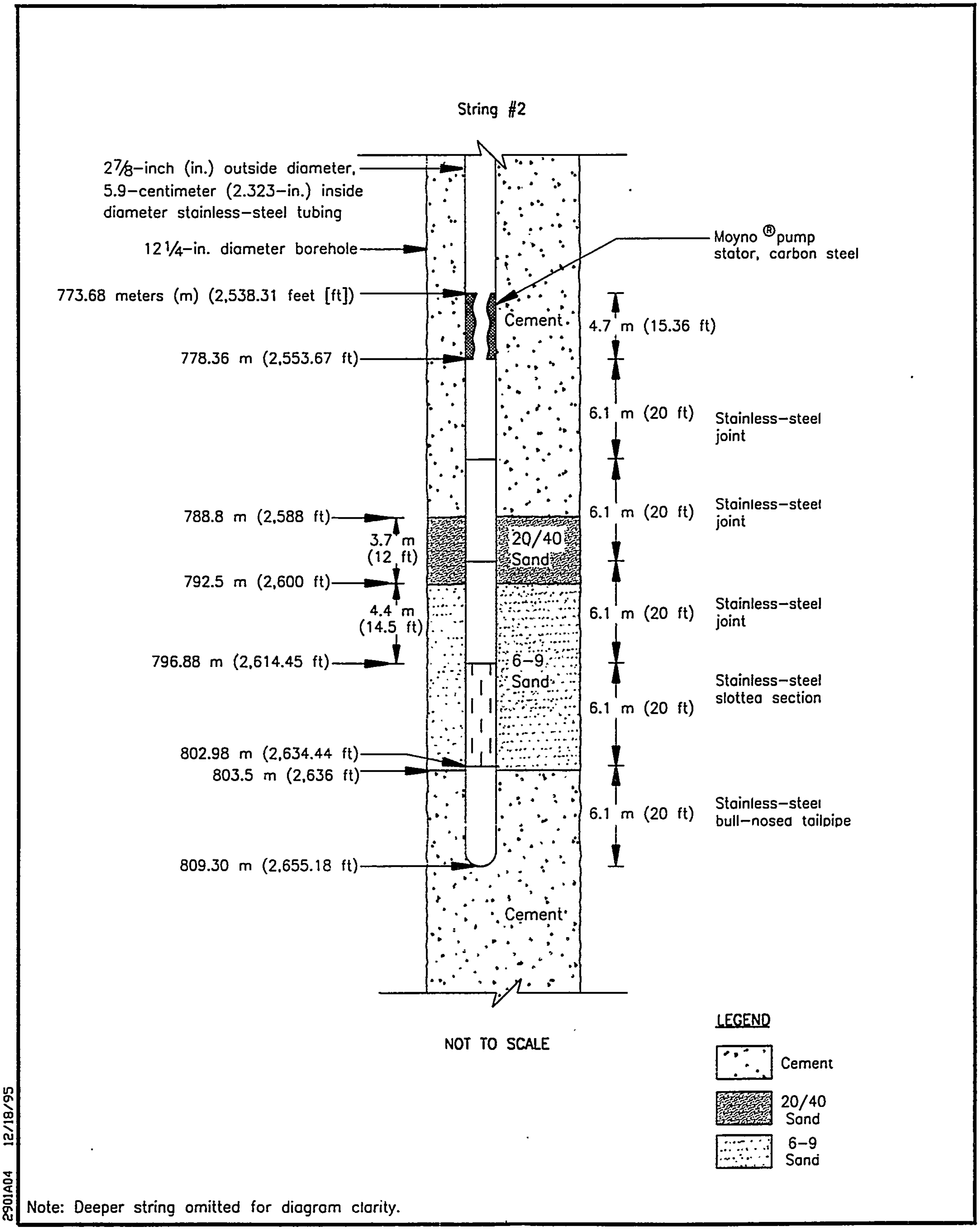


Figure 7-4
Completion Configuration for Well ER-3-2
Intermediate Completion Zone (String #2)

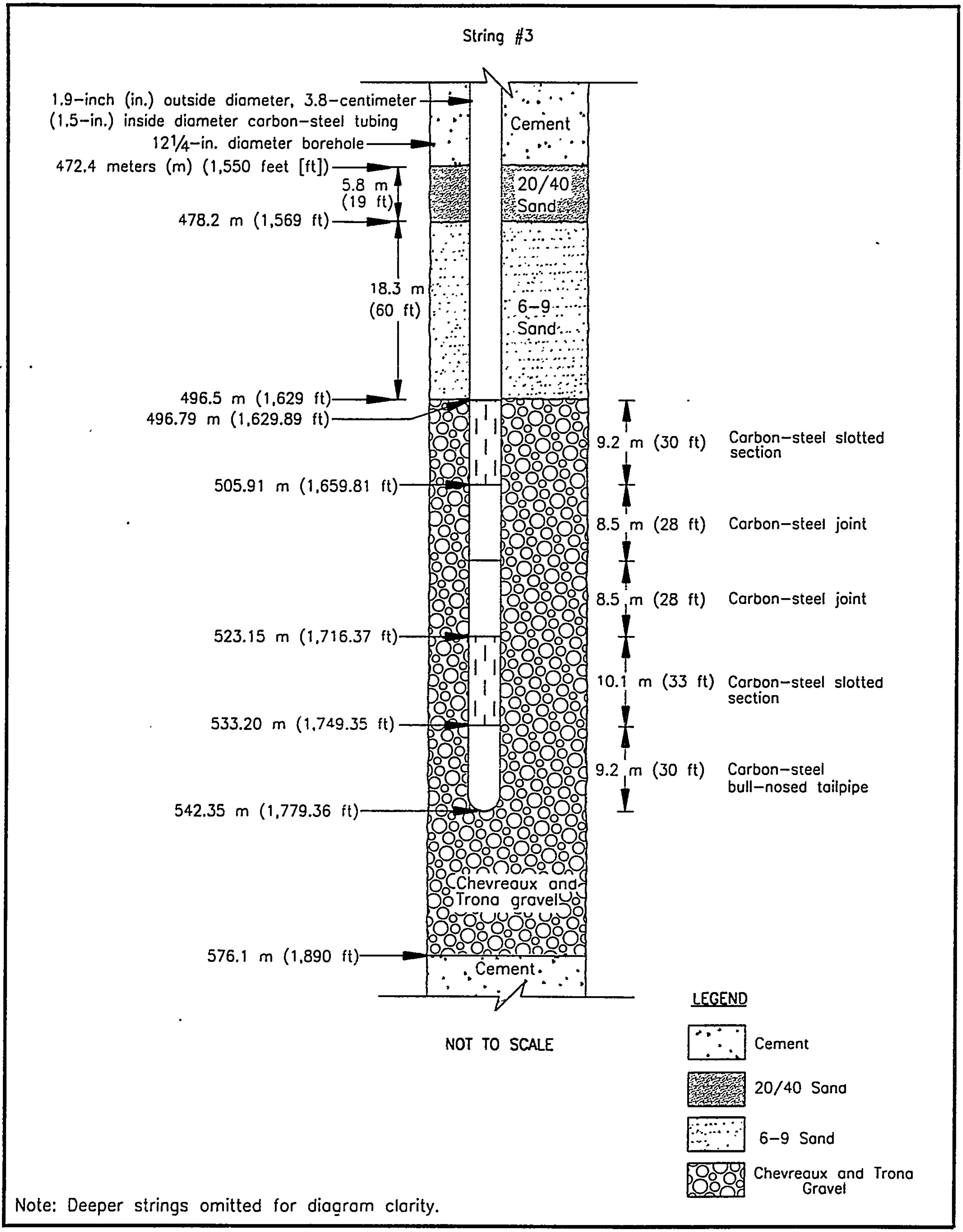


Figure 7-5
Completion Configuration for Well ER-3-2
Upper Completion Zone (String #3)

- A third piezometer was installed to serve as an observation well during pumping and testing activities in WW-A and in the lower two completion zones in Well ER-3-2.

- The intermediate string was screened in the alluvium at the tuff contact instead of within the uppermost portion of the volcanic tuff. This change was made to provide vertical permeability data across the alluvium/tuff boundary and to provide permeability data from the valley-fill aquifer.

- The intermediate and lower strings were placed farther apart than specified to accommodate the revised completion specifications.

- One Moyno® pump stator per string was installed in Strings #1 and #2 instead of two because it was determined that an additional pump stator would not significantly extend the useful life of the well.

- Chevreaux gravel, Trona gravel, and 6-9 sand were used in the filter pack of the upper completion zone instead of only Trona gravel, as specified. In the two lower completion zones, 6-9 sand was substituted for Trona gravel. Both of these changes were implemented to save on the limited stock of Trona gravel. In addition, the smaller diameter 6-9 sand was more compatible with the equipment used to install the filter pack.

- The slot size in the lower and intermediate screened intervals was reduced from 0.32 cm to 0.10 cm (0.038 in. instead of 0.125 in.) to be compatible with the smaller diameter 6-9 sand used in these intervals.

- The bull-nosed tailpipes for the intermediate and lower strings were 6.1 m (20 ft) long instead of 9.1 m (30 ft) long because this pipe is manufactured in standard 6.1-m-long sections.

7.3 Well Completion Methods

7.3.1 Introduction

Well construction materials were inspected in accordance with relevant procedures; standard decontamination procedures were employed to prevent introduction of contaminants into the well. Caliper logs were used to calculate the volumes of cement needed during well completion. The Photon Annulus Investigation Log was used to monitor the rise in cement and the placement of sand and gravel.

7.3.2 Completion Method: Strings #1 and #2

Both Strings #1 and #2 piezometers were assembled and landed prior to the emplacement of filter packs and cement. String #1 was landed at 895.5 m (2,938 ft), and String #2 was landed at 809.3 m (2,655 ft). AWS verified the depth of each piezometer by tagging the top of the Moyno® pump stator with a sinker bar.

Water was pumped down through 2⅞-in. od Hydril® tubing to displace the drilling mud column and allow proper emplacement of the filter pack and cement. The filter pack and cement were then emplaced through the Hydril® tubing. Each stage of cement was allowed to cure for approximately six hours before emplacement of another stage of cement or filter-pack material.

The filter packs for Strings #1 and #2 consist of 6-9 sand, with 20/40 sand emplaced on top to prevent infiltration of cement into the screened portion of the filter pack. Following emplacement of the filter pack, Type II cement with two-percent calcium chloride ($CaCl_2$) was emplaced between Strings #1 and #2 to hydraulically isolate the completion zones. As-built measurements for Strings #1 and #2 are shown on Figures 7-3 and 7-4.

7.3.3 Completion Method: String #3

String #3 was assembled and run into the borehole after cement was emplaced up to a depth of 576.1 m (1,890 ft). After the 1.9-in. od Hydril® tubing was landed at 542.4 m (1,779 ft), dewatering operations commenced using 1.6-in. od Hydril® tubing inside a 2⅞-in. od eductor casing. The fluid level in the hole was lowered from 146.3 m (480 ft) to 442.6 m (1,452 ft) before dewatering operations were halted.

After dewatering the hole, a filter pack consisting of Chevreaux and Trona gravels was emplaced in the upper completion zone. When the supplies of Chevreaux and Trona gravels were exhausted, 6-9 sand was substituted, starting at 0.27 m (0.9 ft) above the top of the upper slotted section of tubing and extending up approximately 18.3 m (60 ft). As an infiltration barrier, 20/40 sand was emplaced above the 6-9 sand, and the well installation was completed with emplacement of Type II cement with two-percent $CaCl_2$ in two stages from the top of the 20/40 sand to the surface. Construction materials for String #3 are listed in Table 7-1, and the as-built measurements are shown on Figure 7-5.

7.3.4 Complications

Comparison between the last caliper log run prior to completion (CA6-7) and the RSN cementing record shows that less cement was used than calculated for much of the completion process. Eight percent less cement was used between the completion zones for Strings #1 and #2. 38 percent less cement was used between Strings #2 and #3, and 6 percent less cement was used between the upper completion zone and the surface. These differences indicate the possibility of a wall-cake buildup, channeling, or both. The cement section between Strings #2 and #3 corresponds to the portion of the borehole that suffered the worst sloughing, as described in Section 2.2.

The construction of Strings #1 and #2 with the Moyno® stators cemented in place above the screens may complicate development. A retainer pin that acts as a stop for the drive rods is located at the bottom of each stator and will prevent the passage of equipment below the stator.

8.0 Actual versus Planned Costs and Scheduling

The RSN Work Order Estimate for Well ER-3-2 (summarized in the Fiscal Year 1994 Cost Summary [RSN, 1994b]) projected that drilling and completion operations would require 20 days to accomplish. The RSN projection allowed for 15 days of drilling and geophysical activities and 5 days of completion activities. Actual time spent drilling and logging Well ER-3-2 was 21 days, while completion required 7 days, for a total of 28 days. The added drilling time reflects the greater-than-expected drilled depth required to reach the target formation and the time spent managing the sloughing problems. The added completion time is a result of the decision to add a third piezometer string to the well.

The planned cost for fifteen days of drilling, geophysical logging, and materials was $421,500. The planned cost for five days of completion and materials was $310,900. The total planned cost for Well ER-3-2 was $732,400.

The actual cost of Well ER-3-2 through completion totaled $1,427,040, or approximately 95 percent more than the planned cost. Table 8-1 provides a comparison of the actual versus predicted costs. Figure 8-1 is a comparison of the planned versus actual drilling costs, and Figure 8-2 is a comparison of the planned versus actual completion costs. These data (taken from the RSN summary report for Fiscal Year 1994 [RSN, 1994b]) show actual costs plotted against the day the charges were received from REECo, not against actual drilling and completion days. The additional days shown for drilling and completion also reflect subsequent activities related to water-level measurements, preparation of the well for future development, and vacating the site.

Table 8-1
Well ER-3-2 Planned versus Actual Costs

Activity	Planned Cost	Actual Cost	Percent Difference Actual versus Planned
Drilling and geophysical logging	$421,500	$864,500	+105%
Well completion	$310,900	$562,540	+81%
Total	$732,400	$1,427,040	+95%

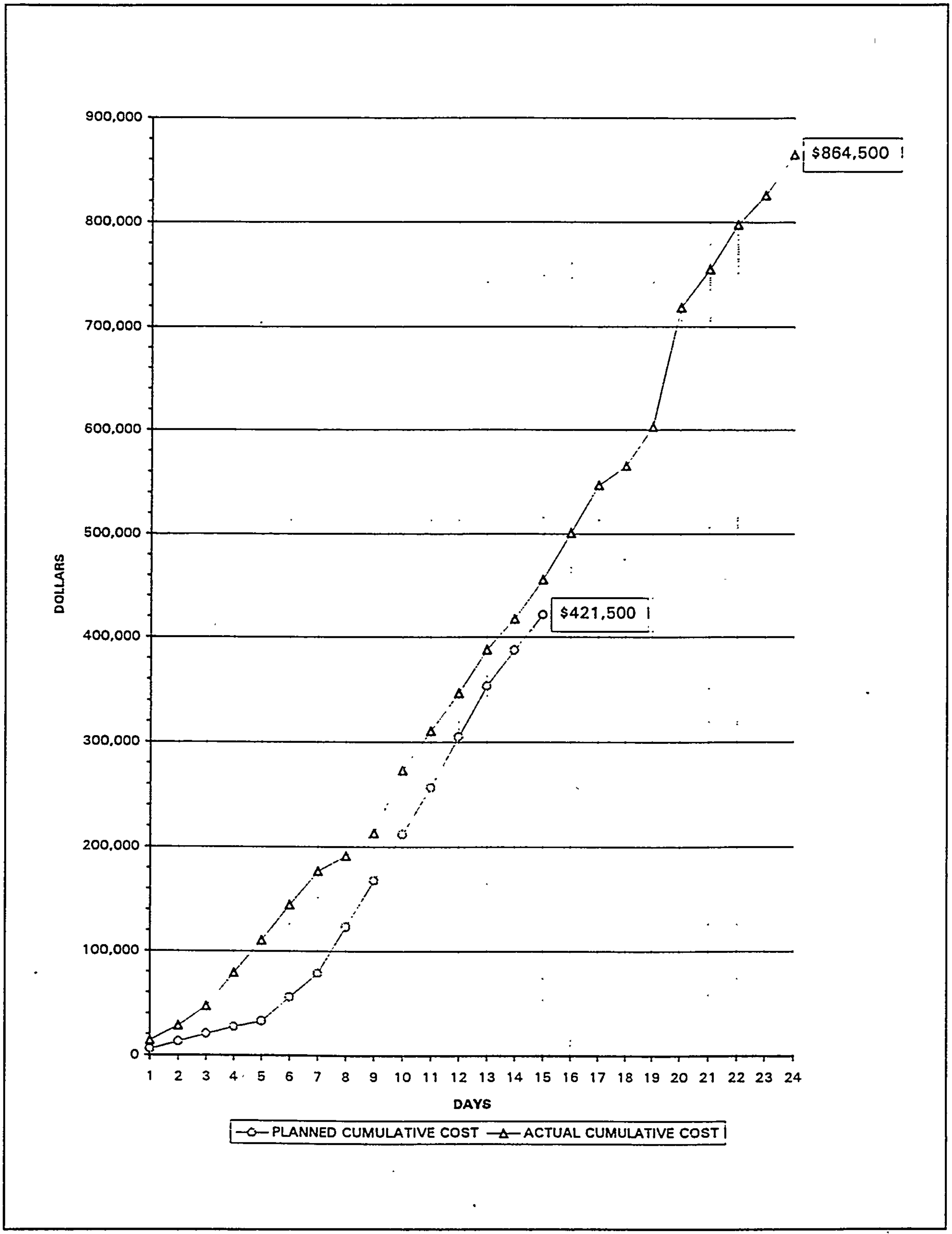


Figure 8-1
Planned versus Actual Costs for Drilling of Well ER-3-2

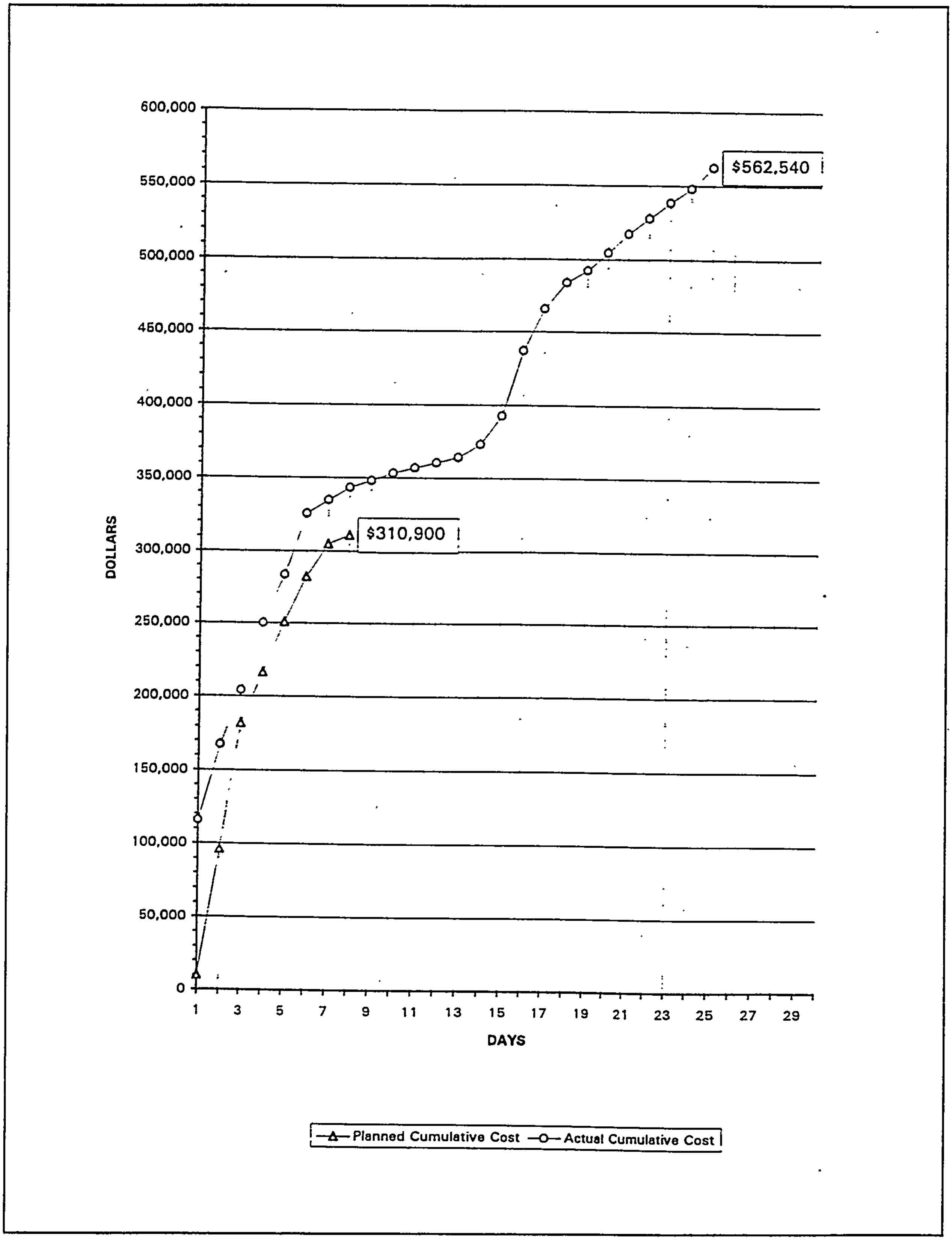


Figure 8-2
Planned versus Actual Costs for Completion of Well ER-3-2

9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Drilling operations commenced at Well ER-3-2 on December 14, 1993, and concluded on February 8, 1994, when the total depth of 914.4 m (3,000 ft) was reached. Well completion activities were finished on February 18, 1994. Crews worked on a five-day-per-week, 24-hour-per-day schedule, and 28 working days were expended in the well-drilling and completion process. Two 2-week drilling hiatuses took place: the first in December 1993 for the holidays and the second in mid-January 1994 while waiting for well-construction materials.

Drilling of Well ER-3-2 took longer than expected because the target formation was deeper than predicted and because of complications due to unstable hole conditions. Shortly after the water table was penetrated, the saturated alluvium began to slough, and contingency plans provided in the drilling program were implemented to manage the problem. The mitigation process required cementing back, redrilling, and eventually using high-viscosity bentonite and sepiolite drilling muds to finish the hole. Loss of drilling fluid to the formation coincided with the onset of drilling with high-viscosity bentonite mud, and most of the bentonite and sepiolite mud (2,703 m^3 [17,000 bbls]) was lost to the formation.

Well-completion activities were accomplished in seven days. Precompletion, open-hole development was not attempted on the well because of unstable hole conditions. Three piezometers were successfully installed in the borehole, instead of two as planned, to maximize data acquisition in a hydrogeologic setting with a thicker than expected valley-fill alluvium section. String #1 was landed at 895.5 m (2,938 ft) in a moderately welded volcanic tuff unit believed (based on degree of welding) to have a higher fracture permeability. String #2 was landed at 809.3 m (2,655 ft), with its completion zone located at the alluvium/tuff contact. String #3 was landed at 542.3 m (1,779 ft), in a zone of coarse gravel within the saturated portion of the valley-fill alluvium aquifer.

The Desert Research Institute installed experimental TDR instrumentation in the fluid discharge line as part of a program to develop a method for "real-time" determination of the onset of groundwater flow during drilling. The results indicated a water level of 490 m (1,608 ft) in the borehole, which agrees with water-level data obtained by other means in Well ER-3-2.

Composite drill cuttings were collected continuously from Well ER-3-2 at 3.05-m (10-ft) intervals as drilling progressed from 36.6 m (120 ft) to 603.5 m (1,980 ft). Below 603.5 m

(1,980 ft), poor-quality cuttings were returned at 612.6 m (2,010 ft) and at 623.6 m (2,046 ft), but no cuttings reached the surface from any deeper in the hole due to lost circulation conditions. Drilling was stopped three times after fluid returns were lost to collect sidewall core samples to verify geology. Sixty-six percussion-gun sidewall cores were obtained in four runs from discrete depths ranging from 611.7 m (2,007 ft) to 911.4 m (2,990 ft). All geologic drill cuttings and core samples are archived at the USGS Core Library in Mercury, Nevada.

The total estimated cost for Well ER-3-2 was $732,400. The actual cost was $1,427,040, which is approximately 95 percent more than the estimated cost.

The hole was successfully drilled and completed in spite of significant sloughing problems and a deeper-than-expected target formation. The objectives of obtaining preliminary water-level data and data on the alluvium thickness were accomplished, but the loss of the bentonite mud to the borehole (as wall-cake and/or through formation invasion) will make the development process difficult. Additionally, if each piezometer string is not adequately developed and the remnant drilling mud is not removed from the completion zones (i.e., from within the tubing and gravel pack), valid water-level measurements and ultimately, vertical gradients cannot be obtained. The objectives of obtaining groundwater samples for chemical analysis may also have been compromised.

Provided that postcompletion development is successful, Well ER-3-2, as completed, is expected to provide data on the vertical permeability between the valley-fill and tuff aquifers; information on lateral permeability within the valley-fill aquifer can be gained in conjunction with recompletion and testing in nearby WW-A.

The construction of the well with the Moyno® stator cemented in place above the screens in Strings #1 and #2, may further complicate development. A retainer pin that acts as a stop for the drive rods is located at the bottom of each stator and will prevent the passage of equipment below the stator. As a result, development across the slotted interval will not be possible without knocking out the retainer pin.

9.2 Recommendations for Additional Data Interpretation

The following paragraphs describe additional work needed to further interpret the geologic, hydrologic, and geophysical data gathered during drilling and completion of Well ER-3-2.

Structural Analysis

Analysis of the structural geologic setting could help explain why the tuff/alluvium contact was deeper than expected. Planning for the rest of the UGTA program for Yucca Flat could be aided by exploring the presence of this subbasin along the Yucca Fault. Information could be gained on the origin of the basin, the character of the inferred hydrologic sink, and ultimately, groundwater flow beneath Yucca Flat.

Hydrologic Analyses

Hole sloughing problems at Well ER-3-2 precluded any open-hole development, and, to date, postcompletion development of the piezometer strings has not been undertaken. It is imperative that the planned postcompletion development be accomplished so that valid water-level measurements may be obtained. Finally, analysis of the subsequent water-level data is necessary to achieve the primary scientific objectives for Well ER-3-2.

9.3 Lessons Learned

The following section describes lessons learned during drilling and construction of Well ER-3-2. As appropriate, these lessons can be applied to other UGTA drilling projects.

Contingency Plans

The development (prior to drilling) of contingency plans for handling possible hole problems seemed to prevent some lost time on Well ER-3-2. In the future, these plans could include the procurement of additional drilling and completion materials to avoid costly delays waiting on materials.

Drilling in Alluvium

The use of liquid mud (as opposed to air foam) contributed to several problems during drilling and geophysical logging and may hamper the development process. In future holes, the use of liquid mud should be avoided if possible.

The possibility of using dual-wall reverse-circulation drilling should be explored for future holes drilled in alluvium or any poorly indurated lithology, such as vitric, friable, bedded tuff, to decrease the likelihood of formation sloughing and related problems.

Operational Problems

The following problems occurred with equipment and materials during logging and completion operations at Well ER-3-2:

- Logging equipment - The presence of high-viscosity mud prevented proper operation of the acoustic televiewer log. Not only were no fracture data obtained, but time was lost trying to get the tool to work. A list of conditions under which the tool will and will not work should be developed, and the tool operators should be made aware of hole conditions. To avoid lost time during fishing operations, proper fishing tools for logging tools should be available on site, and all logging tools should be modified to have appropriate connections for fishing tools. Proper-size sinker bars should be available, especially when equipment is installed downhole that could be damaged by an incorrect-size bar.

- Completion Strings - The inside diameters of the stainless-steel and carbon-steel tubing were different enough that it was not possible to conduct development swabbing of the lower and middle piezometers. All future completion strings should be designed to have the same inside diameter from surface to bottom.

Site Exploration

The alluvium section at Well ER-3-2 was 222.8 m (731 ft) thicker than expected (IT, 1994), mainly because, though numerous holes have been drilled in this area, no drill holes closer than 1.4 kilometers from Well ER-3-2 penetrate the full thickness of the alluvium. Attempts at using surface geophysical methods to determine alluvium thickness have been unsuccessful in Yucca Flat. For future drilling projects in areas with no nearby holes that provide adequate geologic information, sufficient drilling materials should be on hand in case the hole goes deeper than expected.

10.0 References

Hokett, S.L., C.E. Russell, and D.R. Gillespie, Desert Research Institute, 1994, *Water Level Detection During Drilling Using Time Domain Reflectometry*, Las Vegas, NV.

IT Corporation, 1993, *Drilling/Completion Criteria for Underground Test Area Remedial Investigation and Feasibility Study Well ER-3-2*, DOE/NV/10972--76, Las Vegas, NV.

Raytheon Services Nevada, 1994a, *Program for Underground Test Area Remedial Investigation/Feasibility Study (UGTA RI/FS) Well ER-3-2, Surface/Main Hole Drilling and Completion*, Las Vegas, NV.

Raytheon Services Nevada, 1994b, *UGTA Rig/Material Cost Summary for Fiscal Year 1994*, RSN Internal Memorandum, Las Vegas, NV.

Raytheon Services Nevada, 1995, *ER-3-2 Hole History*, Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office, 1994, *Underground Test Area Operable Unit Project Management Plan*, DOE/NV-UC-700, Las Vegas, NV.

U.S. Department of Energy, May 1993, *Fluid Management Plan for Environmental Restoration (ER) Well Construction Activities (FMP)*, Las Vegas, NV (now superseded).

U.S. Department of Energy, 1990, *Nevada Test Site, LASL Areas, Drill Hole Planning Map, Areas 1, 3, 4, 6, 7, Current Status as of 10/1/90*, Drawing No. JS-090-094-C30.

Warren, R.G., Los Alamos National Laboratory, 26 July, 1994. Letter to F.M. Byers, USGS.

Winograd, I.J. and W. Thordarson, 1975, *Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site*, U.S. Geological Survey Professional Paper 712-C, Washington, DC.

Appendix A

Drilling Construction and Completion Data

A-1 List of Records of Verbal Communication for Well ER-3-2

A-2 Drilling Parameter Log

A-3 Casing and Tubing Data for Well ER-3-2

A-4 Well ER-3-2 Drilling Fluids and Cement Composition

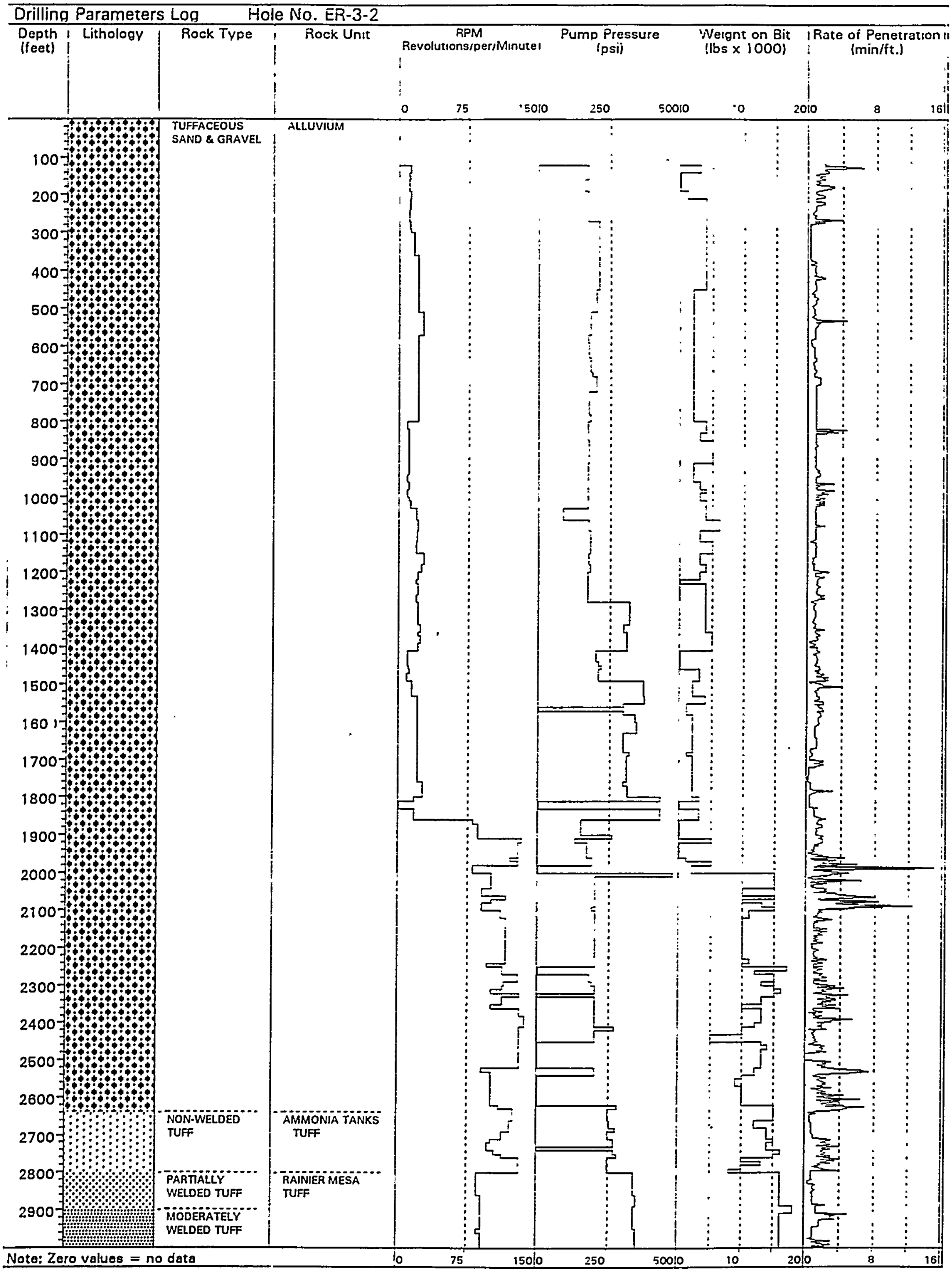
Appendix A-1

List of Records of Verbal Communication for Well ER-3-2

Appendix A-1
Raytheon Services Nevada, Record of Verbal Communications (RVC) Applicable to Well ER-3-2 Drilling and Completion

RVC#	Date	Subject
RVC-0348	01/06/94	Revision to Drilling Program for Underground Test Area (UGTA) Well ER-3-2: Use of Davis Mix Below Water Level
RVC-0349	01/10/94	Revision to Drilling Program for UGTA Well ER-3-2: Revise Moyno®
RVC-0351	01/19/94	Revision to Drilling Program for UGTA Well ER-3-2: Water Well A Revisions
RVC-0352	01/25/94	Revision to Drilling Program for UGTA Well ER-3-2: Fill Actions
RVC-0353	01/26/94	Revision to Drilling Program for UGTA Well ER-3-2: Cleanout
RVC-0354	01/27/94	Revision to Drilling Program for UGTA Well ER-3-2: Second Cementing
RVC-0355	01/28/94	Revision to Drilling Program for UGTA Well ER-3-2: Plan for Drilling Below Depth of 1,848 feet
RVC-0357	02/02/94	Revision to Drilling Program for UGTA Well ER-3-2: Cease Lithium Bromide Analysis
RVC-0358	02/10/94	Revision to Drilling Program for UGTA Well ER-3-2: Piezometer Settings
RVC-0359	02/14/94	Revision to Drilling Program for UGTA Well ER-3-2: Third Piezometer String
RVC-0360	02/16/94	Revision to Drilling Program for UGTA Well ER-3-2: Change in Gravel Brand
RVC-0361	02/17/94	Revision to Drilling Program for UGTA Well ER-3-2: Air-Lift Clean #1 and #2
L-94-055	02/01/94	Logging at Well ER-3-2

Appendix A-2
Drilling Parameter Log



Drilling Parameters Log
Hole No. ER-3-2
Depth (feet)
Lithology
Rock Type
Rock Unit
RPM Revolutions/per/Minute
Pump Pressure (psi)
Weight on Bit (lbs x 1000)
Rate of Penetration (min/ft.)
TUFFACEOUS SAND & GRAVEL
ALLUVIUM
NON-WELDED TUFF
AMMONIA TANKS TUFF
PARTIALLY WELDED TUFF
RAINIER MESA TUFF
MODERATELY WELDED TUFF
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
0
75
150
250
500
10
20
8
16
Note: Zero values = no data

Appendix A-3
Casing and Tubing Data for Well ER-3-2

Appendix A-3
Casing and Tubing Data for Well ER-3-2

Casing	Depth Interval meters (feet)	Type	Grade	Outside Diameter (inches)	Inside Diameter centimeters (inches)	Wall Thickness centimeters (inches)	Weight per foot (pound/foot)
Surface Casing	0 to 35.4 (0 to 116)	Carbon Steel	K-55	20	49.5 (19.5)	0.64 (0.250)	52.73
Tubing							
Piezometer #1	0 to 457.4 (0 to 1,501)	Carbon Steel Hydril®	Range 2	2-7/8	6.2 (2.441)	0.55 (0.217)	6.5
Piezometer #1	457.4 to 859.9 (1,501 to 2,938)	Stainless Steel	304 L	2-7/8	5.9 (2.323)	0.70 (0.276)	7.66
Piezometer #2	0 to 456.1 (0 to 1,496.5)	Carbon Steel Hydril®	Range 2	2-7/8	6.2 (2.441)	0.55 (0.217)	6.5
Piezometer #2	456.1 to 773.7 (1,496.5 to 2,538.3	Stainless Steel	304 L	2-7/8	5.9 (2.323)	0.70 (0.276)	7.66
Piezometer #3	0 to 542.5 (0 to 1,779.4)	Carbon Steel Hydril®	L-80	1.9	3.8 (1.5)	0.51 (0.20)	2.9

Appendix A-4

Well ER-3-2 Drilling Fluids and Cement Composition

Appendix A-4
Well ER-3-2 Drilling Fluids and Cement Composition

Drilling Fluid Name m^3 [a] (bbl)[b]	#3 Davis Mix (Air Foam) m^3 (gal)[c] kg[d] (lb)[e]	#5 Davis Mix (Air Foam) m^3 (gal) kg (lb)	#8 High Vis Mud (Bentonite) kg (lb)	#10 Polymer (Air Foam) kg (lb)	Sepiolite Mud (Sepiolite) kg (lb)
Mixtures 19.1 (120) per load[f]	0.22 (58) detergent 907 kg (2,000 lb) bentonite 110 kg (50 lb) guar gum	0.53 (140) detergent 1,814 kg (4,000 lb) bentonite 221 kg (100 lb) guar gum	1,964 (4,330)	13.6 (30) Baroid[g] EZ-Mud DP® air foam to suit conditions	1,818 (4,000)
Cement Composition	Type II Portland cement with two- percent calcium chloride				

[a]Cubic meter
[b]Barrel
[c]Gallon
[d]Kilogram
[e]Pound
[f]All water used to mix drilling fluids for Well ER-3-2 came from Water Well #4
[g]EZ-Mud DP® is a product of Baroid Drilling Fluids, Inc.

NOTES:

1. Soda Ash (sodium carbonate [Na_2CO_3]) was included in the first 114.6 m^3 (720 bbl) of air foam mixed.
2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of 20 to 40 milligrams per liter.

Appendix B

Well ER-3-2 Fluid Management Status Report

ER Fluid Disposition Status Reporting Form

Site Identification:	ER-3-2	Report Date:	
Site Location:	Area 3, NTS	DOE/NV Project Manager:	S. Lawrence
Site Coordinates:	N833,111.6, E684,014.8 feet	IT Project Manager:	M. Hampton
Well Classification:	New Deep Water-Level Well	IT Site Representative:	G. Mullenmeister
IT Project No.:	301957.09030000	IT Waste Coordinator:	T. Maize

Well Construction Activity	Activity Duration		No. Operation Days (A)	Well Depth meters (m)	Import Fluids cubic meters (m^3)	Lined Sump		Fluid Quality Objectives Met
	From	To				Solids m^3 (B)	Fluids m^3	
Stage I: Unsaturated Zone Drilling	01/06/94	01/24/94	3	489	516	60 (C)	383	Yes
Stage II: Saturated Zone Drilling	01/25/94	02/08/94	11	915	3,311	43 (D)	893	Yes
Stage III: Initial Well Development	NA (E)	NA	NA	NA	NA	NA	NA	NA
Stage IV: Aquifer Testing	NA	NA	NA	NA	NA	NA	NA	NA
Stage V: Well Completion and Final Development/ Testing	02/10/94	02/22/94 (F)	7	915	0	0	1.4	NA
Cumulative Production Totals			21	915	3,827	103	1,277	NA

(A) Operational days refer to the number of days that the drill rig was in operation during at least part of one shift.
(B) Solids volume estimates derived from hole volume determined from caliper logs. Estimates include 30 percent added volume attributed to interstitial spaces.
(C) Includes drilled-out cement.
(D) Includes material from sloughing zones
(E) Not Applicable
(F) Data from activities after this date will be reported in a separate document.
Total Sump Capacity = 1,455 m^3 (51,370 ft^3)
Remaining Sump Capacity (Approximate) as of 06/01/94 = 480 m^3 (16,860 ft^3) (33%)

IT Authorizing Signature/Date: Michael D. O'Hagan 12.20.95

Table B-1
Well ER-3-2 Fluid Management Chemistry - Unsaturated Zone Drilling
(Page 1 of 4)

				Anions/Other Parameters				Total Metals				
Parameter				F	pH	TDS	Br	As	Ba	Cd	Cr	Cu
Fluid Quality Objectives				20	2-12	NA[a]	NA	0.5	10	0.1	0.5	10
Date	Sample ID	Type	Matrix	mg/ℓ[b]	std units	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
UNSATURATED ZONE DRILLING (STAGE I)												
01/06/94	GCP00193	FMS-DL[c,d]	Fluid	1.1	8.05	303	--	0.20	0.36	ND[e]	0.017	0.028
01/06/94	GCP00194	QCS-DL[f]	Fluid	--[g]	--	--	--	--	--	--	--	--
01/06/94	GCP00195	QCS-BT[h]	Fluid	--	--	--	--	--	--	--	--	--
01/06/94	GCP00196	FMS-DL	Fluid	--	--	--	--	--	--	--	--	--
01/06/94	GCP00197	QCS-BT	Fluid	--	--	--	--	--	--	--	--	--
01/06/94	GCP00198	FMS-DL	Fluid	--	--	--	--	--	--	--	--	--
01/07/94	GCP00199	QCS-BT	Fluid	--	--	--	--	--	--	--	--	--
01/07/94	GCP00200	FMS-DL	Fluid	--	--	--	--	--	--	--	--	--
01/07/94	GCP00201	QCS-BT	Fluid	--	--	--	--	--	--	--	--	--
01/07/94	GCP00202	FMS-DL	Fluid	--	--	--	--	--	--	--	--	--
01/07/94	GCP00203	QCS-BT	Fluid	--	--	--	--	--	--	--	--	--
01/07/94	GCP00204	FMS-DL	Fluid	--	--	--	--	--	--	--	--	--
01/11/94	GCP00205	FMS-SP[i]	Fluid	0.91	8.60	1,616.2	--	0.14	0.53	ND	<0.016	0.036
01/24/94	GCP00206A	FMS-DL	Fluid	0.74[j]	11.8[j]	1,800[j]	--	ND[j]	0.32[j]	ND[j]	0.29[j]	0.039[j]
01/26/94	GCP00206B	FMS-DL	Fluid									
01/24/94	GCP00208	QCS-DL	Fluid	--	--	--	--	--	--	--	--	--

Refer to footnotes at end of table.

Table B-1
Well ER-3-2 Fluid Management Chemistry - Unsaturated Zone Drilling
(Page 2 of 4)

				Total Metals					Radiation Chemistry		
Parameter				Hg	Pb	Se	Ag	Zn	U-238	U-235	U-234
Fluid Quality Objectives				0.02	0.5	0.1	0.5	50	NA	NA	NA
Date	Sample ID	Type	Matrix	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	pCi/ℓ[k]	pCi/ℓ	pCi/ℓ
UNSATURATED ZONE DRILLING (STAGE I)											
01/06/94	GCP00193	FMS-DL	Fluid	0.00058	<0.12	<0.0014	ND	0.093	- -	- -	- -
01/06/94	GCP00194	QCS-DL	Fluid	- -	- -	- -	- -	- -	- -	- -	- -
01/06/94	GCP00195	QCS-BT	Fluid	- -	- -	- -	- -	- -	138 ± 20.3	39.9 ± 8.54	176 ± 24.6
01/06/94	GCP00196	FMS-DL	Fluid	- -	- -	- -	- -	- -	45.2 ± 6.51	3.00 ± 1.43	48.9 ± 6.85
01/06/94	GCP00197	QCS-BT	Fluid	- -	- -	- -	- -	- -	198 ± 22.4	8.60 ± 2.93	185 ± 21.3
01/06/94	GCP00198	FMS-DL	Fluid	- -	- -	- -	- -	- -	560 ± 54.9	125 ± 15.5	621 ± 60.9
01/07/94	GCP00199	QCS-BT	Fluid	- -	-	- -	- -	- -	112 ± 18.3	21.7 ± 6.23	153 ± 23.1
01/07/94	GCP00200	FMS-DL	Fluid	- -	- -	- -	- -	- -	597 ± 174	23.6 ± 15.0	631 ± 183
01/07/94	GCP00201	QCS-BT	Fluid	- -	- -	- -	- -	- -	159 ± 23.1	8.71 ± 3.61	169 ± 24.2
01/07/94	GCP00202	FMS-DL	Fluid	- -	- -	- -	- -	- -	215 ± 22.8	6.70 ± 2.44	217 ± 23.0
01/07/94	GCP00203	QCS-BT	Fluid	- -	- -	- -	- -	- -	130 ± 14.8	4.12 ± 1.83	129 ± 14.7
01/07/94	GCP00204	FMS-DL	Fluid	- -	- -	- -	- -	- -	626 ± 60.7	24.4 ± 5.20	611 ± 59.3
01/11/94	GCP00205	FMS-SP	Fluid	<0.00043	ND	0.0036	ND	0.10	- -	- -	- -
01/24/94	GCP00206A	FMS-DL	Fluid						- -	- -	- -
01/26/94	GCP00206B	FMS-DL	Fluid	ND[j]	ND[j]	0.0016[j]	ND[j]	0.012[j]	- -	- -	- -
01/24/94	GCP00208	QCS-DL	Fluid	- -	- -	- -	- -	- -	- -	- -	- -

Refer to footnotes at end of table

Table B-1
Well ER-3-2 Fluid Management Chemistry - Unsaturated Zone Drilling
(Page 3 of 4)

				Radiation Chemistry								
Parameter				Strontium 89	Strontium 90	Gross-A	Uncertainty	Gross-B	Uncertainty	H3	Uncertainty	Field
Fluid Quality Objectives (pCi/ℓ)				NA	NA	15	±	50	±	20,000	±	20,000
Date	Sample ID	Type	Matrix	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ
UNSATURATED ZONE DRILLING (STAGE I)												
01/06/94	GCP00193	FMS-DL	Fluid	--	--	3.97	1.04	7.25	1.73	--	--	--
01/06/94	GCP00194	QCS-DL	Fluid	--	--	--	--	--	--	-5.66	457	--
01/06/94	GCP00195	QCS-BT	Fluid	87.2 ± 63.4	(-)17.2 ± 26.3	--	--	--	--	--	--	--
01/06/94	GCP00196	FMS-DL	Fluid	61.4 ± 53.1	7.13 ± 24.1	--	--	--	--	--	--	--
01/06/94	GCP00197	QCS-BT	Fluid	218 ± 89.2	(-)53.1 ± 34.1	--	--	--	--	--	--	--
01/06/94	GCP00198	FMS-DL	Fluid	170 ± 89.3	(-)9.84 ± 37.2	--	--	--	--	--	--	--
01/07/94	GCP00199	QCS-BT	Fluid	15.3 ± 55.2	21.5 ± 24.7	--	--	--	--	--	--	-
01/07/94	GCP00200	FMS-DL	Fluid	176 ± 93.3	(-)13.1 ± 37.9	--	--	--	--	--	--	--
01/07/94	GCP00201	QCS-BT	Fluid	222 ± 113	(-)15.0 ± 47.7	--	--	--	--	--	--	--
01/07/94	GCP00202	FMS-DL	Fluid	253 ± 123	(-)71.2 ± 46.9	--	--	--	--	--	--	--
01/07/94	GCP00203	QCS-BT	Fluid	72.8 ± 56.4	(-)1.18 ± 24.1	--	--	--	--	--	--	--
01/07/94	GCP00204	FMS-DL	Fluid	205 ± 146	(-)5.96 ± 63.8	--	--	--	--	--	--	--
01/11/94	GCP00205	FMS-SP	Fluid	--	--	11.8	1.49	15.3	1.64	--	--	--
01/24/94	GCP00206A	FMS-DL	Fluid	--	--	3.89	0.969	78.0	2.73	--	--	--
01/26/94	GCP00206B	FMS-DL	Fluid	--	--	1.02	0.629	51.4	2.31	--	--	--
01/24/94	GCP00208	QCS-DL	Fluid	--	--	--	--	--	--	1,920	501	--

Refer to footnotes at end of table.

Table B-1
Well ER-3-2 Fluid Management Chemistry - Unsaturated Zone Drilling
(Page 4 of 4)

				Radiation Chemistry-Gamma Spectrometry							
Parameter				Tl-208	Ac-228	Bi-212	Pb-212	Bi-214	Pb-214	K-40	U-238
Fluid Quality Objectives				NA	NA	NA	NA	NA	NA	NA	NA
Date	Sample ID	Type	Matrix	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ
UNSATURATED ZONE DRILLING (STAGE I)											
01/06/94	GCP00193	FMS-DL	Fluid	--	--	--	--	--	--	--	--
01/06/94	GCP00194	QCS-DL	Fluid	--	--	--	--	--	--	--	--
01/06/94	GCP00195	QCS-BT	Fluid	33.8 ± 19.0	111 ± 66.0	ND	100 ± 31.7	466 ± 197	538 ± 212	ND	561 ± 254
01/06/94	GCP00196	FMS-DL	Fluid	158 ± 31.6	468 ± 107	479 ± 302	607 ± 77.7	1,410 ± 317	1,650 ± 337	6,600 ± 785	353 ± 258
01/06/94	GCP00197	QCS-BT	Fluid	36.1 ± 18.8	118 ± 64.8	ND	125 ± 35.5	650 ± 235	673 ± 255	ND	ND
01/06/94	GCP00198	FMS-DL	Fluid	229 ± 46.3	798 ± 164	753 ± 431	914 ± 112	2,740 ± 584	3,130 ± 617	12,700 ± 1420	529 ± 359
01/07/94	GCP00199	QCS-BT	Fluid	32 1 ± 22.1	167 ± 55.9	ND	101 ± 40.0	327 ± 220	331 ± 211	ND	ND
01/07/94	GCP00200	FMS-DL	Fluid	299 ± 48.7	885 ± 148	989 ± 360	1,070 ± 126	2,530 ± 460	3,100 ± 505	14,300 ± 1470	ND
01/07/94	GCP00201	QCS-BT	Fluid	37.6 ± 20.3	138 ± 52.9	194 ± 169	126 ± 39.4	630 ± 260	655 ± 268	ND	ND
01/07/94	GCP00202	FMS-DL	Fluid	162 ± 34.3	526 ± 106	533 ± 279	628 ± 83.5	2,050 ± 449	2,660 ± 505	5,380 ± 721	ND
01/07/94	GCP00203	QCS-BT	Fluid	28.3 ± 17.3	89.2 ± 59.1	217 ± 173	89.8 ± 33.8	328 ± 201	456 ± 192	232 ± 171	488 ± 681
01/07/94	GCP00204	FMS-DL	Fluid	323 ± 43.9	905 ± 134	1,230 ± 330	1,150 ± 118	4,110 ± 534	4,190 ± 524	13,600 ± 1,310	ND
01/11/94	GCP00205	FMS-SP	Fluid	--	--	--	--	--	--	--	--
01/24/94	GCP00206A	FMS-DL	Fluid	--	--	--	--	--	--	--	--
01/26/94	GCP00206B	FMS-DL	Fluid	--	--	--	--	--	--	--	--
01/24/94	GCP00208	QCS-DL	Fluid	--	--	--	--	--	--	--	--

[a]Not Applicable
[b]Milligram per liter
[c]Fluid Management Sample
[d]Discharge Line
[e]Not Detected
[f]Quality Control Sample
[g]Not Analyzed
[h]Baker Tank
[i]Sump Pit
[j]Daily samples GCP00206A and GCP00206B were composited into a weekly sample
[k]Picocurie per liter

Table B-2
Well ER-3-2 Fluid Management Chemistry - Saturated Zone Drilling and Completion
(Page 1 of 4)

				Anions/Other Parameters				Total Metals				
Parameter				**F**	**pH**	**TDS**	**Br**	**As**	**Ba**	**Cd**	**Cr**	**Cu**
Fluid Quality Objectives				20	2-12	NA[a]	NA	0.5	10	0.1	0.5	10
Date	**Sample ID**	**Type**	**Matrix**	mg/ℓ[b]	std units	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
SATURATED ZONE DRILLING (STAGE II)												
01/25/94	GCP00207	FMS-SP[c,d]	Fluid	0.74	8.08	1,900	--[e]	ND[f]	0.17	ND	0.018	0.030
01/26/94	GCP00209	QCS-DL[g,h]	Fluid	--	--	--	--	--	--	--	--	--
01/28/94	GCP00210	QCS-PM[i]	Cuttings	--	--	--	--	ND	0.63	ND	<0.016	--
01/31/94	GCP00215	FMS-DL	Fluid	0.61	8.67	412	--	ND	0.26	ND	0.068	0.020
02/01/94	GCP00216	QCS-PM	Cuttings	--	--	--	--	ND	0.61	ND	ND	--
02/01/94	GCP00217	QCS-PM	Cuttings	--	--	--	--	ND	0.49	ND	ND	--
WELL COMPLETION/DEVELOPMENT (STAGE V)												
02/14/94	GCP00218	QCS-BT[j]	Water	0.79	8.00	510	--	ND	0.018	ND	ND	0.0090
02/14/94	GCP00219	QCS-BT	Water	--	--	--	--	--	--	--	--	--
02/14/94	GCP00220	QCS-BT	Water	--	--	--	22	--	--	--	--	--
02/17/94	GCP00221	FMS-DL	Fluid	3.0	11.6	810	--	0.21	0.27	<0.014	0.15	0.066
02/22/94	GCP00222	FMS-DL	Fluid	<1.0	10.8	1,100	--	ND	0.051	<0.014	0.018	0.066
02/22/94	GCP00223	QCS-DL	Fluid	--	--	--	--	--	--	--	--	--

Refer to footnotes at end of table.

Table B-2
Well ER-3-2 Fluid Management Chemistry - Saturated Zone Drilling and Completion
(Page 2 of 4)

				Total Metals					Radiation Chemistry		
Parameter				Hg	Pb	Se	Ag	Zn	U-238	U-235	U-234
Fluid Quality Objectives				0.02	0 5	0.1	0.5	50	NA	NA	NA
Date	Sample ID	Type	Matrix	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	pCi/ℓ[k]	pCi/ℓ	pCi/ℓ
SATURATED ZONE DRILLING (STAGE II)											
01/25/94	GCP00207	FMS-SP	Fluid	ND	ND	0.0022	ND	0.017	--	--	--
01/26/94	GCP00209	QCS-DL	Fluid	--	--	--	--	--	--	--	--
01/28/94	GCP00210	QCS-PM	Cuttings	ND	ND	ND	ND	--	--	--	--
01/31/94	GCP00215	FMS-DL	Fluid	ND	ND	<0.0014	ND	0.0079	--	--	--
02/01/94	GCP00216	QCS-PM	Cuttings	ND	ND	ND	ND	--	--	--	--
02/01/94	GCP00217	QCS-PM	Cuttings	ND	ND	ND	ND	--	--	--	--
WELL COMPLETION/DEVELOPMENT (STAGE V)											
02/14/94	GCP00218	QCS-BT	Water	ND	ND	ND	ND	0.011	--		--
02/14/94	GCP00219	QCS-BT	Water	--	--	--	--	--	--	--	--
02/14/94	GCP00220	QCS-BT	Water	--	--	--	--	--	--	--	--
02/17/94	GCP00221	FMS-DL	Fluid	ND	0.20	ND	ND	1.6	--	--	--
02/22/94	GCP00222	FMS-DL	Fluid	ND	ND	<0.0014	ND	0.23	--	--	--
02/22/94	GCP00223	QCS-DL	Fluid	--	--	--	--	--	--	--	--

Refer to footnotes at end of table.

Table B-2
Well ER-3-2 Fluid Management Chemistry - Saturated Zone Drilling and Completion
(Page 3 of 4)

Parameter				Radiation Chemistry								
				Strontium 89	Strontium 90	Gross-A	Uncertainty	Gross-B	Uncertainty	H3	Uncertainty	Field
Fluid Quality Objectives (pCi/ℓ)				NA	NA	15	±	50	±	20,000	±	20,000
Date	Sample ID	Type	Matrix	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ
SATURATED ZONE DRILLING (STAGE II)												
01/25/94	GCP00207	FMS-SP	Fluid	- -	- -	0.00949	0.00151	0.0161	0.00166	- -	- -	- -
01/26/94	GCP00209	QCS-DL	Fluid	- -	- -	- -	- -	- -	- -	244	461	- -
01/28/94	GCP00210	QCS-PM	Cuttings	- -	- -	0.0973	0.0156	0.0422	0.00730	- -	- -	- -
01/31/94	GCP00215	FMS-DL	Fluid	-	- -	1.22	0.727	18.8	1.64	- -	- -	- -
02/01/94	GCP00216	QCS-PM	Cuttings	- -	- -	0.150	0.0839	0.0667	0.0615	- -	- -	- -
02/01/94	GCP00217	QCS-PM	Cuttings	- -	- -	0.0654	0.101	-0.0125	0.0869	- -	- -	- -
WELL COMPLETION/DEVELOPMENT (STAGE V)												
02/14/94	GCP00218	QCS-BT	Water	- -	- -	5.49	1.10	7.47	1.38	- -	- -	- -
02/14/94	GCP00219	QCS-BT	Water	- -	- -	- -	- -	- -	- -	285	447	2,028
02/14/94	GCP00220	QCS-BT	Water	- -	- -	- -	- -	- -	- -	- -	- -	.
02/17/94	GCP00221	FMS-DL	Fluid	- -	- -	0.206	0.713	15.4	1.59	- -	- -	1,120
02/22/94	GCP00222	FMS-DL	Fluid	- -	- -	0.00431	0.422	11.4	1.48	- -	- -	- -
02/22/94	GCP00223	QCS-DL	Fluid	- -	- -	- -	- -	- -	- -	438	451	1,080

Refer to footnotes at end of table

Table B-2
Well ER-3-2 Fluid Management Chemistry - Saturated Zone Drilling and Completion
(Page 4 of 4)

				Radiation Chemistry-Gamma Spectrometry							
Parameter				Tl-208	Ac-228	Bi-212	Pb-212	Bi-214	Pb-214	K-40	U-238
Fluid Quality Objectives				NA	NA	NA	NA	NA	NA	NA	NA
Date	Sample ID	Type	Matrix	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ	pCi/ℓ
SATURATED ZONE DRILLING (STAGE II)											
01/25/94	GCP00207	FMS-SP	Fluid	--	--	--	--	--	-	--	--
01/26/94	GCP00209	QCS-DL	Fluid	--	--	--	--	--	--	--	--
01/28/94	GCP00210	QCS-PM	Cuttings	--	--	--	--	--	--	--	--
01/31/94	GCP00215	FMS-DL	Fluid	-	--	--	--	--	--	--	--
02/01/94	GCP00216	QCS-PM	Cuttings	-	--	--	--	--	--	--	--
02/01/94	GCP00217	QCS-PM	Cuttings	-	--	--	--	--	--	--	--
WELL COMPLETION/DEVELOPMENT (STAGE V)											
02/14/94	GCP00218	QCS-BT	Water	--	-	--	--	--	--	--	--
02/14/94	GCP00219	QCS-BT	Water		--	--	--	--	--	--	--
02/14/94	GCP00220	QCS-BT	Water	-	--	--	--	--	--	--	--
02/17/94	GCP00221	FMS-DL	Fluid	-	--	--	--	--	-	--	--
02/22/94	GCP00222	FMS-DL	Fluid	--	--	--	--	--	--	--	--
02/22/94	GCP00223	QCS-DL	Fluid	--	--	--	--	--	--	--	--

[a]Not Applicable
[b]Milligram per liter
[c]Fluid Management Sample
[d]Sump Pit
[e]Not Analyzed
[f]Not Detected
[g]Quality Control Sample
[h]Discharge Line
[i]Process Material
[j]Baker Tank
[k]Picocurie per liter
[l]Units in picocuries per gram

Appendix C
Stratigraphic and Lithologic Logs of Well ER-3-2

Stratigraphic Log of ER-3-2.
(Compiled by Lance Prothro, RSN, 24 April 1995)

Depth					Thickness	
Meters	Feet	Lithology	Stratigraphic Unit	Symbol	Meters	Feet
0 - 801.9	0 - 2631	**Sand, Gravelly Sand, and Sandy Gravel:** Fine sand to very coarse pebble gravel, poorly to moderately sorted.	Alluvium	QTa	801.9	2631
801.9 - 846.1	2631 - 2776	**Ash-Flow Tuff:** Nonwelded to partially welded, vitric.	Ammonia Tanks Tuff, Timber Mountain Group	Tma	44.2	145
846.1 - 851.9	2776 - 2795	**Bedded Tuff:** Vitric.	Bedded Ammonia Tanks Tuff, Timber Mountain Group	Tmab	5.8	19
851.9 - 914.4 TD	2795 - 3000 TD	**Ash-Flow Tuff:** Nonwelded to moderately welded, vitric to devitrified.	Rainier Mesa Tuff, Timber Mountain Group	Tmr	>62.5	>205

Lithologic Log of ER - 3 - 2

(Compiled by Lance Prothro, RSN, 12 April 1995)

Unless otherwise noted, the following descriptions refer to washed cuttings samples at 3.05 m (10 ft) intervals. The lithologic descriptions follow RSN Department Procedure NTS-GEO-003 and were compiled using the IT Corp. field sample descriptions. In addition, petrographic analysis, quantitative XRD analysis, and sample descriptions provided by R. G. Warren (LANL) were also used. Stratigraphic contacts and lithologic divisions are tied to geophysical logs whenever possible.

Depth Meters/(Feet)	Lithologic Description	Stratigraphic Unit
0 - 115.8 m (0 - 380 ft)	**Interbedded Sandy Gravel and Gravelly Sand**: Samples are unconsolidated mixtures of the coarser clasts that make up the alluvium. Samples are moderate-yellowish-brown in overall color; consist of varying amounts of medium to coarse sand and very fine to medium pebble gravel; poorly to moderately sorted; subangular to subrounded. Gravel and coarse sand fractions consist predominately of tuffaceous clasts and much less siltstone clasts. The smaller sandstone fraction consists of tuffaceous clasts and quartz and feldspar crystals. Samples indicate sandy gravel intervals at 39.6 - 51.8 m (130 - 170 ft), 73.2 - 85.3 m (240 - 280 ft), 91.4 - 100.6 m (300 - 330 ft), and 109.7 - 115.8 m (360 - 380 ft).	Alluvium

Depth Meters/(Feet)	Lithologic Description	Stratigraphic Unit
115.8 - 320.0 m (380 - 1050 ft)	**Sandy Gravel:** Samples are unconsolidated mixtures of the coarser clasts that make up the alluvium. Samples are moderate-yellowish-brown in overall color; consist predominately of fine to medium pebble gravel; moderately sorted; subangular to subrounded. Gravel consists predominately of tuffaceous clasts and lesser siltstone, carbonate, and argillite clasts. Fine pebble gravel dominates samples to 146.3 m (480 ft) becoming mostly medium pebble gravel below.	Alluvium
320.0 - 466.3 m (1050 - 1530 ft)	**Gravelly Sand:** Samples are unconsolidated mixtures of the coarser clasts that make up the alluvium. Samples are moderate-yellowish-brown in overall color; consist predominately of medium to very coarse sand and lesser very fine to fine pebble gravel; poorly to moderately sorted; subangular to subrounded. Sand and gravel consist predominately of tuffaceous clasts and lesser siltstone, carbonate, and argillite clasts. Quartz and feldspar crystals make up a portion of the smaller sand fraction. Samples and geophysical logs indicate minor interbedded sandy gravel to 368.8 m (1210 ft) and below 432.8 m (1420 ft).	Alluvium

Lithologic Log of ER - 3 - 2 (cont.)

Depth Meters/(Feet)	Lithologic Description	Stratigraphic Unit
466.3 - 533.4 m (1530 - 1750 ft)	**Sandy Gravel:** Samples are unconsolidated mixtures of the coarser clasts that make up the alluvium with very minor amounts of intact alluvium. Samples are moderate-yellowish-brown (based on intact fragments of alluvium); consist predominately of very fine to medium pebble gravel increasing in size to coarse pebble gravel near base; moderately sorted, becoming poorly sorted near base; subangular to subrounded. Clasts are mostly tuffaceous with lesser siltstone, carbonate, and sedimentary breccia. Intact fragments of alluvium are moderately cemented with calcite.	Alluvium
533.4 - 588.0 m (1750 - 1929 ft)	**Sandy Gravel:** Samples are unconsolidated mixtures of the coarser clasts that make up the alluvium with minor amounts of intact alluvium. Samples are moderate-yellowish-brown (based on intact fragments of alluvium); consist predominately of fine to very coarse pebble gravel (very coarse pebble gravel is conspicuous); poorly sorted; subangular to subrounded. Gravel consists predominately of tuffaceous clasts with lesser sedimentary clasts representing a variety of lithologies. Intact fragments of alluvium are moderately cemented with calcite.	Alluvium

Lithologic Log of ER - 3 - 2 (cont.)

Depth Meters/(Feet)	Lithologic Description	Stratigraphic Unit
588.0 - 801.9 m (1929 - 2631 ft)	**Sand:** Description is based on percussion gun sidewall core samples. Samples are predominately moderate-yellowish-brown; tuffaceous; mostly vitric, commonly zeolitic, as well as argillaceous and silicified in part; fine to medium sand; moderately sorted; subangular to subrounded; consisting predominately of tuffaceous rock and pumice clasts, quartz and feldspar crystals, and lesser mafic minerals; minor cross-bedded laminae.	Alluvium
801.9 - 837.3 m (2631 - 2747 ft)	**Partially Welded Ash-Flow Tuff:** Description is based on percussion gun sidewall core samples. Moderate-yellowish-brown to approximately 807.7 m (2650 ft) becoming dark-yellowish-brown below; vitric; common very-light-gray and lesser dark-yellowish-orange pumice to approximately 807.7 m (2650 ft) becoming minor in abundance and moderate-brown (5YR 4/4) in color below; common felsic phenocrysts of feldspar and lesser quartz; rare mafic minerals of clinopyroxene and hornblende, and lesser biotite; rare lithic fragments; trace of sphene; conspicuous black glass shards. Tuff/Alluvium contact determined from sidewall core samples and gamma ray log #13.	Mafic-poor Ammonia Tanks Tuff, Timber Mountain Group

Depth Meters/(Feet)	Lithologic Description	Stratigraphic Unit
837.3 - 846.1 m (2747 - 2776 ft)	**Nonwelded Ash-Flow Tuff:** Description is based on percussion gun sidewall core samples. Very-pale-orange; vitric; rare to common white pumice; common to abundant felsic phenocrysts of feldspar and lesser quartz; rare tiny mafic minerals of clinopyroxene, hornblende, and lesser biotite; rare lithic fragments.	Mafic-poor Ammonia Tanks Tuff, Timber Mountain Group
846.1 - 851.9 m (2776 - 2795 ft)	**Bedded Tuff:** Description is based on percussion gun sidewall core samples. Pale- to moderate-yellowish-brown; vitric; rare to common white pumice; common to abundant felsic phenocrysts of feldspar and lesser quartz; rare tiny mafic minerals of clinopyroxene, hornblende, and lesser biotite; rare lithic fragments.	Bedded Ammonia Tanks Tuff, Timber Mountain Group
851.9 - 877.2 m (2795 - 2878 ft)	**Nonwelded to Partially Welded Ash-Flow Tuff:** Description is based on percussion gun sidewall core samples. Grayish-orange-pink; vitric, zeolitic in part; rare white pumice; common felsic phenocrysts of feldspar and lesser but conspicuous quartz; common mafic minerals of biotite and lesser clinopyroxene and hornblende; rare lithic fragments.	Mafic-rich Rainier Mesa Tuff, Timber Mountain Group

Depth Meters/(Feet)	Lithologic Description	Stratigraphic Unit
877.2 - 897.9 m (2878 - 2946 ft)	**Moderately Welded Ash-Flow Tuff:** Description is based on percussion gun sidewall core samples. Pale-yellowish-brown; devitrified; common white pumice; rare to common felsic phenocrysts of feldspar and lesser quartz; rare to common mafic minerals of large biotite and much less clinopyroxene; rare lithic fragments.	Mafic-rich Rainier Mesa Tuff, Timber Mountain Group
897.9 - 914.4 m (2946 - 3000 ft) TD	**Moderately Welded Ash-Flow Tuff:** Description is based on percussion gun sidewall core samples. Grayish-pink; devitrified; minor pale-red pumice; rare to common felsic phenocrysts of feldspar and quartz; rare biotite; trace lithic fragments.	Mafic-poor Rainier Mesa Tuff, Timber Mountain Group

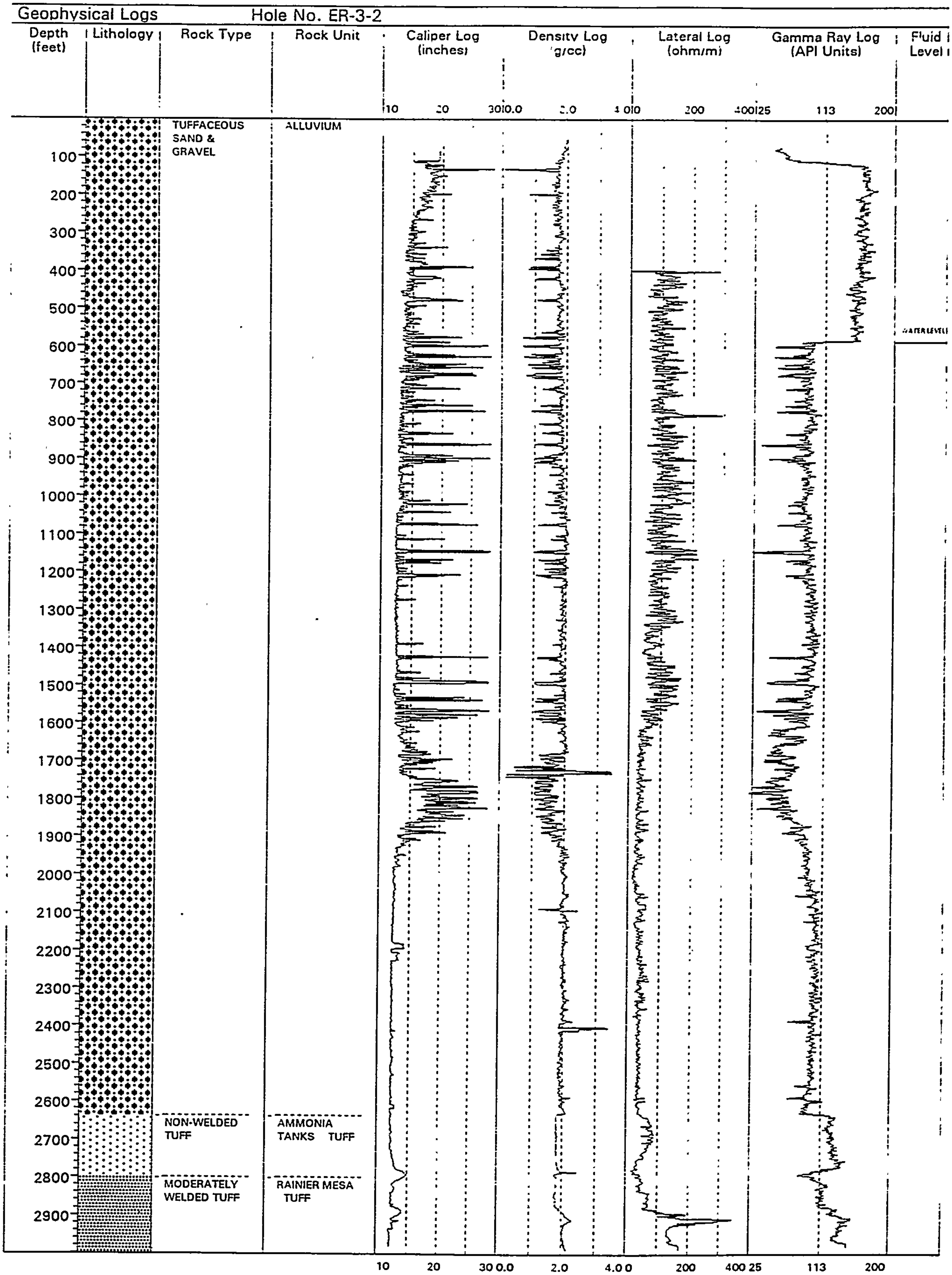
Appendix D
Selected Geophysical Logs

Appendix D is a composite of geophysical logs run at Well ER-3-2 sampled at one-foot intervals. Table D-1 provides information on each composite.

Table D-1
Geophysical Logs

Geophysical Log Type	Date Logged	Run No.	Log Interval (feet BGS)[a]	Composite Interval (feet BGS)
Caliper/Gamma Ray	02/08/94	CA6-7/GR-13	72 to 2,982	NA[b]
Density Log	02/01/94	CDL-1/GR-6	52 to 2,090	52 to 2,090
	02/03/94	CDL-2/GR-9	1,782 to 2,401	2,091 to 2,401
	02/04/94	CDL-3/GR-10	2,293 to 2,781	2,402 to 2,781
	02/08/94	CDL-4/GR-14	2,989 to 2,588	2,782 to 2,989
Lateral Log	02/01/94	DLL-1/GR-5	350 to 2,088	350 to 2,080
	02/08/94	DLL-4/GR-15	2,991 to 1,583	2,081 to 2,991
Spectral Logs	02/07/94	SGR-1	2,248 to 2,780	2,248 to 2,780
	02/08/94	SGR-2	2,750 to 2,992	2,781 to 2,992

[a]Feet below ground surface
[b]No composite performed


Geophysical Logs
Hole No. ER-3-2
Depth (feet)
Lithology
Rock Type
Rock Unit
Caliper Log (inches)
Density Log (g/cc)
Lateral Log (ohm/m)
Gamma Ray Log (API Units)
Fluid Level
TUFFACEOUS SAND & GRAVEL
ALLUVIUM
NON-WELDED TUFF
AMMONIA TANKS TUFF
MODERATELY WELDED TUFF
RAINIER MESA TUFF
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
10
20
30
0.0
2.0
4.0
0
200
400
25
113
200

Distribution List

	Copies
DOE/Nevada Operations Office Technical Information Resource Center P. O. Box 98518 Las Vegas, NV 89193-8518	1
U.S. Department of Energy Office of Scientific and Technical Information 175 Oak Ridge Turnpike Post Office Box 62 Oak Ridge, Tennessee 37831	2