Nevada
Environmental
Management
Operations Activity

DOE/NV--1549

National Nuclear Security Administration

Completion Report for Well ER-20-12

Corrective Action Units 101 and 102: Central and Western Pahute Mesa

Revision No.: 0

August 2016

UNCLASSIFIED

/s/ Joseph P. Johnston 08/11/2016

Joseph P. Johnston, Navarro CO Date

Approved for public release; further dissemination unlimited.

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

Available for sale to the public from:

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312
Telephone: 800.553.6847
Fax: 703.605.6900
E-mail: orders@ntis.gov
Online Ordering: http://www.ntis.gov/help/ordermethods.aspx

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
Phone: 865.576.8401
Fax: 865.576.5728
Email: reports@adonis.osti.gov

DOE/NV--1549

COMPLETION REPORT FOR WELL ER-20-12

CORRECTIVE ACTION UNITS 101 AND 102: CENTRAL AND WESTERN PAHUTE MESA

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

Prepared by:
Underground Test Area Activity
Navarro
Las Vegas, Nevada

Revision No.: 0

August 2016

COMPLETION REPORT FOR WELL ER-20-12

CORRECTIVE ACTION UNITS 101 AND 102:
CENTRAL AND WESTERN PAHUTE MESA

Approved by: /s/ Wilhelm R. Wilborn Date: 08/11/2016

Wilhelm R. Wilborn
Underground Test Area Activity Lead

Approved by: /s/ Wilhelm R. Wilborn Date: 08/11/2016

for Robert F. Boehlecke
Environmental Management Operations Manager

Abstract

Well ER-20-12 was drilled for the U.S. Department of Energy, Nevada National Security Administration Nevada Field Office in support of the Underground Test Area Activity. The well was drilled from October 2015 to January 2016 as an addition to the Central and Western Pahute Mesa corrective action units 101 and 102 the Phase II drilling program. Well ER-20-12 was identified based on recommendations of the Pahute Mesa Guidance Team as a result of anomalous tritium detections in groundwater samples collected from Well PM-3 in 2011 and 2013. The primary purpose of the well was to provide information on the hydrogeology in the area downgradient of select underground tests on Western Pahute Mesa and define hydraulic properties in the saturated Tertiary volcanic rocks.

The main 46.99-centimeter (cm) (18.5-inch [in.]) borehole was drilled to a depth of 765.14 meters (m) (2,510.3 ft) and the hole opened to 66.04 cm (26 in.); followed by the 50.80-cm (20-in.) surface casing, which was installed and sealed with cement; and a piezometer (p4) was set in the Timber Mountain welded-tuff aquifer (TMWTA) between the casing and the open borehole. The borehole was continued with a 46.99-cm (18.5-in.) drill bit to a depth of 1,326.53 m (4,352.16 ft), and an intermediate 24.44-cm (9.625-in.) casing was installed and sealed to 1,188.72 m (3,900.00 ft) A piezometer (p3) was installed across the Calico Hills zeolitic composite unit (CHZCM) (lava-flow aquifer [LFA]) in the annulus of the open borehole. Two additional piezometers were installed and completed between the intermediate casing and the borehole wall, one (p2) in the CHZCM and one (p1) in the Belted Range aquifer (BRA). The piezometers are set to monitor groundwater properties in the completed intervals. The borehole was continued with a 21.59-cm (8.5-in.) drill bit to a total depth of 1,384.80 m (4,543.33 ft), and the main completion 13.97-cm (5.5-in.) casing was installed in the open borehole across the Pre-Belted Range composite unit (PBRCM).

Data collected during hole construction include composite drill cutting samples collected every 3.0 m (10 ft), geophysical logs, hydrophysical logs, percussion core samples, water-quality measurements (including tritium), and water-level measurements. The well penetrated 1,384.4 m (4,543.33 ft) of Tertiary volcanic rocks. The stratigraphy and lithology were generally as expected with one noted exception. A thick lava -flow and related ash-flow tuffs were identified as Calico Hills Formation (Th), and no Crater Flat units were noted. Additionally, many of the Thirsty Canyon and Timber Mountain units were thicker than expected.

Fluid levels measured in the borehole during drilling are the following: (1) on November 2, 2015, Navarro measured the fluid level in the borehole at a depth of 492.33 m (1,615.25 ft) below ground surface (bgs); (2) Schlumberger and COLOG recorded fluid levels during geophysical logging on November 4 and 5, 2015, at a depth of 492.86 m (1,617 ft) and 492.25 m (1,615 ft) bgs, respectively; and (3) on December 4, 2015, COLOG and Navarro measured fluid level in the 20-in. casing with an open borehole to 1,326.54 m (4,352.16 ft) bgs at 575.77 m (1,889.00 ft) and 574.03 m (1,883.3 ft) bgs, respectively. These and subsequent water-level measurements indicate a potential head difference of greater than 76.2 m (250 ft) for groundwater in aquifers above and below the Upper Paintbrush confining unit (UPCU).

As expected, tritium was occasionally measured above the *Safe Drinking Water Act* limit (20,000 picocuries per liter [pCi/L]). Lab analysis on four bailed samples and taken from the undeveloped well indicate that the tritium activities average approximately 36,545 pCi/L. All Fluid Management Plan (FMP) requirements for Well ER-20-12 were met. Analysis of monitoring samples and FMP confirmatory samples indicate that fluids generated during drilling at ER-20-12 met the FMP criteria for discharge to the lined sump and designated infiltration area. All sanitary and hydrocarbon waste generated was properly handled and disposed of.

Table of Contents

Table of Contents *(Continued)*

Table of Contents *(Continued)*

List of Figures

List of Figures *(Continued)*

Number	Title	Page

List of Figures *(Continued)*

Number	Title	Page

List of Tables

List of Tables *(Continued)*

Number	Title	Page

List of Acronyms and Abbreviations

General Acronyms and Abbreviations

amsl	Above mean sea level
AMT	Audio-magnetotelluric
API	American Petroleum Institute
ASTM	ASTM International
bbl	Barrel
bbl/hr	Barrels per hour
BCR	Baseline change request
bgs	Below ground surface
BHA	Bottom hole assembly
C	Carbon
$CaCO_3$	Calcium carbonate
CAIP	Corrective action investigation plan
CAU	Corrective action unit
CDFM	Corehole dynamic flowmeter
cfm	Cubic feet per minute
cm	Centimeter
cps	Counts per second
CS	Carbon steel
DOE	U.S. Department of Energy
DRI	Desert Research Institute
EC	Electrical conductivity
EERF	Eastern Environmental Radiation Facility
EPA	U.S. Environmental Protection Agency
e-tape	Electric tape
°F	Degree Fahrenheit

List of Acronyms and Abbreviations *(Continued)*

FAWP	Field activity work package
FFACO	*Federal Facility Agreement and Consent Order*
FMI	Formation microimager
FMP	Fluid management plan
ft	Foot
ft^3	Cubic foot
gal	Gallon
gpm	Gallons per minute
HASL	Health and Safety Laboratory
HCl	Hydrochloric acid
HFM	Hydrostratigraphic framework model
HGU	Hydrogeologic unit
HSU	Hydrostratigraphic unit
id	Inside diameter
ID	Identification
in.	Inch
K	Potassium
km	Kilometer
kt	Kiloton
L	Liter
LANL	Los Alamos National Laboratory
Lat	Latitude
lb	Pound
LLNL	Lawrence Livermore National Laboratory
Long	Longitude
Lpm	Liters per minute

List of Acronyms and Abbreviations (Continued)

LSC	Liquid scintillation counter
LVF	Load Verification Form
m	Meter
m^3	Cubic meter
Ma	Million years ago
MDA	Minimum detectable activity
MDC	Minimum detectable concentration
mg/L	Milligrams per liter
mi	Mile
min/ft	Minutes per foot
mL	Milliliter
mL/g	Milliliters per gram
mm	Millimeter
M&O	Management and operating
N/A	Not applicable
NAD 27	North American Datum, 1927
NAD 83	North American Datum, 1983
NAIL	Nuclear annular investigation log
NDEP	Nevada Division of Environmental Protection
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NSPC	Nevada State Plane Coordinate
NSTec	National Security Technologies, LLC
NTTR	Nevada Test and Training Range
NWAS	Northwestern Air Services
O_2	Dissolved oxygen

List of Acronyms and Abbreviations *(Continued)*

od	Outside diameter
ohms/m	Ohms per meter
OJT	On-the-job training
pCi/L	Picocuries per liter
PM-OV	Pahute Mesa-Oasis Valley
ppm	Parts per million
psi	Pounds per square inch
Pu	Plutonium
PXD	Pressure transducer
QAP	Quality Assurance Plan
R_c	Cavity radius
RCT	Radiological control technician
RN	Radionuclide
rpm	Rotations per minute
SAA	Satellite accumulation area
SDS	Safety data sheet
SDWA	*Safe Drinking Water Act*
SGR	Spectral gamma ray
SP	Spontaneous potential
SS	Stainless steel
SU	Standard unit
SW	Solid waste
SWL	Static water level
TD	Total depth
Th	Thorium
TIH	Trip into hole

List of Acronyms and Abbreviations *(Continued)*

TL	Temperature log
TOH	Trip out of hole
TWG	Technical working group
U	Uranium
UDI	United Drilling, LLC
UGT	Underground test
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WP	Working point
XRD	X-ray diffraction
XRF	X-ray fluorescence
µmhos/cm	Micromhos per centimeter
µs/ft	Microseconds per foot

List of Acronyms and Abbreviations *(Continued)*

Stratigraphic, Geologic, Hydrostratigraphic, and Hydrogeologic Unit Abbreviations and Symbols

AA	Alluvial aquifer
BFCU	Bullfrog confining unit
BRA	Belted Range aquifer
CHZCM	Calico Hills zeolitic composite unit
LFA	Lava-flow aquifer
LPCU	Lower Paintbrush confining unit
NTMMSZ	Northern Timber Mountain Moat structural zone
PBRCM	Pre-Belted Range composite unit
Pz	Paleozoic Rocks
Qac	Quaternary alluvium/colluvium
Qai	Quaternary intermediate alluvial deposits
Qal	Quaternary alluvial deposits
Qay	Quaternary young alluvial deposits
QTa	Quaternary old alluvial deposits
QTc	Quaternary/Tertiary colluvium
RCSZ	Ribbon Cliff structural zone
SCCC	Silent Canyon caldera complex
Tac	Calico Hills Formation
Tas	Andesite of Sarcobatus Flat
Tb	Belted Range Group
Tbdc	Comendite of Chartreuse
Tbg	Grouse Canyon Tuff
Tbgb	Grouse Canyon bedded tuff
Tbq	Comendite of Quartet Dome

List of Acronyms and Abbreviations *(Continued)*

Tc	Crater Flat bedded tuff
Tc	Crater Flat Group
Tc	Crater Flat lava
TCA	Tiva Canyon aquifer
Tcb	Bullfrog Tuff
Tcbs	Stockade Wash lobe of Bullfrog Tuff
Tct	Tram Tuff
TCVA	Thirsty Canyon volcanic aquifer
Tf	Volcanics of Fortymile Canyon
Tfb	Beatty Wash Formation
Tfbw	rhyolite of Beatty Wash
Tgc	Caldera moat-filling sediments
Tgfc	Furnace Creek formation
Tgy	Basin-fill sediments, undivided
Th	Calico Hills
Th	Calico Hills bedded tuff
Th	Calico Hills Formation
Th	Calico Hills lithic-rich tuff
Thr	Calico Hills mafic-rich tuff
Thrl	Calico Hills rhyolitic lava
Tm	Timber Mountain Group
Tma	Timber Mountain Ammonia Tanks Tuff
Tmab	Timber Mountain Ammonia Tanks bedded tuff
Tmar	Timber Mountain Ammonia Tanks mafic-rich Tuff
Tmat	Rhyolite of Tannenbaum Hill
TMCC	Timber Mountain caldera complex

List of Acronyms and Abbreviations *(Continued)*

TMLVTA	Timber Mountain lower vitric-tuff aquifer
Tmr	Timber Mountain Rainier Mesa Tuff
Tmrb	Timber Mountain Rainier Mountain bedded tuff
Tmrf	Rhyolite of Fluorspar Canyon
Tmrp	Timber Mountain Rainier Mesa mafic-poor Tuff
Tmrr	Timber Mountain Rainier Mesa mafic-rich Tuff
Tmt	Basalt of the Bullfrog Hills
TMWTA	Timber Mountain welded-tuff aquifer
Tp	Paintbrush Group
Tpcm	Tiva Canyon Pahute Mesa Lobe
Tpcx	Tiva Canyon landslide breccia
Tpr	Rhyolite of Silent Canyon
Tpy	Yucca Mountain Tuff
Tq	Volcanics of Quartz Mountain
Tqh	Middle rhyolite
Tqj	rhyolite of Handley
Trb	Lavas of Ribbon Cliff
Tsp	Spearhead member of Stonewall Flat Tuff
Tt	Thirsty Canyon Group
Ttc	Comendite of Ribbon Cliff
Ttg	Gold Flat Tuff
Tth	Trachyte of Hidden Cliff
Ttp	Pahute Mesa Tuff
Ttr	Rocket Wash Tuff
Tts	Trachytic rocks of Pillar Spring and Yellow Cleft
Ttt	Trail Ridge Tuff

List of Acronyms and Abbreviations (Continued)

Typ	Basalt of Thirsty Mountain and other areas
UPCU	Upper Paintbrush confining unit
WTA	Welded-tuff aquifer

1.0 Introduction

1.1 Project Description

Well ER-20-12 was drilled for the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) in support of the Nevada Environmental Management Operations Underground Test Area (UGTA) Activity. Well ER-20-12 was identified in *Addendum #3 to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria for Investigation Well ER-20-12* (Navarro, 2015a) and is a newly identified well based on the recommendations of the Pahute Mesa Technical Guidance Team. The well was drilled to provide additional data as a result of tritium detections in groundwater samples from Well PM-3 in 2011 and 2013 (N-I, 2014). Figure 1-1 shows the Pahute Mesa Phase II investigation area and Well ER-20-12 location.

The Pahute Mesa Phase II drilling program is part of the *Phase II Corrective Action Investigation Plan* (CAIP) *for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada Test Site, Nye County, Nevada* (NNSA/NSO, 2009a). The CAIP is a requirement of the *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended), agreed to by the State of Nevada; DOE, Environmental Management; U.S. Department of Defense; and DOE, Legacy Management.

Well ER-20-12 is located on the Nevada National Security Site (NNSS), approximately 305 meters (m) (1,000 feet [ft]) east of the Nevada Test and Training Range (NTTR). Figure 1-2 shows the location of Well ER-20-12 relative to select wells and tests.

Well ER-20-12 operations conformed to Nevada Division of Environmental Protection (NDEP) policies and regulations, and to the guidelines and requirements of the CAIP (NNSA/NSO, 2009a); *Field Instruction for the Underground Test Area Activity Drilling and Well Completion Operations, Nevada National Security Site, Nevada* (Navarro, 2015b); the addendum to the drilling and completion criteria (Navarro, 2015a); field activity work packages (FAWPs) for participating contractors; *Underground Test Area Quality Assurance Plan* (QAP), *Nevada National Security Site, Nevada* (NNSA/NFO, 2015a); *Underground Test Area (UGTA) Activity Health and Safety Plan* (NSTec, 2015b); *Underground Test Area Project Waste Management Plan*, with *Attachment 1 Fluid*

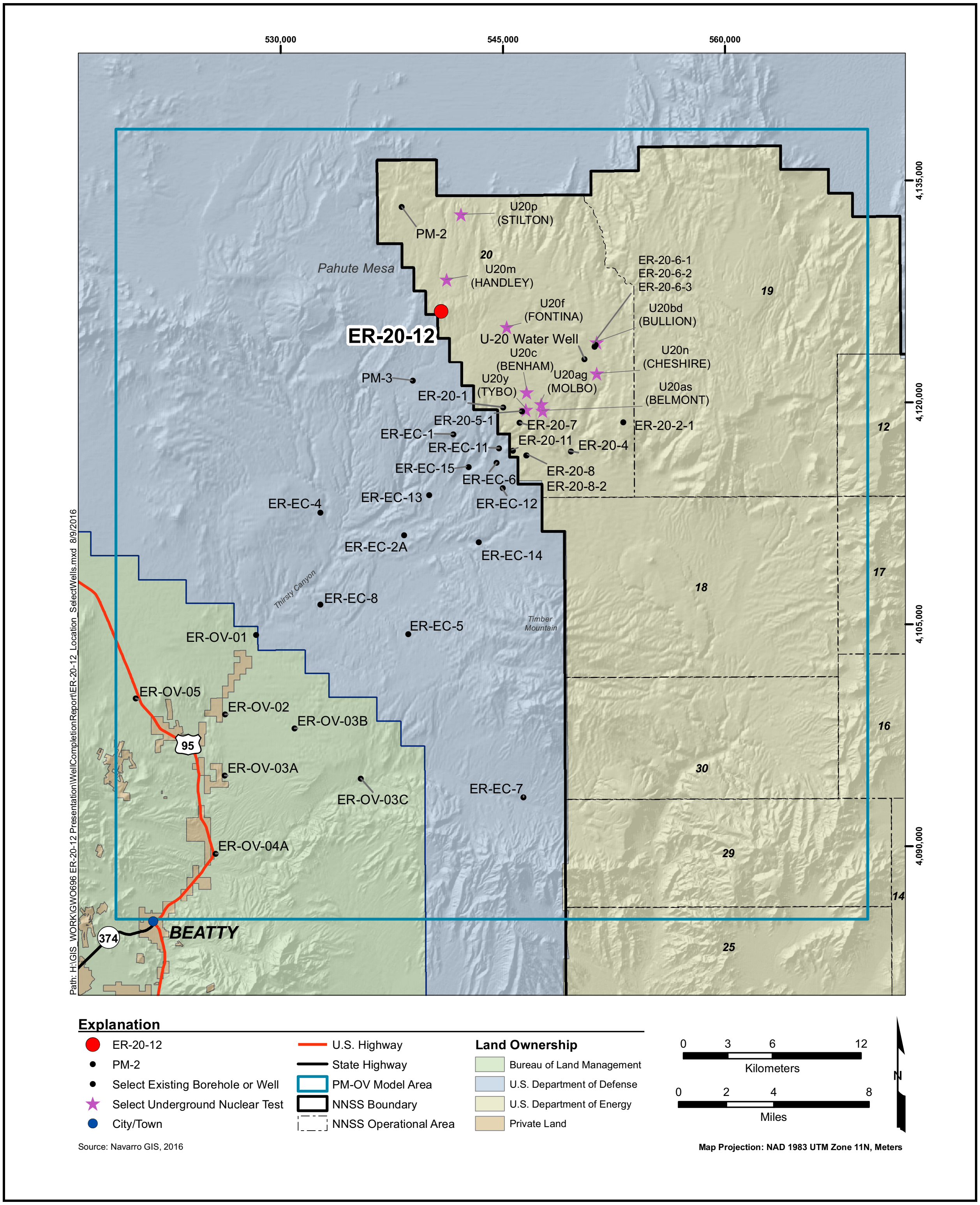


Figure 1-1
Map Showing Location of Well ER-20-12 on the NNSS

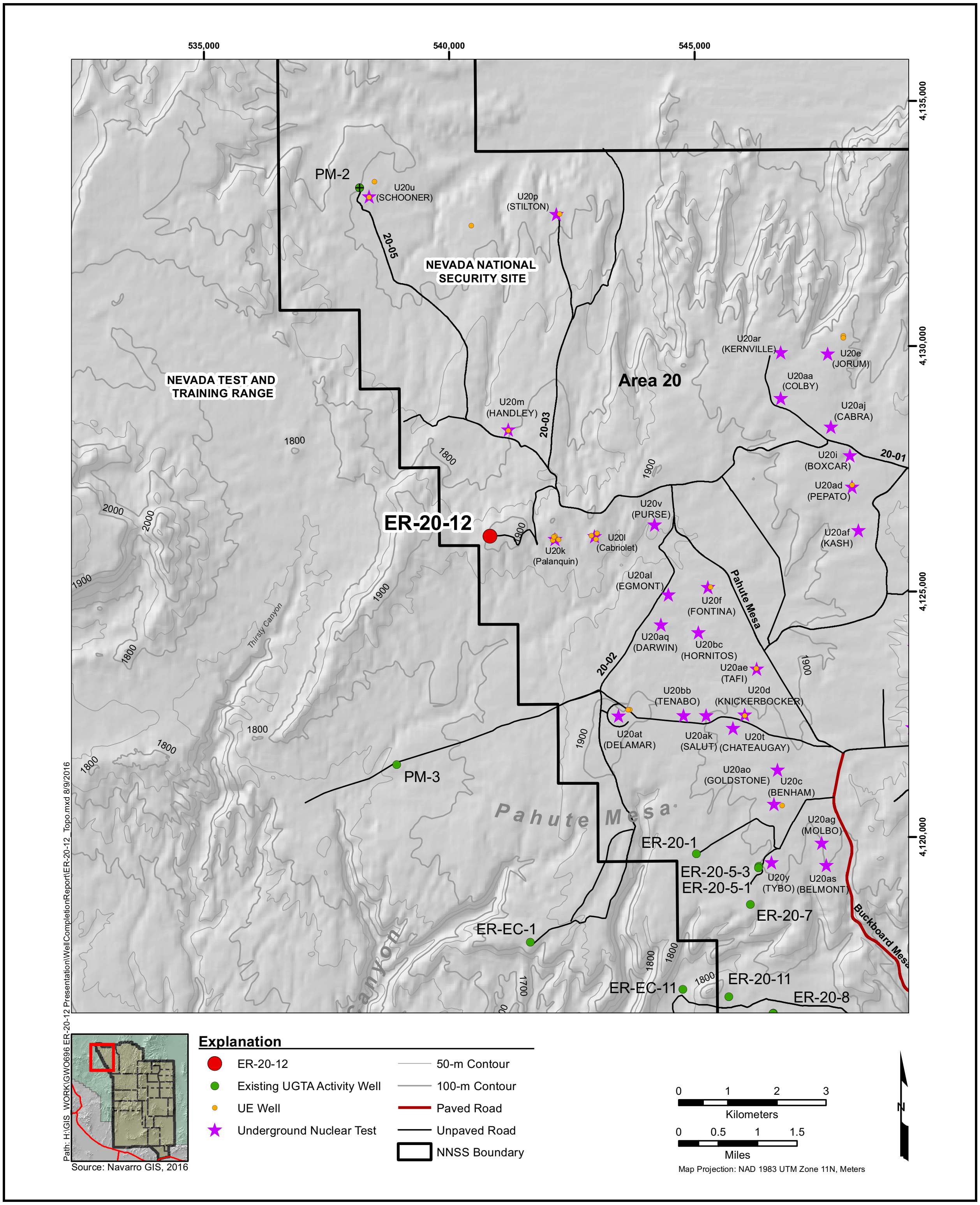


Figure 1-2
Topographic Map of the Well ER-20-12 Area Showing the Locations of Roads and Nearby Wells

Management Plan for the Underground Test Area Project (NNSA/NSO, 2009b); and the FFACO (1996, as amended).

Well ER-20-12 is located on the NNSS approximately 2,200 m (7,218 ft) south–southwest of the HANDLEY underground test (UGT) (Figure 1-3). The well site is some 5.6 kilometers (km) (3.5 miles [mi]) north of the Northern Timber Mountain Moat structural zone (NTMMSZ), and about 4.5 km (2.8 mi) east of the Black Mountain caldera structural margin. (See Figure 5-1 for the surface geology and structures in the area.)

1.2 Project Organization

Well ER-20-12 was constructed as part of the UGTA Activity. Environmental and hydrogeologic field support services were provided by Navarro. Engineering, inspection, geotechnical, and field support were provided by National Security Technologies, LLC (NSTec). Drilling and casing operation services were provided by United Drilling, LLC (UDI); Northwestern Air Services (NWAS); and B&L Casing. Geophysical logging was conducted by Schlumberger and COLOG. Navarro and NSTec (the NNSS management and operating [M&O] contractor) were the prime contractors to NNSA/NFO. Schlumberger, UDI, NWAS, B&L Casing, and COLOG performed work as service subcontractors to NSTec.

The Technical Working Group (TWG) is a group of scientists and engineers from NNSA/NFO, NDEP, Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Desert Research Institute (DRI), U.S. Geological Survey (USGS), NSTec, and Navarro. The TWG's Pahute Mesa Corrective Action Unit (CAU) Guidance Team and the TWG-CAIP subcommittee sited Well ER-20-12 as a result of tritium detections in groundwater sampled from Well PM-3 in 2011 and 2013. The well location is between PM-3 and the suspected source of groundwater contamination at the HANDLEY (U20m) test (Figure 1-2). The TWG's Drilling Advisory Team—which included the NNSA/NFO UGTA Activity Lead, the CAU Lead, the Navarro Senior Hydrogeologist, the Navarro UGTA Project Manager, the NSTec UGTA Manager/drilling engineer, a hydrologist, a geologist, and a radiochemist—provided technical advice during drilling, design, and construction of the well to ensure that the scientific and technical objectives were achieved. Well ER-20-12 was not one of the 12 wells originally proposed in the CAIP (NNSA/NSO, 2009a), and as such was not ranked in priority in the CAIP.

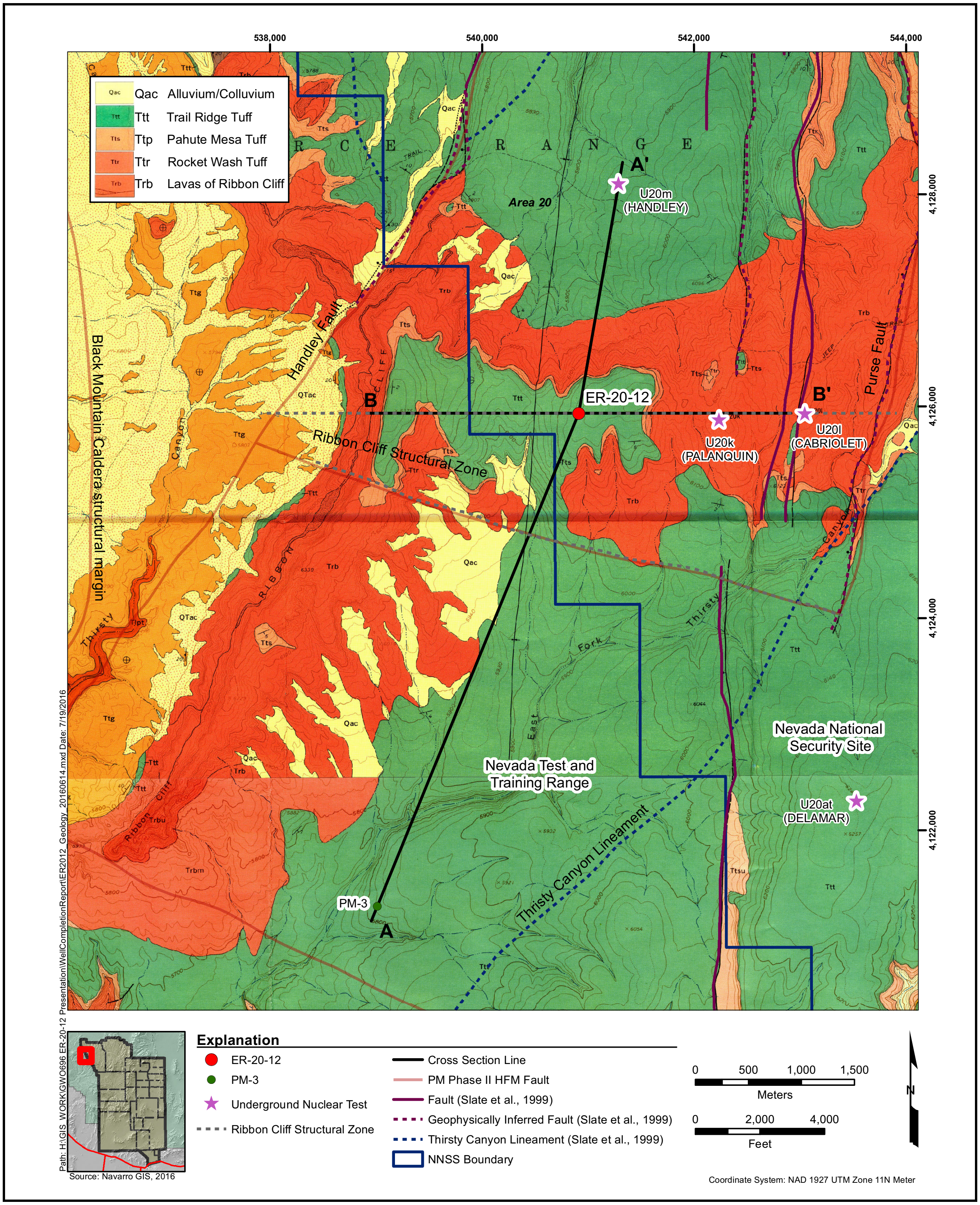


Figure 1-3
Surface Geologic Map of the Well ER-20-12 Area
Source: Modified from Christensen, 1966; and modified from Christiansen and Noble, 1968

NSTec provided site supervision, engineering, construction, inspection, geologic support, and onsite radiological monitoring. UDI, a subcontractor to NSTec, was the drilling company. Roles and responsibilities of these and other contractors involved in the project are described in FAWP numbers D-009-001.15 (NSTec, 2015a).

Navarro was the principal environmental contractor for the project and was responsible for environmental compliance and waste management on site. Navarro collected and analyzed fluid samples for water quality and chemistry, and for monitoring and documenting disposition of fluids and drill cuttings produced from the borehole. In addition, Navarro personnel collected geologic, hydrologic, and drilling parameter data as described in the ER-20-12 drilling data report (Navarro, 2016b).

Guidelines for managing fluids used and generated during drilling, completion, and testing of UGTA wells are provided in the UGTA Fluid Management Plan (FMP) (NNSA/NSO, 2009b). Well-specific fluid management details are further identified in the well-specific fluid management strategy letter (Navarro, 2015c) (reproduced in Attachment B-1 of this report) as required by the FMP and approved by NDEP before fluids are generated. Estimates of expected production of fluid and drill cuttings for ER-20-12 are provided in the drilling and completion criteria document (Navarro, 2015a), along with sampling requirements and contingency plans for management of any hazardous waste produced. All activities were conducted according to specific FAWPs (e.g., NSTec, 2015a; Navarro, 2015c) and the UGTA Activity Health and Safety Plan (NSTec, 2015b).

This report presents well construction, environmental compliance, and waste management data; and summarizes scientific data collected during the drilling of Well ER-20-12. Some of the data were obtained from Navarro's preliminary Well ER-20-12 data package (Navarro, 2016c). Pre-drilling geologic information for this area is compiled in the addendum to the drilling and completion criteria (Navarro, 2015a).

1.3 Location and Significant Nearby Features

Well ER-20-12 is located in the far northwestern portion of the NNSS, within operational Area 20. ER-20-12 is at an elevation of 1,907.56 m (6,258.40 ft) above mean sea level (amsl) along the margin of Western Pahute Mesa. The well is located approximately 305 m (1,000 ft) east of the boundary between the NNSS and the NTTR (Figure 1-3 and Table 1-1) and lies west and south of historical UGTs. The nearest upgradient UGT is HANDLEY (U20m), approximately 2,200 m (7,218 ft) north–northeast of the well location. Other nearby UGTs include STILTON (U20p), located 6,700 m (21,982 ft) north–northeast; and PURSE (U20v), approximately 3,365 m (11,040 ft) east of the Well ER-20-12 site (Table 1-2).

Table 1-1
Site Data Summary for Well ER-20-12

Site Coordinates [a]	**Nevada State Plane - Central Zone, NAD 27** N 921,330.73 ft E 537,330.92 ft
	Nevada State Plane - Central Zone, NAD 83 N 6,280,822.82 m E 511,298.95 m
	UTM - Zone 11, NAD 83 N 4,126,150.03 E 540,844.85
	UTM - Zone 11, NAD 27 N 4,125,952.84 E 540,925.06
	Geographic - NAD 83 (degrees, minutes, seconds) Latitude: 37° 16’ 51.76” Longitude: 116° 32’ 21.28”
	Township and Range [b] Southwest 1/4 of Southeast 1/4 of Section 31 Township 7 south, Range 49 east
Surface Elevation [a, c]	1,907.56 m (6,258.40 ft)
Drilled Depth	1,384.80 m (4,543.33 ft)
Preliminary Fluid Level Depth [d]	563.80 m (1,849.73 ft)
Fluid Level Elevation	1,343.76 m (4,408.67 ft)
Surface Geology	Trail Ridge Tuff (Ttt)

[a] Measurements made by NSTec Survey on 06/08/2016 using NAD 27 Nevada State Plane coordinates in feet. All other coordinates were calculated from NAD 27 feet using ArcMap 10.3.1 (ESRI, 2015).
[b] Quarter and quarter/quarter section values were made using Public Land Survey System (BLM, 2015).
[c] Measurement of elevation of ground at the wellhead made by NSTec Survey on 06/08/2016. Elevations are relative to mean sea level.
[d] Measured in the main completion by Navarro on 05/11/2016.

NAD = North American Datum
UTM = Universal Transverse Mercator

Table 1-2
Information for Underground Nuclear Tests Relevant to Well ER-20-12

Emplacement Hole Name [a]	Test Name [a]	Test Date [a]	Surface Elevation [b] m (ft)	Depth of Burial [b] m bgs (ft bgs)	Estimated Depth to Regional Water Level [b] m bgs (ft bgs)	Announced Yield [a] kt	Working Point HSU	Lateral Distance to Well [c] m (ft)
U20m	HANDLEY	03/26/1970	1,799 (5,902)	1,209 (3,966)	387 (1,270)	>1,000	PBRCM	2,200 (7,218)
U20v	PURSE	05/07/1969	1,856 (6,089)	599 (1,965)	569 (1,867)	20 - 200	UPCU	3,365 (11,040)
U20p	STILTON	06/03/1975	1,695 (5,561)	732 (2,402)	271 (889)	20 - 200	PBRCM	6,700 (21,982)

Source: Modified from Navarro, 2015a

[a] NNSA/NFO, 2015b
[b] Navarro, 2015a
[c] Navarro GIS, 2016

bgs = Below ground surface
HSU = Hydrostratigraphic unit
kt = Kiloton
PBRCM = Pre-Belted Range composite unit
UPCU = Upper Paintbrush confining unit

Well ER-20-12 is located north of a number of existing UGTA Activity hydrogeologic investigation wells that have been drilled in the area of the TYBO (U20y) and BENHAM (U20c) UGTs (Figure 1-1). Well PM-3 is approximately 5,100 m (16,732 ft) south–southwest of Well ER-20-12 and has been used historically by the UGTA Activity for groundwater sampling and monitoring.

Physiographically, ER-20-12 is east of the Black Mountain caldera and its structural margin. Surface drainage in the vicinity is generally to the southwest through Thirsty Canyon (Figure 1-2). The present understanding of groundwater flow in the area of ER-20-12 suggests the well is downgradient of the STILTON (U20p) and HANDLEY (U20m) UGTs. Significant nearby geologic structural features include the Ribbon Cliff structural zone (RCSZ) (inferred geophysically), approximately 1,223 m (4,016 ft) south of the well location; the Handley fault, some 2,275 m (7,465 ft) west; and the Purse fault, approximately 2,755 m (9,041 ft) east (Figure 1-3).

1.4 Objectives

The primary purpose of Well ER-20-12 was to provide detailed hydrogeologic information in the Tertiary volcanic section in the shallow to intermediate depths of Western Pahute Mesa in the area downgradient of UGTs. An important secondary objective was to reduce uncertainties in the Pahute

Mesa-Oasis Valley (PM-OV) hydrostratigraphic framework model (HFM) and to improve the understanding of groundwater flow and transport characteristics. Well ER-20-12 is expected to produce data that will improve flow and transport modeling for CAUs 101 and 102. In addition, the well may be a good location for long-term monitoring.

The objectives for ER-20-12, as described in Appendix P of the addendum to the drilling and completion criteria (Navarro, 2015a), are as follows:

- Obtain geologic information to reduce uncertainties in the Pahute Mesa HFM, and to improve subsequent groundwater flow and transport modeling for the area of Western Pahute Mesa and specifically between the Handley and Purse faults in the potentially near-field environment downgradient of the HANDLEY (U20m) UGT:
    - To provide detailed hydrogeologic information in the shallow-to-intermediate-depth Tertiary volcanic section.
    - To provide information regarding the presence and extent of aquifer-like units (welded-tuff aquifers [WTAs] and lava-flow aquifers [LFAs]).
    - To provide information that may help characterize structural features such as the Handley, Purse, and Ribbon Cliff structural zones/faults; and investigate what effect they may have on groundwater flow.
    - To provide detailed information on the hydrogeology and nature of aquifer units in the upper portion of the saturated section where contaminant transport may be most likely.
- Obtain information on the potential distribution of tritium:
    - Determine the nature of the distribution of tritium in groundwater and vertical extent of tritium in the hydrostratigraphic section at Well ER-20-12.
- Obtain petrophysical and secondary physical properties of saturated hydrogeologic units (HGUs) including detailed fracture data, hydrothermal alteration, and hydrologic information.
- Obtain aqueous geochemistry samples from the Tiva Canyon aquifer (TCA), Belted Range aquifer (BRA), and Pre-Belted Range composite unit (PBRCM) to better define possible groundwater flow paths based on water chemistry.
- Obtain detailed water-level data to determine the regional water level and vertical heads between units to better understand local groundwater flow.

- Investigate the possibility that perched water zones may be present above the regional water level.
- Obtain geologic samples for detailed mineralogical analyses to help define the assignment of geologic units and the potential distribution of reactive minerals in the volcanic section.

1.5 Project Summary

This section summarizes construction operations for Well ER-20-12; details are provided in Sections 2.0 through 8.0.

Construction began with drilling the 137.16-centimeter (cm) (54-inch [in.]) diameter surface conductor hole to a depth of 2.17 m (7.13 ft), and installing 106.68-cm (42-in.) diameter conductor casing to the depth of 2.01 m (6.6 ft). Subsequently, a 91.44-cm (36-in.) borehole was drilled to 19.35 m (63.5 ft) and 19 m (62.5 ft) of 76.2-cm (30-in.) diameter carbon-steel (CS) casing was installed Drilling of the main hole with a 46.9-cm (18.5-in.) chisel tooth tricone bit, using an air-foam drilling fluid in conventional circulation, began on October 8, 2015, and continued to the depth of 765.14 m (2,510.3 ft); the hole was then opened with a 66.04 cm (26-in.) chisel tooth tricone bit to a depth of 765.14 m (2,510.3 ft). A string of 50.8-cm (20-in.) surface casing was set to 762.85 m (2,502.8 ft). The hole diameter was then decreased to 46.9 cm (18.5 in.), and the hole was drilled to a depth of 1,326.53 m (4,352.16 ft). A string of intermediate casing 24.44 cm (9.625 in.) was installed to a depth of 1,188.72 m (3,900 ft). The borehole was continued to a total depth (TD) of 1,384.8 m (4,543.33 ft) with a 21.59-cm (8.5-in.) bit on January 2, 2016, and 13.97-cm (5.5-in.) completion casing was installed. Before installation of the 50.80-cm (20-in.) casing string, an open-hole water level was measured at 492.86 m (1,617 ft) on November 4, 2015, during geophysical logging. Production casing is set at the depth of 1,216.7 m (3,991.81 ft) and consists of 13.97-cm (5.5-in.) stainless-steel (SS) casing suspended from 13.97-cm (5.5-in.) internally epoxy-coated CS casing via a crossover sub. The bottom of the CS casing is positioned in the unsaturated zone at a point approximately 31.7 m (104.2 ft) above the water table. The slotted interval extends from 1,216.7 to 1,349.94 m (3,991.81 to 4,428.95 ft) within the rhyolite of Handley (Tqj). Four piezometer strings were installed in Well ER-20-12. Two piezometer strings are composed of 7.30-cm (2.875-in.) SS tubing that hangs from 6.03-cm (2.375-in.) CS tubing via a crossover sub. The p3 piezometer string was landed at 888.52 m (2,915.08 ft) and is slotted from 777.9 to 887.8 m (2,552.26 to 2,912.96 ft). The p1 piezometer string was landed at 1,117.35 m (3,665.85 ft) and is slotted from 1,043.7 to

1,116.7.0 m (3,424.18 to 3,663.73 ft). Two piezometer strings are composed of 4.82-cm (1.9-in.) CS tubing. The p2 piezometer string was landed at 957.7 m (3,142.13 ft) and is slotted from 938.63 to 957.7 m (3,079.52 to 3,142.13 ft). The p4 piezometer was landed at 579.6 m (1,901.79 ft) and is slotted from 513.8 to 579.7 m (1,685.65 to 1,901.79 ft). On May 11, 2016, a water level of 492.17 m (1,614.74 ft) was measured in the shallow piezometer (p4) and 563.80 m (1,849.73 ft) in the main production casing (m1).

Composite drill cuttings were collected every 3.0 m (10 ft) from the depth of 21.34 m (70.0 ft) to TD. Open-hole geophysical logging of the well 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. Hydrophysical logs provided groundwater flow information. The well was drilled within Tertiary volcanic rocks.

1.6 Contact Information

Inquiries concerning Well ER-20-12 should be directed to the Federal UGTA Activity Lead at the following address:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Field Office
Environmental Management Operations
P.O. Box 98518
Las Vegas, Nevada 89193-8518

2.0 Drilling Summary

2.1 Introduction

This section contains a detailed description of Well ER-20-12 drilling operations. General drilling requirements are provided in the addendum to the drilling and completion criteria (Navarro, 2015a). Well-specific drilling and operational guidance is detailed in the NSTec FAWP (NSTec, 2015a); Navarro FAWP (Navarro, 2015c); and Navarro field instruction (Navarro, 2015b). Changes to requirements in these documents are documented in records of verbal communication, written modifications to the NSTec FAWP (NSTec, 2015a), and Navarro Record of Technical Change notices.

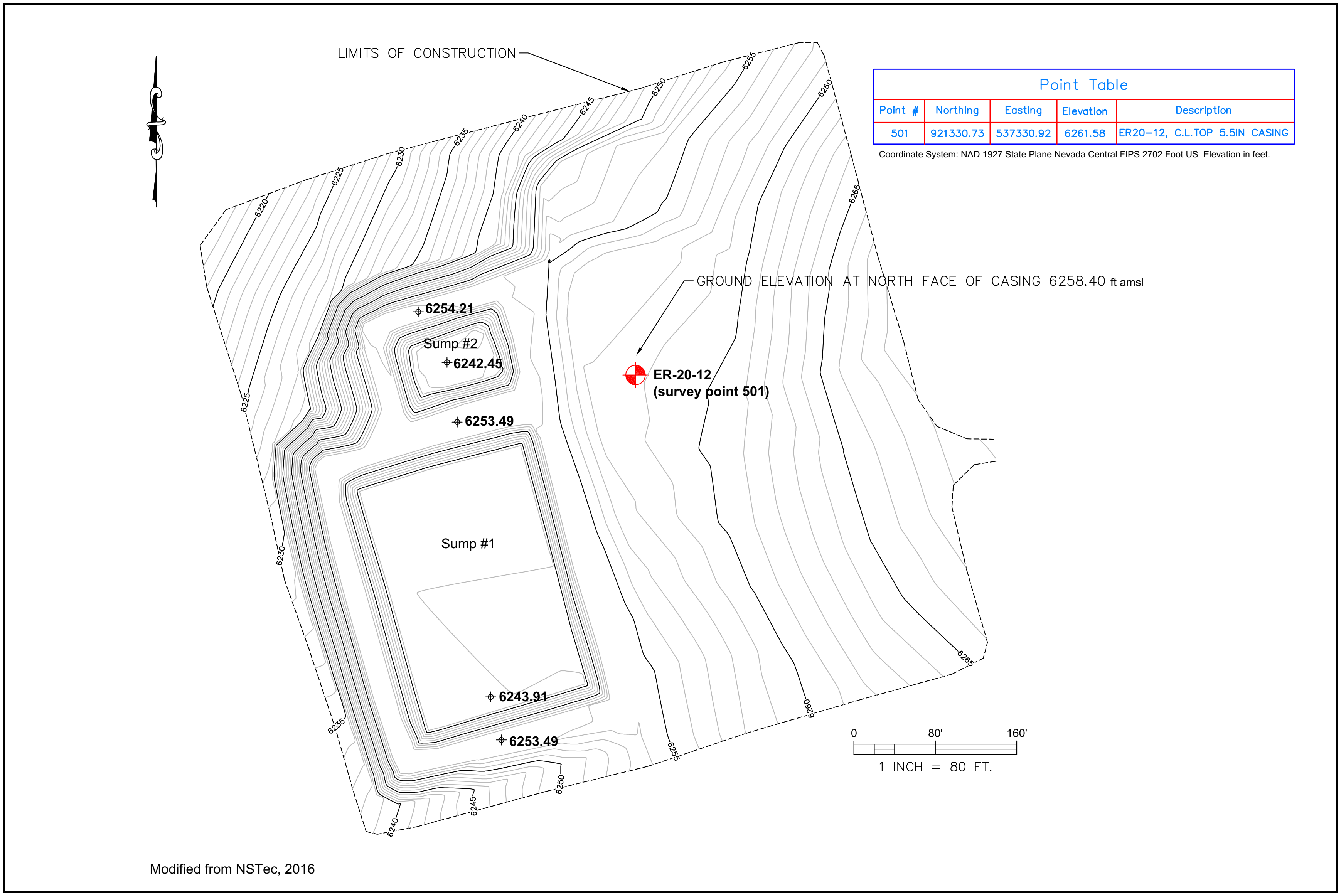
Layout of the drill pad is shown in Figure 2-1. A chart of the drilling and completion history for Well ER-20-12 is provided in Figures 2-2a and 2-2b. A summary of drilling statistics for the well is provided in Table 2-1.

By industry convention, casing and tubing are identified using English units (e.g., 30-in. casing or 2.875-in. CS tubing), which is usually equivalent to the outside diameter (od) of the pipe. In this report, these descriptors are used to designate the type of casing or tubing (its "name"), and no metric conversion is provided. The same is true for drill bits (e.g., 12.25-in. bit), but when the size of the resulting hole is mentioned, both metric and English units are given.

2.2 Drilling History

Construction of an access road, drill pad, and two sumps at the Well ER-20-12 site was completed in September 2015. NSTec advanced a 54-in. diameter, dry-auger borehole to a depth of 7.13 ft bgs; installed 42-in. diameter CS conductor casing within the 54-in. borehole to a depth of 6.6 ft bgs; and cemented the conductor casing in place in September 2015. Additionally, a 36-in. borehole was advanced from 6.6 to 63.5 ft bgs, and 30-in. CS casing was installed to 62.5 ft bgs and cemented the casing in place on September 21, 2015.

Between September 29 and October 6, 2015, the drill rig, drilling support equipment, and support facilities were mobilized to the site. The UDI equipment included a Wilson Mogul 42B double drum,



Point Table

Point #	Northing	Easting	Elevation	Description
501	921330.73	537330.92	6261.58	ER20–12, C.L.TOP 5.5IN CASING

Coordinate System: NAD 1927 State Plane Nevada Central FIPS 2702 Foot US Elevation in feet.

Figure 2-1
Well ER-20-12 As-Built Site Diagram

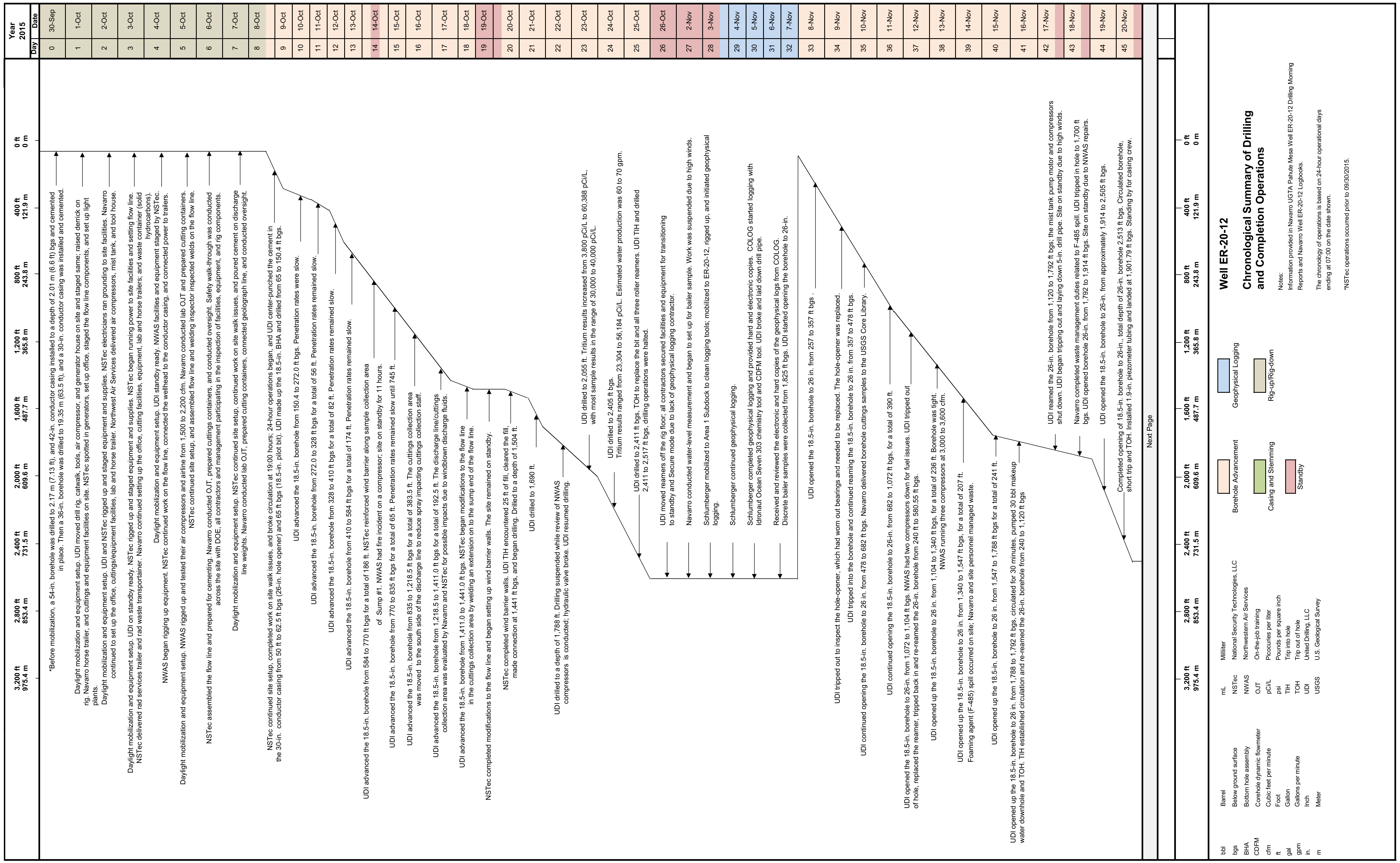


Figure 2-2a
Well ER-20-12 Chronological Summary of Drilling and Completion Operations

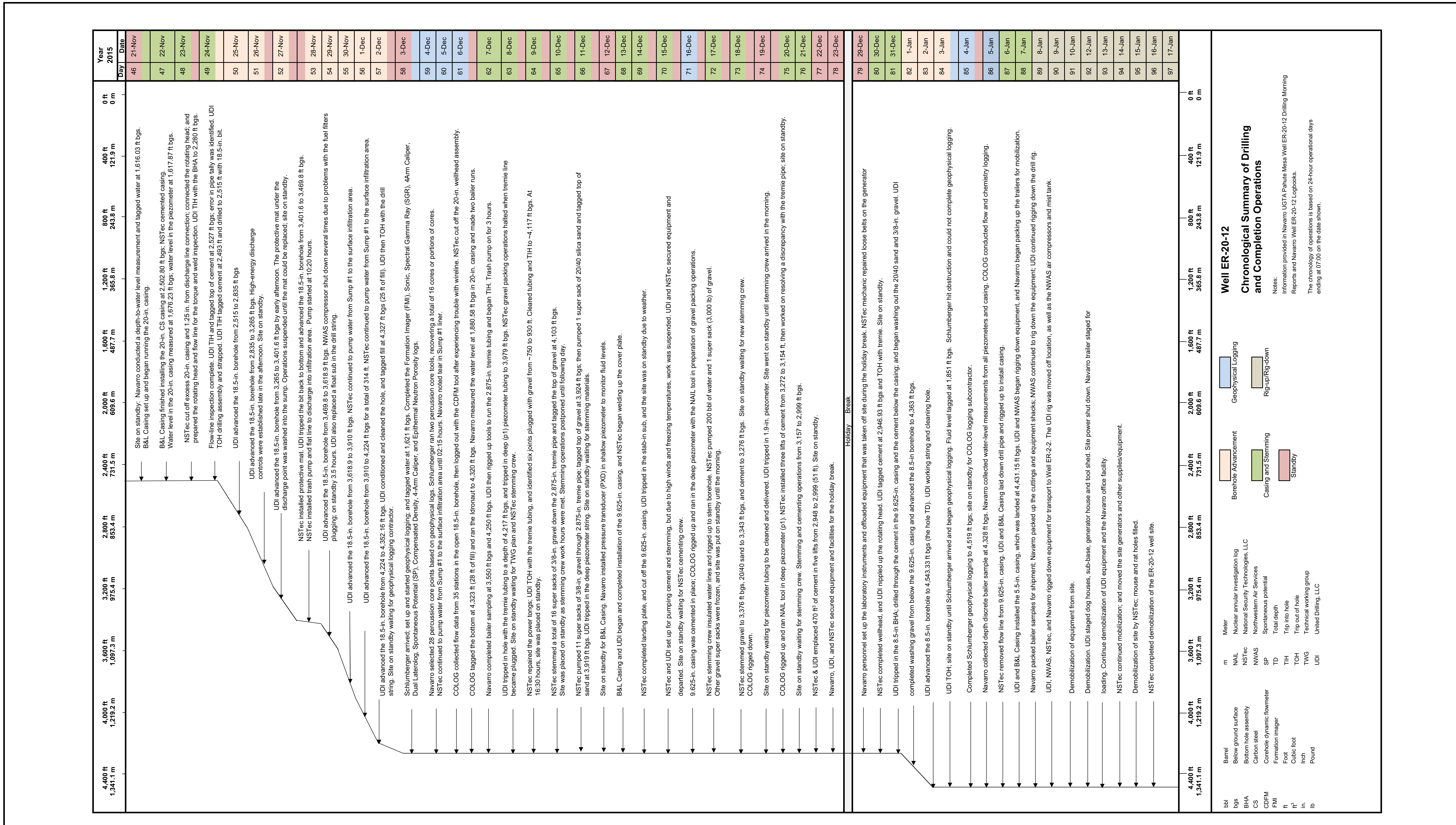


Figure 2-2b
Well ER-20-12 Chronological Summary of Drilling and Completion Operations

Table 2-1
Abridged Drill-Hole Statistics for Well ER-20-12
(Page 1 of 2)

LOCATION DATA:		
Coordinates:	Nevada State Plane (NAD 27)	N 921,330.73 ft E 537,330.92 ft
	Nevada State Plane (NAD 83)	N 6,280,822.82 m E 511,298.95 m
	Universal Transverse Mercator (NAD 27, Zone 11)	N 4,125,952.84 m E 540,925.06 m
	Latitude/Longitude (NAD 83)	37.281047 decimal degrees N 116.5392 decimal degrees W
Collar Elevation:	1,907.56 m (6,258.40 ft) amsl	
DRILLING DATA:		
Spud Date:	10/08/2015	
Date TD Reached:	01/02/2016	
Date Well Completed:	01/06/2016	
TD:	1,384.81 m (4,543.33 ft) bgs	
Hole Diameters:	137.16 cm (54 in.) from surface to 2.17 m (7.13 ft); 91.44 cm (36 in.) from 2.01 m (6.6 ft) to 19.35 m (63.5 ft); 66.04 cm (26 in.) from 19.35 m (63.5 ft) to 765.14 m (2,510.3 ft); 46.99 cm (18.5 in.) from 765.14 m (2,510.3 ft) to 1,326.48 m (4,352 ft); 21.59 cm (8.5 in.) from 1,326.48 m (4,352 ft) to 1,384.8 m (4,543.33 ft)	
Drilling Techniques:	Dry auger drilling using a 137.16 cm (54-in.) diameter bucket style auger bit from surface to 2.17 m (7.13 ft); drilling using a 91.44 cm (36-in.) bit to 19.35 m (63.5 ft); to rotary drilling with air-foam and conventional circulation using a 46.99 cm (18.5-in.) chisel tooth tricone button bit to 765.14 m (2,510.3 ft); rotary drilling with air-foam and conventional circulation using a 66.04 cm (26-in.) chisel tooth tricone button bit to 765.96 m (2,513 ft); rotary drilling with air-foam and conventional circulation using a 46.99 cm (18.5-in.) chisel tooth tricone button bit to 1,326.53 m (4,352.16 ft); rotary drilling with air-foam and conventional circulation using a 21.59 cm (8.5-in.) chisel tooth tricone button bit to 1,384.8 m (4,543.33 ft)	
CASING DATA: [a]	106.68-cm (42-in.) CS conductor casing from ground surface to 2.01 m (6.6 ft); 76.2-cm (30-in.) CS conductor casing from ground surface to 19.05 m (62.5 ft); 50.8-cm (20-in.) CS surface casing from ground surface to 762.85 m (2,502.8 ft); 24.44-cm (9.625-in.) CS intermediate casing from ground surface to 1,188.72 m (3,900 ft); 13.97-cm (5.5-in.) CS blank casing from ground surface to 540.29 m (1,772.63 ft); 13.97-cm (5.5-in.) SS completion casing from 540.29 m (1,772.63 ft) to 1,216.7 m (3,991.81 ft)	
WELL COMPLETION DATA:		
Description of Completion Casing: (m1)	The lower portion of the well within the saturated zone from 540.29 m (1,772.63 ft) to 1,349.94 m (4,428.95 ft) was completed with nominally 12.19-m (40-ft) lengths of 13.97-cm (5.5-in.) od by 12.57-cm (4.95-in.) id blank and slotted SS casing. A bullnose termination was installed on the bottom of the completion string from 1,349.94 m (4,428.95 ft) to 1,350.61 m (4,431.15 ft). The slotted 13.97-cm (5.5-in.) casing has 6.985 cm (2.75-in.) by 0.317-cm (0.125-in.) machine-cut slots. From 1,216.7 m (3,991.81 ft) bgs to 1.349.94 m (4,428.95 ft) bgs, nominally 12.19-m (40-ft) lengths of 13.97-cm (5.5-in.) od by 12.57-cm (4.95-in.) id, of threaded SS slotted casing was installed. From 539.93 m (1,771.43 ft) to 0.966 m (3.17 ft) above ground surface was completed with nominally 12.80 m (42 ft) lengths of 13.97-cm (5.5-in.) CS blank casing was installed above a crossover. Depth intervals for the CS tubing and SS blank and slotted tubing are tabulated below.	
Description of Piezometer Strings:	The deep piezometer (p1) consists of nominally 9.45-m (31-ft) lengths of 6.03-cm (2.375-in.) od by 5.07-cm (1.995-in.) id CS Hydril tubing with upset couplings extending from 0.86 m (2.84 ft) above ground surface to 1,043.43 m (3,423.34 ft). The crossover, from 6.03-cm (2.375-in.) CS tubing to 7.30-cm (2.875-in.) SS tubing, extends from 1,043.43 m (3,423.34 ft) to 1,043.69 m (3,424.18 ft). The slotted SS tubing consists of nominally 9.45-m (31-ft) lengths of 7.30-cm (2.875-in.) od by 5.99-cm (2.36-in.) id tubing with flush joint couplings and a bullnosed termination, extending to 1,117.35 m (3,665.85 ft). Depth intervals for the CS tubing and SS blank and slotted tubing are tabulated below. The intermediate piezometer (p2) consists of nominally 9.45-m (31-ft) lengths of 4.82-cm (1.9-in.) od by 3.83-cm (1.51-in.) id CS Hydril tubing with upset couplings extending from 0.80 m (2.64 ft) above ground surface to 938.65 m (3,079.52 ft). Depth intervals for the Hydril blank and slotted tubing are tabulated below. The intermediate piezometer (p3) consists of nominally 9.45-m (31-ft) lengths of 6.03-cm (2.375-in.) od by 5.07-cm (1.995-in.) id CS Hydril tubing with upset couplings extending from 0.89 m (2.94 ft) above ground surface to 888.51 m (2,915.08 ft). The crossover, from 6.03-cm (2.375-in.) CS tubing to 7.30-cm (2.875-in.) SS tubing, extends from 777.67 m (2,551.42 ft) to 777.93 m (2,552.26 ft). The slotted SS tubing consists of nominally 9.45-m (31-ft) lengths of 7.30-cm (2.875-in.) od by 5.99-cm (2.36-in.) id tubing with flush joint couplings and a bullnosed termination, extending to 888.51 m (2,915.08 ft). Depth intervals for the CS tubing and SS blank and slotted tubing are tabulated below.	

Table 2-1
Abridged Drill-Hole Statistics for Well ER-20-12
(Page 2 of 2)

	The shallow piezometer (p4) consists of nominally 9.45-m (31-ft) lengths of 4.82-cm (1.9-in.) od by 3.83-cm (1.51-in.) id CS Hydril tubing with upset couplings extending from 0.53 m (1.73 ft) above ground surface to 513.78 m (1,685.65 ft). Depth intervals for the Hydril blank and slotted tubing are tabulated below.	
	Slots for SS piezometers are machine-cut, 0.15-cm (0.06-in.) by 6.67-cm (2.625-in.), 8 vertical slots per row, 108 rows per joint on 7.62-cm (3.00-in.) centers, each row offset by 22.5 degrees from the next.	
	Slots for the CS piezometers are machine-cut, 0.20-cm (0.08-in.) by 5.58-cm (2.2-in.), 4 vertical slots per row, 108 rows per joint (432 slots).	
WELL COMPLETION DATA:	Description	Depth Interval
Detail of Surface Casing:	Blank 50.8-cm (20-in.) CS casing:	+0.61 - 762.85 m (+2.01 - 2,502.80 ft)
Detail of Intermediate Casing:	Blank 24.44-cm (9.625-in.) CS casing:	+0.76 - 1,188.72 m (+2.51 - 3,900 ft)
Detail of Completion Casing:	Blank 13.97-cm (5.5-in.) CS casing:	+0.97 - 539.93 m (+3.17 - 1,771.43 ft)
	13.97-cm (5.5-in.) crossover to SS	539.93 - 540.29 m (1,771.43 - 1,772.63 ft)
	Blank 13.97-cm (5.5-in.) SS casing:	540.29 - 1,216.70 m (1,772.63 - 3,991.81 ft)
	Slotted 13.97-cm (5.5-in.) SS casing:	1,216.70 m - 1,349.94 m (3,991.81 - 4,428.95 ft)
	with bullnosed termination:	1,349.94 m - 1,350.61 m (4,428.95 - 4,431.15 ft)
Detail of Shallow Piezometer (p4):	Blank 4.82-cm (1.9-in.) Hydril tubing:	+0.53 - 513.78 m (+1.73 - 1,685.65 ft)
	Slotted 4.82-cm (1.9-in.) Hydril tubing with orange peeled termination:	513.78- 579.66 m (1,685.65 - 1,901.79 ft)
Detail of Intermediate Piezometer (p3):	Blank 6.03-cm (2.375-in.) CS tubing:	+0.90 m - 777.67 m (+2.94 - 2,551.42 ft)
	7.30-cm (2.875-in.) CS crossover:	777.67 - 777.93 m (2,551.42 - 2,552.26 ft)
	Slotted 7.30-cm (2.875-in.) SS tubing	777.93 - 887.87 m (2,552.26 - 2,912.96 ft)
	bullnosed termination:	887.87 - 888.51 m (2,912.96 - 2,915.08 ft)
Detail of Intermediate Piezometer (p2):	Blank 4.82-cm (1.9-in.) Hydril tubing:	+0.82 - 938.63 m (+2.64 - 3,079.52 ft)
	Slotted 4.82-cm (1.9-in.) Hydril tubing with orange peeled termination:	938.63 - 957.72 m (3,079.52 - 3,142.13 ft)
Detail of Deep Piezometer (p1):	Blank 6.03-cm (2.375-in.) CS tubing:	+0.86 m - 1,043.43 m (+2.84 - 3,423.34 ft)
	7.30-cm (2.875-in.) CS crossover:	1,043.43 - 1,043.69 m (3,423.34 - 3,424.18 ft)
	Slotted 7.30-cm (2.875-in.) SS tubing	1,043.69 - 1,116.70 m (3,424.18 - 3,663.73 ft)
	bullnosed termination:	1,116.70 - 1,117.35 m (3,663.73 - 3,665.85 ft)
Detail of Completion Materials:	3/8-in. Gravel pack:	936 - 962.55 m (3,071 - 3,157 ft) 1,029 - 1,135 m (3,376 - 3,725 ft)
	20/40 Sand pack:	962.55 - 936 m (3,053 - 3,071 ft) 1,018.95 - 1,029 m (3,343 - 3,376 ft)
	Type II neat cement	898.24 - 930.55 m (2,946.93 - 3,053 ft) 962.25 - 1,018.95 m (3,157 - 3,343 ft) 1,135.38 - 1,193.59 m (3,725 - 3,916 ft)
FLUID-LEVEL DATA:	Fluid Depth [b]	Fluid Elevation
Main Completion (m1):	563.79 m (1,849.73 ft)	1,345.76 m (4,408.67 ft)
Shallow Piezometer (p4):	492.17 m (1,614.74 ft)	1,415.39 m (4,643.66 ft)
Intermediate Piezometer (p3):	571.90 m (1,876.32 ft)	1,335.66 m (4,382.08 ft)
Intermediate Piezometer (p2):	572.00 m (1,876.65 ft)	1,335.56 m (4,381.75 ft)
Deep Piezometer (p1):	566.93 m (1,860.02 ft)	1,340.63 m (4,398.38 ft)
DRILLING CONTRACTOR:	United Drilling, LLC	
GEOPHYSICAL LOGS BY:	Schlumberger, COLOG	

[a] Casing lengths referenced to ground level. For stick-up heights, see Figure 8-2.
[b] Measurements by Navarro using a calibrated Solinst e-tape on 05/11/2016.

id = Inside diameter
od = Outside diameter
SWL = Static water level

NAD 27 = North American Datum, 1927
NAD 83 = North American Datum, 1983

truck-mounted, air-rotary, drilling rig with a portable sub-base and a maximum rated capacity of 354,000 pounds static hook load. NWAS mobilized three air compressor units rated at 1,500 standard cubic feet per minute at a minimum of 2,300 pounds per square inch (psi). These units had a fluid injection system (mist pump) with a rated capacity of 1 to 46.5 gallons per minute (gpm) at 2,500 psi, and two 30-barrel capacity mix tanks to supply air and drilling fluid for drilling operations.

Equipment and facilities were set up, and safety checks (including inspection of flow-line welds by an NSTec-certified welding inspector) were conducted between September 29 and October 5, 2015. Crews worked 7 days per week, 24 hours per day, once formal drilling operations began on October 8, 2015. Drilling of an 18.5-in. pilot borehole took place over 17 days. Geophysical logging operations were conducted by Schlumberger, and hydrophysical logs were acquired by COLOG. The first set of logs was acquired between November 4 and 5, 2015, in the 18.5-in. borehole to a depth of 2,517 ft bgs. The second set of logs was collected between December 2 and 6, 2015, from 2,500 to 4,352 ft bgs. A third run of geophysical and hydrophysical logging was conducted from January 1 to 5, 2016, to a depth of 4,519 ft bgs. Geophysical and hydrophysical logging are discussed in detail in Section 4.5. Percussion sidewall cores were collected as a portion of the geophysical logging program in the saturated zone and are discussed in Section 4.6.

Drilling operations were initiated on October 8, 2015, by UDI at NSTec's direction. Operations began by drilling the cement inside the 30-in. CS conductor casing from 52 to 63.5 ft bgs using a 18.5-in. tricone bit and drilling assembly. UDI then continued to advance the 18.5-in. borehole reaching a depth of 2,517 ft bgs on October 25, 2015; preparations were then made for geophysical logging. The site was on standby secured for nine days from October 26 to November 3, 2015, waiting for the geophysical logging contract between NSTec and Schlumberger to be completed. After completion of logging operations, UDI began opening the hole from 18.5 in. to 26 in. starting at a depth of 63.5 ft bgs on November 6 and continuing through November 20, 2015, reaching a depth of 2,513 ft bgs. UDI then tripped in the hole with 1.9-in. CS piezometer tubing, which was landed at 1,901.79 ft bgs.

B&L Casing installed 20-in. CS casing to a depth of 2,502.8 ft bgs on November 21, 2015. The NSTec cementing crew then pumped 500 cubic ft (ft^3) of Type II neat cement to the base of the 20-in. casing. UDI tripped into the borehole with a new 18.5-in. bit and resumed drilling from the top of the cement at 2,493 ft bgs. Drilling continued to December 1, 2015, to a depth of 4,352 ft bgs. Schlumberger arrived on site December 2, 2015, and geophysical logging was conducted through December 3, 2015 (see Section 4.5). During this time, sidewall cores were collected (see Section 4.6). COLOG collected hydrophysical log data (flow data, water chemistry) to a depth of 4,320 ft bgs on December 4 to 6, 2015 (see Section 4.5). After evaluating the geophysical and hydrophysical data with the borehole geology, Navarro collected two depth-discrete bailer samples, duplicates, and low-level tritium samples from depths of 3,550 and 4,250 ft bgs for groundwater characterization parameters as defined in the UGTA QAP (NNSA/NFO, 2015a).

Completion operations were conducted from December 7 to December 22, 2015. UDI tripped in the hole with the 2.875-in. CS tremmie to 4,217 ft bgs, and three piezometers were set and two stemmed in with gravel pack, sand, and cement as required at depths of 3,665.85 and 3,142.13 ft bgs, respectively. The third piezometer was set at 2,915.08 ft bgs but was not stemmed in place (see Figure 8-1). B&L Casing and UDI then installed 9.625-in. casing to a depth of 3,900 ft bgs, and NSTec stemming crews completed the intervals as directed. UDI tagged cement with the 8.5-in. bottom hole assembly (BHA) at 3,809 ft bgs, and then advanced the 8.5-in. BHA through the cement and washed gravel stemming from the hole to 4,352 ft bgs on January 2, 2016, reaching the bottom of the 18.5-in. borehole. UDI advanced the 8.5-in. borehole to TD at 4.543.33 ft bgs. Schlumberger conducted geophysical logging, and COLOG ran hydrophysical and chemical tools from January 3 to January 5, 2016.

On January 6, 2015, UDI and B&L Casing installed completion casing to a depth of 4,431.15 ft bgs. The completion casing consists of 5.5-in. SS blank and SS slotted casing. The slotted portions of the completion casing are set from 3,991.81 to 4,428.95 ft bgs. The well completion diagram is provided in Figure 8-1, and Table 2-1 provides borehole and casing dimensional statistics. Well construction was completed on January 6, 2016. Rigging down and site demobilization then began, ending Well ER-20-12 drilling and completion operations.

A graphical depiction of drilling parameters—including weight on the bit, drill bit rotation, pump pressure, estimated water production, and rate of penetration—is presented in Figure A-1 of Appendix A. Table A-1 of Appendix A provides the tubing and casing records; Table A-2 provides background information regarding drilling fluids used during the drilling of Well ER-20-12; and Table A-3 provides the cement composition used in the completion of the well.

The inclination of the borehole was determined from borehole orientation logs run by Schlumberger during three logging operations (November 4 and December 2, 2015; and January 3, 2016). The changes in borehole orientation visible in Figure 2-3 are relatively gentle over the TD of the hole. The upper part of the borehole starts out with a southerly azimuth and gradually turns through the north to an easterly azimuth; however, the borehole orientation changes to a more northerly path starting at the depth of approximately 198.12 m (650 ft), which corresponds to a lithologic break in the Comendite of Ribbon Cliff (Ttc). The borehole continues on a northerly azimuth until approximately 502.92 m (1,650 ft) in the Timber Mountain Rainier Mesa Tuff (Tmr), where it makes a turn and generally moves along a southerly azimuth for the remainder of the hole. The borehole inclination varies from approximately 0.5 degrees to 4.7 degrees. At TD, the bottom of the borehole is approximately 12.80 m (42 ft) from the vertical projection of the surface collar. The deviations in the borehole path are minor and overall gradual in nature, and presented no apparent difficulties during installation of the completion casing. Figure 2-3 presents a three-dimensional view of the borehole showing deviation, the borehole profile from the caliper log, and stratigraphy.

2.3 Drilling Problems

Drilling delays at Well ER-20-12 were mainly due to operational issues at the surface rather than downhole conditions or formation problems. Operational issues included compressor-related problems (i.e., mechanical breakdowns, fuel starvation due to cold weather). High-energy discharges resulted in the erection of wind walls at the flowline discharge point as well as damage to the liner in Sump #1. Periodic contamination of cuttings from sloughing or hole erosion varied from minimal to moderate, and were addressed primarily through adjustments to drilling fluids and circulation practices. Intermediate surface casing was necessary to isolate the BRA from the PBRCM. Although borehole sloughing was not a major problem during most of the drilling, installation of the intermediate surface casing helped mitigate potential hole/formation stability issues that were developing in association with the Grouse Canyon Formation and high water inflow.

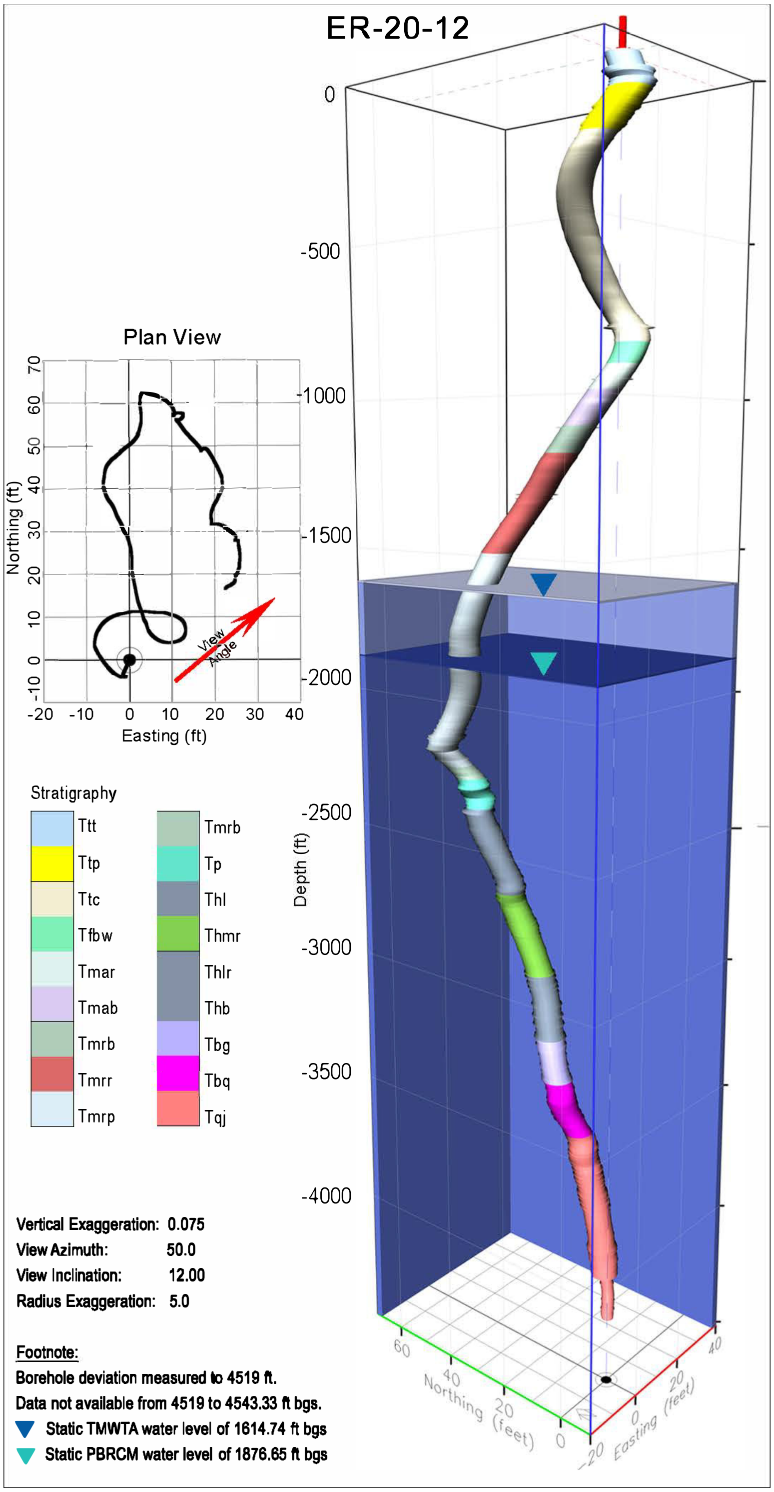


Figure 2-3
Well ER-20-12 Directional Survey Showing Caliper Profile and Stratigraphy

3.0 Management of Fluids, Drill Cuttings, and Waste

3.1 Fluid and Drill Cuttings Management

3.1.1 Fluid Management Strategy

The management of drilling fluids and solid waste (i.e., cuttings) is addressed in the UGTA FMP (NNSA/NSO, 2009b). The well-specific fluid management strategy letter (see Attachment B-1), as required by the UGTA FMP, addresses specific fluid management strategies to be employed at Well ER-20-12 for fluid-generating activities relating to well drilling and well construction. The drilling fluid discharge was monitored routinely during drilling in accordance with these plans to guide operational decisions for proper fluid containment and, ultimately, proper fluid disposal.

Two onsite infiltration basins (Sumps #1 and #2) were constructed to contain fluids and drill cuttings during operations at Well ER-20-12. Sump #1 is lined with a 2.8 million gallon (gal) capacity for drilling fluid containment. A second unlined sump (Sump #2) was not used. The sumps are approximately 3.0 m (10 ft) deep from the floor of the sump to the drill pad surface. A 10.16-cm (4-in.) discharge hose was used to convey fluids from Sump #1 to the surface infiltration area. Figure 2-1 shows the relative size and positions of Sumps #1 and #2 with respect to Well ER-20-12.

The air-foam drilling fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional or direct circulation). The drilling effluent was discharged into Sump #1. As Sump #1 reached capacity, a pump and discharge line were used to pump fluid to the surface infiltration area north of the pad site (and then following the natural drainage to the west) from November 28 to December 7, 2015.

Source water for drilling was provided by ER-20-4 and Water Well 8, existing UGTA wells that were pumped and sampled September 20 and July 19, 2011, respectively. Sample data were reviewed, and all analytes detected were below *Safe Drinking Water Act* (SDWA) (CFR, 2016b) limits.

3.1.2 Fluid Management Sampling Results

An important element of the FMP strategy (NNSA/NSO, 2009b) is the onsite monitoring program. This program is intended to provide the timely detection of indicator contaminants and determines onsite fluid management requirements.

Discharged drilling fluids were collected hourly by Navarro personnel during periods of borehole advancement. NSTec radiological control technicians (RCTs) used NSTec-supplied liquid scintillation counters (LSCs) to analyze the fluid samples on site for tritium for the purpose of fluid management and worker protection. A minimum detectable activity (MDA) is associated with the analysis of each sample; the average minimum MDA for the onsite LSCs at Well ER-20-12 was approximately 1,950 picocuries per liter (pCi/L). Samples were collected and analyzed for tritium for screening purposes, and the reported results are not intended to accurately represent lower concentrations of tritium (i.e., less than approximately 1,950 pCi/L) due to errors in counting statistics or issues relating to the nature of fluids analyzed (e.g., drilling fluids).

The results of onsite monitoring of the drilling fluid (listed in Table B-1 of Appendix B) indicate that tritium levels were occasionally above the SDWA limit of 20,000 pCi/L (CFR, 2016b), as measured by field instruments. Many of the onsite fluid samples with initial tritium results greater than the MDA were recounted. As shown in Table B-1, tritium analyses for discharge samples from both the vadose and saturated zones in Well ER-20-12 ranged from 0 to 83,138 pCi/L.

After drilling activities were completed, Navarro personnel collected an FMP confirmatory sample and duplicate from Sump #1 on April 18, 2016. The samples were analyzed by an offsite laboratory for total and dissolved metals, gross alpha and beta, and tritium. Analytical results for the FMP confirmatory samples are presented in Table B-5 of Appendix B.

3.1.3 Disposition of Fluids and Drill Cuttings

The FMP (NNSA/NSO, 2009b) and the Well ER-20-12 FMP strategy letter (see Attachment B-1) establish concentrations for specified parameters below which drilling fluids may be discharged either to an unlined containment basin or infiltration area, or directly to the ground surface. The monitoring and FMP confirmatory sampling results met the FMP criteria for fluid discharge to a designated infiltration area.

The volumes of fluids produced during vadose and saturated zone drilling are presented in Figure B-1 of Appendix B. At the completion of drilling on January 6, 2016, an estimated combined total of 1,452 cubic meters (m^3) (383,577 gal) of drilling fluid and cuttings remained in lined Sump #1.

3.2 Environmental Compliance and Waste Management

Navarro was responsible for environmental compliance and waste management at the Well ER-20-12 site. Periodic site evaluations were conducted during site operations to ensure compliance with the *Occupational Safety and Health Act* (CFR, 2016a), the *Resource Conservation and Recovery Act* (CFR, 2016c), the UGTA Waste Management Plan (NNSA/NSO, 2009b), and internal contractor procedures.

Waste generated during drilling operations at the Well ER-20-12 site consisted of hydrocarbon and sanitary wastes, typical of UGTA drilling activities. During operations on November 13, 2015, a spill of drilling fluid foaming agent occurred on the drill pad. The spill resulted from the breaching of a drum of foaming agent during transport via forklift on the site. Navarro personnel managed the spill cleanup and associated waste, which consisted of foaming agent and impacted soil. The resulting waste was managed as a hydrocarbon waste stream after the product safety data sheet (SDS) was reviewed and laboratory analysis of the waste was performed. A total of nine 55-gal drums were required to containerize the waste from the spill. A summary of waste type, volume, and disposition of waste streams generated during drilling is provided in Appendix C. Sanitary waste generated during drilling operations was routinely collected by NSTec and disposed of at the Area 23 solid waste landfill. The hydrocarbon waste was removed from the Well ER-20-12 site and transported by Navarro personnel to Building 6-909 for interim storage until disposal by NSTec. The contents of the 7,571-liter (L) (2,000-gal) condensate tank were drained and transported by NSTec to the Area 12 surface impoundment for evaporation. All waste was characterized using process knowledge and onsite monitoring results.

4.0 Geologic Data Collection

4.1 Introduction

This section describes the sources of geologic data obtained from Well ER-20-12 and the methods used to obtain that data. Well ER-20-12 was drilled in the structural block located between the Black Mountain caldera to the west, Area 20 caldera to the east, Ribbon Cliff structural zone (RCSZ) (inferred) to the south, and the West Silent canyon structural zone to the north (see Figure 5-1). Confirming and characterizing the subsurface structure, stratigraphy, and hydrogeology of this area was considered a primary purpose of Well ER-20-12.

Geologic data collected at Well ER-20-12 consist of drill cuttings, side wall (percussion) cores, and geophysical logs. Data collection, sampling, documentation, and chain of custody transfers were conducted according to applicable contractor procedures as identified in the Navarro FAWP (Navarro, 2015c).

4.2 Drill Cuttings

No samples were collected from 0 to 21.3 m (0 to 70 ft) bgs while NSTec was augering/drilling the conductor casing hole. Navarro personnel initiated cuttings collection with the drilling of the main hole. Navarro personnel collected a composite drill cuttings sample on nominal 3.0-m (10-ft) intervals. A total of 448 sample intervals from 21.3 to 1,388 (70 to 4,543 ft) bgs were collected from Well ER-20-12. Overall sample recovery and quality were fair.

Each sample collected was split into three portions of approximately 550 cubic centimeters, where recovery allowed. One of each triplicate sample set was sealed with custody tape at the well site and remains sealed as an archive; one sample was left unsealed in the container; and the third sample was processed according to USGS Core Library procedures. Samples were thoroughly washed at the well site to remove residual drilling fluids. These samples are stored at the USGS Core Library. The third sample set was used by Navarro geologists to construct the detailed lithologic log presented in Appendix D. Additionally, Navarro collected a reference sample, where recovered volume allowed, in a plastic “chip” tray for each sample interval. The chip trays remain in Navarro’s custody and were used to generate the field lithologic log presented in the ER-20-12 Drilling Data Report (Navarro, 2016b).

In the case of "no sample" recovery, the containers from the affected interval were labeled with an "NS" and placed with the filled containers in the onsite secure storage. There were a total of seven "NS" intervals in Well ER-20-12.

4.3 Sidewall Core Samples

Sidewall (percussion) core samples were collected to assist and verify the stratigraphy and lithologic identification. A total of 28 intervals were selected for sampling by Navarro geologists based on available lithologic and geophysical logs. On December 3, 2015, Schlumberger conducted two percussion-gun coring runs. Of the 28 selected intervals, 16 sample intervals were recovered (Table 4-1).

Schlumberger experienced a number of technical and/or operational issues with the core guns. Percussion-gun core run #1 recovered 3 sample intervals and 3 empty barrels, experienced 11 misfires, and lost 7 core barrels downhole. Once the gun experienced multiple sequential misfires, the operating software automatically shut down the percussion gun to prevent safety issues, and the gun was removed from the hole. The second percussion-gun was made ready and was run down hole. Percussion-gun core run #2 recovered 13 sample intervals and 6 empty barrels, experienced 0 misfires, and lost 5 barrels downhole.

Table 4-1 summarizes the results of the sidewall coring operations. Appendix D provides the detailed lithologic log (see Table D-1) and detailed descriptions of the recovered sidewall cores (see Table D-2).

4.4 Sample Analysis

Twenty-one samples of drill cuttings from various depth intervals were submitted to LANL for petrographic, mineralogic, and chemical analysis. Table 4-2 provides a list of the samples analyzed. The primary purpose of the analysis is to confirm stratigraphic identification and characterize mineral alteration. The results of these tests are discussed in Section 5.0.

Table 4-1
Sidewall Core Collection Summary
(Page 1 of 2)

Core Depth [a]		Tool Used [b]	Recovery cm (in.)	Lithology or Remark	Formation	HSU
m	ft					
777.24	2,549.98	CST-C [c, d]	0 (0)	Sample Not Recovered [e]	--	--
777.25	2,550	CST-C [f]	N/A	Sample Not Recovered [f]	--	--
816.87	2,679.99	CST-C [c, f]	3.84 (1.5)	Lava	Th	CHZCM
859.55	2,820.00	CST-C [c, f]	0 (0)	Sample Not Recovered [e]	--	--
868.69	2,850.01	CST-C [c, f]	0 (0)	Sample Not Recovered [g]	--	--
883.94	2,900.02	CST-C	1.27 (0.5)	Ash-Flow Tuff, Nonwelded, Argillic/Zeolitic	Th	CHZCM
905.27	2,970.02	CST-C	0.64 (0.25)	Ash-Flow Tuff, Nonwelded, Argillic/Zeolitic	Th	CHZCM
950.98	3,119.96	CST-C	(1.27 0.5)	Ash-Flow Tuff, Nonwelded, Argillic/Zeolitic(?)	Th	CHZCM
969.28	3,180.00	CST-C [c, h]	0 (0)	Sample Not Recovered [g]	--	--
996.70	3,269.98	CST-C [h]	0 (0)	Sample Not Recovered [h]	--	--
996.71	3,270.02	CST-C	1.27 (0.5)	Ash-Flow Tuff, Nonwelded, Devitrified/Zeolitic(?)	Th	CHZCM
1,018.04	3,339.97	CST-C	2.54 (1.0)	Ash-Flow Tuff/ Bedded Tuff, Nonwelded, Argillic/Zeolitic	Th	CHZCM
1,030.23	3,379.98	CST-C [g]	0 (0)	Sample Not Recovered [g]	--	--
1,030.23	3,379.99	CST-C [c, g]	0 (0)	Sample Not Recovered [g]	--	--
1,085.10	3,559.99	CST-C [c]	0 (0)	Sample Not Recovered [g]	--	--
1,085.10	3,560.00	CST-C [h]	0 (0)	Sample Not Recovered [h]	--	--
1,114.06	3,655.01	CST-C [g]	0 (0)	Sample Not Recovered [g]	--	--
1,114.07	3,655.04	CST-C [c]	1.27 (0.5)	Lava (Pumiceous), Zeolitic	Tbq	BRA
1,127.78	3,700.02	CST-C	1.91 (0.75)	Lava (Pumiceous) Zeolitic/Devitrified(?)	Tbq	BRA

Table 4-1
Sidewall Core Collection Summary
(Page 2 of 2)

Core Depth [a]		Tool Used [b]	Recovery cm (in.)	Lithology or Remark	Formation	HSU
m	ft					
1,139.96	3,739.98	CST-C [h]	0 (0)	Sample Not Recovered [h]	--	--
1,139.98	3,740.03	CST-C [c]	1.91 (0.75)	Moderately. to Densely Welded Ash-Flow Tuff (Basal Flow Breccia?), Altered?	Tbq	BRA
1,152.16	3,780.02	CST-C [e]	0 (0)	Sample Not Recovered	--	--
1,164.34	3,819.98	CST-C	1.91 (0.75)	Lava, Devitrified	Tqj	PBRCM
1,181.10	3,874.96	CST-C [h]	0 (0)	Sample Not Recovered [h]	--	--
1,181.12	3,875.02	CST-C [c]	1.27 (0.5)	Lava, Devitrified/Argillic	Tqj	PBRCM
1,205.50	3,955.00	CST-C	2.54 (1.0)	Lava, Devitrified	Tqj	PBRCM
1,229.87	4,034.97	CST-C	0 (0)	Sample Not Recovered [e]	--	--
1,229.89	4,035.01	CST-C [c]	0 (0)	Sample Not Recovered [e]	--	--
1,260.36	4,135.00	CST-C	1.27 (0.5)	Lava, Devitrified/Argillic	Tqj	PBRCM
1,266.45	4,154.98	CST-C	0 (0)	Sample Not Recovered [e]	--	--
1,274.07	4,179.96	CST-C	1.27 (0.5)	Lava, Devitrified/Argillic	Tqj	PBRCM
1,289.33	4,230.04	CST-C	2.54 (1.0)	Lava (Pumiceous)/ (Altered Ash-Flow Tuff?), Devitrified/Argillic (Chloritic?)	Tqj	PBRCM
1,312.17	4,304.98	CST-C [c]	2.54 (1.0)	Lava (Pumiceous)/ (Altered Ash-Flow Tuff?), Devitrified/Argillic (Chloritic?)/Zeolitic	Tqj	PBRCM
1,312.18	4,304.99	CST-C	0 (0)	Sample Not Recovered [g]	--	--

[a] Drilled depth
[b] CST-C percussion gun sidewall coring tool; core diameter: 0.75 in.
[c] Second attempt
[d] Attempted but no recovery
[e] Empty
[f] Not attempted due to CST-C Safety Protocol
[g] Barrel lost
[h] Misfired

Th = Calico Hills Formation

-- = No sample attempted or recovered.

Table 4-2
Rock Samples from Well ER-20-12 Selected for Petrographic, Mineralogic, and Chemical Analysis

Depth Interval [a]		Analyses Performed [b]		
m	ft	Petrographic	Mineralogic	Chemical
121.9 - 124.9	400 - 410	X	X	X
213.3 - 216.4	710 - 720	X	X	X
256.0 - 259.0	840 - 850	X	X	X
265.2 - 268.2	870 - 880	X	X	X
320.0 - 323.1	1,050 - 1,060	X	X	X
377.9 - 381.0	1,240 - 1,250	X	X	X
490.7 - 493.8	1,610 - 1,620	X	X	X
557.8 - 560.8	1,830 - 1,840	X	X	X
573.0 - 576.1	1,880 - 1,890	X	X	X
609.6 - 612.6	2,000 - 2,010	X	X	X
698.0 - 701.0	2,290 - 2,300	X	X	X
746.8 - 749.8	2,450 - 2,460	X	X	X
847.3 - 850.4	2,780 - 2,790	X	X	X
880.8 - 883.9	2,890 - 2,900	X	X	X
969.3 - 972.3	3,180 - 3,190	X	X	X
1,075.9 - 1,078.9	3,530 - 3,540	X	X	X
1,109.5 - 1,112.5	3,640 - 3,650	X	X	X
1,146.0 - 1,149.1	3,760 - 3,770	X	X	X
1,216.1 - 1,219.2	3,990 - 4,000	X	X	X
1,283.2 - 1,286.2	4,210 - 4,220	X	X	X
1,380 - 1,383.8	4,530 - 4,540	X	X	X

[a] All depths are drilled depths.
[b] "X" indicates analysis complete. Mineralogic analysis by XRD and chemical analysis by XRF (see Appendix H). Analyses represent base of 3.0-m (10-ft) sample interval of drill cutting samples.

XRD = X-ray diffraction
XRF = X-ray fluorescence

4.5 Geophysical Log Data

Geophysical logging, provided by Schlumberger, was conducted in the open borehole and was used to characterize the lithology, structure, and petrophysical character of the rocks penetrated. The geophysical logs were also used to evaluate borehole conditions, determine fluid levels, and collect preliminary hydrologic data. Hydrophysical logging, provided by COLOG, was conducted in the open borehole to characterize hydrophysical properties. A summary of the geophysical and hydrophysical logs is provided in Table 4-3, and selected logs are presented in Appendix E. Three separate geophysical and hydrophysical logging efforts were conducted in Well ER-20-12: (1) within the unsaturated zone and upper portion of the saturated zone before installation of the 50.80-cm (20-in.) CS surface casing, (2) within the saturated zone before installation of the piezometers and 24.4-cm (9.625 in.) intermediate casing, and (3) within the 21.59-cm (8.5-in.) borehole before installation of the 13.97-cm (5.5-in.) completion casing.

Geophysical log quality was generally good, and there were only minor technical issues with the logging tools. During the third geophysical logging run, Schlumberger noted possible obstructions or ledges at approximately 1,328 m (4,358 ft) bgs. Schlumberger made adjustments to the tooling and worked the tools in an attempt to reach the bottom of the borehole. Per discussions with the NSTec Logging Engineer, Navarro Technical Lead, Schlumberger, Navarro Geologic Interpretation Manager, and NSTec UGTA Program Manager, the decision was made to complete the differential temperature log from 1,328 m (4,358 ft) bgs to prevent potential damage to the temperature tool in attempts to bypass the obstruction. The remaining Schlumberger geophysical logs were able to pass the obstruction due to the fact that the tools were heavier and larger. COLOG experienced technical issues while flow logging. The hydrophysical log quality from run #2 (584 to 1,301 m [1,914.8 to 4,270 ft] bgs) was compromised due to wireline depth issues during logging. These issues limited the usefulness of the data from flow logging in run #2, particularly from 1,128 m (3,700 ft) bgs and down.

4.6 Fracture Analysis

Schlumberger also ran the fullbore scanner formation microimager (FMI) geophysical log, which provides a microresistivity image of the borehole. NSTec geologists used the FMI to conduct a fracture analysis to understand the orientation, size, frequency of fractures, bedding features, and

Table 4-3
Well ER-20-12 Geophysical Log Summary
(Page 1 of 2)

Geophysical Log Type [a]	Log Purpose	Date Logged	Run Number	Bottom of Logged Interval m (ft) [b]	Top of Logged Interval m (ft) [b]
Differential Temperature/Temperature, Gamma Ray	Formation/Fluid: Water levels, Water movement in/out of borehole, Depth calibration checks	11/04/2015 12/02/2015 01/02/2016	1, 5, 10	761.4 (2,498) 1,319.2 (4,328) 1,328.3 (4,358)	457.2 (1,500) 411.5 (1,350) 1,158.3 (3,800)
Compensated Neutron, Three Detector Litho Density, Gamma Ray/Caliper, Array Induction, Spontaneous Potential, High Resolution Laterolog Array	Formation: Porosity and lithologic determination; Density; Borehole depth and condition (washouts, fractures); Resistivity, Thin bed analysis; Spontaneous Potential; Resistivity, Fracture Analysis	11/04/2015	2	762.6 (2,502)	9.1 (30)
Compensated Neutron, Three Detector Litho Density, Gamma Ray	Formation: Porosity and lithologic determination; Density	11/04/2015	3	764.4 (2,508)	615.1 (2,018)
4-Arm Caliper, Powered Positioning Device, Full Bore Scanner, Gamma Ray, Gamma Ray Spectroscopy, Natural Gamma Ray	Formation: Borehole condition (washouts, fractures); Stratigraphic and fracture analysis; Depth calibration check; Lithologic/Stratigraphic analysis as a function of relative ^{40}K, ^{232}Th, and ^{238}U concentrations; Lithologic/Stratigraphic analysis, alteration analysis	11/04/2015	4	764.8 (2,509)	0 (0)
Directional Survey, General Purpose Inclinometry Tool, Modular Acoustic Scanning Platform, Gamma Ray, Gamma Ray Spectroscopy, Full Bore Scanner, Four Arm Caliper, 8-Arm Caliper, Powered Positioning Device	Formation: Borehole orientation and deviation; Lithologic/stratigraphic analysis, fracture analysis, cement bonding; Depth calibration check; Lithologic/Stratigraphic analysis as a function of relative ^{40}K, ^{232}Th, and ^{238}U concentrations; Stratigraphic and fracture analysis; Borehole condition (washouts, fractures);	12/02/2015 01/03/2016	6, 11	1,322.2 (4,338) 1,376.8 (4,517)	762.0 (2,500) 1,188.7 (3,900)

Table 4-3
Well ER-20-12 Geophysical Log Summary
(Page 2 of 2)

Geophysical Log Type [a]	Log Purpose	Date Logged	Run Number	Bottom of Logged Interval m (ft) [b]	Top of Logged Interval m (ft) [b]
High Resolution Laterolog Array, Gamma Ray, Spontaneous Potential, Compensated Neutron, Three Detector Litho Density, Gamma Ray/Caliper	Formation: Resistivity, Fracture Analysis; Depth calibration checks; Spontaneous Potential; Porosity and lithologic determination; Density; Borehole depth and condition (washouts, fractures); Resistivity, Thin bed analysis; Spontaneous Potential; Borehole depth and condition (washouts, fractures)	12/03/2015 01/03/2016	7, 12	1,315.8 (4,317) 1,369.2 (4,492)	670.6 (2,200) 1,158.3 (3,800)
Chemistry Log	Fluid: Temperature, Pressure, Electrical Conductivity, pH, O_2, Redox	11/05/2015 12/05/2015 01/04/2016	1, 1, 1	763.9 (2,506.3) 1,301.5 (4,270) 1,326.4 (4,351.5)	494.2 (1,621.5) 748.3 (2,455) 1,173.4 (3,849.7)
Corehole Dynamic Flowmeter	Fluid: Fracture flow and permeability	11/06/2015 12/05/2015 01/04/2016	2, 2, 2	758.9 (2,490) 1,301.5 (4,270) 1,328.3 (4,358)	508.1 (1,667) 583.6 (1,914.8) 1,173.5 (3,850)
Nuclear Annular Investigation	Determine the final height of annular completion materials	12/06/2015 12/16/2015	2, 2	1,117.2 (3,665.3)	731.5 (2,400)

[a] A composite of all runs of each log type is presented in Figures E-1 through E-5 of Appendix E.
[b] Drilled depth

K = Potassium
O_2 = Dissolved oxygen
Th = Thorium
U = Uranium

Note: Geophysical logs provided by Schlumberger; hydrophysical logs provided by COLOG.

other geologic structure information in the borehole. The fracture analysis focused on the readily identifiable features and are representative of the fracture and bedding populations. Fracture data, stereonets, and rose diagrams are presented in Appendix G. Figure 4-1 presents a Tadpole diagram of the depositional and structural features (i.e., fractures, bedding planes, flow layering) and their spatial relationship to estimated water production.

Bedding dip patterns from boreholes in complex volcanic environments like Pahute Mesa can be difficult to interpret and to extrapolate to the regional context because they represent the cumulative dip of structural and depositional processes, some of which maybe local in origin.

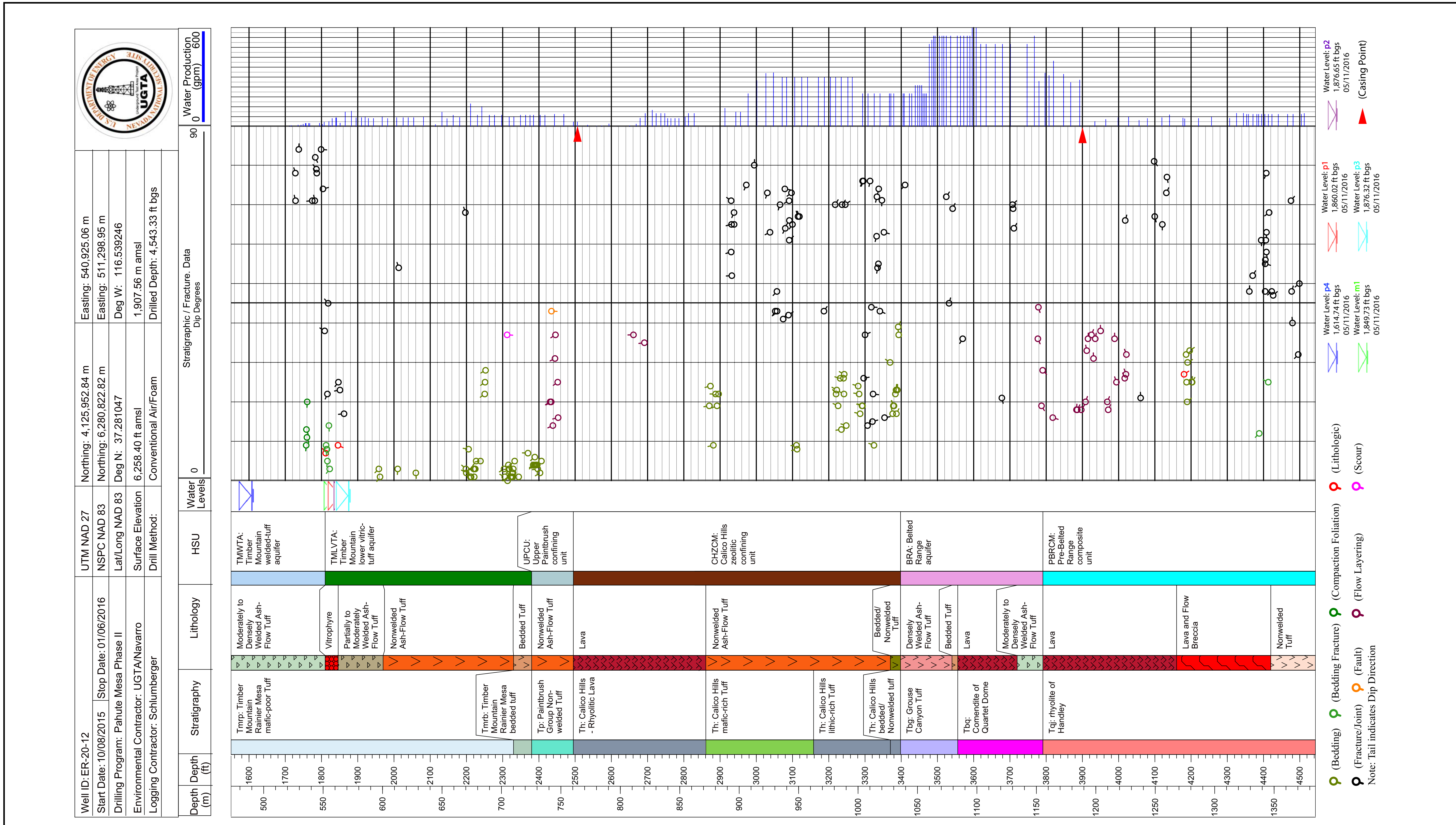


Figure 4-1
Tadpole Diagram for Well ER-20-12

5.0 Geology and Hydrogeology

5.1 Introduction

This section describes the geology and hydrogeology of Well ER-20-12. The following discussion and interpretations are primarily based on the detailed lithologic log presented in Appendix D. The detailed lithologic log was developed using the drill cuttings, sidewall cores, preliminary field lithologic log, and borehole geophysical and hydrophysical logs. Additional information with respect to the geometry and nature of bedding, flow features, and fractures was provided by NSTec geologists using the FMI (e.g., resistivity image log) geophysical log. This log provides detailed information with respect to the true dip and dip azimuth of bedding and fracture features observed in the borehole. This information was available only below the water table. Additionally, select cutting samples obtained from the borehole were analyzed by LANL scientists to provide confirmatory data derived from detailed petrographic, mineralogic, and geochemistry analysis to confirm stratigraphic unit and alteration assignments made based on visual observation and petrophysical data (geophysical logs).

5.2 Geology

The following subsections discuss the geologic setting of the Pahute Mesa area and Well ER-20-12 (see Section 5.2.1), the stratigraphy and lithology of units penetrated by Well ER-20-12 (see Section 5.2.2), and the alteration of the rocks in Well ER-20-12 (see Section 5.2.3). Detailed descriptions of the stratigraphy, lithology, and alteration found are provided in the detailed lithologic log provided in Appendix D. Tables 5-1 and 5-2 provide definitions of stratigraphic units and HSUs used respectively in various other figures and tables in this report.

5.2.1 Geologic Setting

Well ER-20-12 is located in the far northwestern portion of the NNSS, within the topographical margin of Western Pahute Mesa. Pahute Mesa is a high volcanic plateau within the southwestern Nevada volcanic field (Byers et al., 1976). Surface drainage in the vicinity of Well ER-20-12 is generally to the southwest through Thirsty Canyon. Physiographically, the well site lies east of the topographic expression of the Black Mountain caldera and its structural margin, and west of the topographic and structural margins of the buried Silent Canyon caldera complex (SCCC).

Table 5-1
Key to Stratigraphic Units and Symbols of the Well ER-20-12 Area
(Page 1 of 2)

Stratigraphic Unit	Map Symbol
Thirsty Canyon Group	**Tt**
Trail Ridge Tuff	Ttt
Pahute Mesa Tuff	Ttp
Comendite of Ribbon Cliff	Ttc
Volcanics of Fortymile Canyon	**Tf**
rhyolite of Beatty Wash	Tfbw
Timber Mountain Group	**Tm**
Ammonia Tanks Tuff	Tma
Ammonia Tanks mafic-rich Tuff	Tmar
Ammonia Tanks bedded tuff	Tmab
Basalts of Bullfrog Hills	Tmt
Rainier Mesa Tuff	Tmr
Rainier Mesa bedded tuff	Tmrb
Rainier Mesa mafic-rich Tuff	Tmrr
Rainier Mesa mafic-poor Tuff	Tmrp
Rainier Mesa bedded tuff	Tmrb
Rhyolite of Fluorspar Canyon	Tmrf
Paintbrush Group	**Tp**
Tiva Canyon Pahute Mesa Lobe	Tpcm
Calico Hills Formation	**Th**
Calico Hills rhyolitic lava	Thrl
Calico Hills mafic-rich tuff	Thr
Calico Hills lithic-rich tuff	Th
Calico Hills bedded tuff	Th
Crater Flat Group	**Tc**
Bullfrog Tuff	Tcb
Tram Tuff	Tct
Crater Flat bedded tuff	Tc
Belted Range Group	**Tb**
Comendite of Chartreuse	Tbdc
Grouse Canyon Tuff	Tbg
Comendite of Quartet Dome	Tbq

Table 5-1
Key to Stratigraphic Units and Symbols of the Well ER-20-12 Area
(Page 2 of 2)

Stratigraphic Unit	Map Symbol
Volcanics of Quartz Mountain	Tq
rhyolite of Handley	Tqj
middle rhyolite	Tqh
Paleozoic Rocks	Pz (Undifferentiated)

Table 5-2
Key to HSUs and Symbols of the Well ER-20-12 Area

HSU	Map Symbol
Thirsty Canyon volcanic aquifer	TCVA
Timber Mountain welded-tuff aquifer	TMWTA
Timber Mountain lower vitric-tuff aquifer	TMLVTA
Upper Paintbrush confining unit	UPCU
Calico Hills zeolitic composite unit	CHZCM
Belted Range aquifer	BRA
Pre-Belted Range composite unit	PBRCM

Figure 5-1 shows the location of Well ER-20-12, the surficial geology, and the prominent structural and caldera boundaries. Much of Pahute Mesa overlies the buried SCCC, which consists of two overlapping calderas: the Grouse Canyon caldera and the younger Area 20 caldera (Sawyer and Sargent, 1989). These calderas were formed by voluminous eruptions of ash-flow tuffs of generally rhyolitic composition, between approximately 14 million years ago (Ma) and 13 Ma (Sawyer et al., 1994). The SCCC was eventually filled and buried by younger tuff and lava erupted from nearby vents and calderas between approximately 13 Ma and 9 Ma. In the vicinity of Well ER-20-12, these caldera-filling and -burying volcanic units, from oldest to youngest, include tuff and lava of the Crater Flat Group (Tc), the Calico Hills Formation (Th), and the Paintbrush Group (Tp). Overlying these units is a series of welded ash-flow tuffs—including the Rainier Mesa Tuff (Tmr), Ammonia Tanks Tuff (Tma), Rocket Wash Tuff (Ttr), Pahute Mesa Tuff (Ttp), and Trail Ridge Tuff (Ttt)—which cap much of Pahute Mesa (Slate et al., 1999). The Rainier Mesa and Ammonia Tanks tuffs were erupted 11.6 and 11.45 Ma, respectively, from the Rainier Mesa and Ammonia Tanks

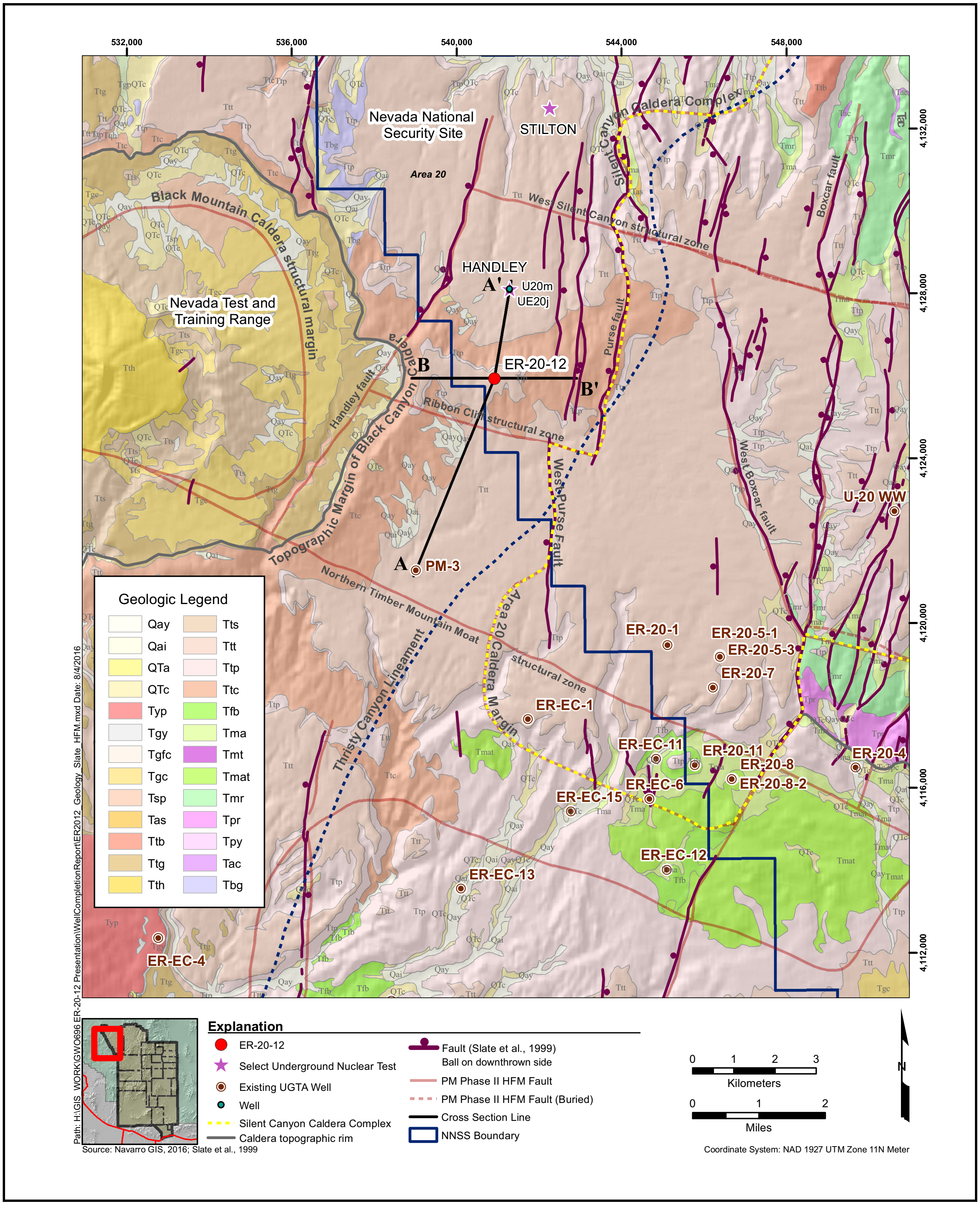


Figure 5-1
Surface Geologic Map of the Well ER-20-12 Area

calderas (Sawyer et al., 1994), both of which are part of the Timber Mountain caldera complex (TMCC), located just south of Well ER-20-7. The Pahute Mesa Tuff and Trail Ridge Tuff were erupted 9.4 and 9.3 Ma, respectively, from the Black Mountain caldera (Slate et al., 1999) located west of Well ER-20-12. The Trail Ridge Tuff forms the ground surface at the well site. (Figure 5-1). In general, the area surrounding Well ER-20-12 consists of relatively flat-lying Miocene-age volcanic rocks, predominately nonwelded to densely welded ash-flow tuff, lavas, and bedded tuffs. Given the present understanding of groundwater flow in the area of Well ER-20-12, the well is downgradient of the STILTON (U20p) and HANDLEY (U20m) UGTs.

Major structural features in the vicinity of Well ER-20-12 are related in some degree to caldera formation; the notable exception may be the Thirsty Canyon lineament, which likely predates caldera formation. Significant nearby geologic structural features are shown in Figure 5-2, including the RCSZ and the NTMMSZ, both of which lie to the south of the well location approximately 1.2 km (0.8 mi) and 5.7 km (3.6 mi), respectively. These west–northwest-trending structures are inferred geophysically by Mankinen et al. (1999) and Grauch et al. (1997), and suggest a down-to-the-southwest normal sense of displacement to the fault blocks. Recent drilling as part of the PM-OV Phase I drilling (DOE/NV, 2000) confirmed displacement along the NTMMSZ of as much approximately 244 m (800 ft). Based on these observations, the RCSZ may have similar displacement, also to the southwest. The Handley fault lies approximately 2.8 km (1.74 mi) to the west, and West Silent Canyon structural zone lies approximately 4.27 km (2.65 mi) to the north. The Purse fault and the Thirsty Canyon lineament (Mankinen et al., 1999; Grauch et al., 1997) are prominent structural features or zones located approximately 2.81 km (1.75 mi) and 3.30 km (2.05 mi), respectively, to the east of Well ER-20-12 location and bound the SCCC to the west.

The Thirsty Canyon lineament is recognized only from its geophysical expression, as shown in Figure 5-3. The lineament appears to be a significant structural feature that extends approximately 38.9 km (24.2 mi) beginning in the area of Oasis Valley to the southwest and extending along a generally northeast direction, where it passes east of Well ER-20-12, in the vicinity of the Purse fault. The Thirsty Canyon lineament appears to predate the onset of volcanism in the area and may have influenced the location and formation of calderas in the region during the Miocene. The location of the Purse fault also suggests that it may be sympathetic to the lineament and may be a near-surface expression of the more prominent yet buried Thirsty Canyon lineament structural feature.

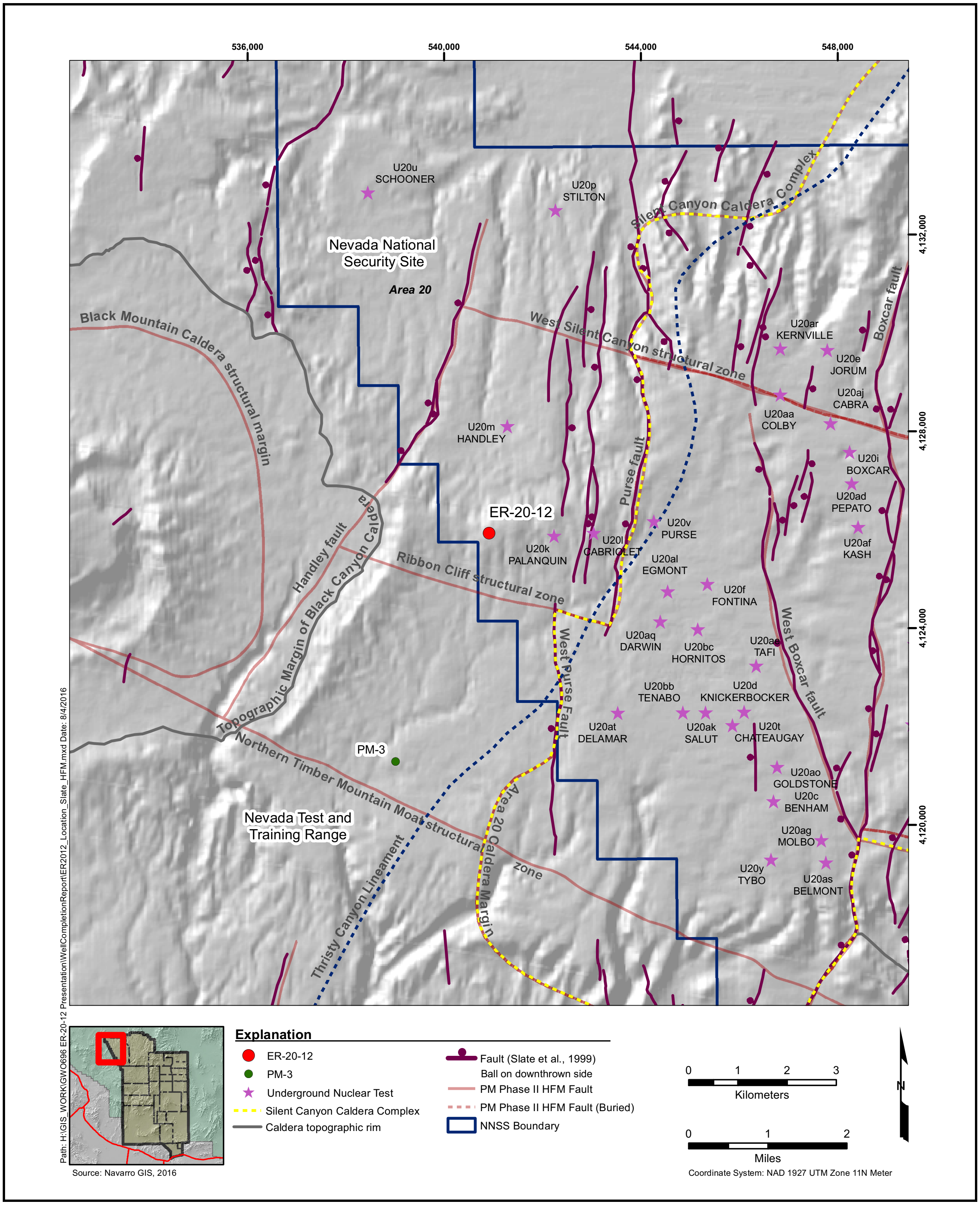


Figure 5-2
Geologic Structure Map of the Well ER-20-12 Area

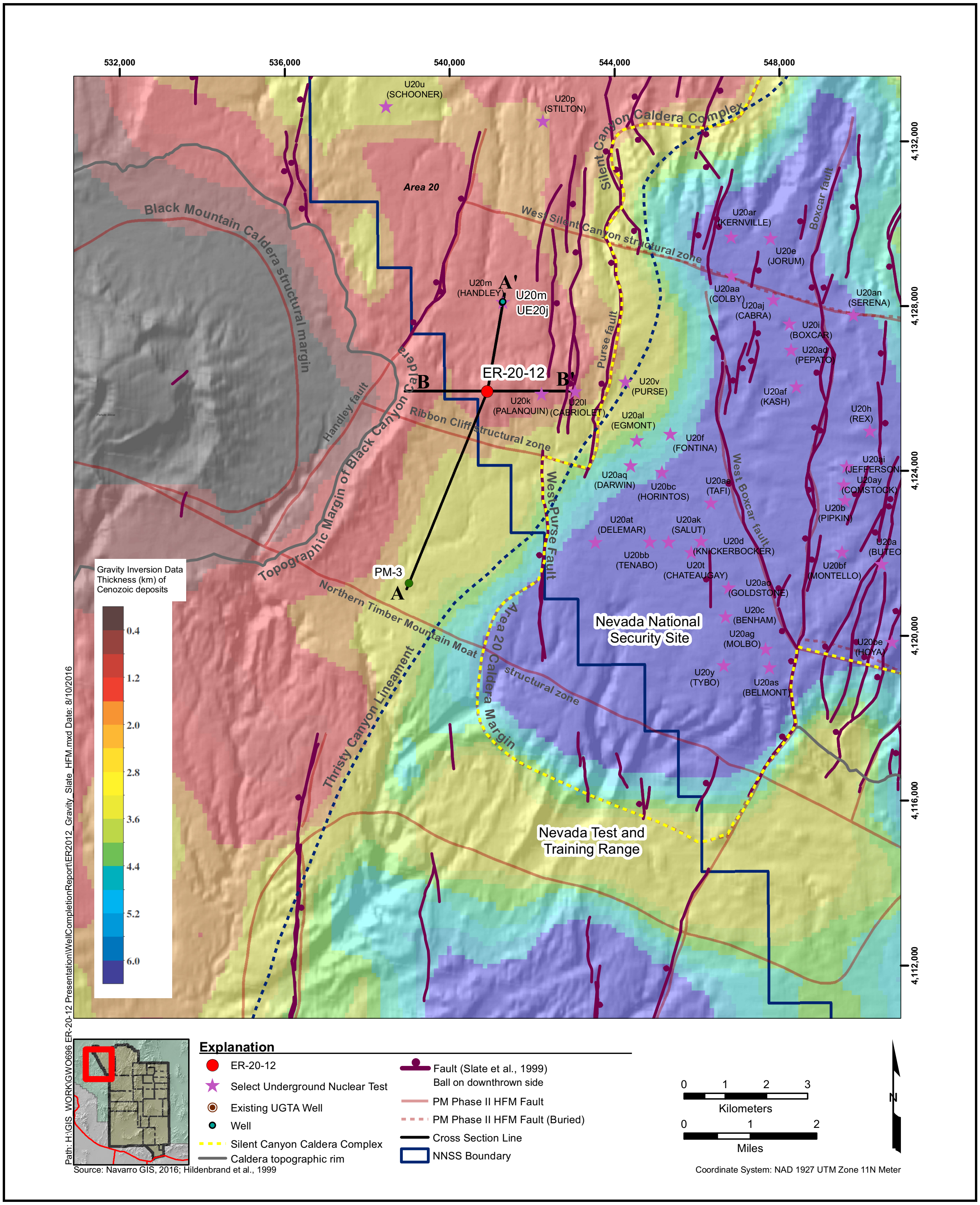


Figure 5-3
Gravity Inversion Map

Geophysical data acquired using gravity inversion and resistivity techniques (such as audio-magnetotelluric [AMT]), which were used to help define the Thirsty Canyon lineament, suggest that areas to the west of the lineament along the approximate trace along the SCCC margin (Purse Fault)—and, more specifically, in the area of Well ER-20-12—may be suggestive of a structural high along the SCCC margin. This structural high, as inferred from these geophysical surveys, may represent the presence of Pre-Cenozoic rocks bounding the SCCC at relatively shallow depths from the present surface. This structural high, if present, would likely be in the area of Well ER-20-12 and would extend along the western margin of the SCCC to the southwest and to the northeast, Numerous other normal faults have also been mapped on the surface in Pahute Mesa (Slate et al., 1999); these faults are shown on Figure 5-2.

5.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated in Well ER-20-12 are illustrated in Figure 5-4, and the distribution of stratigraphic units in the vicinity of the well is shown in cross section in Figure 5-5. Complete lithologic descriptions, stratigraphic assignments, and their respective depth intervals can be found in Appendix D. Identification of stratigraphic and lithologic units was aided by correlation with nearby boreholes (U20m, PM-3, UE20j, U20p), and the PM-OV HFM (BN, 2002). In addition, subsequent petrographic and chemical analysis (XRD/XRF), as performed by LANL, was helpful in the identification and confirmation of stratigraphic assignments. A report detailing these analyses may be found in Appendix H.

Drilling at Well ER-20-12 started in moderately to densely welded ash-flow tuffs assigned to the Trail Ridge Tuff (Ttt) of the Thirsty Canyon Group (Tt), which forms the ground surface in the vicinity of the well. The Thirsty Canyon Group erupted between 9.15 and 9.4 Ma from the Black Mountain caldera (Sawyer et al., 1994) located approximately 1.99 km (1.23 miles [mi]) to the west. The initial samples collected from approximately 21.3 m (70 ft) bgs were bedded tuffs to nonwelded ash-flow tuffs of the Trail Ridge Tuff (Ttt), and the base of the unit was identified at 38.1 m (125 ft) bgs. Below the Trail Ridge Tuff was 33.5 m (110 ft) of nonwelded to moderately welded Pahute Mesa Tuff (Ttp), and 199.7 m (655 ft) of the Comendite of Ribbon Cliff (Ttc). The Comendite of Ribbon Cliff consists of a series of lavas, lava-flow breccia, and basal bedded tuff. This unit was thicker than predicted. A total of 251.5 m (825 ft) of the Thirsty Canyon Group (Tt) was penetrated.

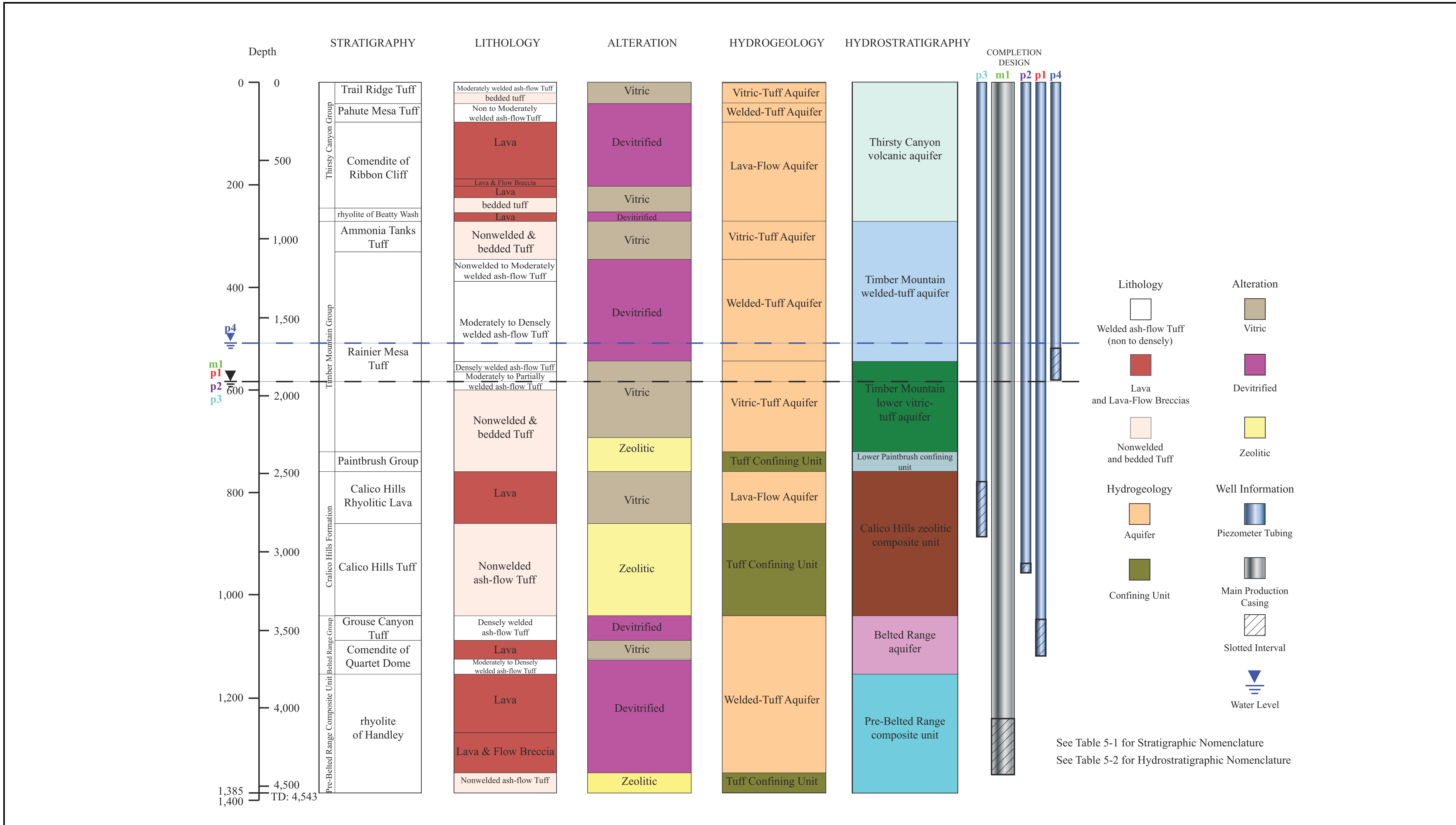


Figure 5-4
Graphical Presentation Showing Geology and Hydrogeology for Well ER-20-12

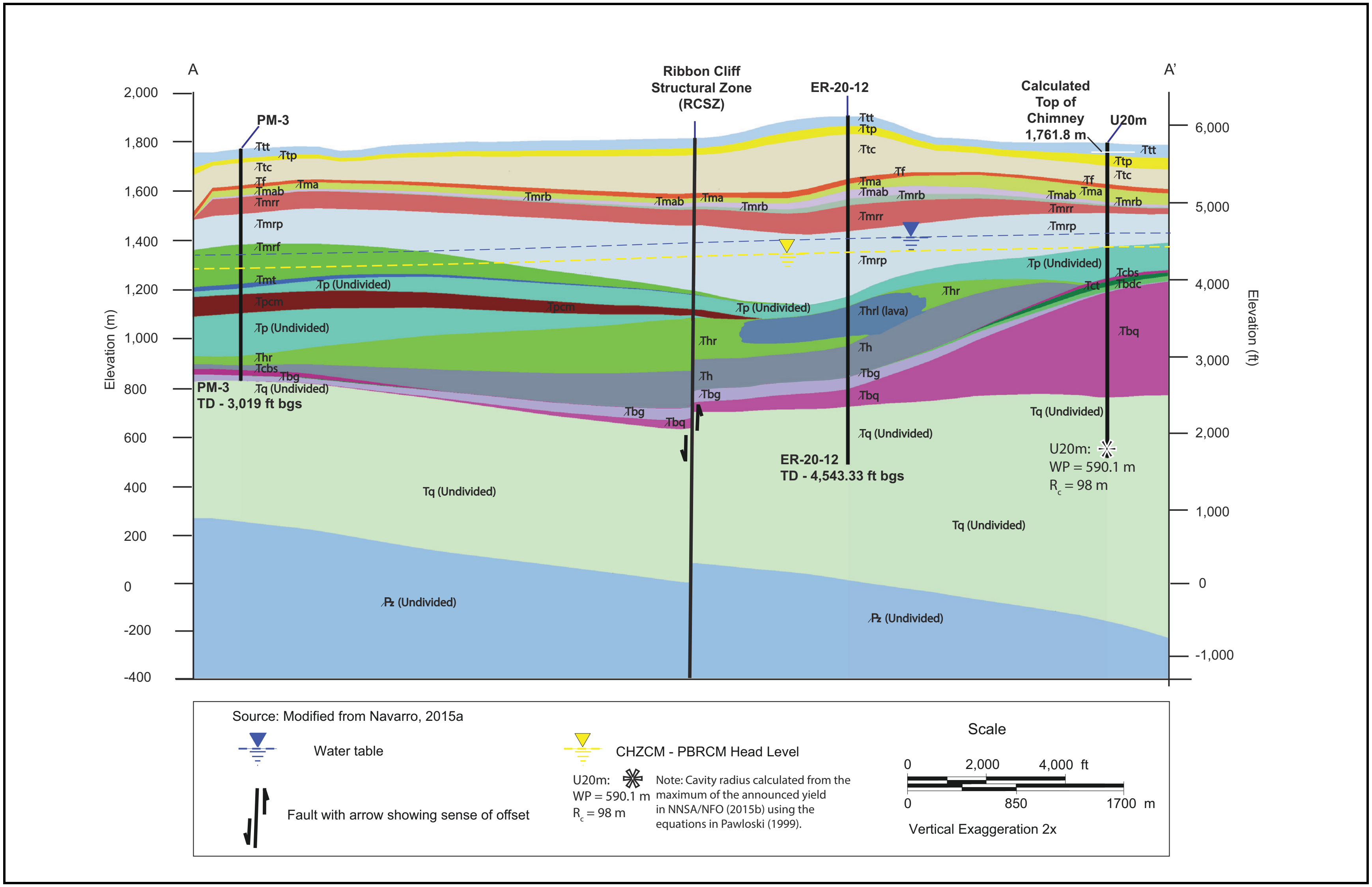


Figure 5-5
Southwest–Northeast Stratigraphic Cross Section A–A' through Well ER-20-12

The Volcanics of Fortymile Canyon (Tf), rhyolite of Beatty Wash (Tfbw) was encountered below the Thirsty Canyon Group (Tt). Well ER-20-12 penetrated a total of 21.0 m (69 ft) from 251.5 to 272.5 m (825 to 894 ft) of devitrified and vapor phase altered lavas. The rhyolite of Beatty Wash (Tfbw) was identified based on stratigraphic position between the Thirsty Canyon Group (Tt) and the Timber Mountain Group (Tm) as well as the lack of lithics and pumice fragments in the lava.

The Timber Mountain Group (Tm) was encountered after penetrating a thin interval of the Volcanics of Fortymile Canyon (Tf). The Timber Mountain Group is composed of the Ammonia Tanks Tuff (Tma), which erupted 11.45 Ma, and the Rainier Mesa Tuff (Tmr), which erupted 11.6 Ma from the TMCC (Sawyer et al., 1994) located approximately 25.6 km (16 mi) to the southwest. The borehole penetrated 452.9 m (1,486 ft) of Timber Mountain Group tuffs from 272.5 to 725.4 m (894 to 2,380 ft). Timber Mountain Ammonia Tanks mafic-rich Tuff (Tmar) was penetrated from 272.5 to 297.2 m (894 to 975 ft), and was identified based on its stratigraphic position below the Thirsty Canyon Group (Tt) and on the mineralogic assemblage, including terminated and dipyramidal quartz crystals, biotite, and sphene. The Timber Mountain Ammonia Tanks and Rainier Mesa bedded tuffs (Tmab/Tmrb) follows from 297.2 to 358.1 m (975 to 1,175 ft). These units are recognizable based on the highly concentrated crystal fragment content due to most of the vitric ash being washed away by the drilling process.

Below the Tmab/Tmrb is a thick section of Timber Mountain Rainier Mesa Tuff (Tmr) identified by its stratigraphic position and the mineralogic assemblage, including the presence of terminated quartz, and biotite. The Timber Mountain Rainier Mesa Tuff is subdivided as follows: from 358.1 to 460.3 m (1,175 to 1,510 ft) is assigned to the Rainier Mesa mafic-rich Tuff (Tmrr); and from 460.3 to 710.2 m (1,510 to 2,330 ft) is assigned to the Rainier Mesa mafic-poor Tuff (Tmrp). A densely welded vitrophyre occurs within this unit from 551.7 to 562.7 m (1,810 to 1,846 ft). Also, this portion of the borehole, from the vitrophyre and below, is vitric with a gradual downward transition to devitrified ash-flow tuffs followed by zeolitic/argillic alteration; from 710.2 to 725.4 m (2,330 to 2,380 ft) is the Rainier Mesa bedded tuff (Tmrb), which marks the base of the Timber Mountain Group (Tm). The water table occurs with the upper portion of the Tmrr with an observed depth to water of approximately 492.2 m (1,615 ft) bgs.

The Paintbrush Group (Tp), undifferentiated, was encountered from 725.4 to 760.5 m (2,380 to 2,495 ft) for a total of 35.1 m (115 ft) penetrated. The unit consists of crystal-poor ash-flow tuffs and is pervasively zeolitized. The Paintbrush Group is represented wholly by a thin zeolitic ash-flow tuff. The Paintbrush Group rocks erupted from calderas and vents that appear to be coincident with the TMCC between 12.7 and 12.8 Ma (Sawyer et al., 1994).

Below the Paintbrush Group (Tp), Well ER-20-12 penetrates a predominantly vitric lava flow and an underlying series of partially zeolitized ash-flow tuffs from 760.5 to 1,035.7 m (2,495 to 3,398 ft). The lava and underlying ash-flow tuffs are assigned to the Calico Hills Formation (Th). The assignment was based on stratigraphic position below the Paintbrush Group (Tp) and the mineral assemblage observed, consisting of phenocrysts of quartz (terminated, frosted to clear, no resorption texture; biotite and textural features). Detailed petrographic and chemical analysis performed by LANL on cuttings samples selected from this interval also confirm the Calico Hills Formation (Th) assignment. The report detailing the LANL analysis and results is presented in Appendix H. The lava within the upper portion of the interval between 758.9 to 871.7 m (2,490 to 2,860 ft) bgs exhibits a typical rhyolitic lava-flow profile (i.e., pumiceous lava top, vitrophyric layer, stoney core, basal vitrophyric layer, basal flow breccia underlain by a pumice fall). The underlying nonwelded to lower lithic-rich ash-flows tuffs are variably zeolitic. Notably, this interval contributed significantly to the produced groundwater flow observed during drilling, based on the fractured nature of both the underlying lavas and ash-flow tuffs (Figure 4-1).

Well ER-20-12 next penetrated rocks of the Belted Range Group (Tb). Belted Range Group units erupted from the now-buried Grouse Canyon caldera, which is included as part of the SCCC located approximately 14 km (8.67 mi) east of the Well ER-20-12 location. Although the exact location of the Grouse Canyon caldera is uncertain, as it is deeply buried in the SCCC, it is clear based on the outflow geometries of the ash-flow tuffs such as the Grouse Canyon Tuff (Tbg) that they are sourced from within the SCCC. The eruption of these units took place between 13.85 and 13.5 Ma (Sawyer et al., 1994). A total of 48.2 m (158 ft) of Grouse Canyon Tuff (Tbg) was identified in Well ER-20-12; the unit was intercepted from 1,035.7 to 1,083.9 m (3,398 to 3,556 ft), including 4.9 m (16 ft) of a basal bedded tuff. Underlying the Grouse Canyon Tuff (Tbg) was 71.6 m (235 ft) of the Comendite of Quartet Dome (Tbq) that was penetrated from 1,083.9 to 1,155.5 m (3,556 to 3,791 ft). The Comendite of Quartet Dome consists of a lava flow, vitrophyric to partially altered, and a moderately to densely welded ash-flow tuff. Alternatively, the ash-flow may also be interpreted as a devitrified lava. The Belted Range units contributed significantly to the observed groundwater production during drilling, which is supported by the nature of fracturing observed in cuttings and resistivity image logs such as the FMI.

Pre-Belted Range rocks were encountered beginning at 1,155.5 m (3,791 ft) bgs. The rhyolite of Handley (Tqj)—consisting of a series of lavas, lava and flow breccia, and a lower nonwelded ash-flow tuff—was intercepted from 1,155.5 to 1,384.8 m (3,791 to 4,543.33 ft) bgs for a total thickness of 229.3 m (752.33 ft). The source of these Pre-Belted Range rocks is believed to be eruptions related to within the SCCC. However, these rocks are not well known, and the information related to these units is restricted to deeper boreholes located near the location of Well ER-20-12, including Wells U20m and UE20j. Well ER-20-12 was drilled to a TD of 1,384.8 m (4,453.33 ft) bgs; at this depth, the borehole continued to penetrate nonwelded ash-flow tuffs of the rhyolite of Handley (Tqj).

5.2.3 Alteration

The volcanic rocks of the Thirsty Canyon Group (Tt), Volcanics of Fortymile Canyon (Tf), and the Timber Mountain Group (Tm) are a mixture of nonwelded to densely welded tuffs, bedded tuffs, and lavas. Unaltered rocks include nonwelded and bedded tuffs that have retained their original vitric (i.e., glassy character). The welded portions of the ash-flow tuffs are mostly devitrified as a result of recrystallization of the original glass matrix to microcrystalline quartz and feldspars during cooling and degassing as the welding process progressed. Portions of the lavas are also locally devitrified. Generally, from 0 to 725.4 m (0 to 2,380 ft) bgs, the nonwelded tuffs and bedded tuffs are vitric to partially devitrified with some minor argillic alteration and/or vapor phase alteration; lavas and densely to moderately welded tuffs at Well ER-20-12 are typically mostly devitrified. The exception to this is the Timber Mountain Rainier Mesa Tuff (Tmr) vitrophyre and lower moderately to nonwelded subzones, which are vitric to partially vitric. Below 725.4 m (2,380 ft) bgs, beginning with the Paintbrush Group (Tp) nonwelded tuffs, the nonwelded tuffs are typically variably but pervasively altered to zeolites, and locally argillized. Lavas along with moderate to densely welded tuffs are less altered and variably devitrified. Due to the dense nature of the glass, the lavas of the Calico Hills Formation (Th) and the Comendite of Quartet Dome (Tbq) are vitric to devitrified with very minor incipient zeolitic or argillic alteration. Portions of the Comendite of Quartet Dome and the rhyolite of Handley (Tqj) show strong devitrification textures overprinted by apparent quartzo-feldspathic alteration. Near the TD of the well, the rhyolite of Handley from 1,268.9 to 1,347.2 m (4,160 to 4,420 ft) bgs exhibits apparent chloritic alteration.

5.3 Predicted and Actual Geology

The observed stratigraphic sequence and lithology encountered in Well ER-20-12 differed from the predicted stratigraphy and associated lithologies in a number of areas, as shown in Figure 5-6. This is not surprising, as the subsurface geology in the area of Well ER-20-12 is not particularly well constrained with the exception of a few nearby wells (i.e., U20m, UE20j, and PM-3). Although these wells provide some sense of the stratigraphic package of rock units locally present, the location of ER-20-12 near the western edge of the SCCC presents some uncertainty with respect to structural influences and the thickness of units related to their nature (i.e., lavas) and their respective eruptive sources. Differences between predicted and actual geology in boreholes are not uncommon, especially in areas with minimal geologic controls. These differences arise from the complex relationships between topographic, volcanic, and structural processes within caldera forming systems. The principal stratigraphic differences between the predicted stratigraphy and the actual stratigraphy beginning at the surface were that the Thirsty Canyon Group (Tt) was approximately 73.1 m (240 ft) thicker than predicted; this is principally attributed to the increased thickness of the lavas present within Comendite of Ribbon Cliff (Ttc). The Timber Mountain Group (Tm) was approximately 36.6 m (120 ft) thicker, and the Paintbrush Group (Tp) was approximately 36.6 m (120 ft) thinner. The Calico Hills Formation (Th) was not expected to be present at Well ER-20-12 and was thought to be restricted to the SCCC to the east of the well location. Well ER-20-12 intersected approximately 102.1 m (335 ft) of the Calico Hills rhyolitic lava (Thrl), approximately 42.7 m (140 ft) thicker than the predicted thickness of the Bullfrog and Tram Formations thought to be present. The underlying Belted Range Group (Tb), consisting of the Grouse Canyon Tuff (Tbg) and Comendite of Quartet Dome (Tbq), was approximately 36.6 m (120 ft) thicker. The Volcanics of Quartz Mountain (Tq), the rhyolite of Handley (Tqj) was encountered approximately 213.4 m (700 ft) lower than anticipated. In addition, the predicted zone of groundwater saturation was apparent at a slightly higher level within the Timber Mountain Group (Tm) units.

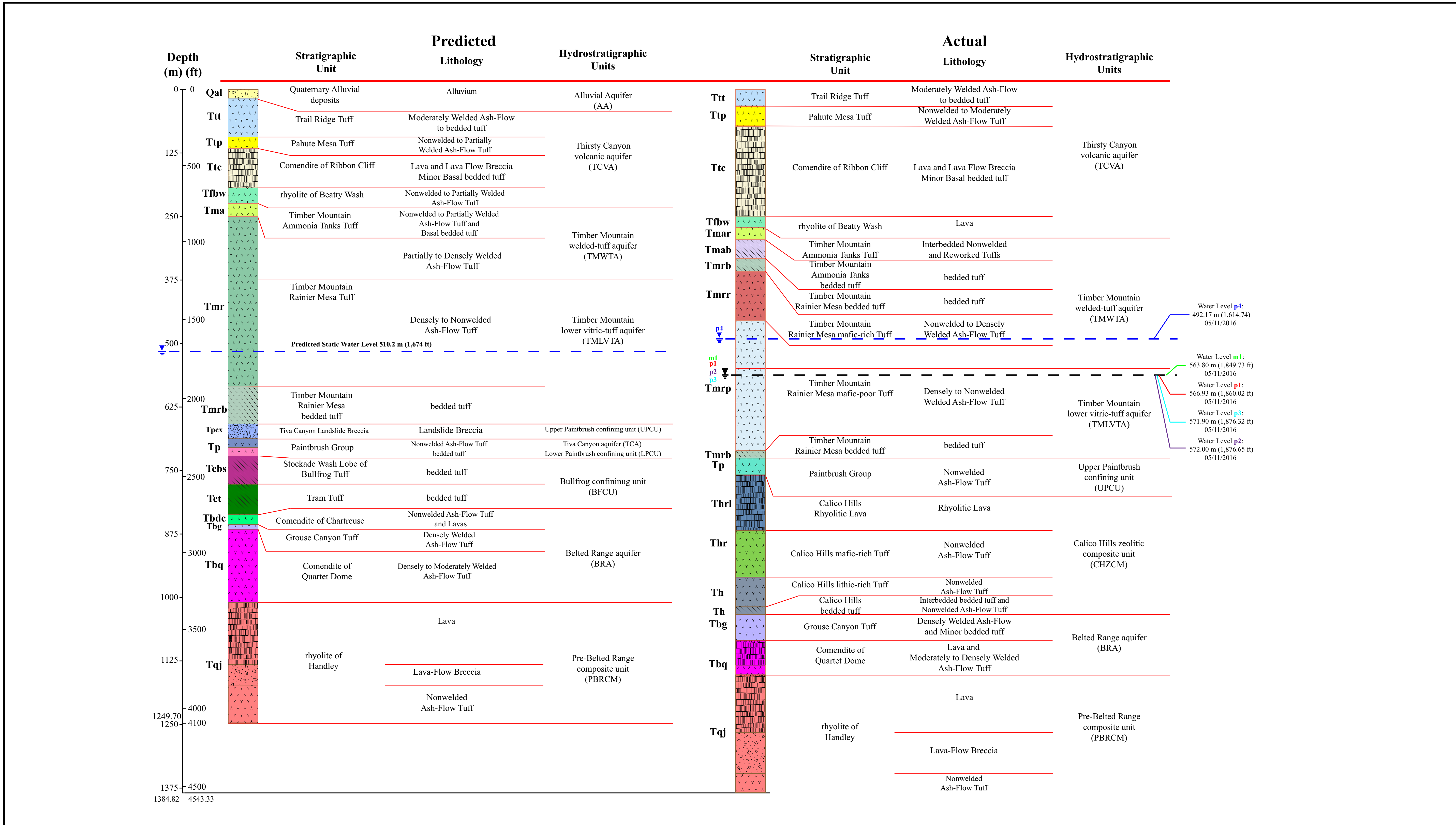


Figure 5-6
Predicted and Actual Stratigraphy at Well ER-20-12

A review of resistivity image logs (FMI) acquired in the open borehole during the drilling of Well ER-20-12 provided information on the nature of fracture and bedding within units encountered in the borehole. Due to the nature of the FMI logging tool, this information is available only for units penetrated below the water table at approximately 492.2 m (1,615 ft) bgs. Detailed information with respect to the nature of FMI observations is provided in Appendix G. Bedding planes from approximately 548.6 to 731.5 m (1,800 to 2,400 ft) bgs are generally flat lying with dips between 0 to 10 degrees, while from approximately 853.4 to 1,371.6 m (2,800 to 4,500 ft) bgs the dip ranges from 10 to 35 degrees. The change in dip magnitude and azimuth of bedding plane features suggests that geologic or structural processes were active, up to and including the eruption and deposition of, at least portions of the Calico Hills Formation (Th). Units from the Paintbrush Group (Tp) and above appear to have shallower bedding dips and a different azimuth orientation of bedding features. These geometries suggest the structural influences in the area had subsided, allowing the younger Timber Mountain and Thirsty Canyon units to be deposited with more flat-lying dips. Figures 5-7 and 5-8 provide cross-section views of the hydrostratigraphy and show the observed bedding geometries noted at the contacts between units.

As a part of the effort to better understand the geology at depth in the area of Well ER-20-12, gravity inversion data (Hildenbrand et al., 1999) as shown in Figure 5-2 was integrated into the PM-OV HFM and referenced in cross-sectional views through Well ER-20-12 as shown in Figures 5-7 and 5-8. The gravity anomalies expressed in these cross sections are shown as thicknesses of Cenozoic units. When rendered in these cross sections, the most conservative gravity measurements are presented and, as such, are biased to a show a greater thickness of Cenozoic units than actually calculated in the original reporting (Hildenbrand et al., 1999). This measured gravity inversion data, when shown in cross section (Figures 5-7 and 5-8), provides the estimated depth to Pre-Cenozoic units in the area. These data in conjunction with geologic data from Wells ER-20-12, PM-3, and U20m allowed for interpretation of the presence of Pre-Cenozoic units in the subsurface beyond the depth of Well ER-20-12. The data suggest that the Pre-Belted Range units may be thinner than previously thought, and a possible structurally influenced high area of Pre-Cenozoic units may exist in the area of Well ER-20-12. This portion of Pahute Mesa is located to the west of the Grouse Canyon and Area 20 calderas, which are included in the larger SCCC. The western margin of these calderas was likely influenced or controlled by the Thirsty Canyon lineament. It is postulated that gravity expression of

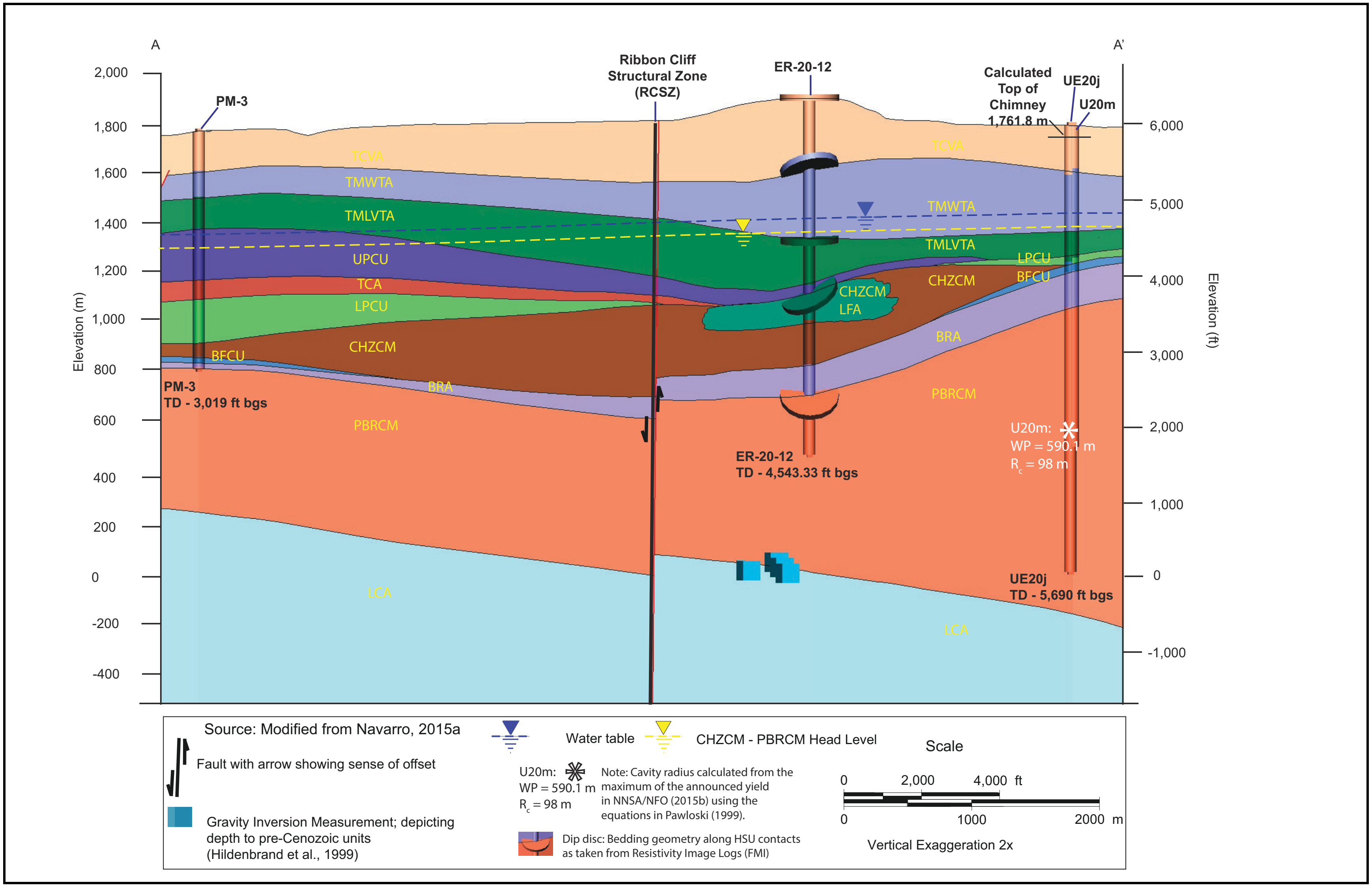


Figure 5-7
Southwest–Northeast Hydrostratigraphic Cross Section A–A' through Well ER-20-12

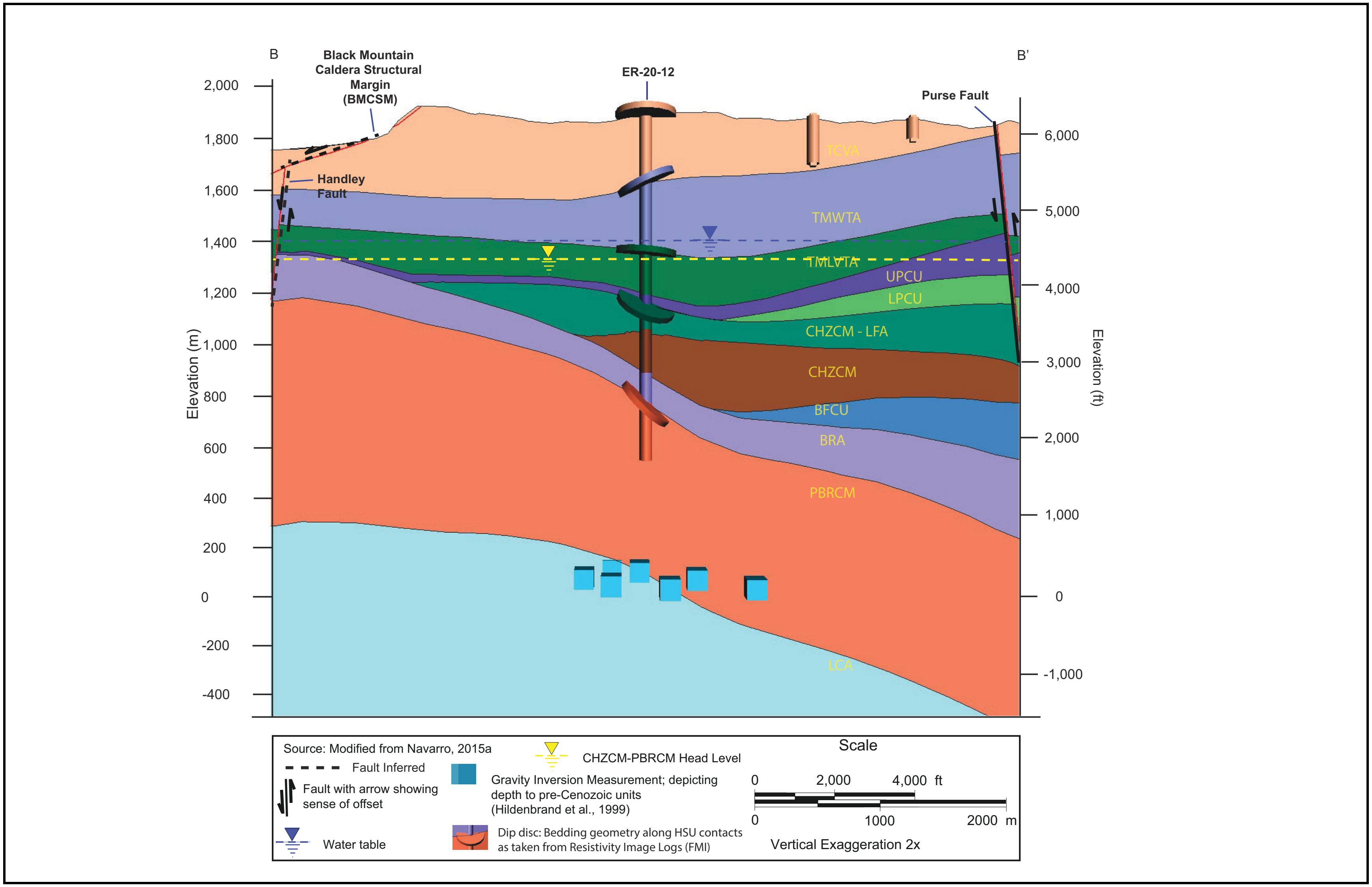


Figure 5-8
East–West Hydrostratigraphic Geologic Cross Section B–B' through Well ER-20-12

Thirsty Canyon lineament as shown in Figure 5-3, suggests a structural high to the west of the lineament, which appears coincident with the structural margin of the SCCC.

5.4 Hydrogeology

The saturated portion of Well ER-20-12 consists of a series of predominantly aquifer-type rocks. These rocks are hydrogeologically assigned to WTAs, VTAs, and LFAs. The package of aquifer-type rock units is divided by tuff confining units that consist of zeolitically altered nonwelded ash flows. The nonwelded tuffs of the Paintbrush group (Tp) are altered to zeolite and locally argillized, and separate the WTAs above from the LFAs of the Calico Hills Formation (Th) below. The nonwelded and zeolitic altered tuffs of the Calico Hills Formation that underlie the lavas of the Calico Hills Formation, although altered, appear to be productive based on water production estimates during drilling. This productivity appears to be related to the extent of fracturing observed within this unit. Below the Calico Hills Formation, Well ER-20-12 encountered predominantly LFAs and WTAs assigned stratigraphically to the Belted Range Group (Tb) and those units of the Pre-Belted Range rocks. Figure 5-6 shows the predicted versus actual stratigraphy and hydrostratigraphic assignments.

The distribution of HSUs in the vicinity of Well ER-20-12 is shown in cross section in Figures 5-7 and 5-8. The well penetrated a total of seven HSUs: the TCVA (unsaturated), TMWTA (saturated below 492 m [1,615 ft] bgs), TMLVTA (saturated), UPCU (saturated), CHZCM (saturated), BRA (saturated), and PBRCM (saturated).

Before drilling, it was predicted that the water table would be encountered at 510.2 m (1,674 ft) bgs within the WTA of the Rainier Mesa Tuff (Tmr). This water level occurs with the lower WTA in the Rainier Mesa Tuff. The observed water table measured on May 11, 2016, was 492.2 m (1,614.74 ft) bgs and was found to occur at a somewhat higher than predicted level but, as predicted, within the WTA of the Rainier Mesa Tuff. During drilling, water production was first noted in Well ER-20-12 at approximately 519.7 m (1,705 ft) bgs in the TMWTA, approximately 30.48 m (100 ft) below the subsequent measurement of the water table at approximately 492 m (1,615 ft) bgs.

During drilling operations, the 66.04-cm (26-in.) borehole was advanced to the tuff confining unit within the Paintbrush Group (Tp), and 50.80-cm (20-in.) surface casing was installed to provide hydraulic isolation of the saturated TMWTA and the TMLVTA as discussed in Section 8.0. Drilling was continued in saturated lavas and WTAs below to a depth of 1,384.7 m (4,543 ft) bgs. During drilling and construction, it was noted that the measured water levels within the borehole and subsequent cased completions on May 11, 2016, indicated a significantly lower water level in those WTA and LFA units below the UPCU. Measurements range from approximately 562.7 to 571.8 m (1,846 to 1,876 ft) bgs. These measurements indicate a potential head difference of up to 79.8 m (262 ft) and indicate that the groundwater in the aquifers above the UPCU is isolated from the units below the confining unit. Figures 5-7 and 5-8 illustrate the observed differences in the measured water levels in cross section.

6.0 Hydrology

Hydrologic data collected at ER-20-12 included water-level measurements, estimates of groundwater production rates during drilling, slug test data, water-level (pressure) responses noted in observation wells during drilling, and borehole water-quality measurements from discharged drilling fluids. In addition, tritium monitoring was conducted to determine the concentrations of this specific radionuclide (RN) in discharge fluids. This section summarizes the well hydrology data obtained during drilling and well completion operations, as modified from Navarro (2016a). The saturated section of Well ER-20-12 consists of the lower portion of the TMWTA along with the TMLVTA, UPCU, CHZCM, BRA, and PBRCM. An interpretation of a distribution of the HSUs in the vicinity of Well ER-20-12 is shown in hydrostratigraphic cross sections Figures 5-7 and 5-8.

6.1 Water Levels

The predicted water level at ER-20-12 was within the TMWTA at a depth of 510.2 m (1,674 ft) bgs (Navarro, 2015a). During drilling operations on November 2, 2015, Navarro measured the fluid level in the borehole at a depth of 492.33 m (1,615.25 ft) bgs. Schlumberger and COLOG recorded similar fluid levels during geophysical logging on November 4 and 5, 2015, at a depth of 492.86 m (1,617.00 ft) bgs and 492.25 m (1,615.00 ft) bgs, respectively. These measurements were made after penetrating the TMWTA, the underlying TMLVTA, and the UPCU. The borehole did not penetrate the underlying CHZCM. After hydraulically isolating the saturated TMWTA, TMLVTA, and the UPCU with casing, the borehole was advanced to a depth of 1,384.7 m (4,353.33 ft) bgs. During this drilling, the well encountered the CHZCM, BRA, and PBRCM, consisting of predominantly LFAs and WTAs. On December 4, 2015, COLOG and Navarro measured fluid level in the 50.80-cm (20-in.) casing with an open borehole at 575.77 m (1,889.00 ft) bgs and 574.03 m (1,883.3 ft) bgs, respectively.

After drilling, the well was completed with four piezometers and a single cased completion. The piezometers and the cased interval were isolated with cement to provide access through slotted intervals and gravel pack to specific HSUs identified during drilling. In May 2016, Navarro obtained depth to water measurements from the respective piezometers and cased open intervals and HSUs as follows: p1 (BRA), 566.93 m (1,860.02 ft) bgs; p2 (CHZCM), 572 m (1,876.65 ft) bgs; p3 (CHZCM), 571.9 m (1,876.32 ft) bgs; and p4 (TMWTA/TMLVTA), 492.17 m (1,614.74 ft) bgs. Figure 8-1 provides a diagram showing the well construction and the respective water-level measurements. Fluid measurements made in the borehole are summarized in Table 6-1.

Table 6-1
Well ER-20-12 Water-Level Measurements
(Page 1 of 2)

Date-Time	Fluid Depth		Fluid Elevation [a]		Notes
	m bgs	ft bgs	m amsl	ft amsl	
11/02/2015 12:45	492.33	1,615.25	1,415.23	4,643.15	Fluid level measured with e-tape No. 11 at 1,615.25 ft bgs.
11/04/2015 12:00	492.86	1,617.00	1,414.70	4,641.40	Fluid level measured by Schlumberger during logging (Run 1).
11/05/2015 22:00	492.25	1,615.00	1,415.31	4,643.40	Fluid level measure by COLOG during logging (Run 1).
11/20/2015 10:20	492.57	1,616.03	1,414.99	4,642.37	Fluid level measurement by Navarro with e-tape No. 36, water level inside 1.9-in. tubing ~12 hours after tubing installation.
11/21/2015 16:30	510.91	1,676.23	1,396.65	4,582.17	Fluid level measurement by Navarro with e-tape No. 36, water level inside 20-in. casing.
11/21/2015 19:17	493.13	1,617.87	1,414.43	4,640.53	Fluid level measurement by Navarro with e-tape No. 36, water level inside 1.9-in. tubing.
12/03/2015 03:48	494.08	1,621.00	1,413.48	4,637.4	Fluid level measurement by Schlumberger in annulus between borehole and 20-in. casing.
12/04/2015 00:00	575.77	1,889.00	1,331.79	4,369.4	Fluid level measurement by COLOG in 20-in. casing.
12/06/2015 02:45	574.03	1,883.30	1,333.53	4,375.1	Fluid level measurement by Navarro with e-tape No. 11, water level inside 20-in. casing after geophysical logging. 18.5-in. hole open to 4,352.16 ft.
12/06/2015 10:42	571.72	1,880.58	1,335.84	4,382.69	Fluid level measurement by Navarro with e-tape No. 11, water level inside 20-in. casing before installing 13.375-in. casing and after geophysical logging.
12/12/2015 04:00	573.20	1,875.71	1,334.36	4,377.82	Fluid level measurement by Navarro with e-tape No. 36, water level inside p1 piezometer.
12/16/2015 23:00	572.11	1,877.00	1,335.45	4,381.4	Fluid level measurement by COLOG in "Deep" - intermediate 2.375-in. piezometer.
12/19/2015 10:24	573.33	1,881.00	1,334.23	4,377.4	Fluid level measurement by COLOG in "Deep" - intermediate 2.375-in. piezometer before second cement lift.
12/22/2015 07:00	491.90	1,613.85	1,415.66	4,644.55	Fluid level measurement by Navarro with e-tape No. 36, water level inside p4 piezometer approximately 5.5 hours after 9.625-in. casing was stemmed.

Table 6-1
Well ER-20-12 Water-Level Measurements
(Page 2 of 2)

Date-Time	Fluid Depth		Fluid Elevation [a]		Notes
	m bgs	ft bgs	m amsl	ft amsl	
12/29/2015 14:15	572.66	1,878.79	1,334.90	4,379.61	Fluid level measurement by Navarro with e-tape No. 36, water level inside p3 piezometer after removal of PXD and recent stemming/cementing operations.
01/04/2016 15:40	492.02	1,614.23	1,415.54	4,644.17	Fluid level measurement by Navarro in "Shallow" 1.9-in. piezometer p4 (between borehole annulus and 20-in. casing), with e-tape No. 36.
01/04/2016 09:00	563.83	1,849.83	1,343.73	4,408.57	Fluid level measurement by Navarro inside 9.625-in. casing m1 with e-tape No. 6.
01/04/2016 16:00	566.97	1,860.14	1,340.59	4,398.26	Fluid level measurement by Navarro in the Intermediate Zone "Deep" 2.375-in. piezometer p1 with e-tape No. 36.
01/04/2016 22:32	571.94	1,876.44	1,335.62	4,381.96	Fluid level measurement by Navarro in the Intermediate Zone "Shallow" 2.375-in. piezometer p3 with e-tape No. 36.
01/04/2016 23:05	571.92	1,876.39	1,335.64	4,382.01	Fluid level measurement by Navarro in the Intermediate Zone "Intermediate" 1.9-in. piezometer p2 with e-tape No. 36.
05/11/2016 12:30	492.17	1,614.74	1,415.39	4,643.66	Fluid level measurement by Navarro in "Shallow" 1.9-in. piezometer p4 (between borehole annulus and 20-in. casing), with e-tape No. 56.
05/11/2016 13:00	572.00	1,876.65	1,335.56	4,381.75	Fluid level measurement by Navarro in the Intermediate Zone "Intermediate" 1.9-in. piezometer p2 with e-tape No. 56.
05/11/2016 13:30	563.80	1,849.73	1,343.76	4,408.67	Fluid level measurement by Navarro inside 9.625-in. casing m1 with e-tape No. 56.
05/11/2016 14:30	566.93	1,860.02	1,340.63	4,398.38	Fluid level measurement by Navarro in the Intermediate Zone "Deep" 2.375-in. piezometer p1 with e-tape No. 6.
05/11/2016 15:00	571.90	1,876.32	1,335.66	4,382.08	Fluid level measurement by Navarro in the Intermediate Zone "Shallow" 2.375-in. piezometer p3 with e-tape No. 6.

[a] Ground surface used as reference datum. Ground surface elevation as-built survey by NSTec at 1,907.56 m (6,258.40 ft) amsl.

PXD = Pressure transducer

Based on the water-level measurements acquired during drilling and after well completion, there is a large head difference between those HSUs that lie above the UPCU (e.g., TMWTA and TMLVTA) and those HSUs that lie below this unit (e.g., CHZCM, BRA, and PBRCM). Although there are some differences between the discrete measurements made in the isolated piezometers and cased intervals below the UPCU, there is an measured maximum difference in head between the units above and below the UPCU of 79.8 m (262 ft).

6.2 Water Production

Water production was estimated during drilling of Well ER-20-12 on the basis of dilution of a lithium bromide tracer, as measured by Navarro field personnel on site. The tracer is added to drilling fluids before being injected downhole as part of the drilling fluids. Concentrations of bromide in the mist tanks and discharge fluids were monitored regularly during drilling. Groundwater production was estimated based on the difference between injected and discharged bromide concentrations and considered other observations, such as visual estimates of flow and changes in the measured sump volume over time. The tracer method of estimating groundwater production is subject to a number of variables and conditions such as high water flow resulting in excessive dilution of the injected tracers concentrations beyond the detection limits of the monitoring instrumentation. Water production estimates recorded within the CHZCM during drilling were uncertain and understated due to the excessive dilution of tracers; this situation was corrected as the drilling penetrated the BRA, and water production estimates are likely more reflective of the actual rates of groundwater produced. Figure A-1 of Appendix A provides water production estimates and associated drilling parameters. Appendix F presents the bromide tracer data without modification based on other methods. Figure 6-1 provides the estimated water production and the tritium concentrations recorded during drilling.

Water production estimated during the drilling of Well ER-20-12 ranged from 0 to 2,271 liters per minute (Lpm) (0 to 600 gallons per minute [gpm]). The first observation of groundwater was based on bromide dilution calculations at a depth of approximately 519.7 m (1,705 ft) bgs within the TMWTA. The water production rate gradually increased as the hole penetrated further into the saturated TMLVTA, where apparent water production leveled off at approximately 227 to 303 Lpm (60 to 80 gpm). The borehole was opened to 66.04 cm (26 in.), and 50.80-cm (20-in.) surface casing was set at 762.9 m (2,502.8 ft) bgs near the UPCU-CHZCM contact. Drilling resumed and penetrated an LFA within the upper CHZCM; apparent water production was less than 37.8 Lpm (10 gpm) as the unit was penetrated below the casing. At approximately 816.9 m (2,680 ft) bgs, water production increased from 94.6 to nearly 302.8 Lpm (25 to nearly 80 gpm) in the lower portion of the LFA within

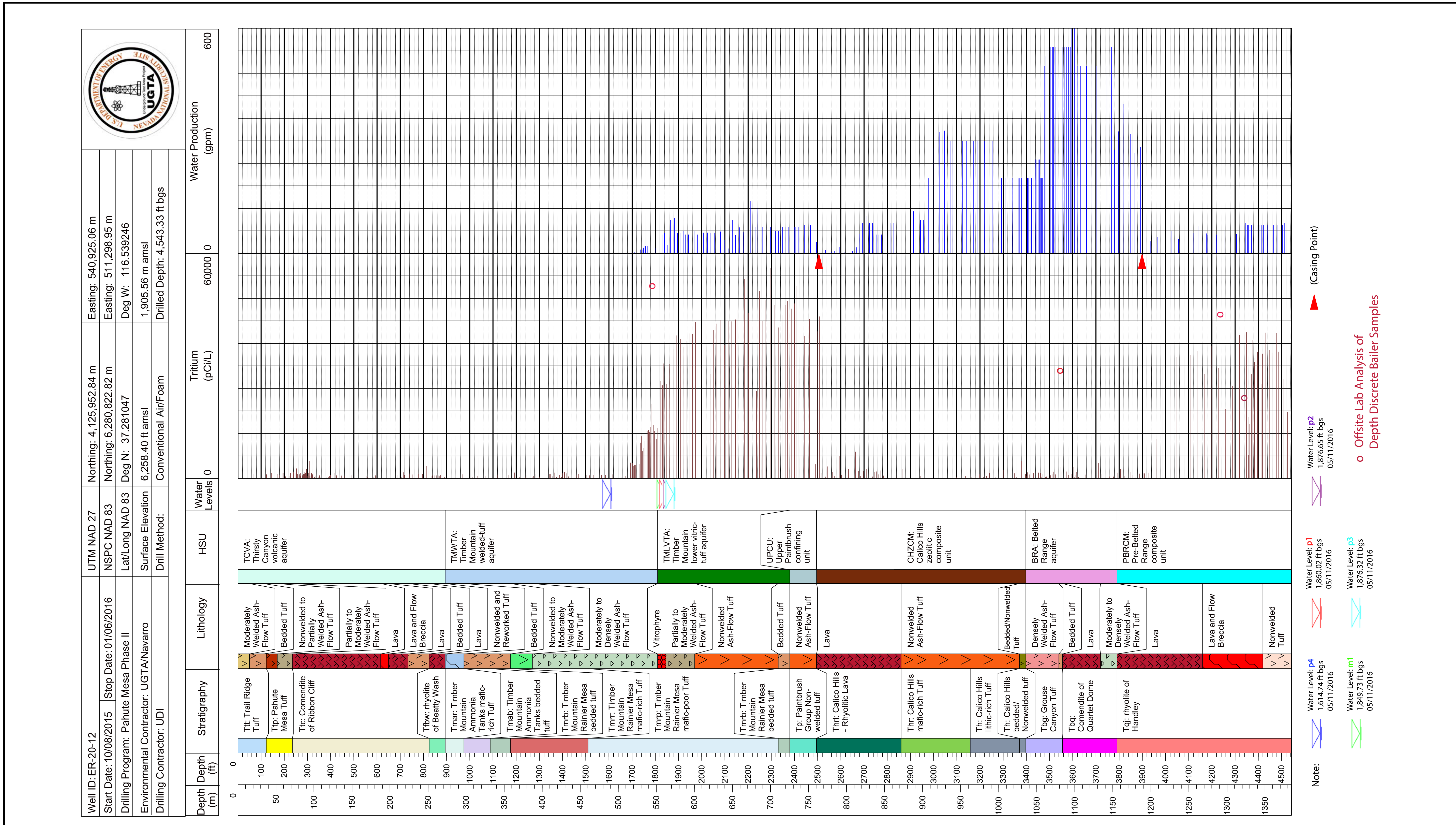


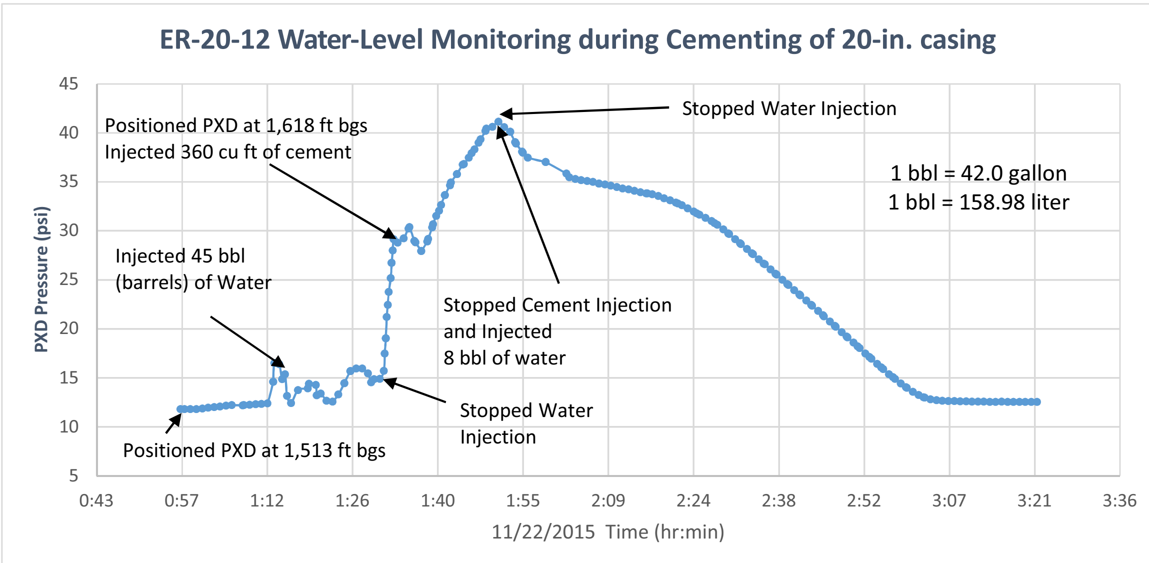
Figure 6-1
Well ER-20-12 Tritium Concentrations and Estimated Water Production during Drilling

the CHZCM. Estimated water production shows increasing trends into the nonwelded tuff portion of the CHZCM. Apparent water production increased to between 681 to 946 Lpm (180 to 250 gpm) from approximately 914.4 to 1,060.7 m (3,000 to 3,480 ft) bgs. This corresponds to the lower portion of the CHZCM nonwelded mafic-rich tuffs through the nonwelded lithic-rich tuffs of the CHZCM and into the BRA. The water production through this interval may be understated due to excessive tracer dilutions experienced to a depth of approximately 1,066.8 m (3,500 ft) bgs. The relative increase in estimated water production corresponds to the features (e.g., fractures/joints) noted in this interval and observed in the analysis of the FMI geophysical log. Water production estimates peaked in the BRA at 1,893 to 2,271 Lpm (500 to 600 gpm) from approximately 1,060.7 to 1,152.1 m (3,480 to 3,780 ft) bgs. Intermediate surface casing, 24.4 cm (9.625 in.), was set to 1,188.72 m (3,900 ft) bgs, and the BRA was isolated. Drilling resumed in the PBRCM, and apparent water production decreased significantly to approximately 114 to 303 Lpm (30 to 80 gpm) until the hole reached TD at 1,384.8 m (4,543.33 ft) bgs.

6.3 Slug Tests

Slug test data were collected during cementing of the 50.8-cm (20-in.) and 24.4-cm (9.625-in.) casings, and the data are presented in Figure 6-2. The first slug test was conducted to obtain data for estimating hydraulic parameters for the TMLVTA and a portion of the TMWTA. These units remain open and available for water-level monitoring through a piezometer located in the annular space between the 50.8-cm (20-in.) casing and the 66.04-cm (26-in.) borehole. The slug test was conducted by introducing known volumes of cement and fresh water required as part of cementing the 50.8-cm (20-in.) casing in place. The casing was configured with a stab-in style float shoe located at a depth of 762.9 m (2,502.8 ft) bgs that allowed pumping of fluid and cement through the shoe directly at the base of the 50.8-cm (20-in.) casing. The shoe, by design, acts as a one-way valve so that once the cement and fluids are pumped, the valve closes and does not allow fluids/cement to return inside the casing. The rise of fluids/cement in the annular space was monitored with a wireline-deployed PXD located within a 4.82-cm (1.9-in.) CS piezometer tube. The results of the test were generally good, and the responses are presented in Figure 6-2.

A second slug test was conducted after installation of the 24.4-cm (9.625-in.) casing at a depth of 1,189 m (3,900 ft) bgs. As described above, a similar approach to performing the test was used. The



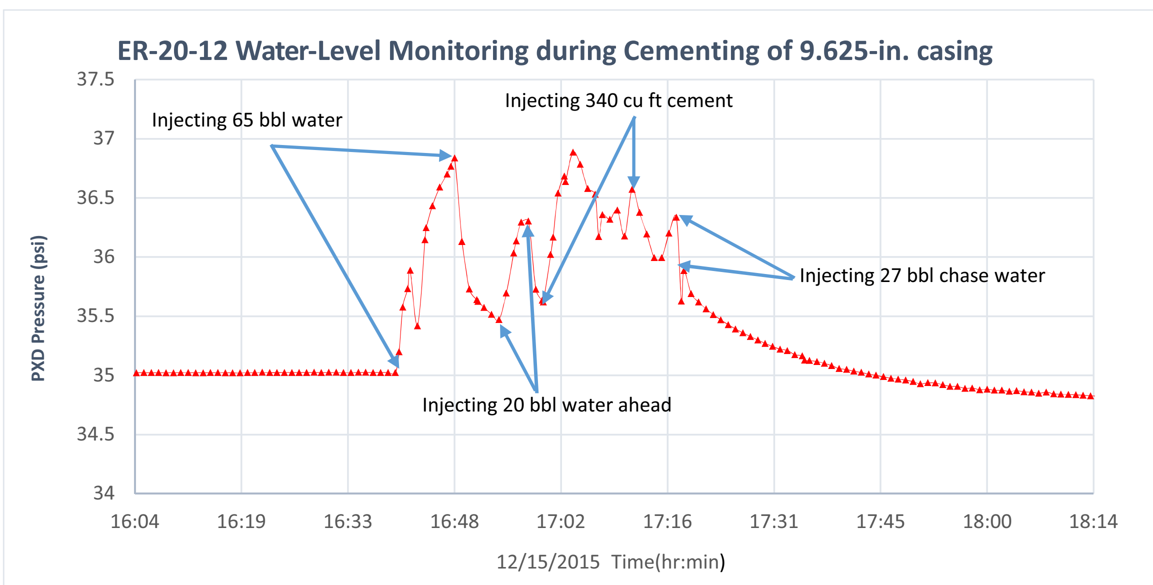


Figure 6-2
Well ER-20-12 Slug Test Data

casing was configured with a stab-in style float shoe that allowed pumping of fluid and cement through the shoe directly at the base of the 24.4-cm (9.625-in.) casing. The rise of fluids/cement in the annular space was monitored with a wireline-deployed PXD located within a 6.03-cm (2.375-in.) CS piezometer tube. This tubing was open to the PBRCM, BRA, and CHCZM HSUs through a slotted 7.30-cm (2.875-in.) SS section located between 777.9 and 887.9 m (2,552.26 and 2,912.96 ft) bgs. The results of this test were generally poor, as shown in Figure 6-2. The pressure response measured by the PXD from each session of pumping (fluid or cement) indicates that the float shoe did not close as designed. The failure of the valve at the float shoe did allow pumped fluids/cement to exit the shoe and enter the annular space between the 24.4-cm (9.625-in.) casing and the 46.9-cm (18.5-in.) borehole as intended; however, once the pumping ceased, the fluids returned inside the casing rather than being taken by the formation. This resulted in dramatic declines in the fluid level that are not indicative of the hydraulic character of the HSUs tested. The responses are presented in Figure 6-2.

6.4 Hydraulic Response Measured in Observation Well PM-3

Several wells located nearest to Well ER-20-12 were instrumented with water-level monitoring equipment including data loggers, barometers, and wireline-deployed PXDs. The equipment was deployed to continuously monitor water levels and associated barometric responses during the entire period of drilling operations. The monitoring of these proximal well locations was established in advance of the drilling operations and was maintained after the drilling operations were completed. Figure 6-3 provides a plot of water-level responses recorded at Well PM-3. The water-level instrumentation will remain in operation as part of the Pahute Mesa long-term water-level monitoring program until aquifer testing is complete. Well PM-3, located approximately 5.08 km (3.16 mi) south–southwest of Well ER-20-12, was the only observation well that had an apparent water-level response related to drilling operations. Well PM-3 is completed with two isolated piezometers. The deep piezometer (PM-3-2) discretely monitors water levels within the TCA. The shallow piezometer allows discrete monitoring of the UPCU.

Drilling at Well ER-20-12 reached the water table at a depth of approximately 492.3 m (1,615 ft) bgs on October 21, 2015. The borehole was advanced below the water table through saturated TMWTA, TMLVTA, and then penetrated the UPCU, at which a casing point was established on October 25, 2015, at a depth of 765.1 m (2,510.3 ft) bgs. The borehole was subsequently reamed to 66.04-cm

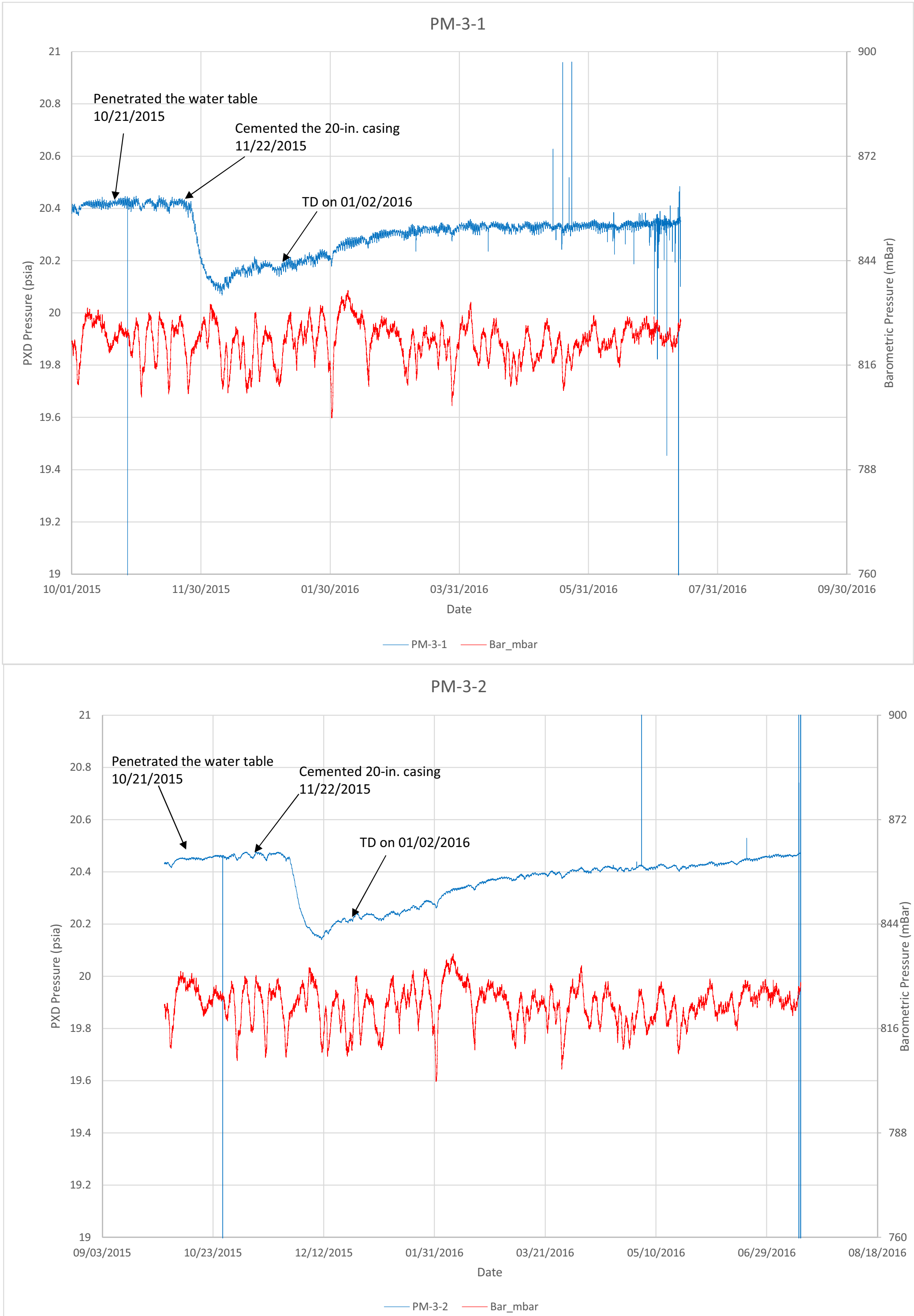


Figure 6-3
Well PM-3 Well Response during Well ER-20-12 Drilling

(26-in.) diameter to allow for the installation of casing. The borehole was not advanced below the UPCU during this segment of drilling. Surface casing was set in the UPCU and cemented in place to hydraulically isolate the TMWTA and the TMLVTA from units to be drilled below the casing. Water-level monitoring conducted at Well PM-3 did not detect any apparent response related to the drilling and hole reaming above the casing point. From November 24 to December 1, 2015, the borehole was advanced below the surface casing in lavas and nonwelded tuffs of the CHCZM, as well as the underlying welded tuffs of the BRA and lavas of PBRCM. The 46.9-cm (18.5-in.) borehole was advanced to a depth of 1,326 m (4,352 ft) bgs within the PBRCM. Water-level monitoring conducted at PM-3 detected abrupt responses in the water levels as drilling progressed below the casing point in the UPCU. The water levels in the shallow piezometer (PM-3-2), which is open to the UPCU, and the deep piezometer (PM-3-1), which is open to the TCA, showed abrupt declines in the static water levels as drilling progressed. These declines are clearly related to the effects of drilling within the CHCZM and may likely reflect effects of water withdrawal in the BRA and PBRCM as the drilling progressed to a TD of 1,386 m (4,543.33 ft) bgs. Interestingly, the water-level responses at PM-3 were restricted to only the period of time when Well ER-20-12 drilling penetrated the CHCZM, BRA, and PBRCM, indicating that there is little or no hydraulic connection between the units above the UPCU (e.g., TMWTA and TMLVTA) in Well ER-20-12 and those intervals monitored in PM-3 (e.g., UPCU and TCA). However, the clearly observable responses recorded in Well PM-3 as the drilling progressed below the UPCU at Well ER-20-12 appear to indicate a good hydraulic connection between the CHCZM, BRA, and PBRCM below the UPCU and clearly demonstrate the strongly confining nature of the UPCU. This appears to be in good agreement with the observed large head difference 79.8 m (262 ft) measured above and below the UPCU as described in Section 6.1.

6.5 Groundwater Chemistry

Navarro monitored discharged drilling fluids during borehole advancement for pH, temperature, and electrical conductivity and used these data to evaluate changes in groundwater conditions during drilling. Water-quality parameters were affected locally by cement used to isolate casing, and may have small changes resulting from the use of drilling foam and polymer during drilling operations. The water-quality measurements may not accurately reflect natural groundwater quality; however, they are generally reflective of changing conditions within the borehole during drilling.

Navarro site personnel collected a depth-discrete bailer sample and a duplicate sample from a depth of 556 m (1,825 ft) bgs in the open borehole on November 6, 2015. Two sets of bailer/duplicate samples were collected on December 6, 2015: one from 1,082 m (3,550 ft) bgs and the other at 1,295 m (4,250 ft) bgs. Additionally, one set of bailer/duplicate samples was collected on January 4, 2016, from 1,319 m (4,328 ft) bgs. Samples were collected using wireline-deployed depth-discrete SS bailers, with varying capacities of 1 to 6 liters. The samples provide initial groundwater chemistry based on select groundwater characterization parameters as identified in the UGTA QAP (NNSA/NFO, 2015a). The bailer and associated sampling equipment were decontaminated according to appropriate procedures before and after sample collection. The analytical results for the bailed groundwater characterization samples are presented in Table B-2 of Appendix B.

6.6 Radionuclides Encountered

Navarro site personnel collected discharged drilling fluid samples on a hourly schedule during borehole advancement. However, based on geologic parameters, hydrologic parameters, or drilling operational criteria, sampling frequency was increased as necessary. The samples were analyzed on site for tritium by NSTec RCTs personnel for fluid management and worker protection screening purposes. Onsite analyses for tritium were performed using LSCs. The average MDA for the LSCs was approximately 1,950 pCi/L. Results from drilling fluid returns ranged from 0 to 83,138 pCi/L. Tritium results were noted above 20,000 pCi/L, the SDWA limit (CFR, 2016b) within the TMLVTA and UPCU HSUs. Tritium concentrations then declined to less than 3,000 pCi/Las the borehole was advanced below the UPCU within the CHZCM and the BRA. Tritium concentrations then increased to levels in excess of 20,000 pCi/L as drilling penetrated the PBRCM. These higher tritium concentrations within the PBRCM persisted at levels at or above the SDWA limit to the total depth of the well. Onsite tritium analyses were also performed on the depth-discrete bailer samples that were collected and analyzed by the offsite laboratory and the results are comparable as shown in Table B-2 of Appendix B. Figure 6-1 provides the onsite tritium monitoring results, analytical results for the depth discrete bailed samples and the estimated water production.

Analyses for RNs were performed by an offsite laboratory, and the results are presented in Table B-1 of Appendix B. Tritium was the only radionuclide reported above the minimum detection limits. Gross alpha, gross beta, and ^{238}U were also noted above the minimum detection limits.

7.0 Precompletion and Open-Hole Development

There was no precompletion or open-hole well development conducted in Well ER-20-12.

8.0 Well Completion

8.1 Introduction

Installation of tubing and casing with screened intervals into the borehole is the process of well completion. Stemming materials are also typically installed around the tubing or casing string, with coarse material (gravel) adjacent to the open intervals and impermeable fill (cement) placed between or above the open intervals to hydraulically isolate the interval. The casing or tubing string provides access to the selected interval for a pump, fluid level measurement instruments, or sampling devices. This equipment is used to conduct hydraulic testing, collect water level data, and collect samples for water chemistry data.

The proposed design for Well ER-20-12 was presented in the addendum to the drilling and completion criteria (Navarro, 2015a). The proposed completion plans are summarized in Section 8.2.1, and the actual well completion design (based on the hydrogeology encountered in the borehole) is presented in Section 8.2.2. Differences between the planned and actual design are discussed in Section 8.2.3. The completion methods are presented in Section 8.3. Figure 8-1 is a schematic diagram of the well completion as-built. Figure 8-2 shows a plan view and profile of the final wellhead surface completion. Figure 8-3 is a photograph showing the ER-20-12 wellhead at the surface. Table 8-1 is a construction summary for the main completion and piezometer strings, and Figure 8-4 is a photograph of the slotted casing or tubing of different sizes installed into Well ER-20-12.

8.2 Well Completion Design

The following subsections provide the well completion design for ER-20-12 and the final well completion as-built in the field. The as-built well completion differs from the proposed design.

8.2.1 Proposed Completion Design

Well ER-20-12 was proposed to be drilled to a TD of 1,249.7 m (4,100 ft) and to reach TD within the rhyolite of Handley (Tqj), which consists of an LFA and WTA. Water was expected at a depth of approximately 510.2 m (1,674 ft) in the Timber Mountain Rainier Mesa bedded tuff (Tmrb). The

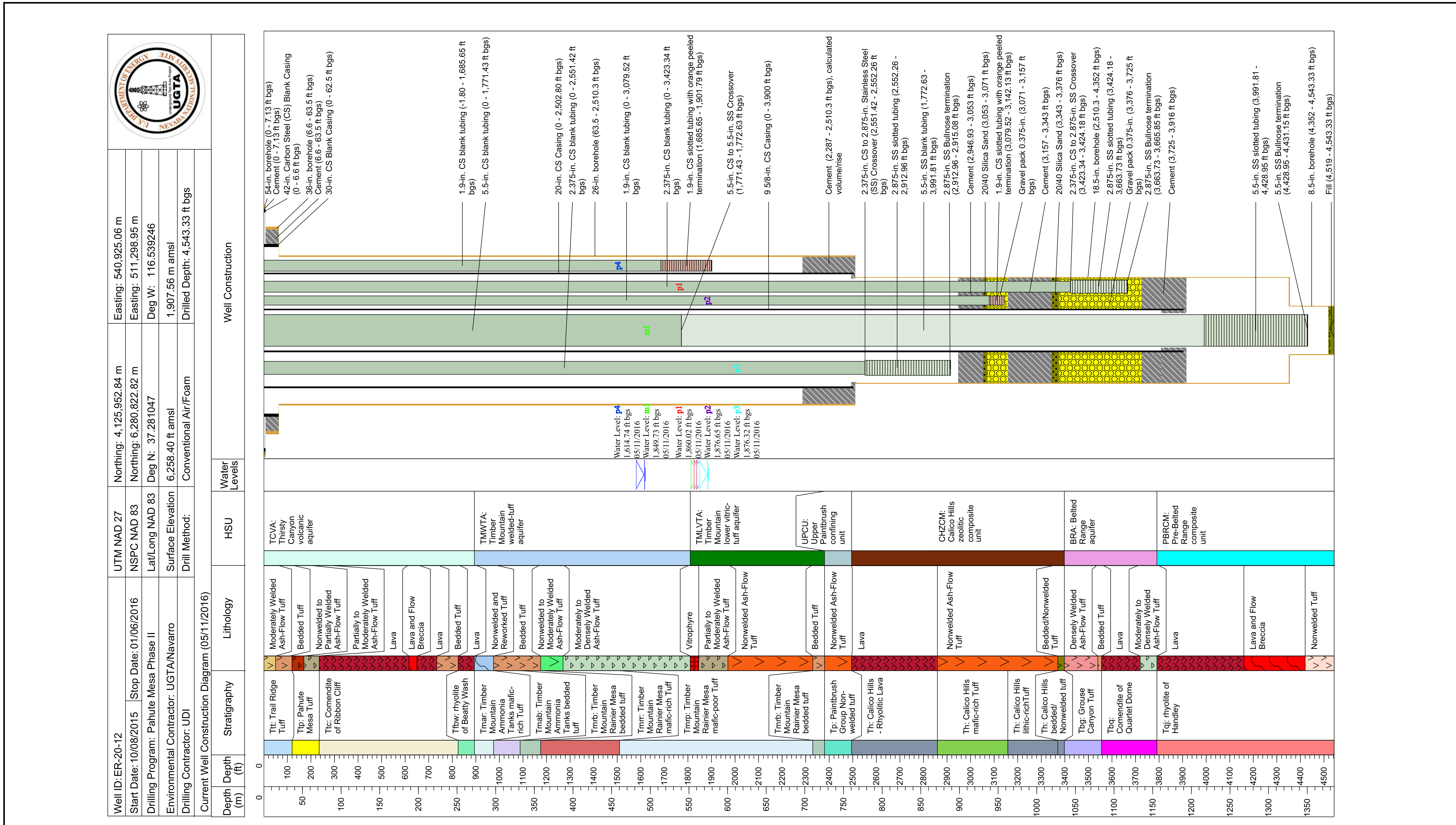


Figure 8-1
Well Completion Diagram for Well ER-20-12

primary purpose of the well completion design was to provide access to the BRA and PBRCM while limiting possible cross communication with other aquifers. Beyond a depth of approximately 551 m (1,810 ft), the well completion was expected to be influenced by the presence of tritium meeting or exceeding the SDWA limit of 20,000 pCi/L(CFR, 2016b), hydrogeologic information, and borehole stability.

The expected HSUs in the saturated portion of the well included the lower portion of the TMLVTA and the UPCU. The portion of the borehole from 0 m (0 ft) to 609.6 m (2,000 ft) was to be drilled to a diameter of 46.9 cm (18.5 in.) and would then be opened to 66.04 cm (26 in.), and 50.80-cm (20-in.) surface casing and a 4.82-cm (1.9-in.) piezometer set. Subsequently, the borehole would be continued as a 46.9-cm (18.5-in.) diameter hole and was expected to penetrate the TCA, a potential target aquifer unit in Well ER-20-12, from approximately 609.6 m (2,000 ft) to 701.0 m (2,300 ft). A piezometer would be installed and isolated to provide access this zone. The borehole would then penetrate a series of confining units, the UPCU and the BFCU. Near the contact between the units, the borehole diameter was planned to be reduced to 31.12 cm (12.25 in.). Typically, the BFCU is characterized by zeolitically altered bedded tuffs. The borehole would continue to advance into the BRA, where it was anticipated that groundwater production would increase and tritium contamination might also increase. The planned 31.12-cm (12.25-in.) borehole would be advanced in the BRA until lavas of the PBRCM were recognized. At this point, the well would be cased to isolate the BRA and a piezometer installed. The borehole size would be reduced to 25.08 cm (9.875 in.) and would penetrate from the bottom of the installed casing within the BRA to the TD of the well within the PBRCM.

Before the main completion string was installed, four piezometers strings were planned to be installed. One optional piezometer tube was to be positioned inside the 66.04-cm (26-in.) borehole and outside the well completion string to monitor water levels during testing and for collecting samples directly from the TMLVTA. Another optional piezometer was to be installed in the TCA and one in the BRA to provide access to these units for water levels, hydraulic test, and water chemistry data. The main completion was to be installed in the same interval as the piezometer in the BRA or in the PBRCM.

8.2.2 As-Built Completion Design

The Well ER-20-12 completion design was determined by the TWG Drilling Advisory Team as the borehole was being drilled. The group modified the initial completion plan based on the onsite evaluation of lithology, water production, water level, borehole conditions, drilling data, geophysical logs, and tritium levels. The final plan required four piezometers and a main completion.

The main completion string (m1) is composed of 13.97-cm (5.5-in.) CS and SS blank with a SS slotted interval from 1,216.70 to 1,349.94 m (3,991.81 to 4,428.95 ft) bgs completed within the PBRCM. The main completion of the well from 0 m (0 ft) ground surface to 539.93 m (1,771.43 ft) was completed with 42 joints of nominally 12.80-m (42-ft) lengths of 13.97-cm (5.5-in.) diameter CS blank casing above a crossover box. In the saturated zone from 540.29 m (1,772.63 ft) to 1,349.94 m (4,428.95 ft), the well was completed with nominal 12.19-m (40-ft) lengths of 13.97-cm (5.5-in.) diameter blank and slotted SS casing. A bullnose termination was installed on the bottom of the completion string from 1,349.94 m (4,428.95 ft) to 1,350.61 m (4,431.15 ft). Table 2-1 provides detailed information regarding slot specifications; nominally 12.19-m (40-ft) lengths of 13.97-cm (5.5-in.) of threaded SS slotted casing was installed as shown in Figure 8-4 (bottom). Depth intervals for the CS tubing and SS blank and slotted tubing are tabulated in Table 8-1.

The deep piezometer (p1) was completed within the BRA and consists of nominal 9.45-m (31-ft) lengths of 6.03-cm (2.375-in.) diameter CS Hydril tubing with upset couplings extending from 0 m (0 ft) ground surface to 1,043.43 m (3,423.34 ft). The crossover, from 6.03-cm (2.375-in.) CS tubing to 7.30-cm (2.875-in.) SS slotted tubing, extends from 1,043.43 m (3,423.34 ft) to 1,043.69 m (3,424.18 ft). The slotted SS tubing consists of nominally 9.45-m (31-ft) lengths of 7.30-cm (2.875-in.) diameter with flush joint couplings, and a bullnosed termination, extending to 1,117.35 m (3,665.85 ft). Table 2-1 provides detailed information regarding slot specifications. Depth intervals for the CS blank and SS slotted tubing are tabulated in Table 8-1.

An intermediate piezometer (p2) was completed within the CHZCM (nonwelded tuffs) and consists of nominally 9.45-m (31-ft) lengths of 4.82-cm (1.9-in.) diameter CS Hydril tubing with upset couplings extending from 0 m (0 ft) ground surface to 938.63 m (3,079.52 ft). The slotted CS tubing consists two joints of nominally 9.45-m (31-ft) lengths of 4.82-cm (1.9-in.) od by 3.83-cm (1.51-in.) id with an orange-peeled termination extending to 957.72 m (3,142.13 ft). Table 2-1 provides detailed

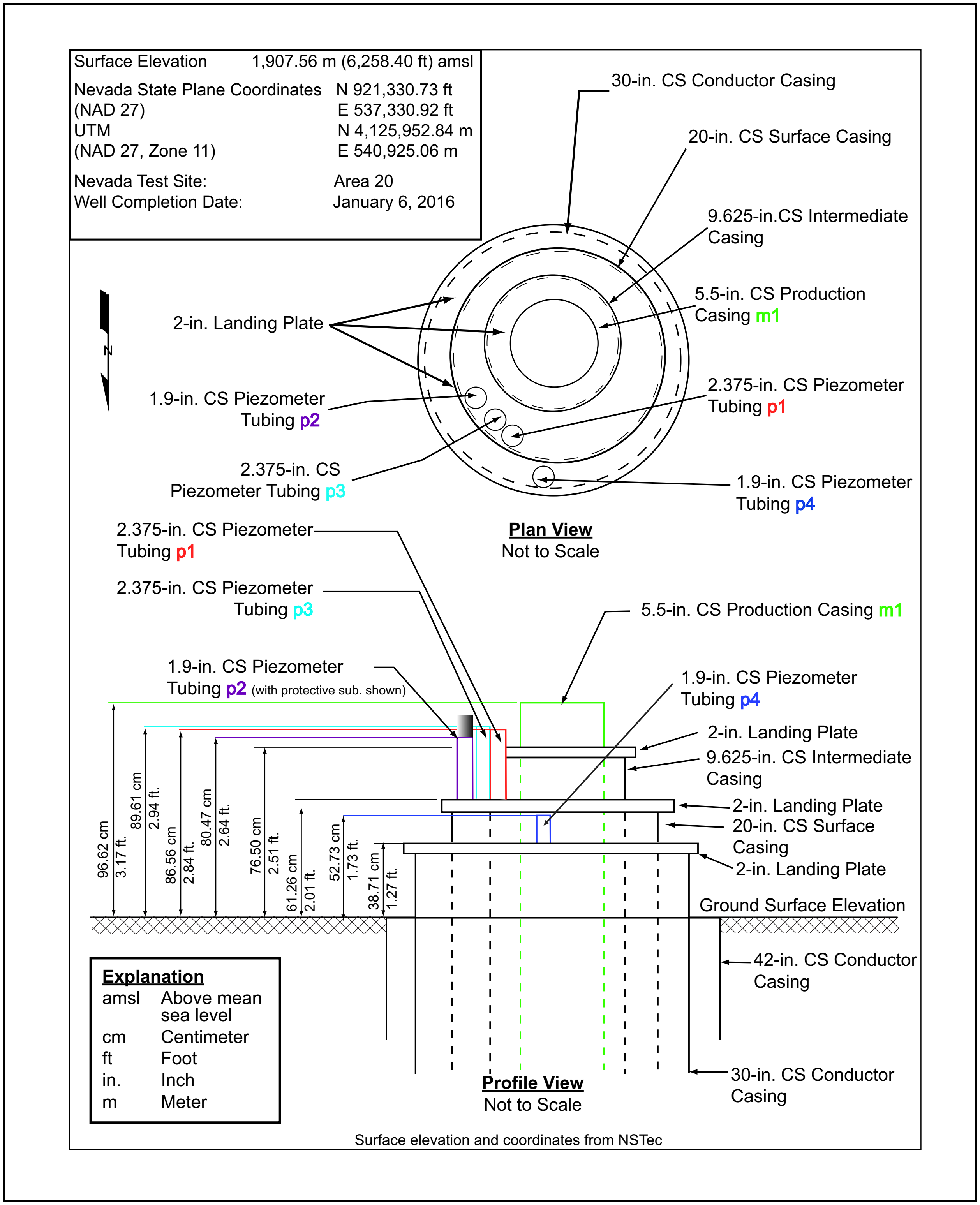


Figure 8-2
Wellhead Diagram for ER-20-12

Table 8-1
Well ER-20-12 Completion String Summary
(Page 1 of 2)

String	Casing and Tubing[a]	Configuration[b] m (ft)	Casing Type	Cement m (ft)	Sand/Gravel m (ft)
Shallow Piezometer (p4)	1.9-in. CS	0 to 513.78 (0 to 1,685.65)	Blank	None	None
	1.9-in. CS with orange-peeled termination	513.78 to 579.67 (1,685.65 to 1,901.79)	Slotted	None	None
Intermediate Piezometer (p3)	2.375-in. CS with crossover	0 to 777.93 (0 to 2,552.26)	Blank	None	None
	2.875-in. SS with bullnose termination	777.93 to 888.51 (2,552.26 to 2,915.08)	Slotted	None	None
Intermediate Piezometer (p2)	1.9-in. CS	0 to 938.64 (0 to 3,079.52)	Blank	Type II Neat Cement 898.24 to 930.57 (2,946.93 to 3,053)	**20/40 Sand** 930.55 to 936 (3,053 to 3,071)
	1.9-in. CS with orange-peeled termination	938.64 to 957.72 (3,079.52 to 3,142.13)	Slotted	None	**0.375-in. Gravel** 936 to 962.25 (3,071 to 3,157)
Deep Piezometer (p1)	2.375-in. CS with crossover	0 to 1,043.43 (0 to 3,424.18)	Blank	Type II Neat Cement 962.25 to 1,018.95 (3,157 to 3,343)	**20/40 Sand** 1,018.95 to 1,029 (3,343 to 3,376)
	2.875-in. SS with bullnose termination	1,043.43 to 1,117.35 (3,424.18 to 3,665.85)	Slotted	None	**0.375-in. Gravel** 1,029 to 1,135.38 (3,376 to 3,725)

Table 8-1
Well ER-20-12 Completion String Summary
(Page 2 of 2)

String	Casing and Tubing[a]	Configuration[b] m (ft)	Casing Type	Cement m (ft)	Sand/Gravel m (ft)
Completion Casing (m1)	5.5-in. CS with crossover	0 to 540.29 (0 to 1,772.63)	Blank	None	None
	5.5-in. SS	540.29 to 1,216.70 (1,772.63 to 3,991.81)	Blank	Type II Neat Cement 1,135.38 to 1,193.60 (3,725 to 3,916)	None
	5.5-in. SS with bullnose termination	1,216.70 to 1,350.61 (3,991.81 to 4,431.15)	Slotted	None	None

[a] Diameters listed are od.
[b] Referenced to ground surface.

Figure 8-3
Photograph of Well ER-20-12 Wellhead

information regarding slot specifications. Depth intervals for the Hydril blank and slotted tubing are presented in Table 8-1.

The intermediate piezometer (p3) was completed in the CHZCM (LFA) and consists of nominally 9.45-m (31-ft) lengths of 6.03-cm (2.375-in.) diameter CS Hydril tubing with upset couplings extending from 0 m (0 ft) above ground surface to 777.67 m (2,551.42 ft). The crossover, from 6.03-cm (2.375-in.) CS tubing to 7.30-cm (2.875-in.) SS tubing, extends from 777.67 m (2,551.42 ft) to 777.93 m (2,552.26 ft). The slotted SS tubing consists of nominally 6.40-m (21-ft) lengths of

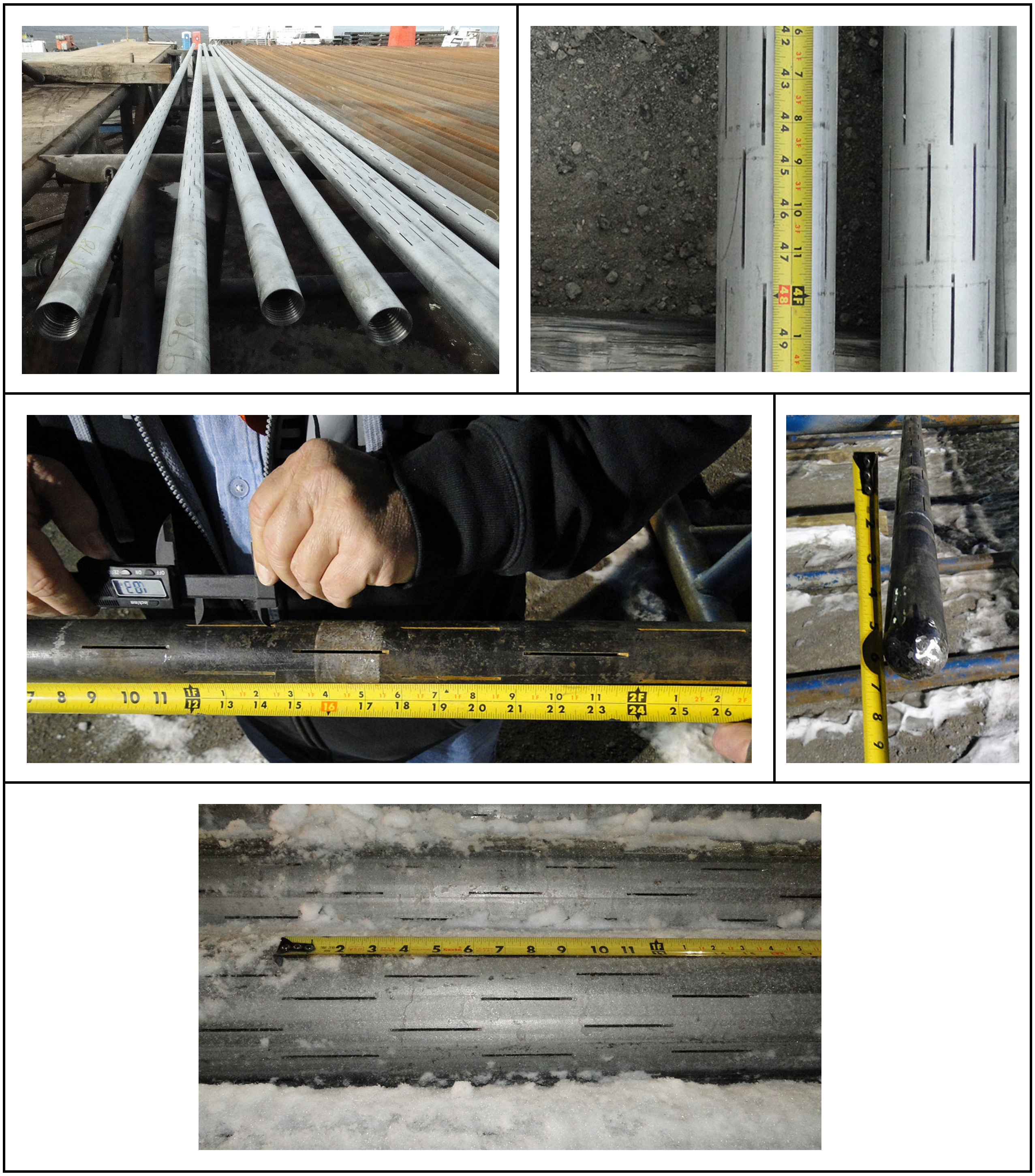


Figure 8-4
Slotted Tubing for ER-20-12

Top left and right: 7.30-cm (2.875-in.) SS slotted tubing; Middle left and right: 4.82-cm (1.9-in.) CS slotted tubing; Bottom: 13.97-cm (5.5-in.) SS slotted main production casing

7.30-cm (2.875-in.) diameter tubing with flush joint couplings and a bullnosed termination, extending to 888.51 m (2,915.08 ft). Table 2-1 provides detailed information regarding slot specifications. Figure 8-4 (top) shows slotted SS tubing installed in Well ER-20-12.

The shallow piezometer (p4) was completed in the TMWTA/TMLVTA and consists of nominally 9.45-m (31-ft) lengths of 4.82-cm (1.9-in.) diameter CS Hydril tubing with upset couplings extending from 0 m (0 ft) above ground surface to 513.78 m (1,685.65 ft) and slotted 4.82-cm (1.9-in.) CS tubing from 513.78 m (1,685.65 ft) to 579.66 m (1,901.79 ft) ending in an orange-peeled termination. Table 2-1 provides detailed information regarding slot specifications. An example of the 4.82-cm (1.9-in.) diameter CS slotted tubing is shown in Figure 8-4 (middle). Depth intervals for the Hydril blank and slotted tubing are provided in Table 8-1.

8.2.3 Rationale for Differences between Planned and Actual Well Design

The original completion design was based on geologic information from nearby UGTA Well PM-3 and the emplacement hole U20m for the HANDLEY UGT (NNSA/NFO, 2015b; NNSA/NSO, 2011), and interpreted geology from the Pahute Mesa HFM (Navarro, 2015a). Because of the scarcity of data in the vicinity of Well ER-20-12, the geology and hydrology predicted in the borehole was somewhat speculative. Completion intervals for piezometer tubing and main completion access points were adjusted to optimize further sampling and testing data collection.

The geology and hydrology of Well ER-20-12 are discussed in Sections 5.3 and 5.4, respectively.

8.3 Well Completion Method

Completion activities began on November 19, 2015, after the 46.99-cm (18.5-in.) borehole was opened to 66.04 cm (26 in.) to 765.99 m (2,513 ft) bgs. UDI ran the shallow (p4) 4.82-cm (1.9-in.) piezometer tubing, which was landed at 579.66 m (1,901.79 ft). On November 21, 2015, the B&L Casing crew ran the 50.80-cm (20-in.) casing and landed it at 762.85 m (2,502.80 ft). NSTec cemented the 50.80-cm (20-in.) casing on November 22, 2015. After geophysical logging was completed, UDI tripped in the tremie tubing on December 7, 2015. Completion operations were on and off through December 31, 2015, due to weather and a five-day break for the holidays. The piezometer (p1) and piezometer (p3) were installed on December 11, 2015, and landed at 1,117.35 m

(3,665.85 ft) and 888.51 m (2,915.08 ft), respectively. The 24.44 cm (9.625-in.) CS surface casing was landed at 1,188.72 m (3,900 ft) and cemented on December 16, 2015. Another intermediate piezometer (p2) was installed on December 18, 2015, and landed at 957.72 m (3,142.13 ft). COLOG ran the nuclear annular investigation log (NAIL) in the deep piezometer to determine depths of annular fill materials. The 13.97-cm (5.5-in.) main completion casing was installed on January 6, 2016, in the open borehole and landed at 1,350.61 m (4,431.15 ft).

All well construction materials used for the completion were inspected according to relevant procedures, as listed in the Navarro FAWP (Navarro, 2015c). Typical stemming operations include installation of 0.95-cm (0.375-in.) gravel (high silica [90+%], sub-rounded to rounded) across the open intervals followed by 20/40 silica sand and finally Type II Neat Cement using a CS 7.30-cm (2.875-in.) tremie. Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

After installation of the main casing on January 6, 2016, the UDI drill rig was rigged down in preparation for demobilizing. Hydrologic testing is planned as a separate effort, and no well development or pumping tests were conducted immediately after completion.

9.0 Planned and Actual Costs and Scheduling

This section provides brief discussions of the planned and actual costs and schedule for the main borehole construction of Well ER-20-12.

The original M&O contractor (NSTec)-approved baseline work package with subsequent approved baseline change requests (BCRs) was based on drilling to a planned TD of 1,219.5 m (4,000 ft), installing one production casing string and up to four piezometer tubing strings. This estimate was submitted before issuance of the drilling criteria document (Navarro, 2015a) with an updated planned TD of 1,250.0 m (4,100 ft). The baseline estimate with approved BCRs included a 67-day schedule for constructing a 1,219.5-m (4,000-ft)-deep well. The baseline estimate included 10 days for mobilization and 57 days for main borehole construction and completion.

The well was drilled 165.5 m (543 ft) deeper than originally planned, to a TD of 1,385.1 m (4,543 ft), and 135.1 m (443 ft) deeper than specified in the drilling criteria document. It took 107 calendar days to construct Well ER-20-12, beginning with the start of mobilization on September 21, 2015, and ending with the installation of the production casing on January 6, 2016. There were a number of factors and unplanned events during the well construction that contributed to the extended construction schedule, including the following:

- Construction of wind walls to protect workers from wind-blown drilling foam
- Slower-than-anticipated drilling rates during drilling of the 46.9-cm (18.50-in.) surface borehole and opening of the 46.9-cm (18.50-in.) borehole to 66.04 cm (26 in.)
- Use of multiple 66.04-cm (26-in.) hole openers and the necessity of reaming the borehole after changing hole openers
- Drilling/opening surface borehole to a depth of 765 m (2,510 ft) rather than 533 m (1,750) ft
- Suspension of field activities waiting for a logging services subcontract
- Drilling of an 46.9-cm (18.50-in.) intermediate borehole from 765 m (2,510 ft) to 1,326 m (4,352 ft) rather than drilling a 31.12-cm (12.25-in.) borehole from 533 m (1,750 ft) to 1,219 m (4,000 ft)
- Stemming and cleaning out stemming material from the 46.9-cm (18.50-in.) intermediate borehole from 1,195 to 1,326 m (3,919 to 4,352 ft)

- Installation of 24.4-cm (9.625 in.) intermediate casing to 1,189 m (3,900 ft) instead of 33.97-cm (13.375-in.) casing to 975 m (3,200 ft)
- Installation of three piezometer tubing strings behind the 24.4-cm (9.625 in.) intermediate casing and stemming/cementing two of those tubes
- Holiday shutdown period of field activities for five days
- Drilling to a TD of 1,385.1 m (4,543 ft) rather than 1,219 m (4,000 ft)
- Miscellaneous field activity downtime associated with snow, sub-freezing temperatures, lightning, and construction resource availability

Figure 9-1 presents a comparison of the planned and actual schedule, by day, for construction of Well ER-20-12.

The cost analysis for Well ER-20-12 begins with UDI's support to the construction of the conductor hole on September 22, 2015. The total M&O construction and completion cost for Well ER-20-12 includes all drilling construction-related costs, including all M&O direct support and all M&O subcontract costs. Subcontract costs include drilling services for the drill rig, crews, and safety personnel on a 24/7 schedule; air compressors and operators; downhole drilling tools; casing services; geophysical logging services; stemming monitoring services; radiological personnel services; and downhole construction hardware (e.g., CS and SS tubular goods, and cementing hardware used to complete the well). The costs of building the access road, drill pad, sumps, and installation of the conductor casing is not included, nor is the cost of well-site or other support from Navarro or support from other NNSA/NFO contractors.

The total planned cost for constructing Well ER-20-12 with a planned TD of 1,219.5 m (4,000 ft) was $8,717,174. The actual cost for constructing the well with the TD of 1,385.1 m (4,543 ft) was $12,014,966, or 37.8 percent more than the estimated cost. Figure 9-2 presents a comparison of the planned and actual costs, by day, for construction of Well ER-20-12. The higher-than-estimated cost is directly related to the extended amount of time associated with the factors/events listed above, which impacted the schedule. There were also additional impacts to the costs associated with safety measures for this remote site (e.g., van transportation of the crews to and from the well site, and 24/7 onsite paramedic coverage).

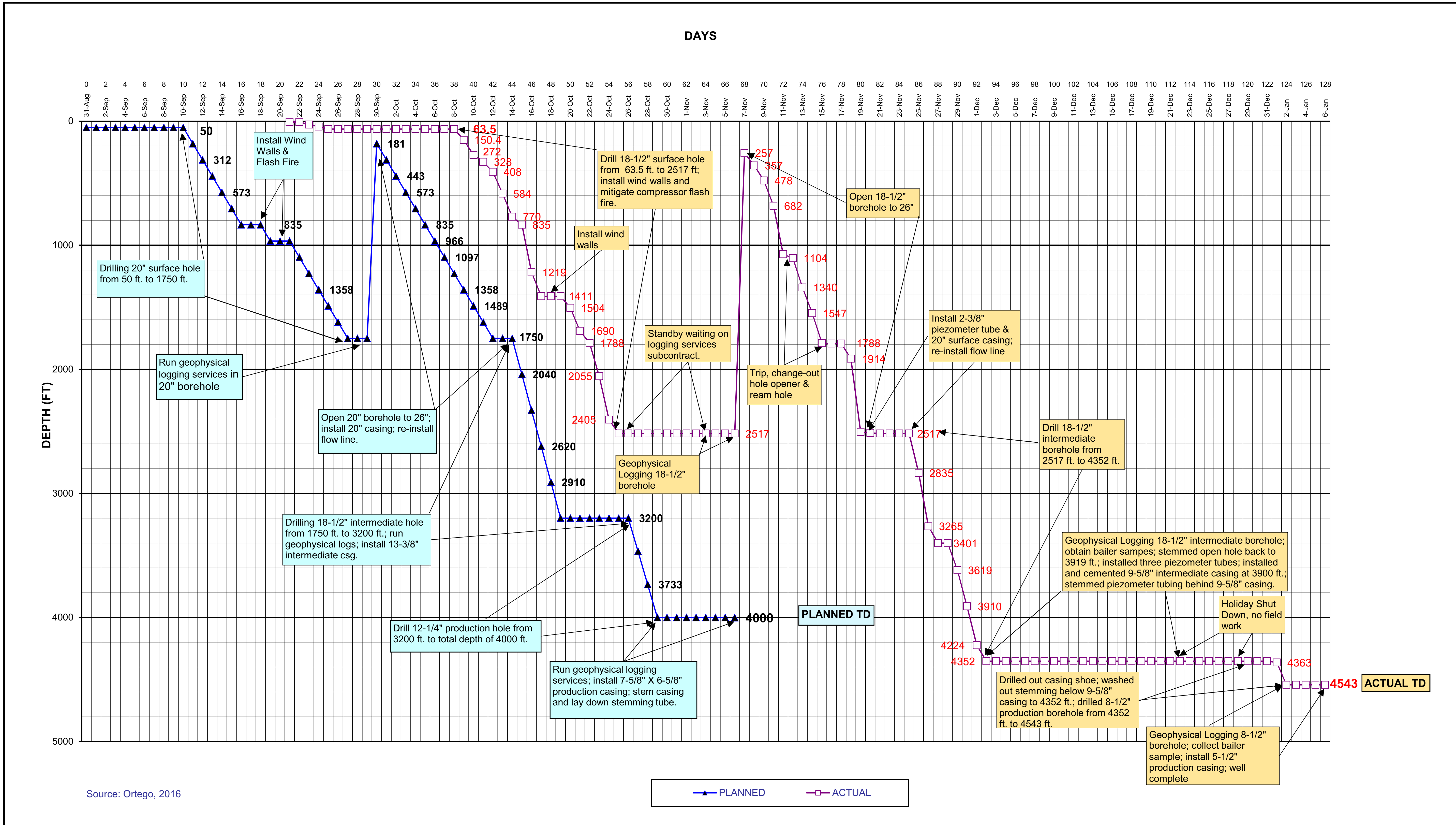


Figure 9-1
Planned and Actual Construction Progress for Well ER-20-12
Note that the planned TD is based on a preliminary plan developed before issuance of the drilling criteria document (Navarro, 2015a).

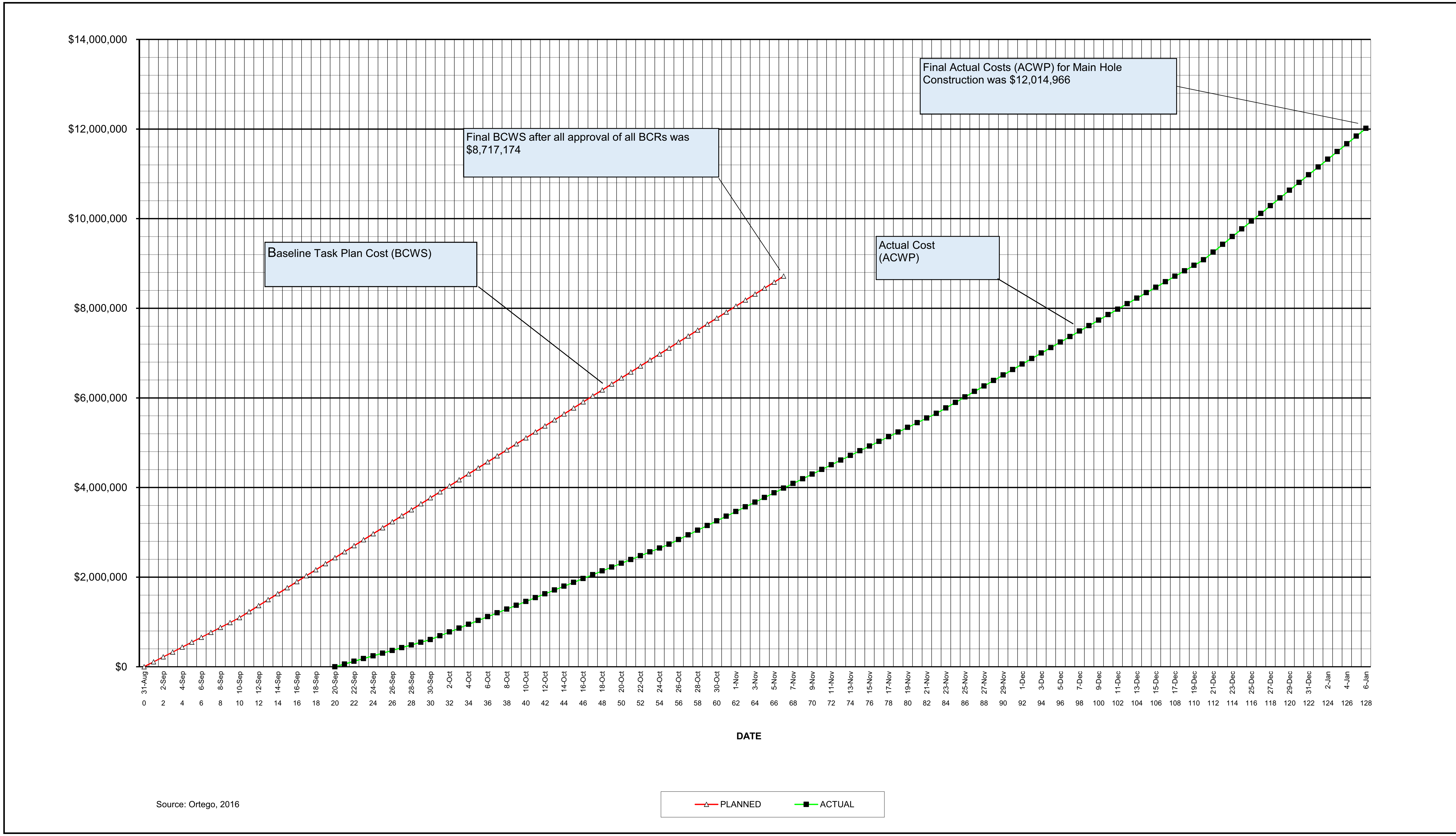


Figure 9-2
Planned and Actual Cost of Constructing Well ER-20-12
Note that the planned cost is based on a preliminary plan developed before issuance of the drilling criteria document (Navarro, 2015a).

10.0 Summary, Recommendations, and Lessons Learned

10.1 Summary

Drilling the main hole at Well ER-20-12 started on October 8, 2015, and concluded on January 6, 2016, to a TD of 1,384.8 m (4,543.33 ft). The borehole reached TD in the nonwelded tuff of the rhyolite of Handley (Tqj), the target formation, which is part of the PBRCM. The well has four piezometers completed outside the main completion casing: two 7.30-cm (2.875-in.) piezometers (p1 and p3) allow access to the hydraulically isolated intervals in the BRA and the CHZCM (LFA), respectively; and two 4.82-cm (1.9-in.) piezometers (p2 and p4) allow access to isolated intervals in the CHZCM and TMLVTA\TMWTA. The main production casing (13.97-cm [5.5-in.]) is completed in the rhyolite of Handley (Tqj) in the PBRCM.

Data collected during drilling of the well include composite drill cutting samples collected every 3.0 m (10 ft) from 21.3 m to TD at 1,384.8 m (70 to 4,543.33 ft) bgs; open-hole geophysical and hydrophysical logging data; percussion sidewall core samples; and water quality and water production parameters.

Well ER-20-12 is collared in the Trail Ridge Tuff (Ttt) and penetrates 1,384.8 m (4,543.33 ft) of Tertiary volcanic rocks. The rocks consist of bedded and nonwelded tuffs, lava flows, and welded ash-flow tuffs. The stratigraphic and lithologic information collected from ER-20-12 is of good quality and identifies new key data, such as significant thickness of the CHZCM, including the presence of an extensive LFA, a thicker-than-average section of Grouse Canyon Tuff (Tbg), and a thinner-than-expected section of the Comendite of Quartet Dome (Tbq). The stratigraphic and lithologic data along with the geophysical information collected will provide a hard data point for the HFM.

Water levels measured on May 11, 2016, are as follows: (p4) piezometer string, 492.17 m (1,614.74 ft) bgs; (p3) piezometer string, 571.90 m (1,876.32 ft) bgs; (p2) piezometer string, 572.00 m (1,876.65 ft) bgs; and (p1) piezometer string, 566.93 m (1,860.02 ft) bgs. The water levels indicate a potential head difference of up to 79.8 m (262 ft). A potential head difference of this magnitude indicates that the groundwater in the TMLVTA\TMWTA units is isolated from the groundwater in the lower portion of the borehole. Based on water levels, location of the piezometers (stratigraphic/HSU), and related well construction information, the UPCU appears to be acting as the principal hydraulic barrier separating the two systems.

Tritium results from the drilling returns ranged from 0 to 83,138 pCi/L (recounted to 16,129 pCi/L), and the highest standing recount was 56,184 pCi/L. Analytical results from the discrete bailed samples ranged from 21,900 to 53,600 pCi/L. The tritium analyses shows a relatively constant profile throughout the entire water column.

Analysis of the monitoring samples and the FMP confirmatory sample indicate that fluids generated during drilling met the FMP criteria for discharge to an unlined sump or designated infiltration area. All sanitary and hydrocarbon waste was properly handled and disposed of.

10.2 Recommendations

The well development and testing program must be completed in order to accomplish the remaining objectives, including groundwater sampling and aquifer testing. This portion of the program will provide key information for understanding the significant head difference that exists in Well ER-20-12.

All the geologic and hydrologic data and interpretations from Well ER-20-12 should be integrated into the PM-OV Phase II HFM. This will provide better characterization of groundwater flow direction and velocity and increased confidence in the PM-OV Phase II HFM. The data collected at Well ER-20-12 will also allow for an improved understanding of the geology and structural features that are influencing the groundwater movement. As all of this information is integrated into the PM-OV Phase II HFM, additional areas for further investigation may be defined.

10.3 Lessons Learned

Drilling operations experienced a number of issues and delays, including the following: equipment issues (e.g., compressors, discharge-line, sump liner); weather (e.g., snow, sub-zero temperatures); and hole/drilling conditions (e.g., high-energy discharge, hole erosion). Contractor and subcontractor teamwork and communication were key to overcoming the challenges presented at Well ER-20-12.

Drilling, construction, scientific, and environmental compliance activities at Well ER-20-12 were generally executed as planned. However, various activities were affected by planning, operational decisions, and equipment-related issues and safety concerns that occurred during the execution of work. Future drilling and well completion efforts may benefit from the following summary of lessons learned and recommendations as well as operational experiences realized during operations at Well ER-20-12. It is anticipated that a formal lessons learned exercise will be conducted. The following subsections describe general areas of importance and offer preliminary recommendations.

10.3.1 Well Site Configuration and Operational Impacts

The Well ER-20-12 well pad was constructed in a fashion typical for UGTA Activity drill pads; however, the grade of the drill pad leading from the well head to the point of flow-line discharge at the lined sump sloped significantly to the west. The sloping grade resulted from a very shallow soil cover on the volcanic cap rock in the area of the drill pad, which would have required extensive fill material to bring the grade to level. This sloping grade required the positioning of the flow line much higher in elevation than typical UGTA configurations. Although the configuration was recognized as non-typical, it was not considered on startup as problematic for operations. Approximately 10 days after the startup of drilling operations, it was apparent that the height of the flow line above the level of the sump allowed drilling discharge (foam and water) to be blown by the prevailing winds outside the sump and into the area of cutting/fluid collection staffed by Navarro personnel. Conditions in the sampling area became unsafe, requiring personnel to don rain gear and face shields to conduct sampling activities that typically do not require this level of personal protective equipment. Efforts made to relocate the area for sampling were partly successful; however, it was clear that given the level of the flow-line discharge, a wind-wall-type barrier and modifications to the flow line would be required to eliminate the blowing spray in the sampling area. Drilling operations were suspended for approximately four days as NSTec construction personnel fabricated wind walls and modified the discharge point of the flow line.

Lessons Learned/Recommendation: It was recognized during the mobilization and site rig up that the elevation of the flow line was a potential operational concern. However, during the pre-operational site safety walk-down, these concerns were not voiced by management or workers. In future operations, conditions such as this should be recognized and addressed so that personnel can safely conduct sampling operations and the progress of drilling operations is not impacted nor standby costs accrued as the appropriate flow-line configuration is put in place.

10.3.2 Operational Standby due to Scheduling and/or Contractual-Related Issues

NSTec, Navarro, NWAS, and UDI crews were on standby at Well ER-20-12 for nearly 600 hours during the drilling and completion of the well. While conducting these types of drilling operations, some standby time is expected, such as delays resulting from safety incidents, weather, or mechanical breakdowns of the drill rig or support equipment; or delays while technical aspects of the hydrogeology and the well construction are evaluated. Well ER-20-12 experienced standby episodes for many of the aforementioned situations, and the length of these standby periods was within reason. However, abnormal periods of standby resulted principally as a result of three operational situations. Nearly 230 hours of operational standby resulted from delays in the award of the geophysical services contract and the arrival of the contractor on the job site to perform work. Substantial delays resulting in standby time were also realized as the operations waited for welding and flange bolt inspections on the flow line. Additional standby delays resulted as NSTec construction crews supporting the emplacement of stemming materials (gravel/sand/cement) were unavailable due to company restrictions on hours worked during a weekly period. For these two elements alone, approximately 125 hours of standby was realized by the project. These delays impacted the completion of the borehole, and added additional schedule and cost to the operation.

Lessons Learned/Recommendation: Ensure all necessary contractors and subcontractors are under contract before field activities begin and are scheduled to be on site with the minimal amount of standby incurred. Various contractors and subcontractors are required on a callout basis, and UGTA personnel should consider the option of calling the contractor or subcontractor early, if necessary, incurring the standby for the contractor or subcontractor as opposed to paying standby for the rig and all other related site contractors. For those necessary services provided by the M&O contractor, efforts should be made to schedule adequate resources to support the drilling and completion activities in advance. For circumstances where these resources may exceed typical work hour requirements by small amounts, due to operational complications or delays, management should pursue special limited work hour exemptions to allow time critical work to be completed, This may result in schedule and cost-savings benefits to the UGTA Activity.

10.3.3 Technical and Scientific Data Acquisition Impacts to Drilling and Well Construction

Well ER-20-12 was predicted to encounter tritium-contaminated groundwater resulting from the historical testing of nuclear weapons from upgradient locations. As a result, Well ER-20-12 was considered a near-field well and subject to specified worker safety requirement in the UGTA Health and Safety Plan (NSTec, 2015b) and fluid management and monitoring requirements of the UGTA Fluid Management Plan (NNSA/NSO, 2009b). Further, the *Nevada Administrative Code* (NAC, 2016) requires that during the drilling process that groundwater encountered during drilling that exceeds the SDWA limit for tritium (20,000 pCi/L) (CFR, 2016b) must not be allowed to cross communicate with groundwater within other aquifers. During drilling, produced fluids are monitored hourly for tritium, and the results are evaluated to determine the presence and concentrations of tritium as well as any trends within the data that may suggest increasing concentrations that would require further controls for work safety and containment of produced fluids.

During drilling operations below a depth of 762.0 m (2,500 ft) bgs, tritium monitoring data indicated low (less than 3,000 pCi/L) but detectable concentrations of tritium within the CHCZM and BRA, with estimated water production rates ranging from 1,135 to 2,082 Lpm (300 to 550 gpm). Drilling operations proceeded to a depth of approximately 1,188.7 m (3,900 ft) bgs, where tritium monitoring data indicated a significant increase in the tritium concentrations (±30,000 pCi/L) as the borehole encountered the PBRCM. These increases in tritium concentration were not recognized by technical field staff as significant, as concentrations were less than the 400,000 pCi/L action level for regulating site operations under a near-field operation scenario as specified in the UGTA Health and Safety Plan (NSTec, 2015b). It was not recognized that lesser tritium-contaminated groundwater produced between 762.0 and 1,188.7 m (2,500 and 3,900 ft) bgs was serving to dilute groundwater with much higher tritium concentrations encountered below approximately 1,188.7 m (3,900 ft) bgs. As a result, drilling was allowed to continue to a depth of approximately 1,325.9 m (4,350 ft) bgs, when this apparent dilution was recognized by senior technical personnel and drilling was suspended.

As a result of the depth of borehole penetration and the distribution of the tritium contamination, it was determined that it would be necessary to hydraulically isolate the PBRCM from lesser contaminated HSUs (BRA and BFCU) above. The process of isolating the BRA and BFCU required filling the existing 46.9-cm (18.5-in.) borehole with gravel to a depth of approximately 1,194.8 m

(3,920 ft) bgs, and installing 24.44-cm (9.625-in.) casing and cementing the casing in place to isolate the groundwater within the PBRCM. Approximately three operational days were spent advancing the 46.9-cm (18.5-in.) borehole from approximately 1,188.7 and 1,326.5 m (3,900 to 4,352 ft) bgs. Subsequently, four operational days were spent stemming gravel and sand to fill the existing 46.9-cm (18.5-in.) borehole from 1,326.5 to 1,188.7 m (4,352 to 3,900 ft) bgs to allow for the installation of casing and the placement of cement. Weather further delayed this cementing operations for another two days due to high winds and freezing conditions. Once drilling operations resumed, an additional three days were required to wash out the gravel and sand from the 46.9-cm (18.5-in.) borehole using an 21.6-cm (8.5-in.) drilling assembly to the previous depth of the 46.9-cm (18.5-in.) borehole of 1,188.7 m (4,352 ft) bgs.

In total, approximately nine days of unplanned operational time were required to configure the well to isolate the contaminated groundwater of the PBRCM from the lesser contaminated groundwater of overlying BRA and BFCU. In addition, the final completion of the well allowed for pumping and aquifer testing only within the PBRCM, eliminating the pumping and testing planned within the BRA.

Lessons Learned/Recommendation: Technical staff supporting the drilling and completion of UGTA Activity wells need to evaluate near real time the data acquired in order to recognize changes and potential implications and impacts to the operations. Questions or concerns should be elevated to senior technical staff immediately. In this particular case, onsite technical staff were not evaluating tritium concentrations against more technical concerns, but rather against a regulatory action level (400,000 pCi/L) that would drive a change in the radiological controls on the site operations. It is recommended in future operations of this type that onsite technical staff maintain a constant and regular interface with senior technical staff to help guide the interpretation of site data and the subsequent actions that may be necessary to ensure adequate data collection during operations, regulatory compliance, and appropriate well construction to meet scientific objectives; and eliminate unnecessary and unplanned operations that equate to greater costs and extended schedules.

10.3.4 Acquisition of Hydraulic Observations during Well Drilling and Completion Operations

During the drilling and completion of Well ER-20-12, there were planned and unplanned opportunities to collect data and observations with respect to the nature of saturated units encountered during drilling. Planned collection of data and observations included the monitoring and estimation of produced groundwater during drilling, and observation of water-level responses in wells proximal to Well ER-20-12 as a result of withdrawal of water during the drilling process. Unplanned collection of water-level responses within the well while performing stemming was also conducted. The following subsections describe the acquisition processes, outcomes and recommendations.

10.3.5 Water Production Estimates during Drilling

During drilling, estimates of water production while advancing and or circulating the borehole are a planned and necessary data collection. These data provide a sense of the apparent productivity of particular HSUs and specific lithologies as well as the influence of faults and fractures on rates of water production. These estimates of water production rely on three principal observations coupled with outside influences that may be accounted for in making the estimate. The primary observation of water production relies on the use of a tracer (lithium bromide) in the mixed drilling fluids. Samples are collected in near-real time from the injected drilling fluids and the discharge from the flow line. The samples are analyzed to determine the concentration of the lithium bromide in each, and a water production value is calculated from the dilution between the two. When conducted appropriately, this methodology has provided reasonable estimates of groundwater production for many years of UGTA drilling. The method is sensitive to a number of factors that must be monitored and accounted for regularly during drilling. These factors include changes in rates of water production and corresponding increases necessary in the tracer concentration; timing of sample collection through mixing of the tracer solution in the mixing tanks; and, finally, accurate laboratory measurements of the tracer. A review of the calculated water production estimates taken solely from the measured tracer suggests that these data may not be very representative of the rates of water production. For example, rates of water production noted from approximately 914.4 to 1,188.7 m (3,000 to 3,900 ft) bgs are highly suspect, as the tracer concentrations for samples collected at the discharge are essentially not detectable by the current laboratory instrument but were reported as estimated water production rates. It is not clear whether other confirmatory observations of water production—such as sump volume increases, apparent visual increases in flow rate at the discharge line, or flow rate of the trash pump—were considered in the estimates. In short, the estimated water production reported from approximately 914.4 to 1,188.7 m (3,000 to 3,900 ft) bgs is suspect and may not necessarily reflect actual or relative water production rates. Estimates of water production obtained during drilling is critically important information that helps direct the ultimate completion intervals in the well, and guides aquifer testing with respect to expected pumping rates and sizing of pumps to be installed.

Lessons Learned/Recommendation: Although some experienced lead technical staff were a part of onsite support to Well ER-20-12 drilling operations, there were a number of inexperienced staff in lead and support roles. In future operations, more emphasis will need to be placed on the fundamental aspects of the drilling activity with respect to the timing of sample collection, the mixing or blending of tracers solutions, and the detection limits of the laboratory instrumentation. Further, staff responsible for leading this work on a shift or project basis in the future should be able to recognize the poor nature of the tracer measurements, and should take action to resolve the issue and reach out to more experienced staff for assistance or input.

10.3.6 Water-Level Monitoring in Proximal Observation Wells

The observation of water levels in nearby wells during drilling operations is not a new concept. UGTA has employed this technique of monitoring during drilling since early 2009. Before Well ER-20-12 was drilled, several nearby wells were continuously monitored using wireline-deployed pressure/temperature sensors for water-level responses related to natural water-level fluctuations related to barometric and diurnal tidal influences. During drilling, these same wells continued to be monitored for water-level changes reflective of hydraulic stress resulting from drilling activities below the water table. Only Well PM-3 responded to the hydraulic stress applied through drilling. This information will help to understand the hydraulic connections that may exist in the groundwater system near Well ER-20-12 and potentially downgradient from areas of underground testing to the north (i.e., U20m HANDLEY). Although the water-level responses noted at observation wells such as PM-3 may not be useful in a wholly quantitative aquifer analysis, they do provide a sense of the nature of the hydraulic connections in a qualitative sense. A further evaluation of these data coupled with data acquired during the development and testing of Well ER-20-12 will be a part of later analysis and reporting.

Lessons Learned/Recommendation: The continuous monitoring of water levels in wells near the sites of active drilling continues to provide good quality data that allow for an early qualitative analysis of the hydraulic connectivity near the drilled well. The overall cost of acquiring these data—not only to monitor the natural system, but during and after periods of applied drilling stress—is very low. Monitoring of this type should be considered for long-term continuous monitoring of the natural system to identify short duration transient changes in the water levels due to tectonic affects (i.e., earthquakes) or water withdrawal due to pumping. Clearly, this type of monitoring has great benefit in the shorter term when known stresses from drilling and/or pumping may influence nearby and not-so-near water levels.

10.3.7 Optimizing Data Collection Opportunities, Slug Testing during Well Completion

During the construction of Well ER-20-12, it was recognized that a simple "slug test" could be conducted during installation of the well casing to help obtain some basic estimates of hydraulic parameters from saturated zones that would otherwise would not be available for testing. In typical UGTA well completion designs, where casing is to be installed below the water table, a piezometer is also installed in the annular space between the borehole wall and the casing. The piezometer allows measurement of discrete formation specific water levels/heads once the casing is cemented in place. It was recognized at Well ER-20-12 that the process of pumping cement could be used to conduct a hydraulic slug test. The pumping of a known volume of cement through the cementing shoe located at the base of the casing would effectively be the hydraulic slug. The effect on the water level from the introduction of the cement slug in the affected formation could be monitored through the deployment of a PXD within the piezometer. This approach was implemented with very good results during the installation of the 50.80-cm (20-in.) surface casing at Well ER-20-12.

Lessons Learned/Recommendation: Based on the data collected during the aforementioned slug test, it is clear that the opportunity to maximize the collection of formation specific hydraulic data exists. This is particularly true when cementing casing through a stab-in type float shoe placed on the bottom of the casing. To ensure that the sensor can be placed appropriately, a piezometer should be placed in the annular space between the casing and the borehole. This approach is optimal. It has been suggested that this slug testing approach may also be effective when stemming with a tremmie line in a more conventional well construction approach. Although some data may be collected, it is likely that the data will be difficult to interpret, as the slug volumes will not be as controlled and the emplacement may require more time. In future drilling and completion operations, when cementing casing through a float shoe, this slug testing approach may provide the opportunity to collect some good quality hydraulic testing data for a low cost and virtually no operational schedule impact. As an additional benefit, the response data measured in the piezometer also serves to assess the nature and quality of the casing cementing operation.

11.0 References

BLM, see Bureau of Land Management.

BN, see Bechtel Nevada.

Bechtel Nevada. 2002. *A Hydrostratigraphic Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada*, DOE/NV/11718--706. Prepared for the U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office. Las Vegas, NV.

Bureau of Land Management. 2015. "BLM Public Land Survey System Data for USA." As accessed at http://www.arcgis.com/home/item.html?id=f4a948575875449b8b4284ecaef84bf5 on 16 June 2016.

Byers, F.M., Jr., W.J. Carr, P.P. Orkild, W.D. Quinlivan, and K.A. Sargent. 1976. *Volcanic Suites and Related Cauldrons of Timber Mountain-Oasis Valley Caldera Complex, Southern Nevada,* Professional Paper 919. Washington, DC: U.S. Geological Survey.

CFR, see *Code of Federal Regulations*.

Christiansen, R.L., and D.C. Noble. 1968. *Geologic Map of the Trail Ridge Quadrangle, Nye County, Nevad*a, Map GQ-774, scale 1:24,000. Washington, DC: U.S. Geological Survey.

Christensen, M.N. 1966. "Late Cenozoic Crustal Movements in the Sierra Nevada of California." In *Geological Society of America Bulletin,* Vol. 77(2): pp. 163-182.

Code of Federal Regulations. 2016a. Title 29 Part 1910, "Occupational Safety and Health Standards." Washington, DC: U.S. Government Printing Office.

Code of Federal Regulations. 2016b. Title 40 CFR Part 141, "National Primary Drinking Water Regulations." Washington, DC: U.S. Government Printing Office.

Code of Federal Regulations. 2016c. Title 40 CFR, Parts 260–282, "Hazardous Waste Management System." Washington, DC: U.S. Government Printing Office.

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

ESRI, see Environmental Systems Research Institute, Inc.

Environmental Systems Research Institute, Inc. 2015. *ArcMap,* Version 10.3.1. Redlands, CA: ESRI.

FFACO, see *Federal Facility Agreement and Consent Order.*

Federal Facility Agreement and Consent Order. 1996 (as amended March 2010). Agreed to by the State of Nevada; U.S. Department of Energy, Environmental Management; U.S. Department of Defense; and U.S. Department of Energy, Legacy Management. Appendix VI, which contains the Underground Test Area Strategy, was last modified June 2014, Revision No. 5.

Grauch, V.J.S., D.A. Sawyer, C.J. Fridrich, and M.R. Hudson. 1997. *Geophysical Interpretations West of and within the Northwestern Part of the Nevada Test Site,* Open-File Report 97-476. Denver, CO: U.S. Geological Survey.

Hildenbrand, T.G., V.E. Langenheim, E.A. Mankinen, and E.H. McKee. 1999. *Inversion of Gravity Data To Define the Pre-Tertiary Surface and Regional Structures Possibly Influencing Ground-Water Flow in the Pahute Mesa-Oasis Valley Region, Nye County, Nevada,* Open-File Report 99-49. Menlo Park, CA: U.S. Geological Survey.

Mankinen, E.A., T.G. Hildenbrand, G.L. Dixon, E.H. McKee, C.J. Fridrich, and R.J. Laczniak. 1999. *Gravity and Magnetic Study of the Pahute Mesa and Oasis Valley Region, Nye County, Nevada,* Open-File Report 99-303, Version 1.0. Reston, VA: U.S. Geological Survey.

NAC, see *Nevada Administrative Code*.

Navarro GIS, see Navarro Geographic Information Systems.

N-I, see Navarro-Intera, LLC.

NNSA/NFO, see U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office.

NNSA/NSO, see U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office.

NSTec, see National Security Technologies, LLC.

National Security Technologies, LLC. 2015a. *Field Activity Work Package for Mainhole Drilling and Completion of Well ER-20-12,* Work Package Number: D-009-001.15. Las Vegas, NV.

National Security Technologies, LLC. 2015b. *Underground Test Area (UGTA) Activity Health and Safety Plan,* Rev. 3. May. Las Vegas, NV.

National Security Technologies, LLC. 2016. As-built engineering drawing titled “As-Built ER-20-12,” 8 June. Las Vegas, NV.

Navarro. 2015a. *Addendum #3 to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria for Investigation Well ER-20-12,* Rev. 0, N/0002653--004-ADD 3. Las Vegas, NV.

Navarro. 2015b. *Field Instruction for the Underground Test Area Project Drilling and Well Completion Operations, Nevada National Security Site, Nevada*, Rev. 0. Las Vegas, NV.

Navarro. 2015c. *Navarro Field Activity Work Package (FAWP) for Underground Test Area (UGTA) Project Drilling Field Operations Wells ER-20-12 and ER-2-2*, NAV-UGTA-092115. Las Vegas, NV.

Navarro. 2016a. Written communication. Subject: *Pahute Mesa ER-20-12 Well Data Package.* Las Vegas, NV.

Navarro. 2016b. Written communication. Subject: "ER-20-12 Drilling Data Report." Las Vegas, NV.

Navarro. 2016c. Written communication. Subject: "ER-20-12 Well Data Package." Las Vegas, NV.

Navarro Geographic Information Systems. 2016. ESRI ArcGIS Software.

Nevada Administrative Code. 2016. NAC 534.375, "Measures Required before Constructing New Water Well and if Contaminant or Contaminated Water Is Encountered during Construction of Water Well." Carson City, NV. As accessed at http://www.leg.state.nv.us/nac on 8 July.

Navarro-Intera, LLC. 2014. *Evaluation of PM-3 Chemistry Data,* Rev 0, N-I/28091-092. Las Vegas, NV.

Ortego, K., National Security Technologies, LLC. 2016. Verbal communication to J. Wurtz (Navarro) regarding planned and actual construction progress for Well ER-20-12, 21 July. Las Vegas, NV.

Pawloski, G.A. 1999. *Development of Phenomenological Models of Underground Nuclear Tests on Pahute Mesa, Nevada Test Site—BENHAM and TYBO*, UCRL-ID-136003. Livermore, CA: Lawrence Livermore National Laboratory.

Sawyer, D.A., and K.A. Sargent. 1989. "Petrologic Evolution of Divergent Peralkaline Magmas from the Silent Canyon Caldera Complex, Southwestern Nevada Volcanic Field." In *Journal of Geophysical Research: Solid Earth*, Vol. 94(B5): pp. 6021–6040.

Sawyer, D.A., R.J. Fleck, M.A. Lanphere, R.G. Warren, D.E. Broxton, and M.R. Hudson. 1994. "Episodic Caldera Volcanism in the Miocene Southwestern Nevada Volcanic Field: Revised Stratigraphic Caldera Framework, $^{40}Ar/^{39}Ar$ Geochronology, and Implications for Magmatism and Extension." In *Geological Society of America Bulletin*, Vol. 106(10): pp. 1304–1318.

Slate, J.L., M.E. Berry, P.D. Rowley, C.J. Fridrich, K.S. Morgan, J.B. Workman, O.D. Young, G.L. Dixon, V.S. Williams, E.H. McKee, D.A. Ponce, T.G. Hildenbrand, W.C. Swadley, S.C. Lundstrom, E.B. Ekren, R.G. Warren, J.C. Cole, R.J. Fleck, M.A. Lanphere, D.A. Sawyer, S.A. Minor, D.J. Grunwald, R.J. Laczniak, C.M. Menges, J.C. Yount, and A.S. Jayko. 1999. *Part A. Digital Geologic Map of the Nevada Test Site and Vicinity, Nye, Lincoln, and Clark Counties, Nevada, and Inyo County, California, Revision 4*, Open-File Report 99-554-A, scale 1:120,000. Denver, CO: U.S. Geological Survey.

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. 2015a. *Underground Test Area Quality Assurance Plan, Nevada National Security Site, Nevada*, Rev. 2, DOE/NV--1450-Rev. 2. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. 2015b. *United States Nuclear Tests, July 1945 through September 1992,* DOE/NV--209-REV 16. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2009a. *Phase II Corrective Action Investigation Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada Test Site, Nye County, Nevada,* Rev. 2, DOE/NV--1312-Rev. 2. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2009b. *Underground Test Area Project Waste Management Plan,* Rev. 3, DOE/NV--343-Rev. 3; *Attachment 1 Fluid Management Plan for the Underground Test Area Project*, Rev. 5, DOE/NV--370-Rev. 5. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 2000. *Completion Report for Well ER-EC-6,* DOE/NV/11718--360. Prepared by Bechtel Nevada. Las Vegas, NV.

Appendix A

Well ER-20-12 Drilling Data

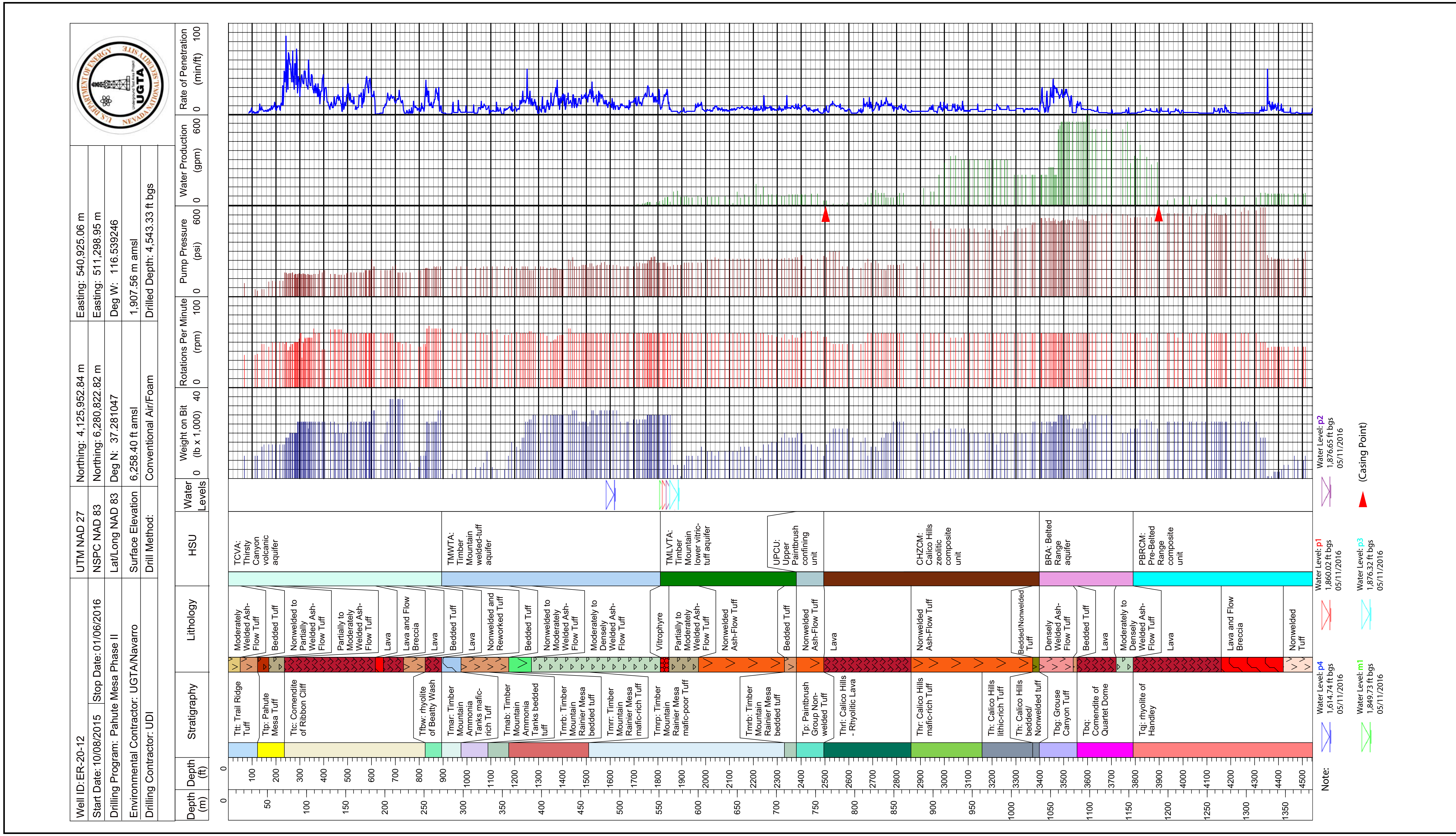


Figure A-1
Drilling Parameters Log for Well ER-20-12

Table A-1
Tubing and Casing Data for Well ER-20-12
(Page 1 of 2)

Casing and Tubing	Depth Interval m bgs (ft bgs)	Type	Grade	Outside Diameter cm (in.)	Inside Diameter cm (in.)	Wall Thickness cm (in.)	Weight per Foot lb
Conductor	0 to 2.01 (0 to 6.6)	CS	--	106.7 (42)	--	--	--
Conductor	0 to 19.05 (0 to 62.5)	CS	K55	76.2 (30)	73.58 (28.97)	1.31 (0.515)	162.33
Surface	0 to 307.42 (0 to 1,008.59)	CS	K55	50.8 (20)	48.26 (19)	1.27 (0.5)	106.50
	307.42 to 762.85 (1,008.59 to 2502.80)	CS	K55	50.8 (20)	48.58 (19.124)	1.11 (0.438)	94
Intermediate	0 to 1,188.72 (0 to 3,900)	CS	K55	24.44 (9.625)	22.44 (8.835)	1.00 (0.395)	40
Completion (with crossover)	0 to 540.29 (0 to 1,772.63)	CS	J55	13.97 (5.5)	12.57 (4.95)	0.699 (0.275)	15.5
Completion (with bullnose termination)	540.29 to 1,216.70 (1,772.63 to 4,431.15)	SS	304L	13.97 (5.5)	12.82 (5.047)	0.699 (0.275)	14.6
Piezometer (p4): with orange-peeled termination	0 to 579.66 (0 to 1,901.79)	CS	L 80	4.82 (1.9)	3.83 (1.51)	0.495 (0.195)	2.90
Piezometer (p3): with crossover	0 to 777.93 (0 to 2,552.26)	CS	N80	6.03 (2.375)	5.07 (1.995)	0.482 (0.190)	4.70
Piezometer (p3): (with bullnose termination)	777.93 to 888.51 (2,552.26 to 2,915.08)	SS	304L	7.30 (2.875)	5.99 (2.36)	0.655 (0.258)	7.66
Piezometer (p2): with orange-peeled termination	0 to 957.72 (0 to 3,142.13)	CS	L 80	4.82 (1.9)	3.83 (1.51)	0.495 (0.195)	2.90

Table A-1
Tubing and Casing Data for Well ER-20-12
(Page 2 of 2)

Casing and Tubing	**Depth Interval** m bgs (ft bgs)	**Type**	**Grade**	**Outside Diameter** cm (in.)	**Inside Diameter** cm (in.)	**Wall Thickness** cm (in.)	**Weight per Foot** lb
Piezometer (p1): with crossover	0 to 1,043.69 (0 to 3,424.18)	CS	N80	6.03 (2.375)	5.07 (1.995)	0.482 (0.190)	4.70
Piezometer (p1): (with bullnose termination)	1,043.69 to 1,117.35 (3,424.18 to 3,665.85)	SS	304L	7.30 (2.875)	5.99 (2.36)	0.655 (0.258)	7.66

-- = No information provided by NSTec.

Table A-2
Drilling Fluids Used in Well ER-20-12

Typical Air-Foam/Polymer Mix
27.0 L (7.1 gal) to 151.4 L (40 gal) Geo-Foam 1, F-485 0.6 L (0.2 gal) to 14.2 L (3.8 gal) GeoLP-701 per 7,949 L (50 bbl) water

Notes:
1. Geo-Foam foaming agent is a product of Geo Western Drilling Fluids; F-485 is a product of Bachman.
2. GeoLP-701 is a product of Geo Western Drilling Fluids.
3. All water used to mix drilling fluid came from Well ER-20-4 and after 11/28/2015 from Well WW-8.
4. A concentrated lithium bromide solution was added to introduced fluids at a rate that varied from 0.825 L to 3.75 L per 50 bbl of injected fluid. The concentration was adjusted as water production increased or decreased.

Table A-3
Well ER-20-12 Cement Composition

Cement Composition	42-in. Conductor Casing	30-in. Conductor Casing	1.9-in. Piezometer String (p4)	20-in. Surface Casing	2.375-in. Piezometer String (p1)	1.9-in. Piezometer String (p2)	2.375-in. Piezometer String (p3)	9.625-in. Intermediate Casing	5.5-in. Production Casing (m1)
Type II Neat Cement	0 to 2.17 m (0 to 7.13 ft)	2.01 to 19.36 m (6.6 to 63.5 ft)	None	697.09 to 765.15 m (2,287 to 2,510.3 ft)	898.24 to 930.57 m (2,946.93 to 3,053 ft) 962.27 to 1,018.96 m (3,157 to 3,343 ft)	898.24 to 930.57 m (2,946.93 to 3,053 ft)	None	898.24 to 930.57 m (2,946.93 to 3,053 ft) 962.27 to 1,018.96 m (3,157 to 3,343 ft) 1,135.39 to 1,193.61 m (3,725 to 3,916 ft)	None

Appendix B

Well ER-20-12 Fluid Management Data and Groundwater Sampling Analytical Results

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 1 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-100615-01	N/A	N/A	74	1,725.84	--	Makeup water ER-20-4
ER-20-12-100915-02	21.34	70	937	1,870.32	--	Discharge Line
ER-20-12-100915-03	21.34	70	1,232	1,870.32	--	Discharge Line
ER-20-12-100915-04	38.40	126	1,036	1,824.84	--	Discharge Line
ER-20-12-100915-05	44.20	145	3,441	1,955.96	1,441	Discharge Line
ER-20-12-100915-06	47.55	156	0	1,505.38	--	Discharge Line
ER-20-12-100915-07	51.82	170	1,207	1,585.91	--	Discharge Line
ER-20-12-100915-08	55.47	182	923	1,627.56	--	Discharge Line
ER-20-12-100915-09	59.74	196	1,505	1,730.13	--	Discharge Line
ER-20-12-100915-10	63.09	207	486	1,585.91	--	Discharge Line
ER-20-12-100915-11	67.67	222	718	1,725.84	--	Discharge Line
ER-20-12-100915-12	69.80	229	1,517	1,903.14	--	Discharge Line
ER-20-12-100915-13	71.32	234	0	1,720.56	--	Discharge Line
ER-20-12-100915-14	72.54	238	11	1,725.84	--	Discharge Line
ER-20-12-100915-15	73.15	240	1,434	1,824.84	--	Discharge Line
ER-20-12-100915-16	73.76	242	1,560	2,468.83	2,518	Discharge Line
ER-20-12-100915-17	73.76	242	1,801	1,505.49	2,062	Discharge Line
ER-20-12-100915-18	73.76	242	1,051	1,584.73	--	Discharge Line
ER-20-12-100915-19	74.68	245	0	1,870.32	--	Discharge Line
ER-20-12-100915-20	75.90	249	94	1,544.10	--	Discharge Line
ER-20-12-100915-21	76.20	250	1,516	1,720.56	--	Discharge Line
ER-20-12-100915-22	76.81	252	2,638	1,720.56	127	Discharge Line
ER-20-12-101015-23	78.33	257	1,231	1,730.13	--	Discharge Line
ER-20-12-101015-24	78.64	258	3,148	1,833.71	704	Discharge Line
ER-20-12-101015-25	79.25	260	0	1,870.32	3,056	Discharge Line
ER-20-12-101015-26	80.16	263	886	1,584.73	--	Discharge Line
ER-20-12-101015-27	81.08	266	2,741	2,076.54	1,096	Discharge Line
ER-20-12-101015-28	81.69	268	1,402	1,544.18	--	Discharge Line
ER-20-12-101015-29	81.99	269	39	1,585.91	--	Makeup water ER-20-4
ER-20-12-101015-30	82.30	270	649	1,504.58	--	Discharge Line
ER-20-12-101015-31	83.52	274	7,008	1,540.62	0	Discharge Line
ER-20-12-101015-32	84.43	277	5,050	1,870.32	794	Discharge Line
ER-20-12-101015-33	85.34	280	3,976	1,833.65	0	Discharge Line
ER-20-12-101015-34	86.26	283	1,088	1,730.13	--	Discharge Line
ER-20-12-101015-35	86.87	285	318	1,676.53	--	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 2 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-101015-36	87.17	286	3,411	1,672.77	1,261	Discharge Line
ER-20-12-101015-37	87.78	288	1,703	1,672.77	--	Discharge Line
ER-20-12-101015-38	88.39	290	1,366	2,316.14	--	Discharge Line
ER-20-12-101015-39	89.61	294	7,340	2,794.22	2,579	Discharge Line
ER-20-12-101015-40	90.83	298	3,041	2,527.39	722	Discharge Line
ER-20-12-101015-41	91.74	301	0	1,941.51	--	Discharge Line
ER-20-12-101015-42	92.96	305	1,442	1,720.56	--	Discharge Line
ER-20-12-101015-43	93.57	307	10,034	2,347.15	4,579	Discharge Line
ER-20-12-101115-44	94.49	310	1,307	1,222.47	--	Makeup water ER-20-4
ER-20-12-101115-45	94.49	310	744	1,815.32	--	Discharge Line
ER-20-12-101115-46	95.40	313	0	1,629.96	--	Discharge Line
ER-20-12-101115-47	96.32	316	1,379	1,585.95	--	Discharge Line
ER-20-12-101115-48	96.93	318	1,771	1,585.91	579	Discharge Line
ER-20-12-101115-49	97.84	321	1,032	2,178.78	--	Discharge Line
ER-20-12-101115-50	98.45	323	936	1,585.91	--	Discharge Line
ER-20-12-101115-51	99.67	327	1,098	1,942.57	--	Discharge Line
ER-20-12-101115-52	100.28	329	402	1,676.53	--	Discharge Line
ER-20-12-101115-53	101.19	332	0	1,544.10	--	Discharge Line
ER-20-12-101115-54	102.41	336	18,663	2,007.32	740	Discharge Line
ER-20-12-101115-55	103.02	338	1,841	2,038.21	--	Discharge Line
ER-20-12-101115-56	104.24	342	0	1,627.56	--	Discharge Line
ER-20-12-101115-57	105.46	346	18,030	2,039.08	191	Discharge Line
ER-20-12-101115-58	106.07	348	0	1,755.13	--	Discharge Line
ER-20-12-101115-59	106.98	351	766	1,707.69	--	Discharge Line
ER-20-12-101115-60	107.90	354	222	1,459.95	--	Discharge Line
ER-20-12-101115-61	109.12	358	1,366	1,627.56	--	Discharge Line
ER-20-12-101115-62	110.64	363	2,694	1,672.77	73	Discharge Line
ER-20-12-101115-63	111.56	366	20,991	2,632.69	2,694	Discharge Line
ER-20-12-101115-64	113.08	371	10,354	1,846.12	1,573	Discharge Line
ER-20-12-101115-65	114.60	376	1,827	1,505.49	1,430	Discharge Line
ER-20-12-101115-66	115.82	380	204	1,707.69	--	Discharge Line
ER-20-12-101115-67	117.04	384	45	1,833.65	--	Discharge Line
ER-20-12-101115-68	119.18	391	2,200	1,870.32	398	Discharge Line
ER-20-12-101215-69	120.40	395	1,986	1,676.53	651	Discharge Line
ER-20-12-101215-70	121.31	398	6,281	1,942.57	893	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 3 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-101215-71	122.53	402	154	1,805.28	--	Discharge Line
ER-20-12-101215-72	124.05	407	0	1,941.51	--	Discharge Line
ER-20-12-101215-73	124.97	410	21,975	1,778.14	1,140	Discharge Line
ER-20-12-101215-74	126.49	415	1,521	1,942.57	--	Discharge Line
ER-20-12-101215-75	129.54	425	3,778	1,778.14	775	Discharge Line
ER-20-12-101215-76	133.50	438	3,528	1,914.69	1,043	Discharge Line
ER-20-12-101215-77	136.25	447	8,567	1,928.77	735	Discharge Line
ER-20-12-101215-78	138.38	454	15,373	2,509.16	1,260	Discharge Line
ER-20-12-101215-79	140.21	460	37,174	3,000.52	564	Discharge Line
ER-20-12-101215-80	142.04	466	1,146	1,824.84	--	Discharge Line
ER-20-12-101215-81	143.87	472	0	1,900.41	--	Discharge Line
ER-20-12-101215-82	146.30	480	2,933	2,105.58	2,185	Discharge Line
ER-20-12-101215-83	149.66	491	817	1,771.17	--	Discharge Line
ER-20-12-101215-84	151.79	498	4,269	1,763.45	1,309	Discharge Line
ER-20-12-101215-85	153.01	502	4,203	1,928.77	1,151	Discharge Line
ER-20-12-101215-86	154.23	506	4,506	2,019.19	3,726	Discharge Line
ER-20-12-101215-87	156.36	513	1,593	2,059.71	--	Discharge Line
ER-20-12-101215-88	158.19	519	6,399	1,870.32	4,960	Discharge Line
ER-20-12-101215-89	161.24	529	1,584	2,000.35	--	Discharge Line
ER-20-12-101215-90	164.59	540	2,952	1,582.58	0	Discharge Line
ER-20-12-101215-91	N/A	N/A	256	1,928.77	--	Discharge Line
ER-20-12-101315-92	168.55	553	3,864	1,784.19	580	Discharge Line
ER-20-12-101315-93	170.08	558	397	1,974.52	--	Discharge Line
ER-20-12-101315-94	172.21	565	930	1,725.84	--	Discharge Line
ER-20-12-101315-95	174.65	573	0	1,815.32	--	Discharge Line
ER-20-12-101315-96	176.17	578	0	2,062.86	--	Discharge Line
ER-20-12-101315-97	177.09	581	0	2,019.19	--	Discharge Line
ER-20-12-101315-98	177.70	583	293	1,453.48	--	Discharge Line
ER-20-12-101315-99	178.61	586	1,051	1,453.48	--	Discharge Line
ER-20-12-101315-100	179.83	590	2,976	1,725.84	0	Discharge Line
ER-20-12-101315-101	180.75	593	16,220	1,870.32	781	Discharge Line
ER-20-12-101315-102	181.66	596	2,794	1,415.23	732	Discharge Line
ER-20-12-101315-103	182.58	599	2,065	1,359.39	1,239	Discharge Line
ER-20-12-101315-104	184.40	605	28,971	1,422.11	0	Discharge Line
ER-20-12-101315-105	186.23	611	5,780	1,700.37	1,578	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 4 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-101315-106	188.98	620	4,485	1,585.95	1,070	Discharge Line
ER-20-12-101315-107	198.12	650	1,067	1,833.65	--	Discharge Line
ER-20-12-101315-108	201.78	662	1,091	1,427.36	--	Discharge Line
ER-20-12-101315-109	204.22	670	0	1,347.17	--	Discharge Line
ER-20-12-101315-110	N/A	N/A	0	1,463.95	--	Makeup water ER-20-4
ER-20-12-101315-111	206.96	679	0	1,627.56	--	Discharge Line
ER-20-12-101315-112	209.09	686	2,269	1,676.53	860	Discharge Line
ER-20-12-101315-113	210.62	691	1,464	1,585.95	--	Discharge Line
ER-20-12-101415-114	212.75	698	2,416	1,941.51	0	Discharge Line
ER-20-12-101415-115	215.19	706	260	1,540.62	--	Discharge Line
ER-20-12-101415-116	217.32	713	2,602	1,676.53	1,599	Discharge Line
ER-20-12-101415-117	218.85	718	2,705	1,974.52	871	Discharge Line
ER-20-12-101415-118	220.98	725	1,655	1,720.56	--	Discharge Line
ER-20-12-101415-119	225.25	739	1,274	1,942.57	--	Discharge Line
ER-20-12-101415-120	229.82	754	1,039	1,730.13	--	Discharge Line
ER-20-12-101415-121	237.44	779	1,253	1,540.62	--	Discharge Line
ER-20-12-101415-122	242.32	795	20,753	1,463.95	1,110	Discharge Line
ER-20-12-101415-123	245.67	806	0	1,248.48	--	Discharge Line
ER-20-12-101415-124	245.67	806	675	1,824.84	--	Discharge Line
ER-20-12-101415-125	245.67	806	878	1,846.12	--	Discharge Line
ER-20-12-101415-126	248.11	814	32,738	1,672.77	808	Discharge Line
ER-20-12-101415-127	N/A	N/A	24,713	1,543.09	764	Discharge Line
ER-20-12-101415-128	251.76	826	136	1,505.49	--	Discharge Line
ER-20-12-101415-129	252.37	828	2,316	1,431.19	1,026	Discharge Line
ER-20-12-101515-130	253.90	833	627	1,858.37	--	Discharge Line
ER-20-12-101515-131	255.42	838	758	1,502.48	--	Discharge Line
ER-20-12-101515-132	258.78	849	776	1,544.18	--	Discharge Line
ER-20-12-101515-133	261.21	857	769	1,359.39	--	Discharge Line
ER-20-12-101515-134	263.96	866	7,419	1,459.54	771	Discharge Line
ER-20-12-101515-135	265.18	870	25,758	1,368.63	558	Discharge Line
ER-20-12-101515-136	266.40	874	820	1,327.77	--	Discharge Line
ER-20-12-101515-137	268.22	880	423	1,543.09	--	Discharge Line
ER-20-12-101515-138	271.58	891	431	1,585.91	--	Discharge Line
ER-20-12-101515-139	283.46	930	38	1,584.73	--	Discharge Line
ER-20-12-101515-140	289.56	950	9,010	1,386.56	0	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 5 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-101515-141	294.74	967	3,282	1,725.84	1,071	Discharge Line
ER-20-12-101515-142	301.14	988	1,033	1,676.53	--	Discharge Line
ER-20-12-101515-143	307.85	1,010	4,627	1,544.18	327	Discharge Line
ER-20-12-101515-144	315.16	1,034	660	1,668.13	--	Discharge Line
ER-20-12-101515-145	320.95	1,053	10,434	1,676.53	773	Discharge Line
ER-20-12-101515-146	324.92	1,066	628	1,846.12	--	Discharge Line
ER-20-12-101515-147	328.88	1,079	120	1,958.00	--	Discharge Line
ER-20-12-101615-148	332.84	1,092	0	1,505.49	--	Discharge Line
ER-20-12-101615-149	N/A	N/A	24	2,007.32	--	Makeup water ER-20-4
ER-20-12-101615-150	341.38	1,120	1,006	2,038.21	--	Discharge Line
ER-20-12-101615-151	348.08	1,142	5,234	1,824.84	0	Discharge Line
ER-20-12-101615-152	356.01	1,168	4,835	1,881.87	946	Discharge Line
ER-20-12-101615-153	359.97	1,181	0	1,584.73	--	Discharge Line
ER-20-12-101615-154	363.63	1,193	1,859	1,585.91	1.544	Discharge Line
ER-20-12-101615-155	368.81	1,210	1,995	1,576.91	0	Discharge Line
ER-20-12-101615-156	371.25	1,218	356	1,629.96	--	Discharge Line
ER-20-12-101615-157	372.77	1,223	2,376	1,733.20	0	Discharge Line
ER-20-12-101615-158	375.51	1,232	143	1,679.24	--	Discharge Line
ER-20-12-101615-159	377.65	1,239	356	1,631.26	--	Discharge Line
ER-20-12-101615-160	379.78	1,246	877	1,540.62	--	Discharge Line
ER-20-12-101615-161	381.30	1,251	2,603	1,672.77	0	Discharge Line
ER-20-12-101615-162	382.52	1,255	298	1,327.77	--	Discharge Line
ER-20-12-101615-163	384.66	1,262	5,313	1,692.60	0	Discharge Line
ER-20-12-101615-164	386.79	1,269	218	1,359.39	--	Discharge Line
ER-20-12-101615-165	388.62	1,275	1,891	1,585.95	606	Discharge Line
ER-20-12-101615-166	391.67	1,285	1,237	1,771.17	--	Discharge Line
ER-20-12-101615-167	396.24	1,300	466	1,629.96	--	Discharge Line
ER-20-12-101615-168	400.81	1,315	966	1,584.73	--	Discharge Line
ER-20-12-101615-169	409.65	1,344	1,105	1,714.46	--	Discharge Line
ER-20-12-101615-170	410.57	1,347	1,094	1,720.56	--	Discharge Line
ER-20-12-101615-171	413.00	1,355	540	1,544.18	--	Discharge Line
ER-20-12-101615-172	415.75	1,364	1,550	1,585.95	--	Discharge Line
ER-20-12-101715-173	N/A	N/A	0	1,815.32	--	Makeup water ER-20-4
ER-20-12-101715-174	416.66	1,367	181	2,057.36	--	Discharge Line
ER-20-12-101715-175	418.49	1,373	1,638	1,540.62	413	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 6 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-101715-176	420.01	1,378	1,671	1,631.26	0	Discharge Line
ER-20-12-101715-177	422.76	1,387	856	1,543.09	--	Discharge Line
ER-20-12-101715-178	425.20	1,395	417	1,941.51	--	Discharge Line
ER-20-12-101715-179	426.72	1,400	1,356	1,629.96	--	Discharge Line
ER-20-12-101715-180	429.16	1,408	1,642	1,771.17	--	Discharge Line
ER-20-12-101715-181	432.21	1,418	1,318	1,543.09	--	Discharge Line
ER-20-12-101715-182	434.95	1,427	7,247	1,725.84	489	Discharge Line
ER-20-12-101715-183	436.17	1,431	0	1,505.49	--	Discharge Line
ER-20-12-101715-184	439.52	1,442	0	1,627.56	--	Discharge Line
ER-20-12-101715-185	439.83	1,443	3,357	1,815.32	0	Discharge Line
ER-20-12-101915-186	441.96	1,450	162	1,662.75	--	Discharge Line
ER-20-12-102015-187	444.70	1,459	820	1,870.32	--	Discharge Line
ER-20-12-102015-188	447.45	1,468	1,241	1,585.91	--	Discharge Line
ER-20-12-102015-189	448.97	1,473	0	1,914.69	--	Discharge Line
ER-20-12-102015-190	N/A	N/A	0	1,974.52	--	Makeup water ER-20-4
ER-20-12-102015-191	451.71	1,482	0	1,755.13	--	Discharge Line
ER-20-12-102015-192	453.54	1,488	104	1,672.77	--	Discharge Line
ER-20-12-102015-193	455.37	1,494	0	2,062.86	--	Discharge Line
ER-20-12-102015-194	457.20	1,500	0	1,771.17	--	Discharge Line
ER-20-12-102015-195	458.42	1,504	937	1,629.96	--	Discharge Line
ER-20-12-102015-196	458.72	1,505	6,301	1,468.77	278	Discharge Line
ER-20-12-102015-197	460.55	1,511	25,606	1,858.37	0	Discharge Line
ER-20-12-102015-198	462.08	1,516	53,718	1,505.49	791	Discharge Line
ER-20-12-102015-199	463.60	1,521	5,663	1,990.99	1,085	Discharge Line
ER-20-12-102015-200	464.82	1,525	1,094	1,575.95	--	Discharge Line
ER-20-12-102015-201	466.95	1,532	11,701	1,624.23	886	Discharge Line
ER-20-12-102015-202	468.17	1,536	0	1,846.12	--	Discharge Line
ER-20-12-102015-203	470.00	1,542	0	1,755.13	--	Discharge Line
ER-20-12-102015-204	472.74	1,551	2,201	1,858.37	0	Discharge Line
ER-20-12-102015-205	474.57	1,557	1,277	1,584.73	--	Discharge Line
ER-20-12-102015-206	476.40	1,563	4,813	1,725.84	157	Discharge Line
ER-20-12-102015-207	477.93	1,568	2,032	1,914.69	869	Discharge Line
ER-20-12-102015-208	480.67	1,577	5,348	1,763.45	52	Discharge Line
ER-20-12-102015-209	483.11	1,585	1,945	1,720.56	970	Discharge Line
ER-20-12-102015-210	486.16	1,595	1,354	1,914.69	--	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 7 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-102015-211	488.90	1,604	1,953	1,824.84	0	Discharge Line
ER-20-12-102115-212	492.56	1,616	1,052	1,627.77	--	Discharge Line
ER-20-12-102115-213	N/A	N/A	419	1,627.77	--	Makeup water ER-20-4
ER-20-12-102115-214	496.52	1,629	0	1,858.37	--	Discharge Line
ER-20-12-102115-215	500.18	1,641	0	1,794.84	--	Discharge Line
ER-20-12-102115-216	503.83	1,653	193	1,914.69	--	Discharge Line
ER-20-12-102115-217	505.66	1,659	111	1,714.46	--	Discharge Line
ER-20-12-102115-218	509.02	1,670	629	1,858.37	--	Discharge Line
ER-20-12-102115-219	512.67	1,682	1,227	2,000.35	--	Discharge Line
ER-20-12-102115-220	515.72	1,692	4,285	1,794.84	4,209	Discharge Line
ER-20-12-102115-221	516.94	1,696	0	1,610.03	--	Discharge Line
ER-20-12-102115-222	516.94	1,696	4,321	1,668.13	4,580	Discharge Line
ER-20-12-102115-223	517.86	1,699	3,887	1,833.65	--	Discharge Line
ER-20-12-102115-224	518.77	1,702	9,837	1,544.18	4,160	Discharge Line
ER-20-12-102115-225	519.68	1,705	83,138	1,755.13	3,285	Discharge Line
ER-20-12-102115-226	521.21	1,710	3,460	1,746.33	--	Discharge Line
ER-20-12-102115-227	522.73	1,715	3,500	1,668.13	--	Discharge Line
ER-20-12-102115-228	524.26	1,720	5,375	1,544.18	3,763	Discharge Line
ER-20-12-102115-229	525.78	1,725	9,667	1,771.17	6,286	Discharge Line
ER-20-12-102115-230	527.30	1,730	10,824	1,707.69	3,814	Discharge Line
ER-20-12-102115-231	528.83	1,735	10,537	2,038.21	9,531	Discharge Line
ER-20-12-102115-232	530.35	1,740	11,139	1,629.96	11,216	Discharge Line
ER-20-12-102115-233	531.88	1,745	7,700	1,672.77	7,222	Discharge Line
ER-20-12-102115-234	533.40	1,750	9,601	1,870.32	8,161	Discharge Line
ER-20-12-102215-235	534.92	1,755	11,196	2,019.19	10,066	Discharge Line
ER-20-12-102215-236	N/A	N/A	0	1,958.00	--	Makeup water ER-20-4
ER-20-12-102215-237	536.45	1,760	12,934	1,958.00	12,555	Discharge Line
ER-20-12-102215-238	537.97	1,765	12,073	1,720.56	12,571	Discharge Line
ER-20-12-102215-239	539.50	1,770	12,555	1,668.13	12,944	Discharge Line
ER-20-12-102215-240	541.02	1,775	14,248	1,672.67	12,312	Discharge Line
ER-20-12-102215-241	542.54	1,780	13,047	1,815.32	13,707	Discharge Line
ER-20-12-102215-242	544.07	1,785	21,222	1,870.32	19,922	Discharge Line
ER-20-12-102215-243	545.90	1,791	14,184	1,504.40	--	Discharge Line
ER-20-12-102215-244	547.42	1,796	12,574	1,436.01	--	Discharge Line
ER-20-12-102215-245	549.86	1,804	10,497	1,333.61	--	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 8 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-102215-246	551.08	1,808	30,305	1,371.57	13,524	Discharge Line
ER-20-12-102215-247	555.04	1,821	26,750	1,714.46	25,949	Discharge Line
ER-20-12-102215-248	556.26	1,825	25,387	1,805.28	24,919	Discharge Line
ER-20-12-102215-249	558.09	1,831	25,481	1,627.56	24,778	Discharge Line
ER-20-12-102215-250	559.61	1,836	32,345	1,624.23	30,653	Discharge Line
ER-20-12-102215-251	561.14	1,841	28,477	1,763.45	26,928	Discharge Line
ER-20-12-102215-252	563.58	1,849	24,452	1,544.18	32,153	Discharge Line
ER-20-12-102215-253	567.54	1,862	34,967	1,833.65	30,634	Discharge Line
ER-20-12-102215-254	573.02	1,880	34,809	1,668.13	35,841	Discharge Line
ER-20-12-102215-255	576.68	1,892	49,295	1,870.32	37,697	Discharge Line
ER-20-12-102215-256	581.86	1,909	37,166	1,629.96	35,780	Discharge Line
ER-20-12-102215-257	586.13	1,923	37,318	1,771.17	32,469	Discharge Line
ER-20-12-102215-258	590.09	1,936	42,272	1,778.14	36,966	Discharge Line
ER-20-12-102215-259	594.06	1,949	38,348	1,958.00	38,643	Discharge Line
ER-20-12-102315-260	N/A	N/A	881	1,720.56	--	Makeup water ER-20-4
ER-20-12-102315-261	597.41	1,960	38,569	1,627.56	38,517	Discharge Line
ER-20-12-102315-262	601.37	1,973	60,388	1,629.96	41,624	Discharge Line
ER-20-12-102315-263	604.72	1,984	41,241	1,585.95	42,204	Discharge Line
ER-20-12-102315-264	609.90	2,001	42,532	1,493.86	39,920	Discharge Line
ER-20-12-102315-265	615.09	2,018	43,088	1,672.77	41,247	Discharge Line
ER-20-12-102315-266	620.57	2,036	29,079	1,585.91	27,829	Discharge Line
ER-20-12-102315-267	624.84	2,050	42,236	1,870.32	39,512	Discharge Line
ER-20-12-102315-268	629.41	2,065	40,144	1,714.46	41,276	Discharge Line
ER-20-12-102315-269	634.59	2,082	40,991	1,585.95	42,291	Discharge Line
ER-20-12-102315-270	639.47	2,098	35,693	1,755.13	35,488	Discharge Line
ER-20-12-102315-271	644.35	2,114	42,028	1,672.77	41,944	Discharge Line
ER-20-12-102315-272	648.31	2,127	41,555	1,755.13	41,872	Discharge Line
ER-20-12-102315-273	653.80	2,145	42,457	1,668.13	42,346	Discharge Line
ER-20-12-102315-274	655.93	2,152	46,059	1,585.95	44,879	Discharge Line
ER-20-12-102315-275	661.11	2,169	46,060	1,672.77	47,584	Discharge Line
ER-20-12-102315-276	665.68	2,184	48,280	1,585.91	53,091	Discharge Line
ER-20-12-102315-277	671.17	2,202	47,347	1,585.91	44,058	Discharge Line
ER-20-12-102315-278	675.44	2,216	42,237	1,668.13	44,509	Discharge Line
ER-20-12-102315-279	681.53	2,236	36,401	1,468.77	23,304	Discharge Line
ER-20-12-102315-280	685.50	2,249	52,393	1,815.32	49,888	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 9 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-102315-281	689.76	2,263	41,322	1,544.18	41,951	Discharge Line
ER-20-12-102315-282	693.72	2,276	45,450	1,585.91	47,480	Discharge Line
ER-20-12-102315-283	699.52	2,295	58,099	1,784.19	56,184	Discharge Line
ER-20-12-102315-284	705.61	2,315	45,073	1,629.96	46,187	Discharge Line
ER-20-12-102415-285	710.18	2,330	40,510	1,498.98	40,232	Discharge Line
ER-20-12-102415-286	N/A	N/A	804	1,540.62	--	Makeup water ER-20-4
ER-20-12-102415-287	715.06	2,346	44,833	1,679.24	43,460	Discharge Line
ER-20-12-102415-288	719.33	2,360	45,441	2,019.19	46,234	Discharge Line
ER-20-12-102415-289	722.38	2,370	47,905	1,629.96	47,307	Discharge Line
ER-20-12-102415-290	727.25	2,386	47,073	1,498.98	45,528	Discharge Line
ER-20-12-102415-291	731.52	2,400	7,824	1,173.57	39,622	Discharge Line
ER-20-12-102415-292	731.52	2,400	35,029	1,720.56	37,435	Discharge Line
ER-20-12-102415-293	734.57	2,410	53,167	1,725.84	51,340	Discharge Line
ER-20-12-102415-294	736.09	2,415	50,705	1,132.00	29,127	Discharge Line
ER-20-12-102415-295	744.32	2,442	37,920	1,460.00	--	Discharge Line
ER-20-12-102415-296	751.33	2,465	41,195	1,498.94	42,416	Discharge Line
ER-20-12-102515-297	758.95	2,490	3,759	1,114.00	45,189	Discharge Line
ER-20-12-102515-298	758.95	2,490	75,823	1,771.06	0	Makeup water ER-20-4
ER-20-12-102515-299	762.00	2,500	39,195	1,794.79	--	Discharge Line
ER-20-12-102515-300	764.44	2,508	44,423	1,858.24	43,163	Discharge Line
ER-20-12-110315-301	548.64	1,800	31,892	1,585.91	--	Bailer
ER-20-12-110615-302	556.26	1,825	54,438	1,672.77	53,055	Bailer
138-110615-1	556.26	1,825	52,700	8,000.00	53,600	Bailer - Lab
ER-20-12-110715-303	N/A	N/A	2,099	1,077.25	3,615	Makeup water ER-20-4
ER-20-12-110815-304	104.55	343	15,921	2,256.87	2,400	Discharge Line
ER-20-12-110915-305	N/A	N/A	1,532	2,178.78	--	Makeup water ER-20-4
ER-20-12-110915-306	137.16	450	0	1,692.60	--	Discharge Line
ER-20-12-111015-307	N/A	N/A	0	2,084.32	--	Makeup water ER-20-4
ER-20-12-111015-308	182.58	599	237	1,900.41	--	Discharge Line
ER-20-12-111115-309	N/A	N/A	617	1,805.28	--	Makeup water ER-20-4
ER-20-12-111115-310	268.53	881	0	1,805.28	--	Discharge Line
ER-20-12-111115-311	N/A	N/A	0	1,805.28	--	Makeup water ER-20-4
ER-20-12-111215-312	88.39	290	767	1,914.69	--	Discharge Line
ER-20-12-111315-313	385.57	1,265	3,960	2,019.19	--	Discharge Line
ER-20-12-111415-314	N/A	N/A	0	1,958.00	--	Makeup water ER-20-4

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 10 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-111415-315	N/A	N/A	0	1,870.32	--	Makeup water ER-20-4
ER-20-12-111415-316	452.93	1,486	72	1,870.32	--	Discharge Line
ER-20-12-111515-317	N/A	N/A	0	1,958.00	--	Makeup water ER-20-4
ER-20-12-111515-318	542.54	1,780	9,060	1,900.41	--	Discharge Line
ER-20-12-111715-319	N/A	N/A	257	2,468.83	--	Discharge Line
ER-20-12-111715-320	544.68	1,787	11,623	2,128.30	--	Makeup water ER-20-4
ER-20-12-111815-321	554.74	1,820	17,141	1,466.97	--	Discharge Line
ER-20-12-111815-322	N/A	N/A	2,413	2,095.67	0	Makeup water ER-20-4
ER-20-12-111915-323	726.64	2,384	59,374	1,815.32	--	Discharge Line
ER-20-12-111915-324	N/A	N/A	0	1,815.34	--	Makeup water ER-20-4
ER-20-12-112415-325	N/A	N/A	180	1,631.26	--	Makeup water ER-20-4
ER-20-12-112415-326	767.79	2,519	1,398	1,833.71	--	Discharge Line
ER-20-12-112415-327	767.79	2,519	518	1,833.71	--	Discharge Line
ER-20-12-112415-328	769.32	2,524	437	1,833.71	--	Discharge Line
ER-20-12-112415-329	772.36	2,534	465	1,870.32	--	Discharge Line
ER-20-12-112415-330	775.41	2,544	3,186	1,730.13	--	Discharge Line
ER-20-12-112415-331	778.46	2,554	844	1,707.69	--	Discharge Line
ER-20-12-112415-332	781.51	2,564	1,658	1,856.77	--	Discharge Line
ER-20-12-112415-333	784.56	2,574	638	1,914.69	--	Discharge Line
ER-20-12-112415-334	787.60	2,584	321	1,794.84	--	Discharge Line
ER-20-12-112415-335	790.65	2,594	5,900	1,833.71	--	Discharge Line
ER-20-12-112415-336	793.70	2,604	819	1,958.00	--	Discharge Line
ER-20-12-112415-337	796.75	2,614	281	1,886.04	--	Discharge Line
ER-20-12-112415-338	799.80	2,624	55	1,914.69	--	Discharge Line
ER-20-12-112415-339	802.84	2,634	2,544	1,629.96	--	Discharge Line
ER-20-12-112415-340	808.63	2,653	0	1,707.69	--	Discharge Line
ER-20-12-112415-341	811.99	2,664	7,107	2,204.31	--	Discharge Line
ER-20-12-112415-342	815.95	2,677	1,953	1,629.96	--	Discharge Line
ER-20-12-112415-343	818.69	2,686	25,050	1,668.13	644	Discharge Line
ER-20-12-112415-344	822.35	2,698	1,906	1,544.10	--	Discharge Line
ER-20-12-112415-345	826.62	2,712	2,423	1,585.91	--	Discharge Line
ER-20-12-112415-346	829.67	2,722	1,352	1,672.77	--	Discharge Line
ER-20-12-112415-347	834.54	2,738	472	1,662.75	--	Discharge Line
ER-20-12-112415-348	836.68	2,745	1,699	1,707.69	--	Discharge Line
ER-20-12-112515-349	N/A	N/A	1,091	2,347.15	--	Makeup water ER-20-4

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 11 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-112515-350	839.42	2,754	1,839	2,173.29	--	Discharge Line
ER-20-12-112515-351	841.86	2,762	1,063	1,585.95	--	Discharge Line
ER-20-12-112515-352	845.21	2,773	2,110	1,990.99	--	Discharge Line
ER-20-12-112515-353	848.56	2,784	738	1,870.32	--	Discharge Line
ER-20-12-112515-354	852.83	2,798	0	2,340.17	--	Discharge Line
ER-20-12-112515-355	856.49	2,810	0	2,129.40	--	Discharge Line
ER-20-12-112515-356	861.06	2,825	0	2,334.34	--	Discharge Line
ER-20-12-112515-357	865.94	2,841	222	2,937.00	--	Discharge Line
ER-20-12-112515-358	874.17	2,868	2,461	2,276.25	--	Discharge Line
ER-20-12-112515-359	882.09	2,894	166	2,041.78	--	Discharge Line
ER-20-12-112515-360	890.02	2,920	737	2,323.40	--	Discharge Line
ER-20-12-112515-361	896.72	2,942	2,078	2,019.19	--	Discharge Line
ER-20-12-112515-362	897.03	2,943	638	2,640.46	--	Discharge Line
ER-20-12-112515-363	900.38	2,954	0	1,871.63	--	Discharge Line
ER-20-12-112515-364	906.78	2,975	0	1,794.84	--	Discharge Line
ER-20-12-112515-365	908.30	2,980	0	2,000.35	--	Discharge Line
ER-20-12-112515-366	913.18	2,996	0	1,833.65	--	Discharge Line
ER-20-12-112515-367	917.75	3,011	371	1,538.43	--	Discharge Line
ER-20-12-112515-368	924.46	3,033	2,426	1,714.46	--	Discharge Line
ER-20-12-112515-369	928.73	3,047	5	1,755.13	--	Discharge Line
ER-20-12-112515-370	933.91	3,064	0	1,615.35	--	Discharge Line
ER-20-12-112515-371	937.26	3,075	0	1,469.54	--	Discharge Line
ER-20-12-112515-372	944.88	3,100	391	1,784.09	--	Discharge Line
ER-20-12-112515-373	950.98	3,120	0	1,700.37	--	Discharge Line
ER-20-12-112515-374	956.46	3,138	687	1,700.37	--	Discharge Line
ER-20-12-112615-375	N/A	N/A	0	1,763.45	--	Makeup water ER-20-4
ER-20-12-112615-376	964.39	3,164	204	1,870.32	--	Discharge Line
ER-20-12-112615-377	969.26	3,180	687	1,700.37	--	Discharge Line
ER-20-12-112615-378	975.06	3,199	1,064	2,347.15	--	Discharge Line
ER-20-12-112615-379	979.93	3,215	375	1,725.84	--	Discharge Line
ER-20-12-112615-380	984.20	3,229	656	1,505.49	--	Discharge Line
ER-20-12-112615-381	988.16	3,242	1,451	2,039.08	--	Discharge Line
ER-20-12-112615-382	993.95	3,261	0	1,974.52	--	Discharge Line
ER-20-12-112615-383	996.39	3,269	430	1,368.63	--	Discharge Line
ER-20-12-112615-384	1,002.18	3,288	158	1,624.23	--	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 12 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-112615-385	1,006.75	3,303	2,217	1,610.03	--	Discharge Line
ER-20-12-112615-386	1,011.94	3,320	32	1,620.12	--	Discharge Line
ER-20-12-112615-387	1,014.98	3,330	0	2,062.86	--	Discharge Line
ER-20-12-112615-388	1,020.78	3,349	1,345	1,900.41	--	Discharge Line
ER-20-12-112615-389	1,023.82	3,359	395	1,668.13	--	Discharge Line
ER-20-12-112615-390	1,026.57	3,368	0	1,344.35	--	Discharge Line
ER-20-12-112615-391	1,030.22	3,380	4,560	2,316.14	--	Discharge Line
ER-20-12-112615-392	1,035.41	3,397	1,146	2,805.49	--	Discharge Line
ER-20-12-112615-393	1,036.32	3,400	2,397	1,720.56	0	Discharge Line
ER-20-12-112615-394	1,036.32	3,400	9,568	1,714.46	700	Discharge Line
ER-20-12-112715-395	1,038.15	3,406	1,591	1,928.77	--	Discharge Line
ER-20-12-112715-396	1,038.76	3,408	188	1,815.32	--	Discharge Line
ER-20-12-112715-397	1,040.89	3,415	1,017	1,627.56	--	Discharge Line
ER-20-12-112715-398	1,043.94	3,425	891	1,707.69	--	Discharge Line
ER-20-12-112715-399	1,046.07	3,432	1,477	1,627.56	--	Discharge Line
ER-20-12-112815-400	1,049.12	3,442	0	1,815.32	--	Discharge Line
ER-20-12-112815-401	1,049.12	3,442	211	1,928.77	--	Discharge Line
ER-20-12-112815-402	1,050.65	3,447	0	1,833.65	--	Discharge Line
ER-20-12-112815-403	1,052.47	3,453	1,547	1,903.14	--	Discharge Line
ER-20-12-112815-404	1,053.08	3,455	20,121	1,435.87	0	Discharge Line
ER-20-12-112815-405	1,054.61	3,460	754	1,870.32	--	Discharge Line
ER-20-12-112815-406	1,055.22	3,462	10,968	1,436.37	1,456	Discharge Line
ER-20-12-112815-407	1,056.74	3,467	444	1,541.09	--	Discharge Line
ER-20-12-112815-408	1,058.27	3,472	1,215	1,543.02	--	Discharge Line
ER-20-12-112815-409	1,059.79	3,477	6,213	1,815.32	1,847	Discharge Line
ER-20-12-112815-410	1,061.62	3,483	361	1,676.53	--	Discharge Line
ER-20-12-112815-411	1,063.14	3,488	1,396	1,364.62	476	Discharge Line
ER-20-12-112815-412	1,063.45	3,489	352	1,928.77	--	Discharge Line
ER-20-12-112815-413	1,064.97	3,494	608	1,374.77	--	Discharge Line
ER-20-12-112815-414	1,066.50	3,499	1,019	1,841.75	--	Discharge Line
ER-20-12-112815-415	1,068.32	3,505	5,889	2,204.31	811	Discharge Line
ER-20-12-112815-416	1,071.37	3,515	1,109	1,668.13	--	Discharge Line
ER-20-12-112815-417	1,071.98	3,517	1,792	1,763.45	--	Discharge Line
ER-20-12-112815-418	1,073.20	3,521	0	1,662.75	--	Discharge Line
ER-20-12-112815-419	1,074.72	3,526	1,039	1,624.23	--	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 13 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-112815-420	1,076.86	3,533	560	1,771.17	--	Discharge Line
ER-20-12-112815-421	1,082.04	3,550	3,030	1,914.69	--	Discharge Line
138-120615-1	1,082.04	3,550	27,100	350.00	28,900	Bailer - Lab
ER-20-12-112815-422	1,083.26	3,554	1,826	1,624.23	--	Discharge Line
ER-20-12-112815-423	1,086.31	3,564	0	1,615.35	--	Discharge Line
ER-20-12-112915-424	1,089.05	3,573	1,832	1,672.77	--	Discharge Line
ER-20-12-112915-425	N/A	N/A	242	1,771.17	--	Makeup water WW-8
ER-20-12-112915-426	1,092.10	3,583	889	2,019.19	--	Discharge Line
ER-20-12-112915-427	1,093.93	3,589	1,842	1,676.53	--	Discharge Line
ER-20-12-112915-428	1,095.45	3,594	1,239	1,805.28	--	Discharge Line
ER-20-12-112915-429	1,098.80	3,605	3,028	1,824.84	--	Discharge Line
ER-20-12-112915-430	1,100.02	3,609	417	1,714.76	--	Discharge Line
ER-20-12-112915-431	1,101.55	3,614	990	1,990.99	--	Discharge Line
ER-20-12-112915-432	1,102.16	3,616	1,696	1,662.75	--	Discharge Line
ER-20-12-112915-433	1,104.90	3,625	423	1,763.45	--	Discharge Line
ER-20-12-112915-434	1,109.78	3,641	0	1,714.46	--	Discharge Line
ER-20-12-112915-435	1,112.22	3,649	929	1,778.15	--	Discharge Line
ER-20-12-112915-436	1,114.65	3,657	1,016	1,613.26	--	Discharge Line
ER-20-12-112915-437	1,121.66	3,680	990	1,870.32	--	Discharge Line
ER-20-12-112915-438	1,128.06	3,701	972	2,038.21	0	Discharge Line
ER-20-12-112915-439	1,131.42	3,712	4,034	1,990.99	--	Discharge Line
ER-20-12-112915-440	1,134.77	3,723	1,094	1,707.69	--	Discharge Line
ER-20-12-112915-441	1,141.17	3,744	492	1,755.13	--	Discharge Line
ER-20-12-112915-442	1,146.05	3,760	515	1,627.56	--	Discharge Line
ER-20-12-112915-443	1,150.62	3,775	738	1,714.46	--	Discharge Line
ER-20-12-112915-444	1,150.92	3,776	415	1,656.77	--	Discharge Line
ER-20-12-112915-445	1,151.23	3,777	240	1,624.23	--	Discharge Line
ER-20-12-112915-446	1,156.72	3,795	1,538	1,805.28	--	Discharge Line
ER-20-12-112915-447	1,160.37	3,807	2,457	1,730.13	--	Discharge Line
ER-20-12-112915-448	1,165.86	3,825	655	1,672.77	--	Discharge Line
ER-20-12-112915-449	N/A	N/A	2,856	1,627.56	--	Makeup water WW-8
ER-20-12-112915-450	1,170.13	3,839	831	1,585.95	--	Discharge Line
ER-20-12-113015-451	1,172.87	3,848	1,790	2,204.31	--	Discharge Line
ER-20-12-113015-452	1,176.53	3,860	841	1,627.56	--	Discharge Line
ER-20-12-113015-453	1,180.49	3,873	362	1,755.13	--	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 14 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-113015-454	1,185.37	3,889	1,269	1,676.53	--	Discharge Line
ER-20-12-113015-455	1,189.94	3,904	1,331	1,833.71	--	Discharge Line
ER-20-12-113015-456	1,191.77	3,910	1,297	1,631.25	--	Discharge Line
ER-20-12-113015-457	1,196.64	3,926	1,543	1,672.77	--	Discharge Line
ER-20-12-113015-458	1,200.00	3,937	669	1,746.33	--	Discharge Line
ER-20-12-113015-459	1,203.35	3,948	432	1,755.13	--	Discharge Line
ER-20-12-113015-460	1,209.75	3,969	1,121	1,672.77	--	Discharge Line
ER-20-12-113015-461	1,212.80	3,979	6,527	1,668.13	1,000	Discharge Line
ER-20-12-113015-462	1,218.59	3,998	298	1,805.28	--	Discharge Line
ER-20-12-113015-463	1,219.50	4,001	798	1,672.77	--	Discharge Line
ER-20-12-113015-464	1,226.82	4,025	1,173	1,714.46	--	Discharge Line
ER-20-12-113015-465	1,230.17	4,036	4,256	1,928.77	735	Discharge Line
ER-20-12-113015-466	1,235.05	4,052	1,222	1,755.13	--	Discharge Line
ER-20-12-113015-467	1,240.23	4,069	1,164	1,871.63	--	Discharge Line
ER-20-12-113015-468	1,244.19	4,082	2,405	1,584.73	--	Discharge Line
ER-20-12-113015-469	1,250.90	4,104	4,177	1,725.84	2,313	Discharge Line
ER-20-12-113015-470	1,259.13	4,131	1,379	1,794.84	--	Discharge Line
ER-20-12-113015-471	1,262.18	4,141	3,770	1,870.32	--	Discharge Line
ER-20-12-120115-472	1,265.53	4,152	5,029	1,974.52	1,172	Discharge Line
ER-20-12-120115-473	N/A	N/A	1,872	1,755.13	--	Makeup water WW-8
ER-20-12-120115-474	1,268.88	4,163	4,845	2,230.36	3,921	Discharge Line
ER-20-12-120115-475	1,272.84	4,176	8,575	1,824.84	6,980	Discharge Line
ER-20-12-120115-476	1,275.28	4,184	8,201	2,204.31	1,681	Discharge Line
ER-20-12-120115-477	1,278.33	4,194	5,826	2,373.87	4,657	Discharge Line
ER-20-12-120115-478	1,280.16	4,200	6,582	2,000.35	4,474	Discharge Line
ER-20-12-120115-479	1,287.17	4,223	5,326	3,667.42	1,097	Discharge Line
ER-20-12-120115-480	1,292.35	4,240	2,931	2,683.51	1,727	Discharge Line
138-120615-5	1,295.40	4,250	43,800	350.00	42,600	Bailer - Lab
ER-20-12-120115-481	1,297.23	4,256	4,462	2,468.83	2,440	Discharge Line
ER-20-12-120115-482	1,301.80	4,271	6,619	1,493.86	4,492	Discharge Line
ER-20-12-120115-483	1,308.81	4,294	14,416	1,725.84	3,938	Discharge Line
ER-20-12-120115-484	1,316.74	4,320	5,097	1,824.84	2,527	Discharge Line
ER-20-12-120115-485	1,317.65	4,323	8,120	1,707.69	2,198	Discharge Line
138-010416-1	1,319.17	4,328	22,000	400.00	21,900	Bailer - Lab
ER-20-12-120115-486	1,319.78	4,330	3,743	1,672.77	3,545	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 15 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-120115-487	1,322.83	4,340	7,956	1,870.32	6,854	Discharge Line
ER-20-12-120115-488	1,325.88	4,350	2,888	1,676.53	963	Discharge Line
ER-20-12-120415-489	N/A	N/A	3,026	3,432.41	--	Sump
ER-20-12-120615-490	1,082.04	3,550	27,502	1,778.14	29,598	Bailer
ER-20-12-120615-491	1,295.40	4,250	43,165	1,672.77	43,859	Bailer
ER-20-12-120615-492	1,295.40	4,250	46,507	1,676.53	46,481	Bailer
ER-20-12-120615-493	1,295.40	4,250	46,290	1,672.77	46,722	Bailer
ER-20-12-120615-494	1,295.40	4,250	40,848	1,544.10	36,125	Bailer
ER-20-12-120615-495	1,295.40	4,250	52,374	1,771.17	53,391	Bailer
ER-20-12-121715-496	N/A	N/A	--	1,784.09	0	Makeup water WW-8
ER-20-12-122015-497	N/A	N/A	3,380	1,720.56	0	Makeup water WW-8
ER-20-12-122115-498	N/A	N/A	0	1,662.75	--	Makeup water WW-8
ER-20-12-123015-499	N/A	N/A	418	1,544.18	--	Discharge Line
ER-20-12-123115-500	1,197.86	3,930	30,478	1,833.71	29,748	Discharge Line
ER-20-12-123115-501	1,207.01	3,960	7,849	4,191.34	10,430	Discharge Line
ER-20-12-123115-502	1,216.15	3,990	30,320	2,054.16	29,900	Discharge Line
ER-20-12-123115-503	1,225.30	4,020	27,402	3,806.28	28,352	Discharge Line
ER-20-12-123115-504	1,234.44	4,050	33,676	1,903.14	32,457	Discharge Line
ER-20-12-123115-505	1,243.58	4,080	34,603	1,733.20	31,850	Discharge Line
ER-20-12-123115-506	N/A	N/A	0	1,805.28	--	Discharge Line
ER-20-12-123115-507	1,252.73	4,110	45,799	2,406.38	32,903	Discharge Line
ER-20-12-123115-508	1,261.87	4,140	33,210	2,560.90	33,915	Discharge Line
ER-20-12-123115-509	1,271.02	4,170	25,298	3,890.57	27,783	Discharge Line
ER-20-12-123115-510	1,280.16	4,200	38,175	2,737.26	35,255	Discharge Line
ER-20-12-123115-511	1,289.30	4,230	29,862	6,048.47	29,452	Discharge Line
ER-20-12-123115-512	1,298.45	4,260	19,610	2,283.77	18,546	Discharge Line
ER-20-12-123115-513	1,307.59	4,290	27,556	2,122.13	24,667	Discharge Line
ER-20-12-123115-514	1,316.74	4,320	36,728	2,173.29	38,243	Discharge Line
ER-20-12-123115-515	1,325.88	4,350	38,437	1,892.86	38,942	Discharge Line
ER-20-12-123115-516	N/A	N/A	825	1,585.95	--	Discharge Line
ER-20-12-010116-517	1,328.01	4,357	19,997	3,400.74	16,421	Discharge Line
ER-20-12-010116-518	1,328.62	4,359	6,259	4,613.95	--	Discharge Line
ER-20-12-010116-519	1,330.15	4,364	14,701	3,667.42	14,503	Discharge Line
ER-20-12-010116-520	1,332.28	4,371	24,283	5,334.43	27,766	Discharge Line
ER-20-12-010116-521	1,334.11	4,377	30,843	2,285.95	36,908	Discharge Line

Table B-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-20-12
(Page 16 of 16)

Sample ID Number	Depth (bgs)		NSTec Onsite Tritium Analysis Results			Sample Description
	m	ft	Tritium Results (pCi/L)	MDA (pCi/L)	Recount (pCi/L)	
ER-20-12-010116-522	1,336.24	4,384	30,985	3,474.28	--	Discharge Line
ER-20-12-010116-523	1,336.85	4,386	26,177	4,391.86	--	Discharge Line
ER-20-12-010116-524	1,336.85	4,386	32,163	3,171.90	--	Discharge Line
ER-20-12-010116-525	1,337.77	4,389	30,980	2,007.32	--	Discharge Line
ER-20-12-010116-526	1,340.21	4,397	33,756	1,980.80	--	Discharge Line
ER-20-12-010116-527	1,342.03	4,403	44,483	4,758.00	34,351	Discharge Line
ER-20-12-010116-528	1,345.08	4,413	25,618	5,002.00	25,210	Discharge Line
ER-20-12-010116-529	1,346.91	4,419	33,269	2,039.00	--	Discharge Line
ER-20-12-010116-530	1,351.18	4,433	38,846	1,726.00	--	Discharge Line
ER-20-12-010116-531	1,356.36	4,450	61,003	1,537.00	34,171	Discharge Line
ER-20-12-010116-532	1,359.41	4,460	33,571	2,188.00	--	Discharge Line
ER-20-12-010116-533	1,365.50	4,480	38,760	1,771.00	--	Discharge Line
ER-20-12-010116-534	1,367.64	4,487	51,787	1,726.00	33,757	Discharge Line
ER-20-12-010116-535	1,374.95	4,511	32,688	4,465.79	--	Discharge Line
ER-20-12-010216-536	1,374.95	4,511	26,500	9,146.21	--	Discharge Line
ER-20-12-010216-537	1,379.83	4,527	16,964	26,132.02	11,052	Discharge Line
ER-20-12-010216-538	1,384.40	4,542	23,798	13,025.21	24,310	Discharge Line
ER-20-12-010216-539	N/A	N/A	760	4,137.46	1,566	Makeup water WW-8
ER-20-12-010216-540	1,384.71	4,543	38,846	2,693.47	--	Discharge Line
ER-20-12-010216-541	1,384.71	4,543	34,171	2,501.08	--	Discharge Line
ER-20-12-010216-542	1,384.71	4,543	33,571	2,593.71	--	Discharge Line
ER-20-12-010416-543	N/A	N/A	18,272	2,737.28	19,921	Bailer

Table B-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (11/06/2015)
(Page 1 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12			
			11/06/2015 Sample Number 138-110615-1 Depth at 1,825 ft bgs		11/06/2015 Sample Number 138-110615-2 (Duplicate) Depth at 1,825 ft bgs	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Aluminum	SW-846 6010 [b]	0.2	0.2 U	0.2 U	0.2 U	0.2 U
Arsenic		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Barium		0.1	0.0032 J-	0.0024 J-	0.0036 J-	0.0016 J-
Cadmium		0.01	0.005 U	0.005 U	0.005 U	0.005 U
Calcium		1	49	49	49	49
Chromium		0.01	0.0011 J-	0.01 U	0.00092 J-	0.01 U
Iron		0.1	0.16	0.094 J-	0.17	0.019 J-
Lead		0.003	0.003 U	0.003 U	0.003 U	0.003 U
Lithium		0.01	0.19 J+	0.19 J+	0.19 J+	0.19 J+
Magnesium		1	2.2	2.3	2.2	2.2
Manganese		0.01	0.022 J	0.023 J	0.024 J	0.021 J
Potassium		1	10	10	10	11
Selenium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Silicon		0.05	28	28	29	28
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Sodium	SW-846 6010 [b]	1	130	130	130	130
Strontium		0.01	0.25	0.25	0.25	0.25
^{238}U	SW-846 6020 [b]	0.0001	0.0081	0.0088	0.0085	0.0086

Table B-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (11/06/2015)
(Page 2 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12			
			11/06/2015 Sample Number 138-110615-1 Depth at 1,825 ft bgs		11/06/2015 Sample Number 138-110615-2 (Duplicate) Depth at 1,825 ft bgs	
			Total	Dissolved	Total	Dissolved
Inorganics (mg/L unless otherwise noted)						
Bromide	EPA 300.0[c]	0.2		0.61		0.59
Chloride		2		130		120
Fluoride		0.1		3.6		3.5
Sulfate		10		150		150
Alkalinity as $CaCO_3$	EPA 310.1 [d]	20	140		130	
Bicarbonate as $CaCO_3$		20	140		130	
Carbonate as $CaCO_3$		20	20 U		20 U	
Total Dissolved Solids	EPA 160.1 [d]	20	600 J-		600 J-	
pH (SU)	EPA 150.1 [d]	0.1	7.5 J-		7.8 J-	
Specific Conductivity (µmhos/cm)	EPA 120.1 [d]	1	950		940	
Radiological Indicator Parameters-Level I (pCi/L)						
		MDC [e]	**Result**	**Error**	**Result**	**Error**
Tritium	EPA 906.0 [f]	400	52,700	8,000	53,600	8,200
Gross Alpha	EPA 900.0 [f]	3.4, 2.8	12.4	3.3	11.8	2.9
Gross Beta		5.8, 5.5	10.1	4.0	6.5 U	3.6
^{238}Pu	HASL 300 [g]/ ASTM D3865-02 [h]	0.017	0.001 U	0.012		
$^{239/240}Pu$	HASL 300 [g]/ ASTM D3865-02 [h]	0.021	-0.001 U	0.012		
Gamma Spectroscopy	EPA 901.1 [g]	Varies by Nuclide	ND	Varies by Nuclide	ND	Varies by Nuclide

Table B-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (11/06/2015)
(Page 3 of 3)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12			
			11/06/2015 Sample Number 138-110615-1 Depth at 1,825 ft bgs		11/06/2015 Sample Number 138-110615-2 (Duplicate) Depth at 1,825 ft bgs	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level II (pCi/L)						
		MDC	Result	Error	Result	Error
^{14}C	EERF C-01 [i]	370, 360	120 U	230	40 U	220

Source: Navarro, 2016

[a] For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits.
[b] EPA, 2015
[c] EPA, 1997
[d] EPA, 1983
[e] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 138-110615-1 and the second corresponds with sample number 138-110615-2.
[f] EPA, 1980
[g] DOE, 1997
[h] ASTM, 2015
[i] EPA, 1984

ASTM = ASTM International
C = Carbon
$CaCO_3$ = Calcium carbonate
EERF = Eastern Environmental Radiation Facility
EPA = U.S. Environmental Protection Agency
HASL = Health and Safety Laboratory
MDC = Minimum detectable concentration
mg/L = Milligrams per liter
Pu = Plutonium
SU = Standard unit
SW = Solid waste
µmhos/cm = Micromhos per centimeter

J = Result is estimated.
J+ = The result is an estimated quantity, but the result may be biased high.
J- = Result is estimated bias low.
ND = No gamma spectroscopy RNs detected above detection limit.
U = Compound was analyzed for but was not detected (“nondetect”).
UJ = Compound was non-detect, but result is biased low.

Table B-3
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (12/06/2015)
(Page 1 of 4)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12							
			12/06/2015 Sample Number 138-120615-1 Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-2 (Duplicate) Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-5 Depth at 4,250 ft bgs		12/06/2015 Sample Number 138-120615-6 (Duplicate) Depth at 4,250 ft bgs	
			Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Metals (mg/L)										
Aluminum	SW-846 6010 [b]	0.2	0.36	0.11 J	0.89	0.11 J	3.4	0.37	4.0	0.46
Arsenic		0.01	0.0062 J-	0.0057 J-	0.0061 J-	0.0065 J -	0.0057 J-	0.0036 J-	0.0038 J-	0.01 U
Barium		0.1	0.0067 J	0.0046 J-	0.0053 J-	0.0025 J-	0.032 J-	0.0036 J-	0.034 J-	0.038 J-
Cadmium		0.005	0.00039 J	0.00027 J	0.00035 J	0.0006 J	0.00052 J	0.00032 J	0.00047 J	0.00037 J
Calcium		1	13	13	13	14	9.6	8.9	9.9	8.8
Chromium		0.01	0.01 U	0.01 U	0.0016 J-	0.0014 J-	0.0027 J-	0.01 U	0.0056 J-	0.01 U
Iron		0.1	1.2	0.2	1.3	0.1 U	3.7	0.16	5.4	0.2
Lead		0.003	0.003 U	0.003 U	0.003 U	0.003 U	0.0037	0.003 U	0.003 U	0.003 U
Lithium		0.01	0.099 J	0.10 J	0.099 J	0.097 J	0.12 J	0.12 J	0.12 J	0.12 J
Magnesium		1	0.17 J	0.15 J	0.2 J	0.15 J	0.33 J	0.068 J	0.42 J	0.1 J
Manganese		0.01	0.025	0.015	0.028	0.011	0.071	0.0099 J-	0.086	0.011
Potassium		1	5.0 J	4.9 J	5.2 J	4.8 J	5.8 J	4.2 J	5.8 J	4.3 J
Selenium		0.005	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Silicon		0.05	30	29	31	29	34	28	35	28
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Sodium		1	150	150	150	140	180	180	190	180
Strontium		0.01	0.025	0.025	0.024	0.023	0.028	0.02	0.028	0.02
^{238}U	SW-846 6020 [b]	0.0001	0.0038	0.0039	0.0037	0.0038	0.0057	0.0052	0.0052	0.0065

Table B-3
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (12/06/2015)
(Page 2 of 4)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12							
			12/06/2015 Sample Number 138-120615-1 Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-2 (Duplicate) Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-5 Depth at 4,250 ft bgs		12/06/2015 Sample Number 138-120615-6 (Duplicate) Depth at 4,250 ft bgs	
			Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Inorganics (mg/L unless otherwise noted)										
Bromide	EPA 300.1 [c]	2		2.0 U		2.0 U		0.89 J		0.81 J
Chloride	EPA 300.1 [c]	2		130 J-		150 J-		140 J-		110 J-
Fluoride	EPA 300.1 [c]	1		2.2		2.3		2.2		2.1
Sulfate	EPA 300.1 [c]	10		140		140		140		130
Alkalinity as $CaCO_3$	EPA 310.1 [d]	20	120		120		130		130	
Bicarbonate as $CaCO_3$	EPA 310.1 [d]	20	120		120		130		130	
Carbonate as $CaCO_3$	EPA 310.1 [d]	20	20 U		20 U		20 U		20 U	
Total Dissolved Solids	EPA 160.1 [d]	20	520 J-		510 J-		590 J-		610 J-	
pH (SU)	EPA 150.1 [d]	0.1	8.0 J-		8.1 J-		8.3 J-		8.3 J-	
Specific Conductivity (μmhos/cm)	EPA 120.1 [d]	1	750		760		780		790	

Table B-3
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (12/06/2015)
(Page 3 of 4)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12							
			12/06/2015 Sample Number 138-120615-1 Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-2 (Duplicate) Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-5 Depth at 4,250 ft bgs		12/06/2015 Sample Number 138-120615-6 (Duplicate) Depth at 4,250 ft bgs	
			Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level I (pCi/L)										
		MDC [e]	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
Tritium	EPA 906.0 [f]	300, 400	27,100	4,200	28,900	4,400	43,800	6,700	42,600	6,500
Gross Alpha	EPA 900.0 [f]	1.9, 2.1, 2.0 2.4	5.4	1.7	4.4	1.7	8.3	2.1	11.1	2.7
Gross Beta	EPA 900.0 [f]	2.1, 2.5, 1.8, 2.4	6.2	1.7	6.1	1.9	8.0	1.8	8.1	2.1
^{238}Pu	HASL 300 [g]/ ASTM D3865-02 [h]	0.022, 0.031,0.077, 0.031	-0.001 U	0.012	-0.006 U	0.17	-0.014 UJ	0.035	-0.002U	0.017
$^{239/240}$Pu	HASL 300 [g]/ ASTM D3865-02 [h]	0.008, 0.025, 0.019, 0.025	0.014 U	0.013	0.005 U	0.017	0.064 UJ	0.045	0.009 U	0.017
Gamma Spectroscopy	EPA 901.1 [g]	Varies by Nuclide					ND	Varies by Nuclide	ND	Varies by Nuclide

Table B-3
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (12/06/2015)
(Page 4 of 4)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12							
			12/06/2015 Sample Number 138-120615-1 Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-2 (Duplicate) Depth at 3,550 ft bgs		12/06/2015 Sample Number 138-120615-5 Depth at 4,250 ft bgs		12/06/2015 Sample Number 138-120615-6 (Duplicate) Depth at 4,250 ft bgs	
			Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level II (pCi/L)										
		MDC	Result	Error	Result	Error	Result	Error	Result	Error
^{14}C	EERF C-01 [i]	400, 410, 410, 420	-100 U	230	120 U	250	210 U	250	140 U	250

Source: Navarro, 2016

[a] For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits.
[b] EPA, 2015
[c] EPA, 1997
[d] EPA, 1983
[e] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 138-120615-1 and 138-120615-2 and the second corresponds with sample numbers 138-120615-5 and 138-120615-6.
[f] EPA, 1980
[g] DOE, 1997
[h] ASTM, 2015
[i] EPA, 1984

J = Result is estimated.
J- = Result is estimated bias low.
ND = No gamma spectroscopy RNs detected above detection limit.
U = Compound was analyzed for but was not detected (“nondetect”).
UJ = Compound was non-detect, but result is biased low.

Table B-4
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (01/04/2016)
(Page 1 of 2)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12			
			01/04/2016 Sample Number 138-010416-1 Depth at 4,328 ft bgs		01/04/2016 Sample Number 138-010416-2 (Duplicate) Depth at 4,328 ft bgs	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Aluminum	SW-846 6010 [b]	0.2	6.7	0.12 J	6.5	0.3
Arsenic		0.01	0.0021 J-	0.01 U	0.0058 J-	0.004 J
Barium		0.1	0.11	0.0031 J	0.11	0.0055 J
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Calcium		1	11	7.2	11	7.4
Chromium		0.01	0.09	0.01 U	0.0091	0.01 U
Iron		0.1	64	1.0	64	1.7
Lead		0.003	0.003 U	0.003 U	0.003 U	0.003 U
Lithium		0.01	0.19 J+	0.18 J+	0.19 J+	0.17 J+
Magnesium		1	1.0 U	1.0 U	1.0 U	1.0 U
Manganese		0.01	0.77 J	0.077 J	0.79 J	0.09 J
Potassium		1	7.4	4.5	7.3	4.5
Selenium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Silicon		0.05	37	22	37	23
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Sodium		1	190	180	190	180
Strontium		0.01	0.06	0.02	0.058	0.021
^{238}U	SW-846 6020 [b]	0.0001	0.0062	0.0037	0.0063	0.0038
Inorganics (mg/L unless otherwise noted)						
Bromide	EPA 300.1 [c]	0.4		0.55		0.51
Chloride		4		95		94
Fluoride		0.2		2.0		1.9
Sulfate		2		120		120
Alkalinity as $CaCO_3$	EPA 310.1 [d]	20	150		140	
Bicarbonate as $CaCO_3$		20	150		140	
Carbonate as $CaCO^3$		20	20 U		20 U	
Total Dissolved Solids	EPA 160.1 [d]	20	540		550	
pH (SU)	EPA 150.1 [d]	0.1	8.2 J-		8.1 J-	
Specific Conductivity (μmhos/cm)	EPA 120.1 [d]	1	790		800	

Table B-4
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-12 (01/04/2016)
(Page 2 of 2)

Analyte	Analytical Method [a]	Detection Limit	Depth-Discrete Bailer Samples from Well ER-20-12			
			01/04/2016 Sample Number 138-010416-1 Depth at 4,328 ft bgs		01/04/2016 Sample Number 138-010416-2 (Duplicate) Depth at 4,328 ft bgs	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level I (pCi/L)						
		MDC [e]	Result	Error	Result	Error
Tritium	EPA 906.0 [f]	400	22,000	3,400	21,900	3,400
Gross Alpha	EPA 900.0 [f]	2.5, 2.1	10.8	2.6	11.4	2.5
Gross Beta		2.8, 2.4	13.4	2.9	13.6	2.7
^{238}Pu	HASL 300 [g]/ ASTM D3865-02 [h]	0.036, 0.03	-0.005 U	0.016	-0.003 U	0.015
$^{239/240}Pu$	HASL 300 [g]/ ASTM D3865-02 [h]	0.036, 0.022	0.03 U	0.027	0.001 U	0.015
Gamma Spectroscopy	EPA 901.1 [g]	Varies by Nuclide	ND	Varies by Nuclide	ND	Varies by Nuclide
Radiological Indicator Parameters-Level II (pCi/L)						
		MDC	Result	Error	Result	Error
^{14}C	EERF C-01 [i]	460, 460	90 U	280	390 U	290

Source: Navarro, 2016

[a] For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits.
[b] EPA, 2015
[c] EPA, 1997
[d] EPA, 1983
[e] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 138-010416-1 and the second corresponds with sample number 138-010416-2.
[f] EPA, 1980
[g] DOE, 1997
[h] ASTM, 2015
[i] EPA, 1984

J = Result is estimated.
J+ = The result is an estimated quantity, but the result may be biased high.
J- = Result is estimated bias low.
ND = No gamma spectroscopy RNs detected above detection limit.
U = Compound was analyzed for but was not detected (“nondetect”).
UJ = Compound was non-detect, but result is biased low.

Table B-5
Analytical Results for FMP Confirmatory Samples from Sump #1 (Lined) at Well ER-20-12

Analyte	Analytical Method [a]	Detection Limit	FMP Samples from Well ER-20-12 Sump #1			
			Sample Number 138-041816-1		Sample Number 138-041816-2 (Duplicate)	
			Total	Dissolved	Total	Dissolved
Metals (mg/L)						
Arsenic	SW-846 6010 [b]	0.01	0.0044 J	0.01 U	0.01 U	0.01 U
Barium		0.1	0.034 J	0.0052 J	0.037 J	0.0022 J
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Chromium		0.01	0.0076 J	0.00093 J	0.0075 J	0.01 U
Lead		0.003	0.0015 J	0.003 U	0.0023 J	0.003 U
Selenium		0.005	0.0039 J	0.0065	0.01	0.0027 J
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Mercury	SW-846 7470 [b]	0.002	5.9 E-006 J	0.0002 U	8.8 E-006 J	0.0002 U
Radiological Indicator Parameters (pCi/L)						
		MDC [c]	Result	Error	Result	Error
Tritium	EPA 906.0 [d]	300	9,100	1,400	9,200	1,400
Gross Alpha	EPA 900.0 [d]	1.9, 1.8	3.3	1.4	1.2 U	1.1
Gross Beta		2.5, 2.6	7.2	2.0	6.9	2.0

Source: Navarro, 2016

[a] For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits.
[b] EPA, 2015
[c] MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 139-041816-1 and the second with 138-041816-2.
[d] EPA, 1980

J- = Result is estimated bias low.
U = Compound was analyzed for but was not detected (“nondetect”).
UJ = Compound was non-detect, but result is biased low.

Note: Analyses were performed by ALS Laboratory Group.

UGTA FLUID DISPOSITION REPORTING FORM

Site Identification: ER-20-12
Site Location: Nevada National Security Site
Site Coordinates (UTM NAD 27, Zone 11) N 4,125,952.84; E 540,925.06
Well Classification: ER Hydrogeologic Investigation Well
Navarro Project No: UN15-215

Report Date: 6/16/2016
NNSA/NFO Activity Lead: Bill Wilborn
Navarro Project Manager: Ken Rehfeldt
Navarro Site Representative: Jeff Wurtz
Navarro Field Environmental Specialist: Mark Heser

Well Construction 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 [c] (m^3)	Other [d] (m^3)	Fluid Quality Objective Met?
	From	To				Solids [b]	Liquids	Solids [b]	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	10/8/2015 11/8/2015	10/21/2015 11/15/2015	21	492.25	1096.00	252.92	3748.00	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	10/22/2015 11/15/2015	10/25/2015 1/3/2016	22	892.55	1550.00	319.81	7,764.00	N/A	N/A	12,893	N/A	Yes
Phase II: Initial Well Development	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			43	1384.80	2646.00	572.73	11,512.00	N/A	N/A	12,893	N/A	-

[a] Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift.

[b] Solids volume estimates include calculated added volume attributed to rock bulking factor.

[c] Discharge to an NDEP approved infiltration area as defined in the Well-Specific Fluid Management Strategy Letter for ER-20-12

[d] Other refers to fluid conveyance to other fluid management devices or facilities: e.g., baker tank or transported to another well site for storage.

N/A = Not Applicable; m = meters; m^3 = cubic meters

Total Facility Capacities (at 8 ft fluid level): Sump # 1 = 10,900 m^3 Sump #2 = 1,547 m^3 Infiltration Area (assuming very low/no infiltration) = N/A

Remaining Facility Capacity (Approximate) as of 01/07/2016: Sump #1 = 9,448 m^3 Sump #2 = 1,547 m^3

Current Average Tritium, Sump #_1_ FMP samples = 9,150 pCi/L

Notes: On 12/04/2015 Navarro personnel noted a tear in the liner material of Sump #1, the fluid level was pumped down to approximately 0.5 ft and NSTec staff began cleaning the area for potential repair. On 12/29/2015 NNSA/NFO authorized the resumption of drilling activities without repairs being made to the liner.

Navarro Authorizing Signature/Date: /s/ Jefferey Wurtz 8-10-16

Figure B-1
Well ER-20-12 Fluid Disposition Reporting Form

B.1.0 References

ASTM, see ASTM International.

ASTM International. 2015. *Standard Test Method for Plutonium in Water*, ASTM D3865-09(2015). West Conshohocken, PA.

DOE, see U.S. Department of Energy.

EPA, see U.S. Environmental Protection Agency.

Navarro, 2016. Written communication. Subject: "Analytical Data for Well ER-20-12," 25 April. Las Vegas, NV.

U.S. Department of Energy. 1997. *The Procedures Manual of the Environmental Measurements Laboratory*, HASL-300. 28th edition, Vol. 1. February. New York, NY.

U.S. Environmental Protection Agency. 1980. *Prescribed Procedures for Measurement of Radioactivity in Drinking Water,* EPA 600/4-80-032. Cincinnati, OH: Environmental Monitoring and Support Laboratory Office of Research and Development.

U.S. Environmental Protection Agency. 1983. *Methods for the Chemical Analysis of Water and Wastes,* EPA/600/4-79/020. Cincinnati, OH: Environmental Monitoring and Support Laboratory Office of Research and Development.

U.S. Environmental Protection Agency. 1984. *Eastern Environmental Radiation Facility Radiochemical Procedures Manual,* EPA 520/5-84-006. Montgomery, AL: Office of Radiation Programs, Eastern Environmental Radiation Facility (renamed the National Air and Radiation Environmental Laboratory [NAREL] in 1989).

U.S. Environmental Protection Agency. 1997. *Determination of Inorganic Anions in Drinking Water by Ion Chromatography,* Method 300.1, EPA/815-R-00-014. Cincinnati, OH: National Exposure Research Library Office of Research and Development.

U.S. Environmental Protection Agency. 2015. *SW-846 On-Line, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.* As accessed at http://www.epa.gov/epaoswer/hazwaste/test/main.htm on 5 December.

Attachment B-1

Final Well Specific Fluid Management Strategy for UGTA Well ER-20-12, Nevada National Security Site

(8 Pages)

FINAL
WELL SPECIFIC FLUID MANAGEMENT STRATEGY
FOR UGTA WELL ER-20-12
NEVADA NATIONAL SECURITY SITE

September 11, 2015

INTRODUCTION

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO), Underground Test Area Activity (UGTA) is proposing to drill and construct Well ER-20-12, as part of the Phase II drilling program for Western Pahute Mesa. The acquisition of hydrogeological data from this well will be used to further develop groundwater flow and contaminate transport models of the area. Drilling operations will be conducted in accordance with the *Phase II Corrective Action Investigation Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa* (NNSA/NSO 2009a).

Proposed Well ER-20-12 is located within Area 20, in the far northwestern portion of the Nevada National Security Site (NNSS). Figure 1 shows the location of Well ER-20-12 relative to other wells and underground tests conducted in the area. The closest underground nuclear test to the proposed well site is HANDLEY detonated in emplacement well U-20m, located approximately 2,150 m (7,400 ft) to the north-northeast. Based on the distance of the proposed well from the HANDLEY (U-20m) test and available analytical data from the closest wells, Well ER-20-12 is considered to have potential to be a Near-field well, but will be addressed as a Far-field well. This well specific fluid management strategy letter describes the monitoring and management of fluids generated during fluid-producing activities at Well ER-20-12 in accordance with the requirements of the Fluid Management Plan (FMP) for the Underground Test Area, Rev 5 (NNSA/NSO, 2009b). The scope of this fluid management strategy letter includes fluid generating activities relating to drilling, well completion, well development and testing, well purging, and groundwater sampling at Well ER-20-12.

BACKGROUND AND ANALYTICAL DATA

Given the present understanding of groundwater flow in the area of proposed Well ER-20-12, the location is down gradient of two principal underground tests and up gradient of monitoring Well PM-3. The well lies down gradient of the HANDLEY (U-20m) underground test detonated in 1970 at a depth of 3966 ft bgs with an estimated yield of > 1 mega ton and the STILTON (U-20p) underground test detonated in 1975 at a depth of 2398 ft bgs and a yield range of 20 to 200 kilotons. The proposed well will be located approximately 2,150 m (7,400 ft) south of the HANDLEY (U-20m) test and 6,700 m (22,000 ft) south-southwest of the STILTON (U-20p) test.

Post-shot well U20-m PS 1D, which was drilled directly into the HANDLEY cavity, was sampled in July 2015. Sampling occurred at two discrete depths with the well using a bailer. At the time of this writing, analytical results from the laboratory analysis of groundwater samples collected are still pending. However, on-site tritium monitoring performed during sampling of U20-m PS 1D detected tritium concentrations at approximately 7,600,000 pCi/L (2,100 ft bgs) and 8,300,000 pCi/L (1,361 ft bgs). Well PM-3 is approximately 7,200 m (23,600 ft) south-southwest of the proposed Well ER-20-12 site. The PM-3 well was constructed to access two discrete isolated intervals below the water table and has been monitored for tritium regularly since 1998, however, tritium was not detected in the groundwater above the minimum detection limit until 2010. Groundwater samples collected each year since 2010 have shown detectable tritium; the maximum tritium detected in the most recent groundwater sample collected from PM-3-2 (shallow interval) in 2013 was 355 pCi/L. Well ER-20-12 has been purposefully sited between the HANDLEY (U-20m) test and Well PM-3 in an effort to intersect groundwater flow paths from the HANDLEY (U-20m) test in the direction of Well PM-3. Given the results of the recent monitoring at the

HANDLEY (U-20m) post-shot well U-20m PS 1D and the consistent detection of tritium in Well PM-3 over the last several years, groundwater encountered in Well ER-20-12 is expected to contain tritium, above the Safe Drinking Water Act (SDWA) limit of 20,000 picocuries per liter (pCi/L) and potentially in excess of 400,000 pCi/L

Multiple groundwater aquifers may have been affected as a result of the HANDLEY (U-20m) underground test as suggested in the monitoring and sampling results of Well PM-3. As a result the proposed Well ER-20-12 will be drilled to a depth of approximately 4,100 ft bgs and constructed to allow isolated access to multiple aquifers for the purposes of aquifer testing and groundwater sampling. Contaminated groundwater aquifers observed during drilling will be specifically isolated to prevent the cross communication of contaminated groundwater between aquifers. A proposed well construction diagram for Well ER-20-12 is presented in Figure 2.

WELL OPERATIONS STRATEGY

Based on the information presented above with respect to the location of Well ER-20-12, hydrogeologic setting and proximity of underground testing, Well ER-20-12 is considered to be a potential Near-field well site. However, because it is not certain that Near-field conditions will be encountered in the well, it is proposed that fluid generating activities during the drilling and construction of Well ER-20-12 be conducted using the Far-field well site operations strategy for wells located on the NNSS. Should Near-field conditions be encountered, Well ER-20-12 operations will transition to a Near-field Strategy, as specified in the FMP and this strategy letter.

On-Site Monitoring – In accordance with the FMP, tritium monitoring samples will be collected at a minimum hourly from the discharge line during fluid generating activities at Well ER-20-12. The results of on-site monitoring will be compared to the FMP discharge criteria as results are available. Eight hour on-site monitoring for lead will commence if Near-field conditions (i.e., tritium in excess of 400,000 pCi/L) are encountered.

Notifications – NDEP will be notified of on-site monitoring results that exceed action levels as specified in the FMP.

Fluid Containment and Discharge Criteria - The NNSA/NFO proposes the following fluid containment and discharge strategy for Well ER-20-12:

- A single lined sump with a 3.5 million gallon capacity has been constructed at the Well ER-20-12 site for fluid containment. Groundwater generated from the well during drilling, well completion, well development and testing, pumping, and groundwater sampling will be routed from the well through a well head, well head manifold, through flexible piping or hard piping and ultimately discharged to the lined sump. Based on the projected groundwater production in Well ER-20-12, the sump has the required capacity to contain all fluids produced during drilling operations.
- A second unlined sump has also been constructed on the ER-20-12 site. This sump is not anticipated to be utilized unless fluid storage capacities on the site are limited. In the event this sump is used, it may be lined to accommodate fluids that exceed the Far-field criteria (> 400,000 pCi/L) or remain un-lined to contain those fluids that meet Far-field FMP criteria (i.e. < 400,000 pCi/L) tritium.
- It is anticipated that fluids generated during vadose (unsaturated) zone drilling will not contain tritium above Near-field FMP criteria (i.e., 400,000 pCi/L). Prior to reaching the saturated zone, the level of fluids in the lined sump and the results of on-site tritium monitoring will be reviewed to determine if discharge of fluids from the sump to an infiltration area is feasible. If on-site monitoring indicates tritium at concentrations less than 400,000 pCi/L, NNSA/NFO may exercise the option to discharge such fluids from the lined sump to the designated infiltration area using a pump with flexible tubing (e.g., trash pump). The infiltration area is shown on Figure 3.

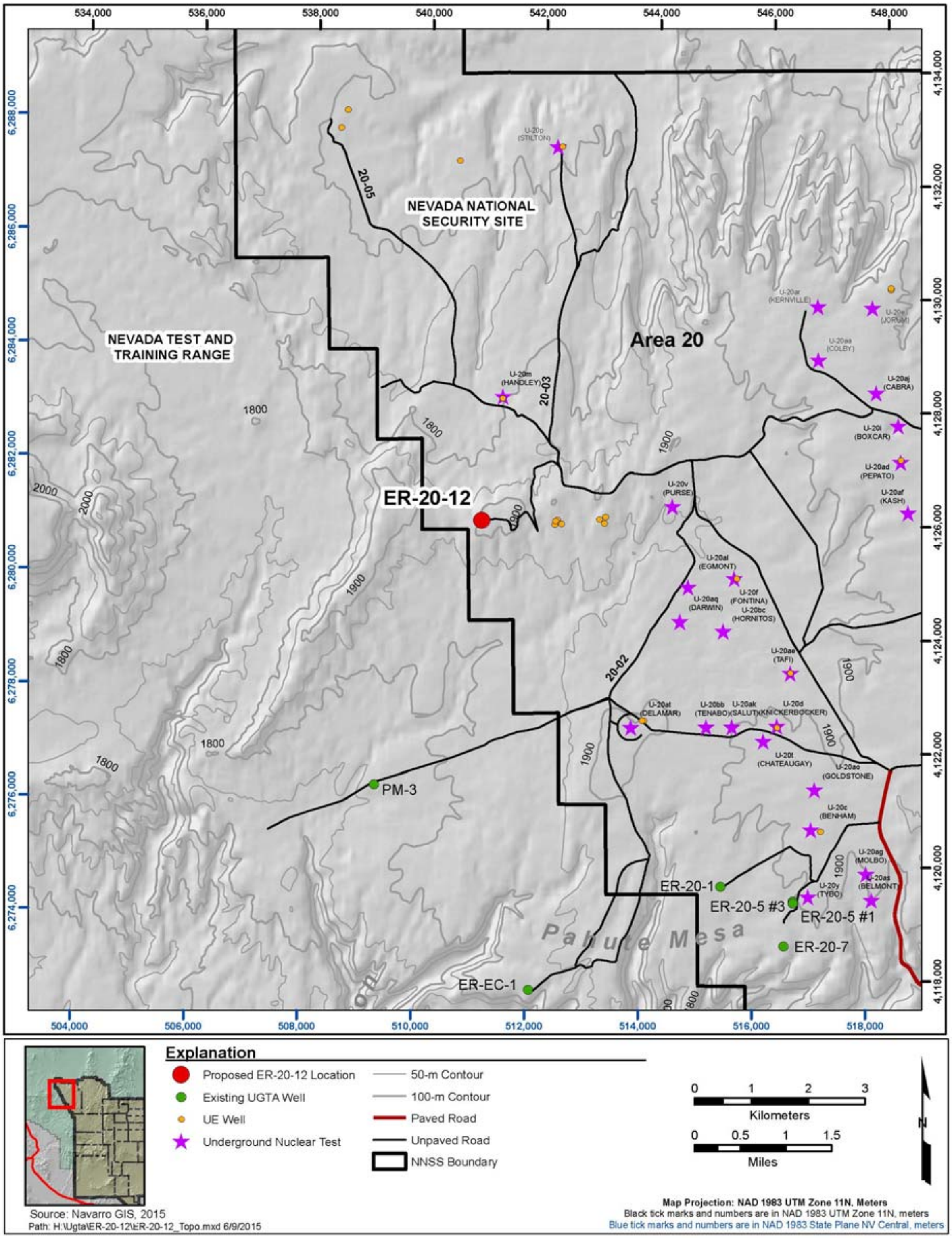


Figure 1
Well ER-20-12 Location Map

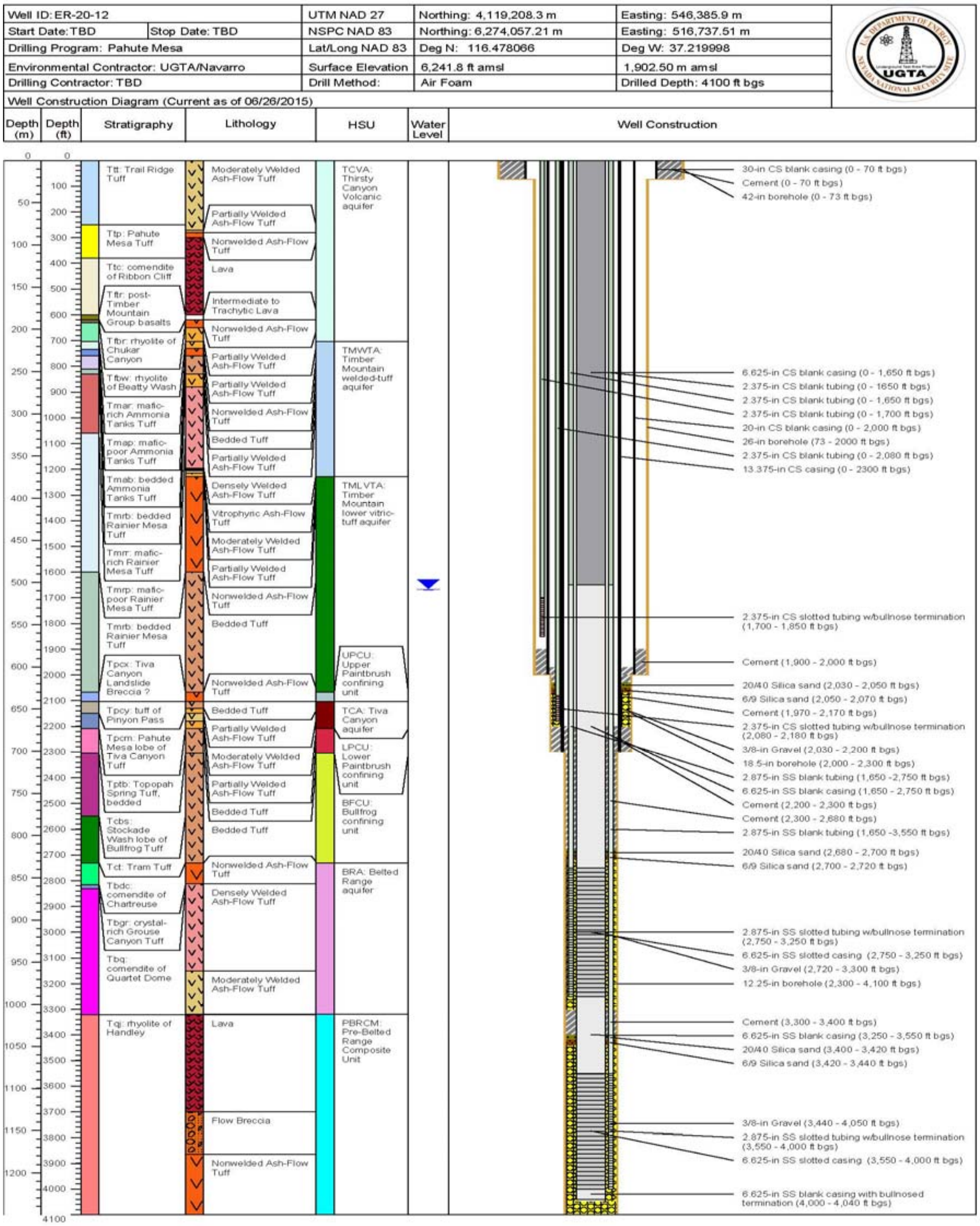


Figure 2
Proposed Well ER-20-12 Construction Diagram

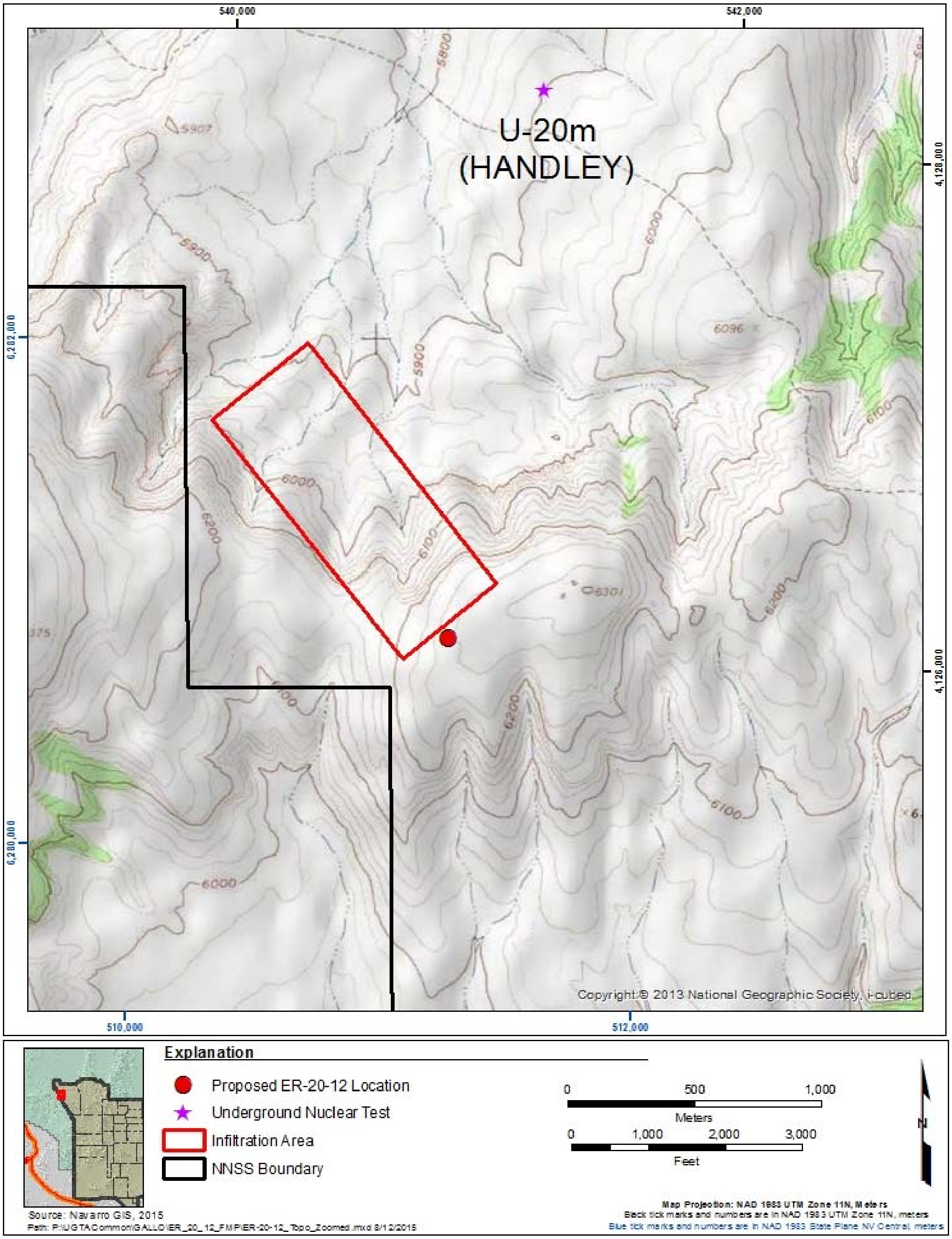


Figure 3
Proposed Infiltration Area at Well ER-20-12

REFERENCES

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2009a. *Phase II Corrective Action Investigation Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa*, *Nevada Test Site*, *Nevada*, Rev. 2, DOE/NV--1312. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2009b. *Underground Test Area Project Waste Management Plan,* Rev. 3, DOE/NV--343; *Attachment 1 Fluid Management Plan for the Underground Test Area Project*, Rev. 5; DOE/NV--370-Rev. 5. Las Vegas, NV.

NEVADA DIVISION OF
ENVIRONMENTAL PROTECTION

STATE OF NEVADA
Department of Conservation & Natural Resour
Brian Sandoval, Gover
Leo M. Drozdoff, P.E., Dire
David Emme, Administr

ERD.150917.0001

September 16, 2015

Mr. Robert F. Boehlecke
Manager
Environmental Management Operations
National Nuclear Security Administration
Nevada Field Office
P.O. Box 98518
Las Vegas, Nevada 89193-8518

RE: SUBMITTAL OF FINAL WELL SPECIFIC FLUID MANAGEMENT STRATEGY FOR THE UNDERGROUND TEST AREA (UGTA) ER-20-12, AREA 20, NEVADA NATIONAL SECURITY SITE (NNSS), SEPTEMBER 2015
Federal Facility Agreement and Consent Order

Dear Mr. Boehlecke:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities has received and reviewed the *Final Well Specific Fluid Management Strategy for UGTA ER-20-12, Area 20, NNSS*, Rev 0, dated September 15, 2015. The strategy describes the monitoring and management of fluids generated during the drilling, pumping, purging and sampling of ER-20-12. The proposed strategy is in accordance with the "Fluid Management Plan for the Underground Test Area Project, Revision 5" and is hereby approved for use.

If you have questions regarding this matter, please contact either Mark McLane or me at (702) 486-2850, ext. 226 or 232, respectively.

Sincerely,

/s/ Christine D. Andres

Christine D. Andres
Chief
Bureau of Federal Facilities

CDA/MM

2030 E. Flamingo Road, Suite 230 • Las Vegas, Nevada 89119 • p: 702.486.2850 • f: 702.486.2863 • ndep.nv.gov

ec: EM Records, AMEM, NNSA/NFO
Mark McLane, NDEP, Las Vegas
Navarro Central Files, Las Vegas, NV

cc: EM Records, AMEM, NNSA/NFO
FFACO Group, PSG, NNSA/NFO, Las Vegas, NV
J. T. Fraher, DTRA/CXTS, Kirkland AFB, NM
NSTec Correspondence Management, Las Vegas, NV
W. R. Wilborn, ERP, NNSA/NFO, Las Vegas, NV

Appendix C

Waste Management Data for Well ER-20-12

Table C-1
Final Waste Disposition for Well ER-20-12 Drilling Operations
(Page 1 of 3)

Container ID #	Start Date	Container Size	Container Type	Contents	Characterization	Disposition	Status/ Comments
ER-20-12-01A (NAVSAA002)	08/27/2015	5 gal	Poly drum	Hach Lead Check Test Kit SAA Unit	Hazardous Waste Pending Analysis	B6-909	Pending Disposal
ER-20-12-01	10/02/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-02	10/10/2015	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-20-12-03	10/10/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-04	10/10/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-05	10/10/2015	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-20-12-06	10/19/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-07	10/19/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent, filters	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-08	11/12/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent, filters	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF

Table C-1
Final Waste Disposition for Well ER-20-12 Drilling Operations
(Page 2 of 3)

Container ID #	Start Date	Container Size	Container Type	Contents	Characterization	Disposition	Status/ Comments
ER-20-12-09	11/13/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-10	11/13/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-11	11/13/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-12	11/13/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-13	11/13/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-14	11/13/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-15	11/14/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-16	11/17/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent and plastic liner	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-17	11/17/2015	55 gal	Open-top steel drum	Soil with F-485 foaming agent and plastic liner	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-18	11/12/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent, filters	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-19	11/21/2015	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal

Table C-1
Final Waste Disposition for Well ER-20-12 Drilling Operations
(Page 3 of 3)

Container ID #	Start Date	Container Size	Container Type	Contents	Characterization	Disposition	Status/ Comments
ER-20-12-20	11/26/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-21	12/02/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-22	12/04/2015	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF
ER-20-12-23	12/04/2015	55 gal	Bung steel drum	Used Oil	Non-Haz, Non-Rad Hydrocarbon	B6-909	Pending Disposal
ER-20-12-24	01/07/2016	55 gal	Open-top steel drum	Hydrocarbon Solids: absorbent pads, absorbent	Non-Haz, Non-Rad Hydrocarbon	Disposed 05/03/2016	Completed LVF

Total Waste Containers
Lab Analytical waste: 1
Pads/debris: 20
Used oil (liquid): 4
Total number of 5-gal waste containers: 1
Total number of 55-gal waste containers: 24
Total number of 2,000-gal waste containers: 1

ID = Identification
LVF = Load Verification Form
SAA = Satellite accumulation area

Appendix D

Detailed Lithologic Log for Well ER-20-12 and Sidewall Core Descriptions

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 1 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
0-15.2 (0-50)	15.2 (50)	DA	N/A	**Moderately to Densely Welded Ash-Flow Tuff:** Drilled under NSTec supervision - no samples were collected by Navarro. Lithology inferred from bedrock exposures.	Trail Ridge Tuff (Ttt)
15.2-38.1 (50-125)	22.9 (75)	DA	N/A	**Bedded to Nonwelded Tuff:** vitric, crystal-poor, visible glass shards & bubbles with minor incipient alteration; matrix light gray (5YR 7/1) to light brown (5YR 5/6) with minor (<10%) pink (7.5YR 7/3) to pink (5YR8/4) fragments (ash shards and bubbles altered to clay, matrix partially altered); Phenocrysts (2-3%), plagioclase, quartz, mafics (<1%) biotite (black), magnetite (rare, some oxidized); Lithics: (<1%), lava (?), black (N2); Pumice (5-15%), light gray (5YR 7/1) > white (5YR 8/1) > gray (5YR 6/1), pumice range from 2-8 mm, vesicular/tubular structure with plagioclase phenocrysts; Comments: base of unit revised down to 125 ft bgs based on geophysics.	Trail Ridge Tuff (Ttt)
38.1-51.8 (125-170)	13.7 (45)	DB4, DA	N/A	**Nonwelded to Partially Welded Ash-Flow Tuff:** partially vitric to devitrified, vapor phase corrosion and mineralization; matrix reddish brown (5YR 5/3) to weak red (5R 4/2) to reddish black (5YR 2.5/1); Phenocrysts (3-5%), sanidine, plagioclase, olivine, mafics (<1%), biotite (some partially oxidized); Lithics: None noted; Pumice (5-15%), pumice cavities (rounded/blocky to weakly flattened); Comments: vapor phase mineralization, white (N9) coating (silica or analcime??) on some fractures? and cavities, from 125-150, (~50% contamination from above).	Pahute Mesa Tuff (Ttp)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 2 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
51.8-71.6 (170-235)	19.8 (65)	DA	N/A	**Partially to Moderately Welded Ash-Flow Tuff:** crystal-poor, devitrified, vapor phase altered; matrix reddish-gray (10R 6/1) mottled with red (10R 5/6) and minor dusky red (5R 3/2, vitric); Phenocrysts (5-7%), sanidine, plagioclase, olivine (partially altered to iddingsite?), mafics (<1%), biotite, pyroxene (?); Lithics: None noted; Pumice (1-3%?), light gray (5YR 7/1, devitrified) and dark reddish brown (5YR 2.5/2), flattened and partially vitric; Comments: vapor phase corroded/mineralized spots and anastomosing veins, light gray (5YR 7/1), rare fragments of white (N9) to very pale blue (5B 8/2) silica (possibly vein/fracture filling).	Pahute Mesa Tuff (Ttp)
71.6-187.8 (235-616)	116.1 (381)	DA	122-125 (400-410)	**Lava:** crystal rich, variable vapor phase alteration, partially devitrified/partially vitric; matrix dark reddish-gray (10R 4/1) to reddish-gray (10R 5/1), with light gray (10R 7/1) mottling; Phenocrysts (10-15%), sanidine (5 -10%, some chatoyant), plagioclase (3-5%), mafics (1-3%), olivine (2%) (greenish pyroxene?), magnetite (1%), very fine (<0.5 mm, common) crystal grains (pyroxene/olivine?) increasing downward with devitrification; Lithics: None noted; Pumice: None noted; Comments: Some fragments weakly reactive with HCl. Loose fragments of chalcedony (possibly analcime?), mottled white (N9) and strong brown (7.5YR 5/8), were observed throughout the interval - these are probably fracture fillings and coatings.	Comendite of Ribbon Cliff (Ttc)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 3 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
187.8-198.1 (616-650)	10.4 (34)	DB4	N/A	**Lava and Lava-Flow Breccia:** devitrified to partially vitric, vapor phase alteration; matrix weak red (10R 4/2) mottled with minor red (10R 4/6) and light gray (5YR 7/1) to pale red (10R 7/4), altered (vapor phase?) material, some fine material may be ash coating lava fragments; Phenocrysts (5-10%), sanidine (some chatoyant), plagioclase, mafics (1%), olivine (fayalite), pyroxene (?), magnetite (partially oxidized); Lithics: None noted; Pumice: None noted; Comments: Alteration/Color change possibly represents oxidized base of the above lava flow, or a hiatus during which the top of the underlying vitric lava was oxidized/altered. The underlying unit is composed of vitric lava while the lava in the overlying interval is crystallized. Crystallized lava fragments in this interval may be the result of sloughing from the overlying unit.	Comendite of Ribbon Cliff (Ttc)
198.1-223.7 (650-734)	25.6 (84)	DA	216-219 (710-720)	**Lava:** devitrified, vapor phase altered/mineralized; matrix reddish-gray (10R 5/1) with light gray (10R 7/1) to light reddish brown (5YR 6/3) mottling; Phenocrysts (5-10%), sanidine (4%, some chatoyant), plagioclase (3%), mafics (1%), biotite, greenish pyroxene (?),magnetite; Lithics: None noted; Pumice (?), distinctive yellowish red (5YR 4/6) to strong brown (7.5YR 5/6), clay altered and vapor phase corroded material with abundant phenocrysts, possibly mixed pumiceous/blocky lava (?); Comments: loose fragments of white (N9) to very pale blue (5B 8/2) chalcedony observed throughout interval.	Comendite of Ribbon Cliff (Ttc)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 4 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
223.7-251.5 (734-825)	27.7 (91)	DA, DB4	N/A	**Bedded Tuff:** vapor phase altered; from 734-754: matrix light brownish gray (2.5Y 6/2) and brown (7.5YR 4/4) to dark reddish brown (5YR 3/4), vitric; Phenocrysts (5-15%, mostly loose with some matrix), plagioclase, sanidine, qtz (?), mafics (<1%), biotite (?,oxidized), magnetite (oxidized); Lithics (1-2%) brown (7.5YR 4/4) and dark reddish brown (5YR 3/4) welded tuff fragments, corroded and vuggy with high porosity. Bedded Tuff: from 754-810: matrix gray (7.5Y 6/1) to pinkish gray (7.5Y 6/2) vitric with sugary texture; Phenocrysts (7%) primarily plagioclase and sanidine with minor quartz; Lithics: 1-2% fragments of welded tuff and other volcanics; pumice (5%), white (10YR 8/1), vitric; from 800-810: ~50% of sample: Lava (Basalt?): very dark gray (3/N) to black (2.5N); vuggy/vesicular with olivine altered to iddingsite, fragments of very pale blue (5B 8/2) chalcedony observed; Comment: May represent a thin Post Timber Mountain Basalt (Tftr) flow (?). Bedded Tuff: devitrified, vapor phase altered: from 810-825: ~5% basalt fragments, 15% welded tuff fragments, dark reddish gray (10R 4/1), remainder bedded material (?); Comments: possible/ uncertain contamination?	Comendite of Ribbon Cliff (Ttc)
251.5-272.5 (825-894)	21.0 (69)	DA	256-259 (840-850), 265-268 (870-880)	**Lava:** devitrified, vapor phase altered, crystal-poor; from 825-855: matrix light gray (7.5YR 7/1) to pale red (10R 6/2), from 855-894: fragments dark reddish gray (5YR 4/2) to reddish brown (5YR 4/3) and dark gray (10YR 4/1) to gray (10YR 6/1); Phenocrysts (5-10%) plagioclase, sanidine, sphene(?), mafics (<1%) biotite (black), hornblende, many phenocrysts are loose with little to no matrix; Lithics: None noted; Pumice: None noted.	rhyolite of Beatty Wash (Tfbw)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 5 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
272.5-297.2 (894-975)	24.7 (81)	DB4, DA	N/A	**Nonwelded Ash-Flow Tuff:** vitric, crystal rich, mafic-rich; matrix white (2.5Y 8/1); Phenocrysts (10-15%) sanidine, quartz (term., dipyramidal, some with faint pink tint), plagioclase, sphene (?), mafics (1-2%+), biotite (black), pyroxene(?); Lithics (5-<10%), welded tuff/lava pinkish gray (7.5YR 7/1), pale red (7.5YR 7/4), and dark reddish gray (7.5YR 3/1), abundance appears to decrease with depth; Pumice (2-10%), light gray (5YR 7/1) and minor pinkish white (5YR 8/2), vitric to altered, vesicular/tubular structure; Comments: possible dark brown (7.5YR 3/3) volcanic glass, possible vapor phase alteration, heavy contamination from 894-940 (50-80%) decreasing (<50%).	Timber Mountain Ammonia Tanks mafic-rich Tuff (Tmar)
297.2-358.1 (975-1,088)	61.0 (200)	DA	320-323 (1,050-1,060)	**Bedded Tuff:** vitric to clay altered; From 975-1050: cuttings consist of ~50% phenocrysts; quartz (term., dipyramidal, some with faint pink tint), sanidine and plagioclase, matrix appears to have been washed away and crystals concentrated due to the drilling process; from 1,050-1,088: **Bedded to Nonwelded Ash-Flow Tuff:** vitric, crystal rich; matrix white (5Y 8/1) to pinkish gray (5YR 7/2); Phenocrysts (>15%), sanidine, quartz (some partially resorbed, dipyramidal, faint pink tint), plagioclase; Lithics, vitric to devtrified volcanics, Dark gray (5YR 4/1) to dark reddish gray (5YR 4/2).	Timber Mountain Ammonia Tanks bedded tuff (Tmab)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 6 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
331.6-358.1 (1,088-1,175)	26.5 (87.0)	DA	N/A	**Bedded/Reworked Tuff:** vitric with some clay (?) alteration; matrix white (5YR 8/1) with some subordinate reddish yellow (7.5YR 8/6); Lithics (5-10%), lava gray (5YR 6/1) light reddish brown (5YR 6/3) with lesser amounts of welded tuff reddish yellow (5YR 6/8); Pumice (5-10%) white (5YR 8/1) and light gray (5YR 7/1), size range 1-2 mm most common, vitric, some vapor phase alteration, decreasing percentage with depth; Phenocrysts (10-15%): sanidine, 6% (some chatoyant); plagioclase, 3%; quartz, 3% (faint pink tint, dipyramidal), sphene (?); mafics (2%), biotite (black), rare pyroxene, magnetite(?).	Timber Mountain Rainier Mesa bedded tuff (Tmrb)
358.1-387.1 (1,175-1,270)	29.0 (95)	DA	378-381 (1,240-1,250)	**Nonwelded to Moderately Welded Ash-Flow Tuff:** devitrified, crystal rich, mafic-rich, vapor phase altered; matrix weak red (5R 5/3) to pale red (5R 6/1); Phenocrysts (10-20%), sanidine (6%), quartz (4%) (term., dipyramidal), plagioclase (3%), mafics (2%), biotite (unoxidized to oxidized), pyroxene (?), magnetite (?); Lithics (1-5%), welded tuff pale red (7.5YR 7/4); Pumice (2-5%) gray (5YR 6/1), white (5YR 8/1), reddish gray (5YR 5/2), flattening ratio increasing with depth, vapor phase altered, some relict vitric texture.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)
387.1-460.3 (1,270-1,510)	73.2 (240)	DA	N/A	**Moderately to Densely welded Ash-Flow Tuff:** devitrified, crystal rich, mafic-rich, vapor phase altered; matrix mottled weak red (5R 4/2) to weak red (5R 5/4) with light gray (5YR 7/1) to white (5YR 8/1) spots or anastomosing veins, possibly collapsed pumice or vapor phase partings; Phenocrysts (10-15%), sanidine (some chatoyant), quartz (term., dipyramidal), plagioclase, mafics (1-2%), biotite (black), pyroxene (?). Lithics: None noted; Pumice (3-7%), color listed in matrix section; Comments: vapor phase alteration appears to be increasing with depth.	Timber Mountain Rainier Mesa mafic-rich Tuff (Tmrr)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 7 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
460.3-551.7 (1,510-1,810)	91.4 (300)	DA	491-494 (1,610-1,620)	**Moderately to Densely welded Ash-Flow Tuff:** devitrified, crystal rich, mafic-poor, vapor phase altered; matrix mottled weak red (5R 4/2) to weak red (5R 5/4) with light gray (5YR 7/1) to white (5YR 8/1) spots or anastomosing veins, possibly collapsed pumice or vapor phase partings; Phenocrysts (10-15%), sanidine (some chatoyant), quartz (term., dipyramidal), plagioclase, mafics (<1%), biotite (unoxidized to oxidized); Lithics: None noted; Pumice (10-15%), color listed in matrix section.	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)
551.7-562.7 (1,810-1,846)	11.0 (36)	DA	558-561 (1,830-1,840)	**Densely Welded Ash-Flow Tuff:** vitrophyre, crystal rich: matrix black (10YR 2/1), dark gray (10YR 4/1), light gray (10YR 7/1); Phenocrysts (10-15%): sanidine (4%, some chatoyant), plagioclase (3%, blocky), quartz (2%), mafic (<1%); Lithics: None noted; Pumice (% uncertain, probably low): light gray (5YR 7/1); Comments: glassy vitrophyre (shards) to granophyric texture, chips are typically tabular (platy) to sub-blocky.	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)
562.7-600.5 (1,846-1,970)	37.8 (124)	DA	573-576 (1,880-1,890)	**Moderately to Partially Welded Ash-Flow Tuff:** devitrified, crystal rich, mafic-poor: matrix red (10R 4/6), weak red (10R 5/3); Phenocrysts (10-15%): sanidine (7-8%), quartz (2-3%), plagioclase (<1%), mafics (<1%), biotite (unoxidized); Lithics (2-5%), lava yellowish red (5YR 5/8), reddish brown (5YR 5/3), volcanic glass (including spherules) very dark brown (7.5YR 2.5/2) > black (7.5YR 2.5/1); Pumice (1-3%), white (5YR 8/1) to reddish yellow (5YR 7/8), vitric (tabular) texture and varying amounts of alteration, generally 1-5 mm and evenly distributed; Comments: Significant increase in water production in this interval, down from the virtophyre through moderate and nonwelded vitric (?) zones, volcanic glass exhibits iridescent color play on external/internal surfaces.	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 8 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
600.5-710.2 (1,970-2,330)	109.7 (360)	DA	610-613 (2,000-2,010), 698-701 (2,290-2,300)	**Nonwelded Ash-Flow Tuff:** mafic-poor, vitric to devitrified, altered (clay?) matrix; matrix from 1,970-2,080: light red (10R 6/6) to pinkish white (10R 8/2) with light gray (5YR 7/1); Phenocrysts (10+%): sanidine (4-6%, some chatoyant); quartz (2-4%), (term., dipyramidal); plagioclase (2%); mafics (<1%), biotite (unoxidized to oxidized); Lithics (2-5%), lava (vitric/ aphyric) red (7.5R 4/8) to red (10R 4/6), welded tuff mottled reddish brown (2.5YR 4/4) and pale red (5YR 4/6), from 2,195-2,330 lithic rich interval (15-25%), size ranges from 2-8 mm, lithics show some to abundant matrix; Pumice (15-20%), light gray (5YR 7/1), pinkish white (5YR 8/2), white (10R 8/1); from 2,080-2,160: matrix red (10R 4/6), pumice (% as above), light gray (5YR 7/1), pink (5YR 7/4) - more vitric, less argillically altered than above.from 2,160-2,340: matrix light reddish brown (5YR 6/4), pumice (% as above), white (10R 8/1), light gray (5YR 7/1).	Timber Mountain Rainier Mesa mafic-poor Tuff (Tmrp)
710.2-725.4 (2,330-2,380)	15.2 (50)	DB4	N/A	**Bedded and Reworked Tuff:** moderately to poorly indurated, crystal rich, mafic-poor; matrix brown (7.5YR 4.3 to 4.4), gray (7.5YR 5/1); Phenocrysts (10-15%): sanidine (3-4%); quartz (3-4%, rare terminations), plagioclase (<1%), mafics (1%), biotite (black), pyroxene(?); Lithics (3-7%), lava dark reddish gray (2.5YR 4/1), dusky red (10R 3/4), reddish gray (10R 5/1), size from <0.5-2 mm, rare up to 5 mm; Pumice (3-7%), white (N9), pinkish white (10R 8/2), light gray (10R 7/1), sub-rounded to rounded/blocky, altered; Comments: cuttings are a mix of bedded and reworked (some grading-crude?), fine grained material and contamination from above.	Timber Mountain Rainier Mesa bedded tuff (Tmrb)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 9 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
725.4-760.5 (2,380-2,495)	35.1 (115)	DA	747-750 (2,450-2,460)	**Nonwelded Ash-Flow Tuff and Tephra(?):** crystal-poor, pervasive zeolitic/argillic alteration: from 2,380-2,425: matrix pale olive (5Y 6/3), white (5Y 8/1), pink (7.5YR 8/3); Phenocrysts (2-5%), sanidine, plagioclase, mafics (<1%), biotite (black); Lithics (1-3%), welded tuff/lava dark reddish gray (2.5YR 4/1), pale red (10R 7/2), gray (7.5YR 5/1), sizes range from 1-4 mm; Pumice (5-15%?), pale yellow (5Y 8/3), yellow (10YR 8/6), very pale brown (10YR 8/2), and reddish yellow (7.5YR 8/6), exhibiting relict vitric texture, zeolitized; Comments: abundant contamination from bedded/reworked unit above.from 2,425-2,495: matrix white (7.5YR 8/1) and pinkish white (7.5YR 8/2); Phenocrysts (2-3%), sanidine, plagioclase, quartz (??), mafics (<1%), biotite, rare magnetite (?); Lithics (<1-3%), welded tuff red (10R 5/6), reddish gray (10R 6/1), dark red (10R 3/6), lava dark gray (5YR 4/1), reddish black (2.5YR 2.5/1); Pumice (1-2%?), white (7.5YR 8/1), altered, mostly 1-2 mm, with some exhibiting erosion and others having relict vitric textures; from 2,480-2,490 crystallized tuff with minor silicification and pervasive zeolitic alteration.	Paintbrush Group Undivided (Tp)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 10 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
760.5-871.7 (2,495-2,860)	111.3 (365)	DA, DB4, PSWC	847-850 (2,780-2,790)	**Lava:** crystal-poor, mafic-poor, vitric to devitrified, variable alteration near the top and base of flow; Phenocrysts (1-5%), sanidine, quartz, plagioclase, mafics (<1-1%), biotite (unoxidized to oxidized), hornblende (granular, very rare), phenocrysts difficult to distinguish from vitric matrix, numerous very fine (<0.5 mm) mafics/oxides (??); Lithics (<1-3%), welded tuff/lava pale red (7.5R 7/4) to weak red (5R 4/2); Comments: vitric material exhibits perlitic/spherulitic features and crackle textures; From 2,495-2,530: Pumiceous Lava; with minor intercalated bedded tuff (?); matrix (altered pumiceous material) light yellowish brown (10YR 6/4), pale yellow (5Y 7/3), and matrix (vitric material) gray (2.5YR 6/1) to dark reddish gray (2.5YR 4/1), grading into vitric lava; Pumice (10-15%), pale yellow (5Y 8/2) to white (2.5YR 8/1), blocky to prismatic, size ranges from <1-4 mm+. From 2,530-2,660: Lava (Vitrophyric); matrix pale green (5G 6/2) to light greenish gray (10GY 7/1) and light gray (N7) to dark gray (N4); Comments: fragments of chalcedony (<1-1%), light bluish gray (5B 8/1); From 2,660-2,770: Lava (Stoney Core), devitrified to aphyric; matrix mottled weak red (10R 4/3) to pale red (10R 6/2) with dark reddish gray (10R 3/1); Comments: fragments of chalcedony light bluish gray (5B 8/1) to white N9); From 2,770-2,800: Lava (Vitrophyric); same as at 2,530-2,660; From 2,800-2,860: Lava (Basal Flow Breccia); devitrified/vitric, zeolitic alteration; matrix olive gray (5Y 4/2) mottled reddish gray (5R 6/1) and weak red (5R 5/3), minor pinkish white (10R 8/2); Lithics: angular to rounded, from (<1-5 mm+), some sorting?; Pumice (5-15%), white (7.5R 8/1), pinkish white (7.5R 8/2), light greenish gray (10GY 8/1), zeolitic/argillically altered; Comments: base of lava revised downward to 2,860 ft bgs based on geophysics.	Calico Hills rhyolitic lava (Thrl)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 11 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
871.7-877.8 (2,860-2,880)	6.1 (20)	DB4	N/A	**Nonwelded Tephra:** crystal-poor, mafic-poor, argillic/zeolitic alteration; matrix brown (7.5YR 5/3) mottled with white (7.5 8/1); Phenocrysts (5-7%), sanidine, quartz (term., some partially resorbed), plagioclase, mafics (1%), biotite (black), magnetite(?) (oxidized rims); Lithics (1-2%), lava/welded tuff weak red (5R 4/2), dusky red (5R 3/2), weak red (7.5R 4/2), most are <2 mm but rarely to 5 mm; Pumice (20-40%), white (7.5R 8/1), pink (5YR 8/3), light red (2.5YR 7/6), mostly altered with felsic phenocrysts, some relict vitric texture; Comments: rare blebs of very pale blue (5B 8/2) chalcedony, interval may be pumice fall precursor eruption for lava flow? Interval may represent the basal/precursor eruptive flow of lava?	Calico Hills rhyolitic lava (Thrl)
877.8-962.6 (2,880-3,158)	84.7 (278)	DA, PSWC	881-884 (2,890-2,900)	**Nonwelded Ash-Flow Tuff:** crystal-poor, mafic-rich, argillic/ zeolitically altered: matrix brown (7.5YR 5/3), pink (7.5YR 7/3), white (7.5YR 8/1); Phenocrysts (5-10%), sanidine, quartz (term.), plagioclase, mafics (2-3%) biotite (black), magnetite (very fine grains); Lithics (1-3%), lava/welded tuff weak red 5R4/2, dusky red (5R 3/2), weak red (7.5R 4/2), most are <2 mm but some up to 5 mm across; Pumice (20-30%), white (7.5R 8/1), pinkish white (7.5YR 8/2), pink (5YR 8/4), mostly <2-3 mm (possibly much larger), blocky/non-flattened, some have relict vitric textures; Comments: first observation at 3,100 ft of greenish gray (10Y 8/1) and light pink (7.5R 8/2) pumice, distinctive texture of ash-flow with blocky pumice, moderately to well indurated.	Calico Hills mafic-rich Tuff (Thr)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 12 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
962.6-1,027.2 (3,158-3,370)	64.6 (212)	DA, PSWC	969-972 (3,180-3,190)	**Nonwelded Ash-Flow Tuff:** crystal-poor, lithic rich, argillic/ zeolitically altered, moderately to well indurated; from 3,158-3,190: matrix weak red (7.5R 5/4) to pale red (7.5R 6/3), and pale yellow (2.5Y 8/3), pink (5YR 8/3), white (5YR 8/1) spots (pumice fragments); Phenocrysts (2-5%), sanidine, quartz (term., frosted), plagioclase(?), mafics (1%) biotite (black), rare white (N9) to light bluish gray (5B 8/1) coating/ fracture filling (soft); Lithics (5-15%), lava weak red (7.5R 5/4), weak red (10R 4/2), red (10R 4/8), range from (<1-5 mm+); Pumice (25-30%), pale yellow (2.5Y 8/3), pink (5YR 8/3), white (5YR 8/1), blocky/prismatic pumice, sugary textures, some relict vitric textures. From 3,190-3,370: matrix reddish brown (5YR 5/3) mottled red (7.5R 5/6), mottled texture for overall sample (matrix and pumice); Phenocrysts (3-7%), sanidine, quartz (term., frosted, clear, good crystal faces, no resorption), plagioclase, mafics (1%), biotite (black), very fine phenocrysts mafic & clear, to small to identify; Lithics (10-20%), lava/welded tuff weak red (10R 4/2), dusky red (10R 3/3), dark reddish gray (2.5YR 3/1), range from (<1-4 mm+); Pumice (20-40%), pinkish white (7.5YR 8/2), very pale brown (10YR 8/2), white (N9), distinctive blocky pumice ash-flow texture; Comments: some fragments appear as graded/reworked and bedded/ash-falls.	Calico Hills (Th)
1,027.2-1,035.7 (3,370-3,398)	8.5 (28)	NS	N/A	**Bedded to Nonwelded Ash-Flow Tuff:** crystal-poor, argillic/ zeolitically altered; matrix pale yellow (5Y 8/3), white (N9 and 10YR 8/1), pinkish white (5YR 8/2); Phenocrysts: 1-2% sanidine, quartz, mafics (<1%?); Pumice white (N9), pinkish white (2.5YR 8/2); Comments: No Sample recovered in this interval, interpreted from geophysical logs and sample from 3,400-3,410.	Calico Hills (Th)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 13 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
1,035.7-1,079.0 (3,398-3,540)	43.3 (142)	DA	1,076-1,079 (3,530-3,540)	**Densely Welded Ash-Flow Tuff:** devitrified, crystal-poor; from 3,398-3,540: matrix mottled dark red (10R 3/6) with pale red (10R 6/4), ~10% nonwelded tuff, altered pinkish white (7.5YR 8/2) fragments - contamination from above; Phenocrysts (3-5%), sanidine (some chatoyant), plagioclase, mafics (<1%), biotite (unoxidized); Lithics (<1%), lava (?) very dark gray (7.5 YR 3/1); Pumice: None noted; Comments: ~1-2% of fragments appear brecciated (micro?), fragments are the same as the general tuff material with lighter colored (pink [7.5YR 8/3]) material. From 3,450-3,460: Zone of heavier contamination? From 3,480-3,540: Contains white (N8) to clear silica (some botryoidal) fracture filling, ~3-5%	Grouse Canyon Tuff (Tbg)
1,079.0-1,083.9 (3,540-3,556)	4.9 (16)	DA	N/A	**Bedded Tuff:** crystal-poor, altered (clay/zeolite?); from 3,540-3,556: matrix white (2.5YR 8/1) to pinkish white (2.5YR 8/2) to very pale brown (10YR 8/2), mixed with material from above, contacts adjusted by geophysics; Phenocrysts (2-3%), sanidine, plagioclase, mafics (<1%), biotite; Lithics (1%?), lava (?) light red (10R 6/8), dark reddish gray (10R 3/1), may be contamination from up hole?; Pumice (3%?), pinkish white (2.5YR 8/2) to very pale brown (10YR 8/3), very small; Comments: Some fragments appear granular texture with possible sorting?	Grouse Canyon bedded tuff (Tbgb)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 14 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
1,083.9-1,133.9 (3,556-3,720)	50.0 (164)	DA, PSWC	1,109-1,113 (3,640-3,650)	**Lava:** vitrophyric; From 3,556-3,660: matrix greenish gray (5G 6/1) to grayish green (5G 5/2) to pale yellow (5Y 7/3), 3,660-3,680: pale yellow (5Y 8/2), ~50% of lava chips show incipient alteration (clay/zeolite ??); Phenocrysts (3-5%?), sanidine, quartz (??), mafics (1%), biotite (unoxidized), pyroxene (rare), oxides (manganese) forms thin sheets/ coatings on fractures/flow partings, difficult to distinguish clear felsic phenocrysts in glassy matrix; Lithics: None noted, lava fragments have no matrix - most likely contamination; Pumice (<1%), fused in glass - possible tubular texture); Comments: crackle and perlitic textured glass, 3,650-3,660: no returns.	Comendite of Quartet Dome (Tbq)
1,133.9-1,155.5 (3,720-3,791)	21.6 (71)	DB4, PSWC	1,146-1,149 (3,760-3,770)	**Moderately to Densely Welded Ash-Flow Tuff:** devitrified, spherulitic, altered; matrix reddish brown (2.5YR 4/4) to light reddish brown (2.5YR7/4) to reddish yellow (5YR 6/6); Phenocrysts (2-3%), sanidine, plagioclase, quartz (?), mafics (1%), biotite (oxidized to unoxidized), pyroxene (??, granular blebs), oxides (?) appear in trains or disseminated in granular (devitrified?) matrix, possible oxide coating on "rare" surfaces; Lithics: None noted; Pumice (3-5%?), light pink (7.5YR 8/3), white (7.5YR 8/1), relict tubular structures (?) (alternatively may be radiating structures in masses of altered spherulites); Comments: chalcedony clear, white (N9), light bluish gray (10B 8/1), filling spherulitic cavities and fractures, possible foliation/flow banding features at 3,780-3,790, some fragments appear brecciated or flow laminated - alternatively interval may include or be a Basal Flow Breccia?	Comendite of Quartet Dome (Tbq)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 15 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
1,155.5-1,268.0 (3,791-4,160)	112.5 (369)	DA, PSWC	1,216-1,219 (3,990-4,000)	**Lava:** crystal-poor, spherulitic, altered, devitrified (granular texture); matrix from 3,791-3,880: pinkish gray (5YR 7/2) to pinkish white (5YR 8/2), from 3,880-4,160 light gray (5YR 7/1) to pinkish gray (5YR 7/2); Phenocrysts (2-3%), sanidine, plagioclase?, mafics (<1%), biotite (unoxidized), oxides (very fine, in trains? or disseminated) similar to lava's above; Lithics (<1%), lava (?) black (5YR 2.5/1) [see percussion core descriptions]; Pumice: None noted; Comments: some fragments are a mix (single piece) of vapor phase/granular material and devitrified/spherulitic lava, spherulites are most abundant from 3,791-3,880 ft and decrease in abundance with depth.	rhyolite of Handley (Tqj)

Table D-1
Detailed Lithologic Log for Well ER-20-12
(Page 16 of 16)

Depth Interval m (ft)	**Thickness** m (ft)	**Sample Type** [a]	**Depth of Analytical Samples** [b] m (ft)	**Lithologic Description** [c]	**Stratigraphic Unit** (Map symbol)
1,268.0-1,347.2 (4,160-4,420)	79.2 (260)	DA, DB4, PSWC	1,283-1,286 (4,210-4,220)	**Lava and Flow Breccia:** crystal-poor, mafic-rich, vapor phase altered, chloritic?/ clay?, devitrified (granular texture); matrix from 4,160-4,250 dark red (2.5 YR 6/8) to light red (2.5 YR 6/8) to light gray (5YR 7/1); from 4,250-4,370 greenish gray (10YR 5/1), from 4,370-4,380 gravel/contamination, from 4,380-4,420 reddish brown (5YR 5/4) grading downward to pink (5YR 7/4); Phenocrysts (5-7%), sanidine, plagioclase, quartz (?), mafics (2-5%) biotite (oxidized, oxidized decreases with depth), oxides (very fine, in trains?); Lithics (<1%), lava (?) gray (N5), bluish black (10B 2.5/1); Pumice: None noted; Comments: 4,170-4,200: altered zone with strong silicification?	rhyolite of Handley (Tqj)
1,347.2-1,384.8 (4,420-4,543.33)	37.6 (123.33)	DB4	1,381-1,384 (4,530-4,540)	**Nonwelded Ash-Flow Tuff:** devitrified, altered (clay, vapor phase); matrix very pale brown (10YR 8/2) to white (10YR 8/1); Phenocrysts (5-10%), sanidine, plagioclase, quartz(?), mafics (<1-1%), biotite (oxidized-unoxidized, most are broken). Lithics (2-3%), lava (?) pink (7.5YR 8/4), gray (7.5YR 6/1); Pumice (3-7%?), white (7.5YR8/1) to reddish yellow (7.5 YR 8/6), many pumice have been plucked out blocky to subround, some relict tubular structures.	rhyolite of Handley (Tqj)

[a] Lithologic samples collected from interval during drilling and logging operations and utilized for lithologic interpretation. **DA** = drill cuttings that represent lithologic character of interval; **DB4** = cuttings intimate mixtures of units and/or drilling material, generally less than 50% of drill cuttings represent lithologic character of interval; **PSWC** = percussion sidewall core; **NS** = no sample.
[b] Depth of lithologic samples selected for laboratory analyses. Laboratory analyses include petrography (from polished thin sections), mineralogy (XRD), and chemistry (XRF). See Table 4-2 for a complete list of samples analyzed.
[c] Descriptions are based mainly on visual examination of lithologic samples using a 10x- to 40x-zoom binocular microscope, and incorporating observations from geophysical logs and sidewall cores (see Table 4-1 for sidewall core descriptions). Colors describe wet sample color unless otherwise noted.

mm = Millimeter

Table D-2
Sidewall Core Descriptions
(Page 1 of 2)

Sample Depth (ft)	Stratigraphic Symbol	Stratigraphy	Lithology
2,680	Tc	Calico Hills rhyolitic lava	Bedded tuff/altered lava; light gray (N7/1) matrix, granular, very soft, altered (clay and possibly zeolites), 10% phenocrysts of quartz, sanidine (perhaps much higher %); 1% mafics of biotite, black, altered and very soft, and lesser magnetite; contains 2-3% rounded vitric nodules (silicified), preserved lava/pumiceous lava; no lithics noted.
2,900	Tcb	Calico Hills mafic-rich Tuff	Ash-flow tuff; non to partially welded/light brown (7.5YR 6/3) to brown (7.5YR 5/3); devitrified; 2-3% phenocrysts of sanidine, plagioclase, and quartz (?); <1% biotite, black; <1% lithics, very dark gray (7.5YR 3/1); basalt and lava-vitrophyre, angular, up to 2 mm; 10% pumice, white (N9), partially to moderately flattened, banded parallel to flattening, up to 1 cm, foliation in ash mixed with pumice.
2,970	Tcb	Calico Hills mafic-rich Tuff	Ash-flow tuff; nonwelded; pale red (10R 6/4) to pink (7.5YR 7/3), altered (soft); 5-7% phenocrysts of sanidine, plagioclase, rare quartz (?); <1% biotite, black; 1-2% pumice, pinkish white (5YR 8/2), non-flattened, porous, eroded out; <1% lithics (?), red (10R 5/6), altered volcanic, soft and friable.
3,120	Tcb	Calico Hills mafic-rich Tuff	Ash-flow tuff; nonwelded; white (7.5YR 8/1) to pinkish gray (7.5YR 7/2), devitrified, friable; 3-5% phenocrysts of sanidine, plagioclase and quartz; 1% biotite, black; 15-20% pumice, white (N9) to pinkish white (5YR 8/2) up to 5 mm, altered (soft), some with relic vitric textures; 2-4% lithics, weak red (2.5YR 4/2), lava/welded tuff, angular, up to 2 mm.
3,270	Tct	Calico Hills	Ash-flow tuff; nonwelded, bedded (?), very soft, friable, granular matrix; pinkish gray (7.5YR 7/2); 8-10% pumice, white (N9), soft but does not appear zeolitic, up to 8 mm across, minor flattening on orientation of pumice; 3-5% phenocrysts of sanidine, lesser quartz, some terminated crystals, plagioclase; <1% biotite, black, some bronze, rare magnetite; 3-5% lithics, lava, weak red (2.5YR 4/2), up to 5 mm. Also light gray (N7) and dark gray (N4) lava (?), distinctive lithic (?) (pumice?) fragments, pale yellow (5YR 8/4), vitric?
3,340	Tct	Calico Hills	Ash-flow tuff; bedded to nonwelded, soft clay (?) altered matrix and pumice, relict vitric textures; matrix white (10YR 8/1) to very pale brown (10YR 8/2 to 10YR 7/3), pumice, white (10YR 8/1); phenocrysts 5-7%, sanidine (2%), quartz (2%) many terminated, plagioclase; mafics, biotite (1%), trace magnetite; lithics 3-5%, mostly small to fine (<1 mm to 2 mm) lava (welded tuff ?), reddish brown (5YR 5/3); pumice 10-15% clay altered, some relict vitric texture; small fragments (pumice) and matrix rimming lithics altered by zeolite (?), pale yellow (5Y 7/3) to pale olive (5Y 6/4).
3,655	Tbq	Comendite of Quartet Dome	Pumiceous lava (?), altered (zeolitic?), matrix olive (5Y 5/3), semi-translucent in large areas mottled by altered pumice/ash, white (7.5YR 8/1) to pinkish white (7YR 8/2); phenocrysts 2-5%, sanidine, plagioclase (?); mafic biotite 1%, magnetite 1% partially oxidized; lithics, 1-2% gray (5YR 5/1) to bluish gray (GLY2 10B 6/1), lava (?); dark opaque (oxides?), fine-grained appear as short trains/stringers?
3,700	Tbq	Comendite of Quartet Dome	Pumiceous lava, altered (clay?), matrix pale red (10R 6/2) to pale red (10R 6/4) to white (10R 8/1); pumice, small <1 mm, blocky, white (7.5YR 8/1); phenocrysts 3-5%, sanidine 1%, plagioclase 1%; mafics, biotite (oxidized to fresh) 2-3%; relict flow banding/foliation? from 1 direction (along/looking into long axis of core?); no lithics.

Table D-2
Sidewall Core Descriptions
(Page 2 of 2)

Sample Depth (ft)	Stratigraphic Symbol	Stratigraphy	Lithology
3,740	Tbq	Comendite of Quartet Dome	Ash-flow tuff (possibly altered lava); moderately welded; matrix devitrified/clay altered, yellowish red (5YR 5/6) to reddish yellow (5YR 6/6); phenocrysts 5-7%, sanidine, plagioclase; mafics, biotite 1-2%, oxides (hematite?); lithics (?), lava (?), reddish gray (5YR 5/2). (Alternatively: could be differentially altered lava instead of moderate to densely welded tuff).
3,820	Tqj	rhyolite of Handley	Lava, altered - possibly vapor phase (crystallized, granular) with less unaltered fragments, spherulitic; matrix, white (5YR 8/1), unaltered fragments light reddish brown (5YR 6/4), spherulites, pink (5YR 8/4); phenocrysts 1-3%, sanidine, plagioclase?; mafics, biotite <1% (mostly oxidized, some fresh cores), oxides (appear in trains? similar to unaltered lava), very small/fine; no pumice; typically spherulites are least/last altered.
3,875	Tqj	rhyolite of Handley	Lava, altered (crystallized, granular, vapor phase corroded); fragments as above are completely altered (soft clay); matrix light gray (5YR 7/1) with minor areas of white (5YR 8/1); relict altered lava areas with sphene, pink (5YR 8/3); phenocrysts 2-4%, sanidine, plagioclase; mafics, biotite (1-2% oxidized with fresh cores); oxides (trains, very small, fresh to partially oxidized); pumice <1% white (5YR 8/1).
3,955	Tqj	rhyolite of Handley	Lava, altered (crystallized, granular, completely altered – vapor phase), no less/ unaltered relict lava remains; matrix white (5YR 8/1) to white (7.5YR 8/1), minor reddish yellow area around oxidized oxides; phenocrysts 2-3%, sanidine; mafics, biotite (1-2% mostly oxidized); oxides (spec hematite??/magnetite?), very small/fine; no pumice noted.
4,135	Tqj	rhyolite of Handley	Lava, spherulitic, altered (partially – clay?); matrix mottled light gray (5YR 7/1) and pinkish gray (5YR 7/2), zones of matrix (patches) (spherulitic?), light red (2.5YR 7/6); phenocrysts 2-4%, sanidine, plagioclase?, quartz? (rare); mafics, biotite (1% oxidized), oxides (very fine/small, trains, partially oxidized); no pumice noted. Brecciated layer (?) or fragments, appears to be same material (fragmented lava) with possible inclusion of other (unidentified material). Breccia zone altered (possibly silicified?, harder than surrounding lava), reddish brown (2.5YR 5/4) to reddish gray (2.5YR 5/1).
4,188	Tqj	rhyolite of Handley	Lava, altered (matrix – soft/mod, complete clay?); matrix pinkish white (2.5YR 8/2) to light reddish brown (2.5YR 7/3); phenocrysts 3-5%, sanidine, plagioclase; mafics, biotite (1-2%, fresh to partially oxidized), oxides (very small/fine to small, fresh to partially oxidized); unaltered (fresh) volcanic glass, spherulitic and fragments.
4,230	Tqj	rhyolite of Handley	Pumiceous lava (?)/ash-flow tuff (?), nonwelded; mafic rich; altered (chlorite?/ clay); matrix greenish gray (5BG 6/1) to bluish gray (5BG 5/1); phenocrysts 7-10% (crystal rich), sanidine, plagioclase, quartz; mafics, biotite (2-3%, unoxidized), oxides (specular hematite?/magnetite?); crude foliation or flattened pumice?
4,305	Tqj	rhyolite of Handley	Pumiceous lava (?)/ash-flow tuff, nonwelded to partially welded, altered (chlorite, clay/zeolitic?), less altered fragments (lithics? with some breccia?), dark bluish gray (5B 4/1); phenocrysts 7-10%, sanidine, plagioclase, quartz; mafics, biotite (2-3% unoxidized), oxides; no pumice noted. Small isolated patches/features relict volcanic glass spherulites (?), yellow (5Y 7/8) possibly glass shards.

Appendix E

Geophysical Logs Run in Well ER-20-12

E.1.0 Geophysical Logs Run in Well ER-20-12

This appendix contains plots of selected geophysical logs (Figures E-1 through E-5) collected in Well ER-20-12. Table E-1 provides descriptions of the geophysical logs presented. (Table 4-3 presents a summary of the logs run in ER-20-12.)

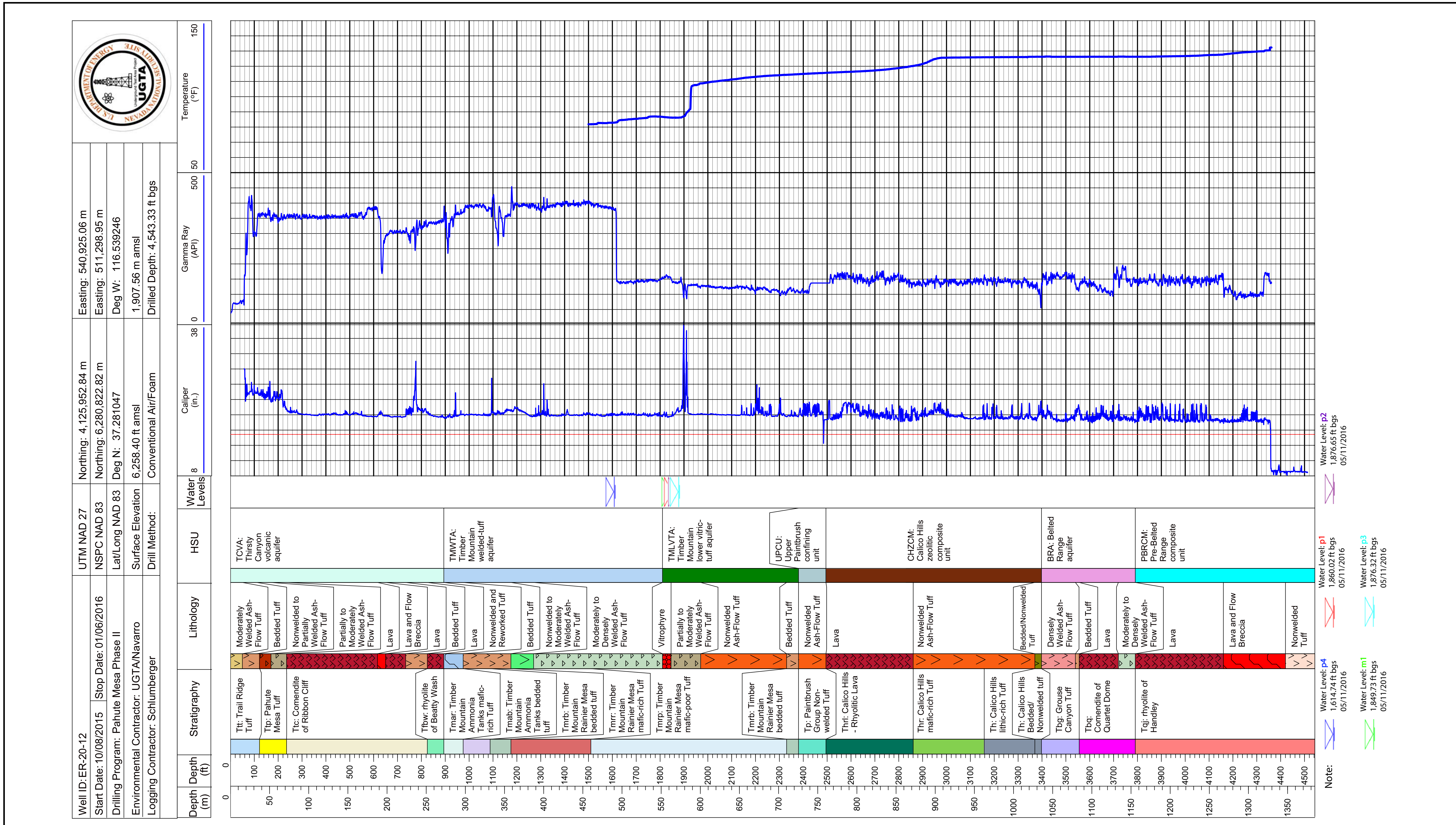


Figure E-1
Geophysical Log Traces of Caliper, Gamma Ray, and Temperature

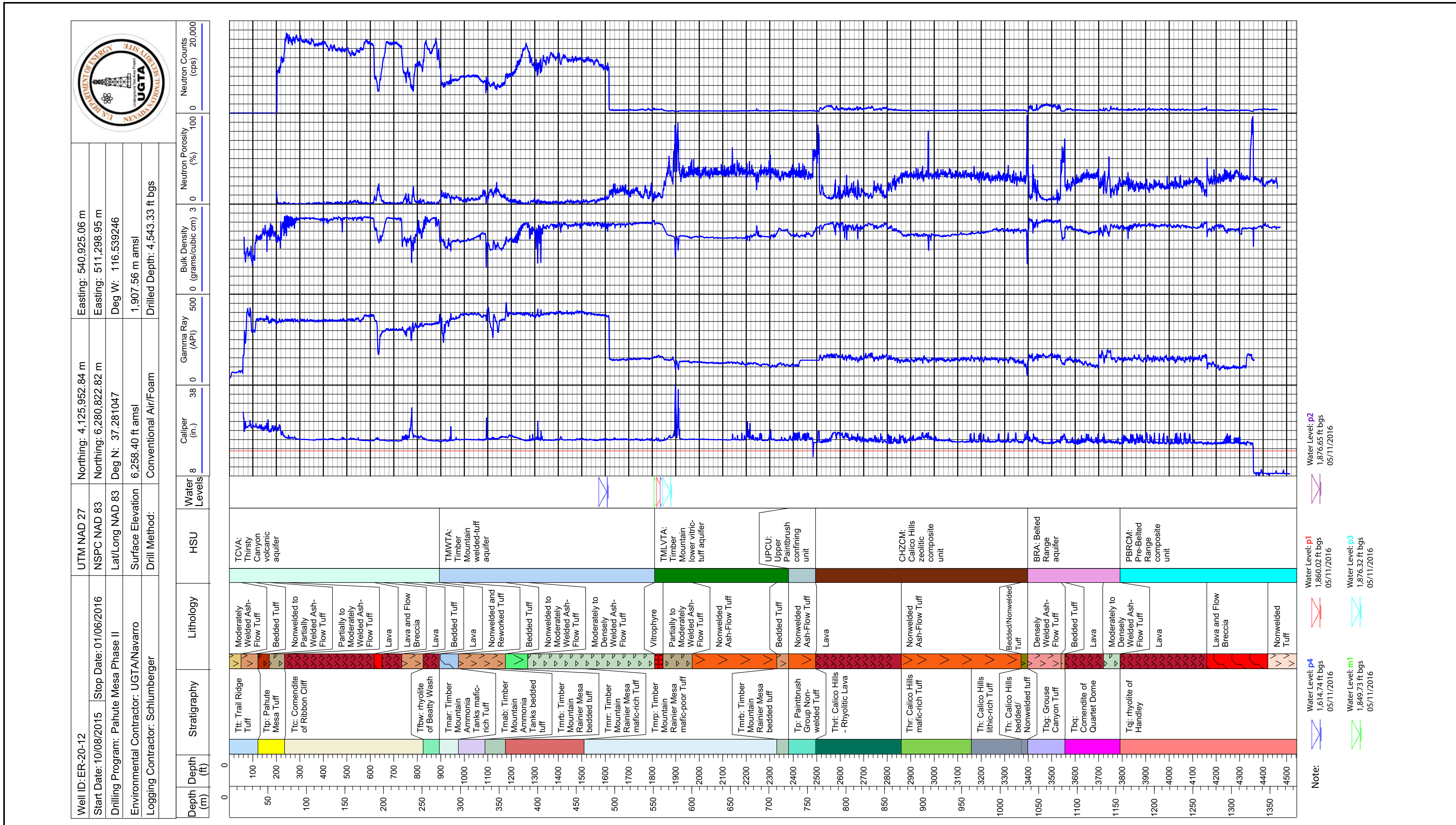


Figure E-2
Geophysical Log Traces of Caliper, Gamma Ray, Bulk Density, and Neutron Porosity

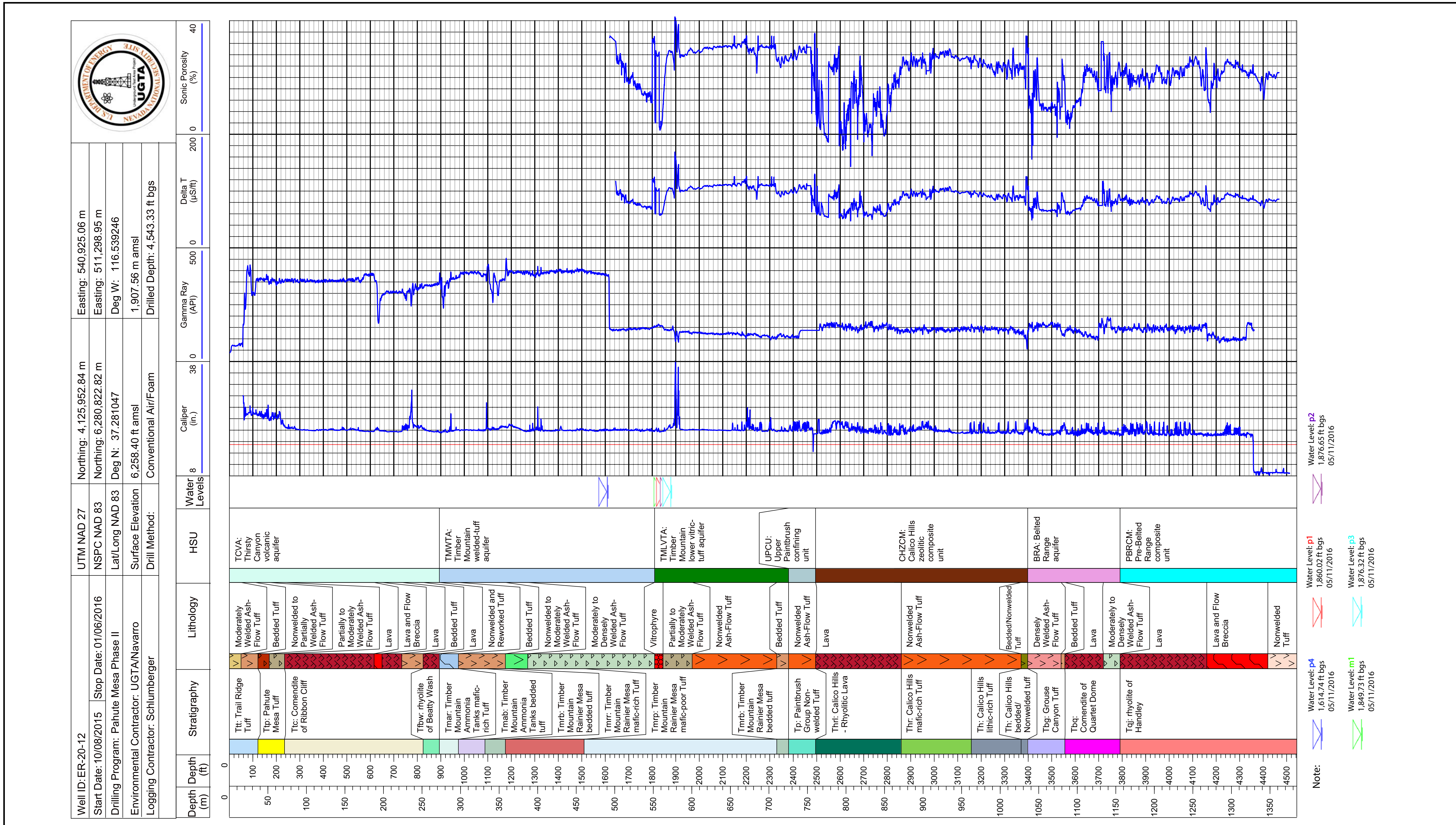


Figure E-3
Geophysical Log Traces of Caliper, Gamma Ray, Delta T, and Sonic Porosity

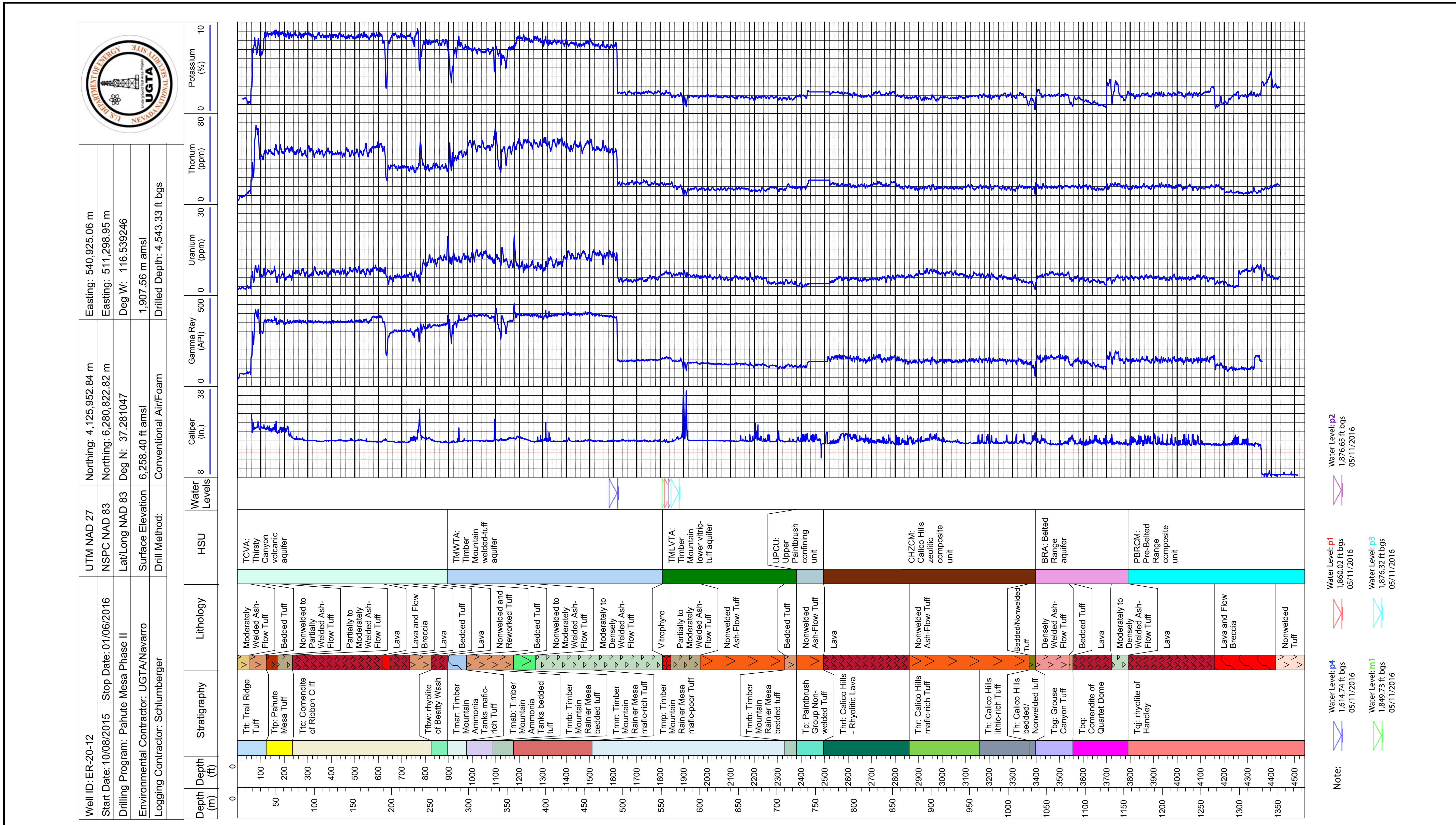


Figure E-4
Geophysical Log Traces of Caliper, Gamma Ray, and Digital Spectralog

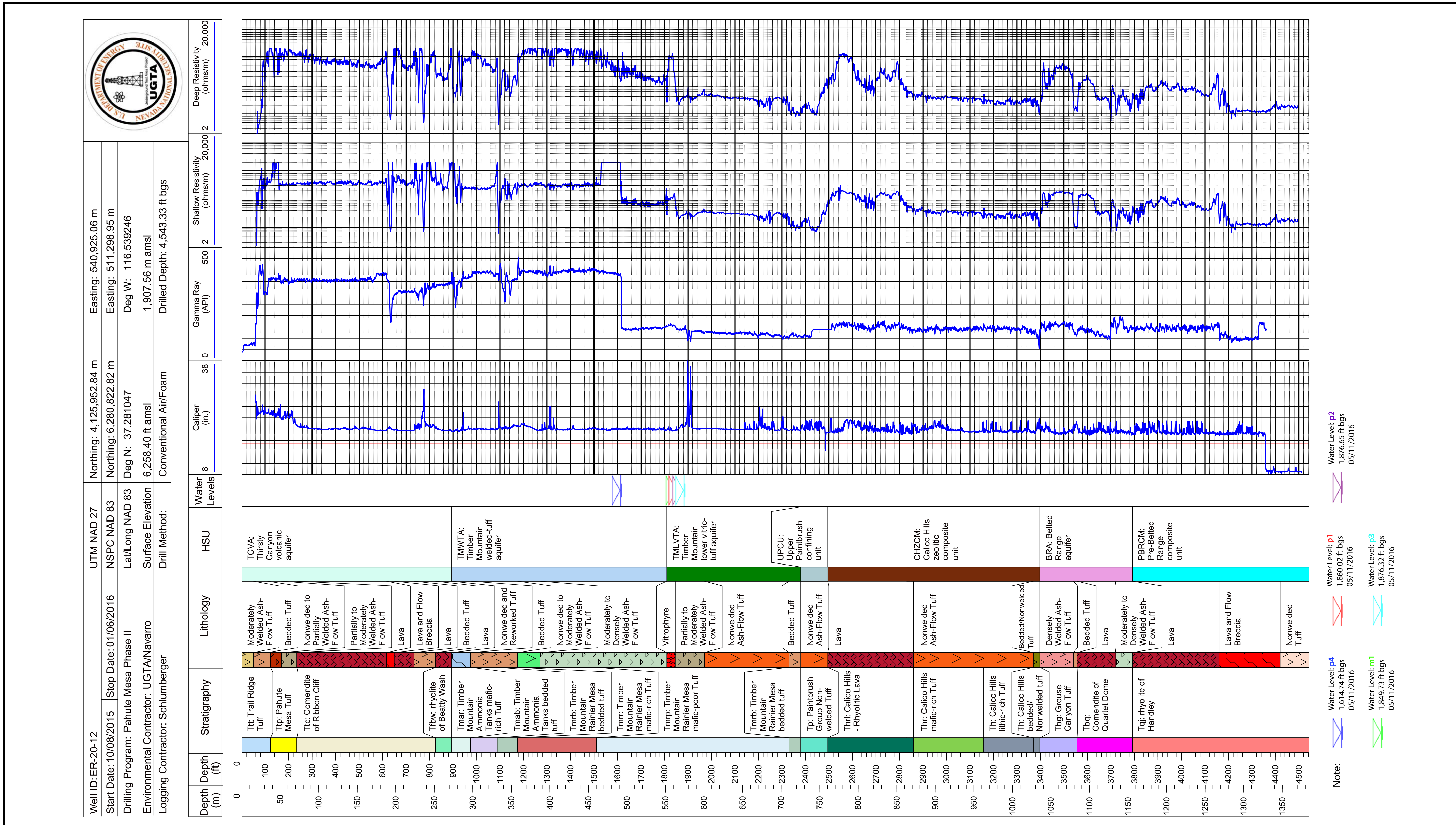


Figure E-5
Geophysical Log Traces of Caliper, Gamma Ray, and Shallow and Deep Resistivity

Table E-1
Well ER-20-12 Descriptions of Geophysical Logs
(Page 1 of 2)

Geophysical Log	Log Purpose	Logging Service	Date Logged	Run Number	Top of Logged Interval (ft bgs)	Bottom of Logged Interval (ft bgs)
Borehole: 0 to 2,510 ft bgs						
Differential Temperature/Temperature, Gamma Ray	Formation/Fluid: Water levels, Water movement in/out of borehole, Depth calibration checks	Schlumberger	11/04/2015	1	1,500	2,498
Compensated Neutron, Three Detector Litho Density, Gamma Ray/Caliper, Array Induction, Spontaneous Potential, High Resolution Laterolog Array	Formation: Porosity and lithologic determination; Density; Borehole depth and condition (washouts, fractures); Resistivity, Thin bed analysis; Spontaneous Potential; Resistivity, Fracture Analysis	Schlumberger	11/04/2015	2	30	2,502
Compensated Neutron, Three Detector Litho Density, Gamma Ray	Formation: Porosity and lithologic determination; Density	Schlumberger	11/04/2015	3	2,018	2,508
4-Arm Caliper, Powered Positioning Device, Full Bore Scanner, Gamma Ray, Gamma Ray Spectroscopy, Natural Gamma Ray	Formation: Borehole condition (washouts, fractures); Stratigraphic and fracture analysis; Depth calibration check; Lithologic/Stratigraphic analysis as a function of relative ^{40}K, ^{232}Th, and ^{238}U concentrations; Lithologic/Stratigraphic analysis, alteration analysis	Schlumberger	11/04/2015	4	0	2,509
Chemistry Log	Fluid: Temperature, Pressure, Electrical Conductivity, pH, O_2, Redox	COLOG	11/05/2015	1	1,621.5	2,506.3
Borehole: 2,500 to 4,352 ft bgs						
Differential Temperature/Temperature, Gamma Ray	Formation/Fluid: Water levels, Water movement in/out of borehole, Depth calibration checks	Schlumberger	12/02/2015	5	1,350	4,328
Directional Survey, General Purpose Inclinometry Tool, Modular Acoustic Scanning Platform, Gamma Ray, Gamma Ray Spectroscopy, Full Bore Scanner, Four Arm Caliper, 8-Arm Caliper, Powered Positioning Device	Formation: Borehole orientation and deviation; Lithologic/ stratigraphic analysis, fracture analysis, cement bonding; Depth calibration check; Lithologic/Stratigraphic analysis as a function of relative ^{40}K, ^{232}Th, and ^{238}U concentrations; Stratigraphic and fracture analysis; Borehole condition (washouts, fractures);	Schlumberger	12/02/2015	6	2,500	4,338
High Resolution Laterolog Array, Gamma Ray, Spontaneous Potential, Compensated Neutron, Three Detector Litho Density, Gamma Ray/Caliper	Formation: Resistivity, Fracture Analysis; Depth calibration checks; Spontaneous Potential; Porosity and lithologic determination; Density; Borehole depth and condition (washouts, fractures); Resistivity, Thin bed analysis; Spontaneous Potential; Borehole depth and condition (washouts, fractures)	Schlumberger	12/03/2015	7	2,200	4,317
Chemistry Log	Fluid: Temperature, Pressure, Electrical Conductivity, pH, O_2, Redox	COLOG	12/05/2015	1	2,455	4,270
Corehole Dynamic Flowmeter Log	Fluid: Fracture flow and permeability	COLOG	12/05/2015	2	1,914.8	4,270
Nuclear Annular Investigation Log	Determine the final height of annular completion materials	COLOG	12/16/2015	2	2,400	3,665

Table E-1
Well ER-20-12 Descriptions of Geophysical Logs
(Page 2 of 2)

Geophysical Log	Log Purpose	Logging Service	Date Logged	Run Number	Top of Logged Interval (ft bgs)	Bottom of Logged Interval (ft bgs)
Borehole: 3,900 to 4,519 ft bgs						
Differential Temperature/Temperature, Gamma Ray	Formation/Fluid: Water levels, Water movement in/out of borehole, Depth calibration checks	Schlumberger	01/03/2016	10	3,800	4,358
Directional Survey, General Purpose Inclinometry Tool, Modular Acoustic Scanning Platform, Gamma Ray, Gamma Ray Spectroscopy, Full Bore Scanner, Four Arm Caliper, 8-Arm Caliper, Powered Positioning Device	Formation: Borehole orientation and deviation; Lithologic/ stratigraphic analysis, fracture analysis, cement bonding; Depth calibration check; Lithologic/Stratigraphic analysis as a function of relative ^{40}K, ^{232}Th, and ^{238}U concentrations; Stratigraphic and fracture analysis; Borehole condition (washouts, fractures);	Schlumberger	01/03/2016	11	3,900	4,517
High Resolution Laterolog Array, Gamma Ray, Spontaneous Potential, Compensated Neutron, Three Detector Litho Density, Gamma Ray/Caliper	Formation: Resistivity, Fracture Analysis; Depth calibration checks; Spontaneous Potential; Porosity and lithologic determination; Density; Borehole depth and condition (washouts, fractures); Resistivity, Thin bed analysis; Spontaneous Potential; Borehole depth and condition (washouts, fractures)	Schlumberger	01/03/2016	12	3,800	4,492
Chemistry Log	Fluid: Temperature, Pressure, Electrical Conductivity, pH, O_2, Redox	COLOG	01/04/2016	1	3,849.7	4,351.5
Corehole Dynamic Flowmeter Log	Fluid: Fracture flow and permeability	COLOG	01/05/2016	2	3,850	4,358

K = Potassium
O_2 = Dissolved oxygen
Th = Thorium
TL = Temperature log
U = Uranium

Appendix F

Water Production Data for Well ER-20-12

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 1 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
10/10/2015	03:59	21.34	70	11.5	9.92	55.65	21	8.86	2
10/10/2015	07:15	45.11	148	27.5	28.8	58.30	22	-3.79	-1
10/10/2015	10:30	59.74	196	10.9	16.5	58.30	22	-20.55	-5
10/10/2015	14:30	71.32	234	14	16	58.30	22	-7.29	-2
10/10/2015	18:30	73.76	242	16.8	26.4	58.30	22	-21.20	-6
10/10/2015	22:30	76.20	250	11.9	9.62	74.20	28	18.93	5
10/10/2015	02:30	79.25	260	6.96	6.4	74.20	28	6.49	2
10/10/2015	06:30	82.30	270	5.7	6.84	74.20	28	-12.36	-3
10/10/2015	10:30	85.95	282	11.2	10.7	53.00	20	2.48	1
10/10/2015	18:30	88.70	291	13.2	14.2	53.00	20	-3.73	-1
10/10/2015	22:30	93.27	306	7.88	6.98	45.05	17	5.81	2
10/11/2015	02:30	96.32	316	6.73	9.14	45.05	17	-11.88	-3
10/11/2015	06:30	99.36	326	6.76	7.12	45.05	17	-2.28	-1
10/11/2015	10:30	103.33	339	8.06	9.09	58.30	22	-6.60	-2
10/11/2015	14:30	106.98	351	5.45	5.88	37.10	14	-2.71	-1
10/11/2015	18:30	111.56	366	11.5	12.6	37.10	14	-3.24	-1
10/11/2015	22:30	117.04	384	6.9	6.25	37.10	14	3.86	1
10/12/2015	02:30	122.83	403	6.25	7.3	37.10	14	-5.34	-1
10/12/2015	10:30	136.25	447	5.11	7.75	37.10	14	-12.64	-3
10/12/2015	14:30	143.87	472	6.47	6.68	37.10	14	-1.17	0
10/12/2015	18:30	153.01	502	7.82	8.91	37.10	14	-4.54	-1
10/12/2015	22:30	161.24	529	11.4	13.4	37.10	14	-5.54	-1
10/13/2015	02:30	172.82	567	43.9	46.4	37.10	14	-2.00	-1
10/13/2015	03:40	175.26	575	29.1	34.2	37.10	14	-5.53	-1
10/13/2015	06:30	177.70	583	36.4	41.7	37.10	14	-4.71	-1
10/13/2015	11:00	179.83	590	40.7	47.8	37.10	14	-5.51	-1
10/13/2015	15:00	184.40	605	18.7	20.8	37.10	14	-3.74	-1
10/13/2015	19:00	201.78	662	25.8	26.8	37.10	14	-1.38	0
10/13/2015	23:00	209.70	688	42.2	46.3	37.10	14	-3.28	-1
10/14/2015	02:30	217.93	715	27.3	38.3	37.10	14	-10.65	-3
10/14/2015	06:30	231.65	760	22.6	23.5	37.10	14	-1.42	0
10/14/2015	21:30	251.76	826	21.4	23.6	37.10	14	-3.46	-1
10/15/2015	06:30	253.90	833	29.6	24.2	37.10	14	8.28	2

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 2 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
10/15/2015	10:30	263.65	865	29.4	21.8	37.10	14	11.36	3
10/15/2015	14:30	272.49	894	30.7	27.8	37.10	14	3.87	1
10/15/2015	18:30	302.06	991	16.6	30.1	37.10	14	-16.64	-4
10/15/2015	22:30	324.92	1,066	21.1	18.3	37.10	14	5.68	1
10/16/2015	02:30	347.47	1,140	23.3	21	37.10	14	4.06	1
10/16/2015	06:30	368.81	1,210	35.6	34	37.10	14	1.75	0
10/16/2015	10:30	377.65	1,239	51.2	50.7	37.10	14	0.37	0
10/16/2015	14:30	384.66	1,262	33.3	31.2	37.10	14	2.50	1
10/16/2015	18:30	397.46	1,304	42.8	33.3	37.10	14	10.58	3
10/16/2015	22:30	413.00	1,355	13.6	30.4	37.10	14	-20.50	-5
10/17/2016	00:30	416.36	1,366	20	19.6	37.10	14	0.76	0
10/17/2016	02:30	419.71	1,377	21.9	18.7	37.10	14	6.35	2
10/17/2015	06:30	429.16	1,408	34.6	31.2	37.10	14	4.04	1
10/17/2015	10:30	438.91	1,440	24.6	17.9	37.10	14	14.75	4
10/19/2015	22:30	439.83	1,443	51.8	43.2	37.10	14	7.38	2
10/20/2015	02:30	449.58	1,475	46.8	41.9	37.10	14	4.34	1
10/20/2015	03:30	451.71	1,482	27.9	29.8	37.10	14	-2.36	-1
10/20/2015	04:30	453.85	1,489	20.6	21.6	37.10	14	-1.72	0
10/20/2015	05:30	455.68	1,495	22.2	21.3	37.10	14	1.57	0
10/20/2015	06:30	457.81	1,502	27.1	24.3	37.10	14	4.27	1
10/20/2015	07:30	458.42	1,504	31.9	25	37.10	14	10.24	3
10/20/2015	08:30	459.03	1,506	35.6	25	42.40	16	17.97	5
10/20/2015	09:30	460.55	1,511	28.9	31.7	42.40	16	-3.74	-1
10/20/2015	10:30	462.08	1,516	30.3	31.1	42.40	16	-1.09	0
10/20/2015	11:30	463.60	1,521	28.9	30.7	42.40	16	-2.49	-1
10/20/2015	12:30	464.82	1,525	29.4	33.6	42.40	16	-3.79	-1
10/20/2015	13:30	466.95	1,532	16.9	31	42.40	16	-19.28	-5
10/20/2015	14:30	468.17	1,536	15.5	14	42.40	16	4.54	1
10/20/2015	15:30	470.00	1,542	13.7	17.4	42.40	16	-9.01	-2
10/20/2015	16:30	472.44	1,550	14.3	15.9	42.40	16	-4.27	-1
10/20/2015	17:30	474.57	1,557	10.1	15.2	42.40	16	-14.22	-4
10/20/2015	18:30	476.40	1,563	8.64	9.45	42.40	16	-3.63	-1
10/20/2015	19:30	477.93	1,568	9.28	8	42.40	16	6.78	2

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 3 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
10/20/2015	20:30	480.67	1,577	7.09	7.83	42.40	16	-4.01	-1
10/20/2015	21:30	483.11	1,585	37.5	8.46	42.40	16	145.52	38
10/20/2015	22:40	487.07	1,598	28.2	30.5	42.40	16	-3.20	-1
10/20/2015	23:55	490.42	1,609	56.3	28.4	42.40	16	41.65	11
10/21/2015	00:30	493.47	1,619	69.7	68.1	42.40	16	1.00	0
10/21/2015	01:30	497.43	1,632	76	72.6	42.40	16	1.99	1
10/21/2015	02:30	501.09	1,644	31.1	36.3	42.40	16	-6.07	-2
10/21/2015	03:30	504.14	1,654	30.8	23.2	42.40	16	13.89	4
10/21/2015	04:30	506.27	1,661	27.4	17.2	42.40	16	25.14	7
10/21/2015	05:30	509.63	1,672	14.1	11.4	42.40	16	10.04	3
10/21/2015	06:30	513.28	1,684	14.8	9.02	42.40	16	27.16	7
10/21/2015	07:30	515.72	1,692	14.5	9.94	42.40	16	19.45	5
10/21/2015	15:00	518.16	1,700	16.2	9.64	37.10	14	26.50	7
10/21/2015	16:20	520.29	1,707	49	29.5	42.40	16	28.02	7
10/21/2015	18:00	522.12	1,713	21.3	14.6	42.40	16	19.45	5
10/21/2015	19:00	524.26	1,720	33	14.1	42.40	16	56.82	15
10/21/2015	20:15	527.61	1,731	26	12.3	42.40	16	47.22	12
10/21/2015	21:15	530.66	1,741	7.83	15.5	42.40	16	-20.98	-6
10/21/2015	22:15	532.18	1,746	28.4	5.32	42.40	16	183.91	49
10/21/2015	23:15	533.70	1,751	30.2	12.3	42.40	16	61.69	16
10/22/2015	00:15	534.92	1,755	31.1	11.1	42.40	16	76.38	20
10/22/2015	01:15	536.14	1,759	28.6	9.21	42.40	16	89.25	24
10/22/2015	02:15	537.06	1,762	43.4	11.9	42.40	16	112.21	30
10/22/2015	03:15	538.58	1,767	43.5	14.7	42.40	16	83.05	22
10/22/2015	04:15	540.11	1,772	45.6	14.9	42.40	16	87.34	23
10/22/2015	05:15	541.93	1,778	17.6	8.16	42.40	16	49.04	13
10/22/2015	06:15	543.76	1,784	18.5	5.67	42.40	16	95.92	25
10/22/2015	07:15	545.90	1,791	16.5	4.82	42.40	16	102.73	27
10/22/2015	08:15	546.81	1,794	13	4.55	42.40	16	78.73	21
10/22/2015	09:15	549.25	1,802	11.6	5.24	42.40	16	51.45	14
10/22/2015	10:15	550.77	1,807	9	2.62	42.40	16	103.23	27
10/22/2015	11:15	554.43	1,819	11.6	3.01	42.40	16	120.98	32
10/22/2015	12:15	556.26	1,825	11.8	7.3	42.40	16	26.13	7

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 4 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
10/22/2015	13:15	557.78	1,830	12.6	2.32	42.40	16	187.84	50
10/22/2015	14:15	559.31	1,835	8.96	4.78	42.40	16	37.07	10
10/22/2015	15:15	560.83	1,840	15.2	2.63	42.40	16	202.61	54
10/22/2015	16:15	562.97	1,847	15.3	5.24	42.40	16	81.39	22
10/22/2015	17:15	566.62	1,859	20.4	2.27	42.40	16	338.58	89
10/22/2015	18:15	571.80	1,876	20.1	2.14	42.40	16	355.78	94
10/22/2015	19:15	576.07	1,890	11.6	8.52	42.40	16	15.32	4
10/22/2015	20:15	580.95	1,906	12.1	2.09	42.40	16	203.04	54
10/22/2015	21:15	586.13	1,923	17.8	2.83	42.40	16	224.24	59
10/22/2015	22:15	590.09	1,936	10.8	1.98	42.40	16	188.84	50
10/22/2015	23:15	593.75	1,948	11.4	2.2	42.40	16	177.28	47
10/23/2015	00:15	597.10	1,959	15.8	3.02	42.40	16	179.39	47
10/23/2015	01:15	601.07	1,972	14.6	2.41	42.40	16	214.42	57
10/23/2015	02:15	604.11	1,982	14.8	2.65	42.40	16	194.36	51
10/23/2015	03:15	609.30	1,999	19.5	2.75	42.40	16	258.21	68
10/23/2015	04:15	615.09	2,018	20.1	3.29	42.40	16	216.60	57
10/23/2015	05:15	620.27	2,035	104	28.2	42.40	16	113.95	30
10/23/2015	06:15	624.54	2,049	20.2	14.8	42.40	16	15.47	4
10/23/2015	07:15	629.11	2,064	48.4	6	42.40	16	299.57	79
10/23/2015	08:15	633.68	2,079	55.2	8.89	42.40	16	220.83	58
10/23/2015	09:15	638.25	2,094	47	11.7	45.05	17	135.89	36
10/23/2015	10:15	643.43	2,111	25.6	12.1	45.05	17	50.25	13
10/23/2015	11:15	647.70	2,125	37.8	4.5	45.05	17	333.31	88
10/23/2015	12:15	652.58	2,141	32.2	4.73	45.05	17	261.58	69
10/23/2015	13:15	655.32	2,150	37.6	7.35	45.05	17	185.37	49
10/23/2015	14:15	660.50	2,167	25.8	3.81	45.05	17	259.96	69
10/23/2015	15:15	664.46	2,180	39	6.91	45.05	17	209.17	55
10/23/2015	16:15	669.95	2,198	13.6	2.39	45.05	17	211.26	56
10/23/2015	17:15	674.52	2,213	47.8	3.76	45.05	17	527.56	139
10/23/2015	18:15	680.01	2,231	52.2	7.55	45.05	17	266.37	70
10/23/2015	19:15	683.67	2,243	67.3	5.96	45.05	17	463.56	122
10/23/2015	20:15	689.46	2,262	23	3.49	45.05	17	251.79	67
10/23/2015	21:15	693.42	2,275	24.6	3.52	45.05	17	269.74	71

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 5 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
10/23/2015	22:15	699.21	2,294	23.8	3.8	45.05	17	237.06	63
10/23/2015	23:15	705.00	2,313	16.3	3.02	45.05	17	198.06	52
10/24/2015	00:15	709.88	2,329	16.9	3.66	45.05	17	162.94	43
10/24/2015	01:15	713.84	2,342	37.8	2.31	45.05	17	692.00	183
10/24/2015	02:15	718.41	2,357	39.4	5.87	45.05	17	257.28	68
10/24/2015	03:15	722.38	2,370	12.6	4.22	45.05	17	90.84	24
10/24/2015	04:15	726.34	2,383	10.6	2.19	45.05	17	172.97	46
10/24/2015	05:15	731.22	2,399	21.5	2.88	45.05	17	291.21	77
10/24/2015	21:30	736.09	2,415	30.4	12.8	45.05	17	61.93	16
10/24/2015	23:30	750.42	2,462	32.6	4.44	45.05	17	285.67	75
10/24/2015	00:30	758.04	2,487	40.2	11.6	45.05	17	111.05	29
10/24/2015	01:30	762.00	2,500	39.7	10.2	45.05	17	130.27	34
10/24/2015	02:30	763.83	2,506	50.7	15.2	45.05	17	105.20	28
11/24/2015	07:20	767.79	2,519	12.7	12.1	47.70	18	3.79	1
11/24/2015	08:25	770.84	2,529	19.4	11.3	47.70	18	34.19	9
11/24/2015	09:25	773.89	2,539	16.1	14.8	47.70	18	4.19	1
11/24/2015	10:20	776.94	2,549	16.4	11.9	37.10	14	14.03	4
11/24/2015	11:15	779.98	2,559	18.4	11.5	37.10	14	22.26	6
11/24/2015	12:00	783.03	2,569	43.1	24.5	31.80	12	24.14	6
11/24/2015	12:30	786.08	2,579	40.9	21.4	31.80	12	28.97	8
11/24/2015	13:00	789.43	2,590	48.2	16.2	31.80	12	62.80	17
11/24/2015	13:30	792.18	2,599	42.2	21.1	31.80	12	31.79	8
11/24/2015	14:15	795.22	2,609	24.3	15	31.80	12	19.71	5
11/24/2015	14:30	798.27	2,619	18	14.1	31.80	12	8.79	2
11/24/2015	14:45	801.32	2,629	16.8	9.69	31.80	12	23.33	6
11/24/2015	15:45	810.16	2,658	15.6	5.33	31.80	12	61.26	16
11/24/2015	16:45	813.82	2,670	8.78	2.55	31.80	12	77.68	21
11/24/2015	17:45	816.86	2,680	10	1.39	31.80	12	196.94	52
11/24/2015	18:45	819.91	2,690	19.3	1.25	31.80	12	459.11	121
11/24/2015	19:45	820.83	2,693	27.4	2.26	31.80	12	353.67	93
11/24/2015	20:45	826.62	2,712	28.9	2.4	26.50	10	292.55	77
11/24/2015	21:45	830.88	2,726	41.9	3.44	26.50	10	296.22	78
11/24/2015	22:45	834.54	2,738	36.7	2.92	26.50	10	306.51	81

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 6 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
11/24/2015	23:30	836.98	2,746	22	3.69	26.50	10	131.47	35
11/25/2015	00:30	839.42	2,754	23.4	4.68	26.50	10	105.98	28
11/25/2015	01:30	841.86	2,762	23.7	3.46	26.50	10	154.99	41
11/25/2015	02:30	845.21	2,773	27.9	3.65	37.10	14	246.44	65
11/25/2015	03:30	848.87	2,785	29.6	4.9	37.10	14	186.98	49
11/25/2015	04:30	853.14	2,799	28.4	3.94	37.10	14	230.28	61
11/25/2015	05:30	856.49	2,810	47.4	4.78	37.10	14	330.73	87
11/25/2015	06:30	861.06	2,825	28.6	4.12	37.10	14	220.40	58
11/25/2015	07:30	865.94	2,841	31	4	37.10	14	250.38	66
11/25/2015	08:30	875.08	2,871	18.6	2.82	37.10	14	207.56	55
11/25/2015	09:30	883.01	2,897	23.2	1.86	37.10	14	425.57	112
11/25/2015	10:30	891.54	2,925	18.4	2.08	37.10	14	291.04	77
11/25/2015	12:00	897.94	2,946	19.5	1.93	37.10	14	337.68	89
11/25/2015	13:00	904.95	2,969	27.2	1.27	37.10	14	757.34	200
11/25/2015	14:30	908.91	2,982	28.6	2.65	37.10	14	363.23	96
11/25/2015	15:30	913.79	2,998	29.9	1.01	37.10	14	1,061.01	280
11/25/2015	16:30	918.67	3,014	29.9	0.93	37.10	14	1,155.47	305
11/25/2015	17:30	924.76	3,034	30.9	0.91	37.10	14	1,222.44	323
11/25/2015	18:30	929.64	3,050	33.7	0.98	37.10	14	1,238.45	327
11/25/2015	19:30	934.21	3,065	20.7	1.35	37.10	14	531.67	140
11/25/2015	20:30	937.26	3,075	26.6	1.3	26.50	10	515.63	136
11/25/2015	21:30	944.88	3,100	19.3	0.99	26.50	10	490.02	129
11/25/2015	22:30	950.98	3,120	31.3	0.88	26.50	10	915.88	242
11/25/2015	23:30	956.46	3,138	23.1	1.1	26.50	10	529.90	140
11/26/2015	00:30	964.39	3,164	23.7	1.2	26.50	10	496.78	131
11/26/2015	01:30	969.26	3,180	40.3	1.17	26.50	10	886.11	234
11/26/2015	02:30	975.06	3,199	42.3	1.11	26.50	10	983.18	260
11/26/2015	03:30	979.93	3,215	23.4	1.27	26.50	10	461.68	122
11/26/2015	04:30	984.20	3,229	24.8	1.12	26.50	10	560.18	148
11/26/2015	05:30	988.16	3,242	37.9	1.47	26.50	10	656.61	173
11/26/2015	06:30	993.95	3,261	37.5	1.43	26.50	10	668.30	177
11/26/2015	07:30	996.39	3,269	24	2.01	26.50	10	291.45	77
11/26/2015	08:30	1,002.18	3,288	24.3	0.938	26.50	10	659.89	174

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 7 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
11/26/2015	09:30	1,006.75	3,303	29	1.03	26.50	10	719.48	190
11/26/2015	10:30	1,012.24	3,321	29.9	1.98	26.50	10	373.61	99
11/26/2015	11:30	1,015.59	3,332	32.4	1.48	26.50	10	553.53	146
11/26/2015	12:30	1,020.78	3,349	32.2	1.52	26.50	10	534.78	141
11/26/2015	13:30	1,023.82	3,359	31.7	1.24	26.50	10	650.84	172
11/26/2015	14:30	1,026.57	3,368	33.9	1.51	26.50	10	568.33	150
11/26/2015	15:30	1,030.22	3,380	No analyses	N/A	26.50	10	N/A	N/A
11/26/2015	16:45	1,036.32	3,400	42.4	3.1	26.50	10	335.89	89
11/27/2015	20:30	1,038.76	3,408	16.9	1	26.50	10	421.27	111
11/27/2015	21:30	1,040.28	3,413	21.1	0.99	29.15	11	592.02	156
11/27/2015	22:30	1,043.64	3,424	20.2	1.01	29.15	11	553.75	146
11/27/2015	23:30	1,046.07	3,432	37.9	1.11	29.15	11	965.97	255
11/28/2015	00:30	1,049.12	3,442	40.7	1.24	29.15	11	927.45	245
11/28/2015	01:30	1,050.65	3,447	42.1	1.44	29.15	11	822.93	217
11/28/2015	02:30	1,051.86	3,451	48.8	1.34	29.15	11	1,032.24	273
11/28/2015	03:30	1,053.39	3,456	50.3	1.65	29.15	11	859.32	227
11/28/2015	04:40	1,054.61	3,460	42.5	1.58	29.15	11	754.81	199
11/28/2015	05:30	1,055.22	3,462	41.9	1.57	29.15	11	748.66	198
11/28/2015	06:30	1,056.74	3,467	46.6	1.51	29.15	11	870.28	230
11/28/2015	07:30	1,058.27	3,472	48.8	1.63	29.15	11	843.40	223
11/28/2015	08:30	1,059.79	3,477	46.3	1.21	29.15	11	1,086.05	287
11/28/2015	09:30	1,061.62	3,483	48.4	1.44	29.15	11	950.43	251
11/28/2015	10:30	1,063.14	3,488	47.2	1.06	29.15	11	1,268.61	335
11/28/2015	11:30	1,063.75	3,490	57.7	1.38	26.50	10	1,081.30	286
11/28/2015	12:30	1,064.97	3,494	67.2	1.36	26.50	10	1,282.67	339
11/28/2015	13:30	1,066.50	3,499	48	1.6	26.50	10	768.36	203
11/28/2015	14:30	1,068.32	3,505	64.3	3.09	26.50	10	524.84	139
11/28/2015	17:30	1,071.98	3,517	18	1.16	26.50	10	384.63	102
11/28/2015	18:30	1,073.20	3,521	28	0.641	26.50	10	1,130.85	299
11/28/2015	19:30	1,074.72	3,526	54.9	0.719	26.50	10	1,996.56	527
11/28/2015	20:30	1,077.47	3,535	60.5	1.73	26.50	10	900.06	238
11/28/2015	22:45	1,083.56	3,555	72	1.2	26.50	10	1,563.21	413

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 8 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
11/28/2015	23:30	1,086.31	3,564	78.2	1.79	26.50	10	1,131.00	299
11/29/2015	00:30	1,089.36	3,574	27.8	2.27	26.50	10	297.98	79
11/29/2015	02:00	1,093.01	3,586	30	1.6	26.50	10	470.29	124
11/29/2015	03:00	1,094.54	3,591	88.8	1.39	26.50	10	1,666.14	440
11/29/2015	03:30	1,090.88	3,579	90.3	1.69	26.50	10	1,389.18	367
11/29/2015	04:30	1,099.72	3,608	58.8	3.84	26.50	10	379.21	100
11/29/2015	05:30	1,100.02	3,609	49.6	2	26.50	10	630.58	167
11/29/2015	06:30	1,101.55	3,614	72.2	2	26.50	10	929.97	246
11/29/2015	08:30	1,102.16	3,616	60.9	1.58	26.50	10	994.74	263
11/29/2015	09:30	1,104.90	3,625	72.8	2.42	26.50	10	770.54	204
11/29/2015	10:30	1,109.78	3,641	82	2.38	26.50	10	886.36	234
11/29/2015	12:30	1,114.65	3,657	83.3	1.92	26.50	10	1,123.00	297
11/29/2015	13:30	1,121.66	3,680	81	3.58	26.50	10	572.97	151
11/29/2015	14:30	1,128.06	3,701	82.8	3.56	26.50	10	589.74	156
11/29/2015	15:30	1,131.42	3,712	85.5	2.26	26.50	10	975.86	258
11/29/2015	16:30	1,134.77	3,723	101	2.26	26.50	10	1,157.57	306
11/29/2015	17:30	1,141.17	3,744	79.6	2.9	26.50	10	700.75	185
11/29/2015	18:30	1,146.05	3,760	80.1	1.42	26.50	10	1,468.05	388
11/29/2015	19:30	1,150.01	3,773	72	2.66	29.15	11	759.73	201
11/29/2015	21:40	1,153.06	3,783	87.9	2.18	26.50	10	1,041.81	275
11/29/2015	22:30	1,157.63	3,798	113	2.38	26.50	10	1,231.46	325
11/29/2015	23:30	1,160.37	3,807	102	2.25	26.50	10	1,174.61	310
11/30/2015	00:30	1,165.86	3,825	103	1.78	26.50	10	1,506.64	398
11/30/2015	01:30	1,170.13	3,839	95.7	1.77	26.50	10	1,406.03	371
11/30/2015	02:30	1,172.87	3,848	106	2.28	26.50	10	1,205.29	318
11/30/2015	03:30	1,176.83	3,861	94.4	2.05	26.50	10	1,193.57	315
11/30/2015	04:30	1,180.49	3,873	99.5	2.53	26.50	10	1,015.50	268
11/30/2015	05:30	1,185.67	3,890	96.1	2.32	26.50	10	1,070.99	283
11/30/2015	06:30	1,189.94	3,904	97.8	2.22	26.50	10	1,140.72	301
11/30/2015	07:30	1,192.38	3,912	118	2.49	26.50	10	1,229.09	325
11/30/2015	08:30	1,196.95	3,927	88.3	1.91	26.50	10	1,198.38	317
11/30/2015	09:30	1,200.61	3,939	108	1.57	26.50	10	1,796.09	475
11/30/2015	12:15	1,209.75	3,969	126	4.11	26.50	10	785.76	208

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 9 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
11/30/2015	13:20	1,212.49	3,978	148	2.16	26.50	10	1,788.90	473
11/30/2015	14:25	1,218.29	3,997	132	1.68	26.50	10	2,055.26	543
11/30/2015	15:30	1,219.50	4,001	96.2	2.83	26.50	10	874.15	231
11/30/2015	16:30	1,227.12	4,026	110	1.52	26.50	10	1,890.91	500
11/30/2015	17:30	1,230.17	4,036	57.2	1.06	31.80	12	1,683.88	445
11/30/2015	18:30	1,235.35	4,053	114	1.66	31.80	12	2,151.65	568
11/30/2015	19:30	1,239.93	4,068	43.6	2.14	31.80	12	615.97	163
11/30/2015	20:30	1,244.19	4,082	48.4	2.16	31.80	12	680.63	180
11/30/2015	21:30	1,252.12	4,108	86.2	1.9	31.80	12	1,410.65	373
11/30/2015	22:30	1,259.13	4,131	55.1	4.66	31.80	12	344.14	91
11/30/2015	23:30	1,262.18	4,141	70.9	1.77	31.80	12	1,241.76	328
12/01/2015	00:30	1,265.53	4,152	79.6	1.62	26.50	10	1,275.36	337
12/01/2015	01:30	1,268.88	4,163	75.9	2.27	26.50	10	859.40	227
12/01/2015	02:30	1,272.84	4,176	69.8	2.64	26.50	10	674.02	178
12/01/2015	03:30	1,275.59	4,185	70.2	1.85	26.50	10	978.88	259
12/01/2015	04:30	1,278.33	4,194	84.2	1.64	26.50	10	1,333.80	352
12/01/2015	05:30	1,280.77	4,202	79.2	2.15	26.50	10	949.51	251
12/01/2015	06:30	1,287.17	4,223	107	2.29	26.50	10	1,211.48	320
12/01/2015	07:30	1,292.35	4,240	65.8	2.12	26.50	10	795.85	210
12/01/2015	08:30	1,297.23	4,256	82.3	6.48	26.50	10	310.01	82
12/01/2015	09:30	1,302.72	4,274	65.7	2.24	26.50	10	750.61	198
12/01/2015	11:00	1,313.38	4,309	144	3.11	26.50	10	1,200.28	317
12/01/2015	11:30	1,316.74	4,320	132	2.37	26.50	10	1,449.18	383
12/01/2015	12:00	1,317.04	4,321	149	4.37	26.50	10	876.88	232
12/01/2015	12:30	1,319.17	4,328	130	4.34	26.50	10	767.13	203
12/01/2015	13:30	1,322.22	4,338	82.6	5.48	26.50	10	372.86	99
12/01/2015	14:30	1,325.88	4,350	45.1	2.87	26.50	10	389.86	103
12/31/2015	04:50	1,197.86	3,930	64	11.5	26.50	10	120.96	32
12/31/2015	06:40	1,207.01	3,960	56.4	7.8	26.50	10	165.08	44
12/31/2015	07:40	1,216.15	3,990	64.5	7.34	26.50	10	206.33	55
12/31/2015	08:50	1,225.30	4,020	70.9	7.54	26.50	10	222.64	59
12/31/2015	10:05	1,234.44	4,050	69.6	10.8	26.50	10	144.25	38
12/31/2015	11:15	1,243.58	4,080	67.1	8.19	26.50	10	190.58	50

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-20-12
(Page 10 of 10)

Date	Time	Depth		Bromide Concentration (mg/L)		Injection Rate		Water Production	
		m bgs	ft bgs	Mixing Tank	Discharge Line	Lpm	bbl/hr	Lpm	gpm
12/31/2015	13:00	1,252.73	4,110	69	7.77	26.50	10	208.79	55
12/31/2015	14:05	1,261.87	4,140	107	9.45	26.50	10	273.50	72
12/31/2015	15:35	1,271.02	4,170	109	12.8	26.50	10	199.13	53
12/31/2015	17:00	1,280.16	4,200	87.1	11	26.50	10	183.30	48
12/31/2015	18:15	1,289.30	4,230	85.5	10.5	26.50	10	189.25	50
12/31/2015	19:40	1,298.45	4,260	66.3	6.93	26.50	10	226.99	60
12/31/2015	20:45	1,307.59	4,290	54.9	6.62	26.50	10	193.23	51
12/31/2015	22:00	1,316.74	4,320	121	9.58	26.50	10	308.15	81
12/31/2015	23:15	1,325.88	4,350	116	9.28	26.50	10	304.69	81
01/01/2016	06:00	1,328.01	4,357	46.5	5.92	26.50	10	183.41	48
01/01/2016	06:30	1,328.62	4,359	42.4	5.89	26.50	10	164.23	43
01/01/2016	07:30	1,330.15	4,364	69.5	7.36	26.50	10	223.70	59
01/01/2016	08:30	1,332.28	4,371	68	8.16	26.50	10	194.30	51
01/01/2016	09:30	1,334.11	4,377	67.6	8.68	26.50	10	179.85	48
01/01/2016	10:30	1,336.24	4,384	46.9	5.02	26.50	10	221.04	58
01/01/2016	11:30	1,336.85	4,386	50.9	6.88	26.50	10	169.52	45
01/01/2016	13:30	1,337.77	4,389	57	9.35	26.50	10	135.03	36
01/01/2016	14:30	1,340.21	4,397	78.7	10	26.50	10	182.02	48
01/01/2016	15:30	1,342.03	4,403	67	8.75	26.50	10	176.38	47
01/01/2016	16:30	1,345.08	4,413	111	14.5	26.50	10	176.33	47
01/01/2016	17:30	1,346.91	4,419	122	26.5	26.50	10	95.48	25
01/01/2016	18:30	1,353.31	4,440	40.7	10.6	26.50	10	75.70	20
01/01/2016	19:30	1,356.36	4,450	47.2	7.64	26.50	10	137.19	36
01/01/2016	20:30	1,359.41	4,460	22.9	3.51	26.50	10	146.36	39
01/01/2016	22:30	1,367.64	4,487	55	7.72	26.50	10	162.26	43
01/01/2016	23:30	1,374.95	4,511	50.2	10.8	26.50	10	96.66	26
01/02/2016	01:00	1,375.87	4,514	40.7	5.01	26.50	10	188.74	50
01/02/2016	02:00	1,384.40	4,542	61.9	4.88	26.50	10	309.58	82

bbl/hr = Barrels per hour

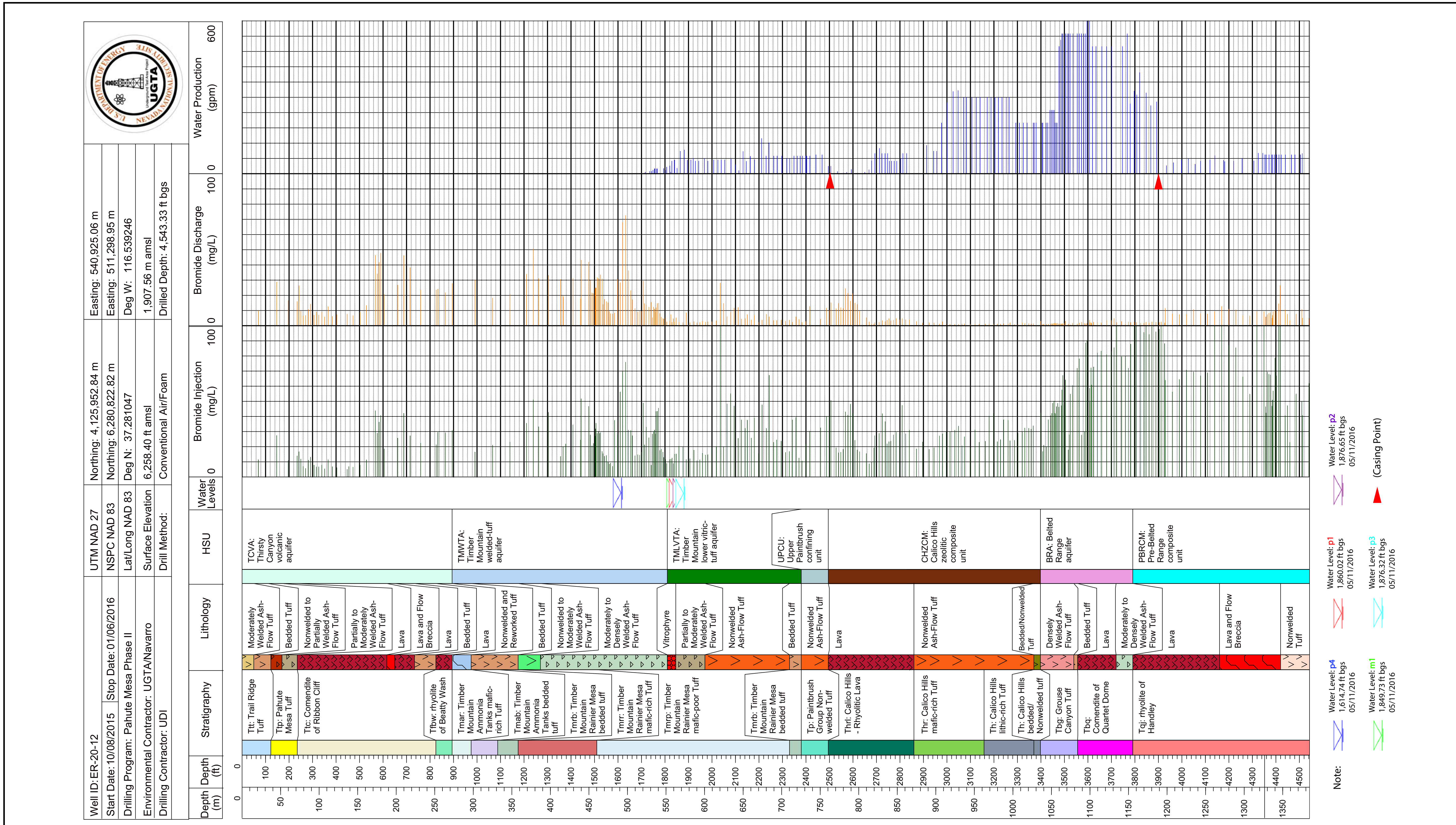


Figure F-1
Bromide and Water Production at ER-20-12

Appendix G

Fracture Data and Analysis for Well ER-20-12

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12
(Page 1 of 8)

Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
526.67	1,727.93	72.80	77.72	Joint
526.86	1,728.54	76.00	71.03	Joint
529.52	1,737.28	92.00	84.15	Joint
535.78	1,757.80	275.15	8.66	Compaction Foliation
535.98	1,758.47	251.01	12.90	Compaction Foliation
536.41	1,759.87	251.01	11.20	Compaction Foliation
536.62	1,760.55	272.23	19.82	Compaction Foliation
540.91	1,774.64	354.55	71.20	Joint
543.01	1,781.54	78.93	70.73	Joint
543.44	1,782.93	246.91	81.85	Joint
544.36	1,785.96	52.67	79.17	Joint
544.66	1,786.95	51.67	78.49	Joint
548.34	1,799.02	185.21	84.42	Joint
549.87	1,804.03	165.80	73.82	Joint
551.36	1,808.91	31.23	38.49	Joint
552.18	1,811.61	55.35	6.97	Lithologic
552.50	1,812.67	288.25	8.58	Bedding Fracture
553.02	1,814.37	251.75	8.15	Bedding Fracture
553.25	1,815.12	277.59	8.10	Bedding Fracture
553.61	1,816.29	277.13	4.83	Bedding Fracture
553.62	1,816.33	292.55	22.17	Joint
554.24	1,818.37	49.72	45.33	Joint
554.87	1,820.45	267.88	13.97	Bedding Fracture
555.56	1,822.70	307.19	3.15	Bedding Fracture
562.54	1,845.62	204.67	8.92	Lithologic
562.91	1,846.81	307.97	24.79	Joint
564.19	1,851.02	350.36	22.69	Joint
567.62	1,862.26	354.22	16.76	Joint
596.92	1,958.41	316.13	2.87	Bedding
597.89	1,961.57	304.94	1.04	Bedding
612.77	2,010.39	274.05	2.83	Bedding

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12
(Page 2 of 8)

Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
613.61	2,013.15	71.75	53.69	Joint
628.06	2,060.55	266.34	1.97	Bedding
669.68	2,197.10	71.75	68.07	Joint
670.10	2,198.49	41.41	2.84	Bedding
670.39	2,199.46	28.91	2.07	Bedding
672.42	2,206.12	9.43	7.78	Bedding
673.85	2,210.79	47.97	1.18	Bedding
674.11	2,211.63	58.20	1.47	Bedding
674.32	2,212.35	38.95	1.30	Bedding
674.49	2,212.90	52.07	1.32	Bedding
676.67	2,220.05	347.29	3.38	Bedding
677.11	2,221.48	18.45	1.28	Bedding
677.41	2,222.49	353.03	2.55	Bedding
677.74	2,223.55	4.51	3.12	Bedding
678.04	2,224.54	353.03	3.15	Bedding
678.74	2,226.83	307.11	5.35	Bedding
682.38	2,238.77	351.39	5.07	Bedding
685.96	2,250.54	323.51	22.17	Bedding
686.23	2,251.40	324.33	25.37	Bedding
686.71	2,252.98	330.89	27.89	Bedding
702.23	2,303.90	328.43	3.10	Bedding
702.84	2,305.90	26.65	1.03	Bedding
704.83	2,312.43	183.69	37.06	Scour
705.91	2,315.97	259.13	4.18	Bedding
706.23	2,317.02	299.73	3.38	Bedding
706.78	2,318.84	353.85	3.38	Bedding
707.85	2,322.35	76.67	0.79	Bedding
708.59	2,324.78	41.41	0.53	Bedding
709.06	2,326.31	17.34	2.22	Bedding
709.33	2,327.20	357.95	1.34	Bedding
709.61	2,328.11	19.27	1.08	Bedding

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12
(Page 3 of 8)

Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
709.83	2,328.82	46.33	1.89	Bedding
709.98	2,329.33	50.43	3.24	Bedding
711.15	2,333.16	320.30	5.40	Bedding
714.50	2,344.17	351.13	1.13	Bedding
722.34	2,369.88	2.87	7.24	Bedding
726.74	2,384.33	314.49	4.32	Bedding
727.76	2,387.67	331.71	4.17	Bedding
728.13	2,388.89	321.05	5.58	Bedding
728.64	2,390.55	336.49	3.68	Bedding
729.07	2,391.95	326.79	4.18	Bedding
729.59	2,393.67	330.07	4.27	Bedding
730.13	2,395.46	321.87	4.00	Bedding
730.56	2,396.84	351.13	2.64	Bedding
732.47	2,403.12	327.61	2.08	Bedding
733.70	2,407.14	305.47	5.37	Bedding
740.99	2,431.08	328.43	19.99	Flow layering
741.48	2,432.67	328.01	19.59	Flow layering
741.91	2,434.10	330.07	20.09	Flow layering
742.14	2,434.85	182.31	43.13	Fault
743.33	2,438.73	334.99	13.87	Flow layering
745.04	2,444.36	332.53	30.94	Flow layering
745.50	2,445.87	328.43	37.15	Flow layering
747.33	2,451.86	324.33	25.35	Flow layering
747.69	2,453.06	346.47	16.08	Flow layering
811.11	2,661.12	358.51	37.28	Flow layering
820.28	2,691.22	351.57	35.27	Flow layering
874.86	2,870.28	349.59	19.12	Bedding
875.84	2,873.49	345.62	23.54	Bedding
878.30	2,881.55	346.61	8.73	Bedding
880.12	2,887.53	359.50	22.25	Bedding
881.36	2,891.62	337.69	19.33	Bedding

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12

Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
882.73	2,896.08	348.60	22.31	Bedding
893.26	2,930.66	344.63	58.04	Joint
893.31	2,930.79	35.21	71.16	Joint
893.57	2,931.66	345.62	65.02	Joint
893.84	2,932.56	355.54	52.48	Joint
895.69	2,938.61	293.55	68.16	Joint
895.81	2,939.03	357.52	64.77	Joint
906.05	2,972.61	293.06	75.48	Joint
912.69	2,994.38	92.23	80.40	Joint
923.73	3,030.62	287.60	72.90	Joint
925.98	3,038.00	333.72	63.32	Joint
930.38	3,052.43	301.98	43.24	Joint
931.78	3,057.01	312.89	48.42	Joint
931.87	3,057.30	312.40	42.95	Joint
934.40	3,065.63	289.09	69.89	Joint
937.06	3,074.34	123.47	41.43	Joint
938.44	3,078.88	189.92	74.34	Joint
938.81	3,080.09	295.54	64.00	Joint
941.51	3,088.94	145.29	42.21	Joint
942.02	3,090.61	332.23	71.27	Joint
942.13	3,090.99	136.86	60.54	Joint
942.25	3,091.37	303.47	66.43	Joint
944.02	3,097.19	322.81	73.48	Joint
944.85	3,099.89	304.96	64.58	Joint
948.23	3,110.98	355.54	9.46	Bedding
948.71	3,112.56	345.62	8.29	Bedding
949.53	3,115.27	70.91	66.64	Joint
950.67	3,118.98	68.93	66.91	Joint
971.34	3,186.80	124.46	43.49	Joint
980.79	3,217.80	120.99	70.46	Joint
981.50	3,220.16	51.07	21.63	Bedding

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12
(Page 5 of 8)

Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
982.13	3,222.22	30.25	23.36	Bedding
983.26	3,225.93	23.31	19.38	Bedding
984.87	3,231.20	15.30	25.50	Bedding
986.03	3,235.00	351.57	12.87	Bedding
986.57	3,236.79	125.95	70.26	Joint
987.87	3,241.03	0.50	25.59	Bedding
988.15	3,241.97	26.28	22.14	Bedding
988.40	3,242.78	28.26	27.13	Bedding
989.30	3,245.74	142.81	69.63	Joint
990.10	3,248.38	17.36	13.60	Bedding
990.90	3,251.00	214.21	--	Tens. Frac
991.01	3,251.36	33.72	--	Tens. Frac
991.27	3,252.21	45.62	--	Tens. Frac
991.57	3,253.18	218.18	--	Tens. Frac
991.67	3,253.52	47.60	--	Tens. Frac
991.75	3,253.78	228.10	--	Tens. Frac
991.95	3,254.43	33.72	--	Tens. Frac
991.95	3,254.44	221.16	--	Tens. Frac
992.53	3,256.33	228.10	--	Tens. Frac
993.76	3,260.38	41.80	--	Tens. Frac
995.04	3,264.58	230.56	--	Tens. Frac
996.26	3,268.56	44.49	--	Tens. Frac
1,000.15	3,281.32	15.37	23.87	Bedding
1,000.89	3,283.77	9.42	22.17	Bedding
1,001.75	3,286.59	11.40	17.04	Bedding
1,003.36	3,291.86	17.36	18.98	Bedding
1,003.75	3,293.13	21.32	18.78	Bedding
1,004.52	3,295.67	291.57	75.73	Joint
1,004.71	3,296.29	169.59	26.43	Joint
1,005.23	3,298.00	291.60	75.70	Fracture/Joint
1,005.94	3,300.34	155.04	37.12	Joint

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12
(Page 6 of 8)

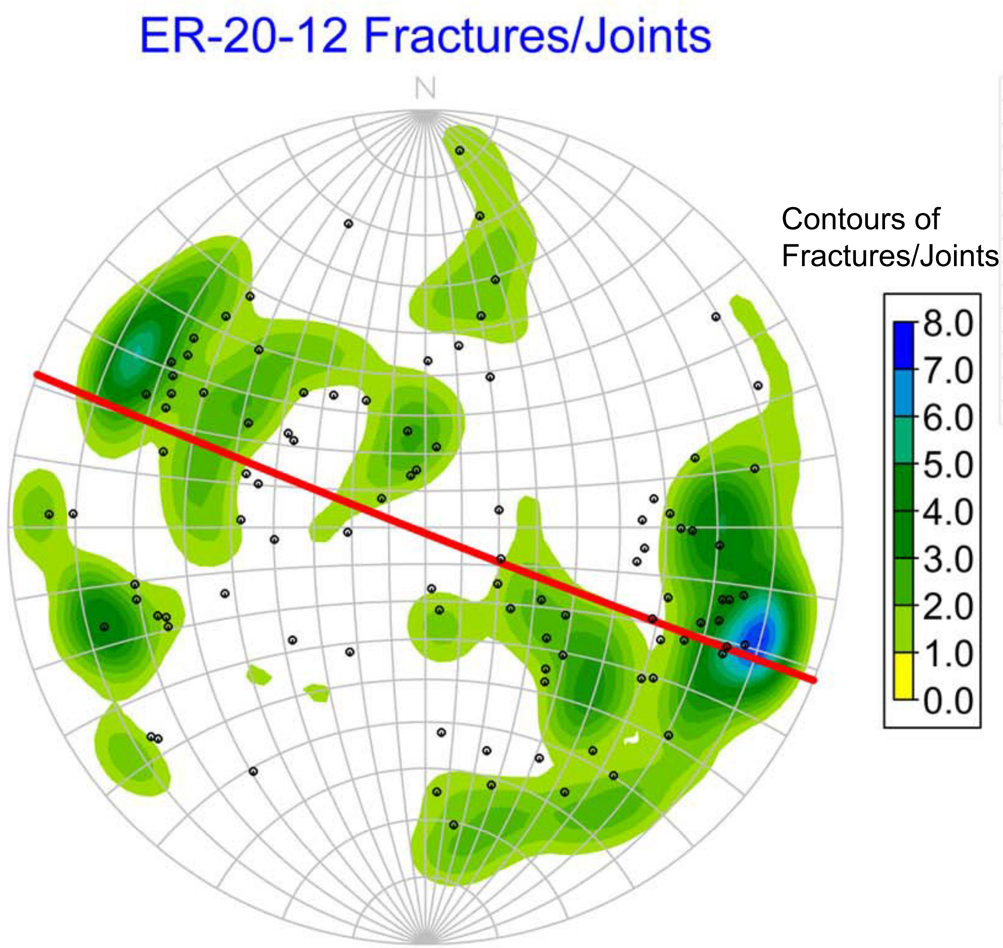
Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
1,008.02	3,307.14	123.50	14.35	Joint
1,010.10	3,313.98	282.04	75.94	Joint
1,011.20	3,317.58	180.88	43.53	Joint
1,012.08	3,320.48	164.23	14.74	Joint
1,012.62	3,322.24	187.88	22.07	Joint
1,013.44	3,324.94	20.33	8.83	Bedding
1,015.64	3,332.16	286.12	62.40	Joint
1,015.91	3,333.03	283.64	72.47	Joint
1,016.45	3,334.80	279.17	54.39	Joint
1,017.14	3,337.06	268.03	54.97	Joint
1,017.43	3,338.02	283.36	73.67	Joint
1,018.43	3,341.30	203.31	42.89	Joint
1,020.19	3,347.08	273.47	70.53	Fracture/Joint
1,021.77	3,352.25	195.77	63.35	Joint
1,022.31	3,354.03	171.24	15.88	Joint
1,026.98	3,369.35	33.22	30.25	Bedding
1,029.13	3,376.40	76.86	16.59	Bedding
1,029.70	3,378.29	68.93	19.32	Bedding
1,030.24	3,380.05	64.96	18.54	Bedding
1,031.41	3,383.88	98.68	21.81	Bedding
1,031.99	3,385.79	94.71	22.94	Bedding
1,032.30	3,386.83	116.53	17.32	Bedding
1,033.01	3,389.13	91.74	22.54	Bedding
1,033.78	3,391.68	111.57	38.77	Bedding
1,034.20	3,393.06	81.82	37.39	Lithologic
1,039.57	3,410.67	310.51	74.97	Joint
1,074.20	3,524.28	123.07	72.00	Joint
1,076.54	3,531.95	104.63	44.98	Joint
1,079.56	3,541.86	114.74	68.83	Joint
1,088.06	3,569.77	301.98	36.29	Joint
1,120.99	3,677.79	256.64	20.57	Joint

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12
(Page 7 of 8)

Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
1,129.93	3,707.12	136.64	69.69	Joint
1,130.46	3,708.86	117.81	69.07	Joint
1,131.08	3,710.89	121.31	63.75	Joint
1,151.26	3,777.10	247.44	36.43	Flow layering
1,151.73	3,778.66	253.39	43.73	Flow layering
1,154.35	3,787.22	238.51	18.61	Flow layering
1,155.30	3,790.37	226.61	28.04	Flow layering
1,163.80	3,818.24	198.39	15.58	Flow layering
1,183.77	3,883.77	94.16	18.05	Flow layering
1,184.43	3,885.92	117.81	17.81	Flow layering
1,187.82	3,897.04	123.94	17.83	Flow layering
1,191.40	3,908.80	108.60	19.70	Flow layering
1,192.41	3,912.11	77.85	33.46	Flow layering
1,193.43	3,915.47	92.73	36.26	Flow layering
1,196.41	3,925.22	110.58	37.30	Flow layering
1,198.07	3,930.69	86.78	30.96	Flow layering
1,199.57	3,935.59	98.68	36.45	Flow layering
1,204.04	3,950.27	86.62	37.91	Flow layering
1,209.73	3,968.93	111.57	20.28	Flow layering
1,210.47	3,971.36	114.55	18.45	Flow layering
1,215.86	3,989.04	89.75	36.26	Flow layering
1,217.40	3,994.10	70.91	25.07	Flow layering
1,224.39	4,017.03	67.88	26.25	Flow layering
1,224.78	4,018.30	106.12	66.36	Joint
1,225.43	4,020.45	69.92	26.69	Flow layering
1,225.76	4,021.53	68.93	31.87	Flow layering
1,237.74	4,060.83	86.53	21.15	Joint
1,249.08	4,098.04	234.06	81.40	Joint
1,249.58	4,099.66	255.56	67.45	Joint
1,256.02	4,120.81	270.69	65.26	Joint
1,259.37	4,131.80	115.49	73.12	Joint

Table G-1
Stratigraphic Feature, Fracture and Fault Data for Well ER-20-12
(Page 8 of 8)

Depth		True Dip Direction	True Dip Magnitude	Contact Type (Fracture Type)
m bgs	ft bgs			
1,259.91	4,133.57	259.86	77.48	Joint
1,274.29	4,180.73	147.27	26.83	Lithologic
1,275.98	4,186.27	145.29	31.79	Bedding
1,276.41	4,187.71	141.32	24.66	Bedding
1,276.87	4,189.19	139.83	20.19	Bedding
1,277.19	4,190.27	148.76	30.39	Bedding
1,278.97	4,196.08	145.79	33.04	Bedding
1,280.75	4,201.93	122.98	25.32	Bedding
1,281.06	4,202.96	91.74	25.00	Bedding
1,329.17	4,360.81	92.39	47.75	Joint
1,332.00	4,370.09	120.58	52.45	Joint
1,337.48	4,388.06	314.89	11.91	Bedding Fracture
1,339.20	4,393.70	266.75	60.85	Joint
1,342.49	4,404.50	194.75	55.36	Joint
1,342.52	4,404.59	190.41	47.80	Joint
1,342.67	4,405.10	275.42	55.65	Joint
1,343.06	4,406.37	291.90	60.79	Joint
1,343.46	4,407.67	290.17	78.43	Joint
1,343.57	4,408.03	262.84	57.81	Joint
1,343.62	4,408.22	270.22	62.99	Joint
1,345.12	4,413.12	24.72	24.80	Bedding Fracture
1,345.85	4,415.53	323.13	67.55	Joint
1,348.05	4,422.73	319.66	47.99	Joint
1,349.18	4,426.46	137.93	47.05	Joint
1,364.23	4,475.82	129.25	71.27	Joint
1,364.76	4,477.57	106.70	48.31	Joint
1,365.50	4,480.00	85.45	39.93	Joint
1,370.34	4,495.87	313.59	31.51	Joint
1,371.30	4,499.03	322.27	50.12	Joint



Statistical Summary	
Projection:	Wulff (Equal Angle)
Number of Sample Points:	99
Mean Lineation Azimuth:	111.7
Mean Lineation Plunge:	7.4
Great Circle Azimuth:	111.5
Great Circle Plunge:	88.5
1st Eigenvalue:	0.491
2nd Eigenvalue:	0.304
3rd Eigenvalue:	0.204
LN (E1 / E2):	0.48
LN (E2 / E3):	0.398
(LN(E1/E2)] / (LN(E2/E3)):	1.206
Spherical Variance:	0.4947
Rbar:	0.5053

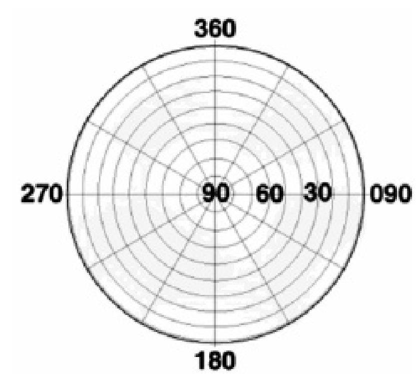
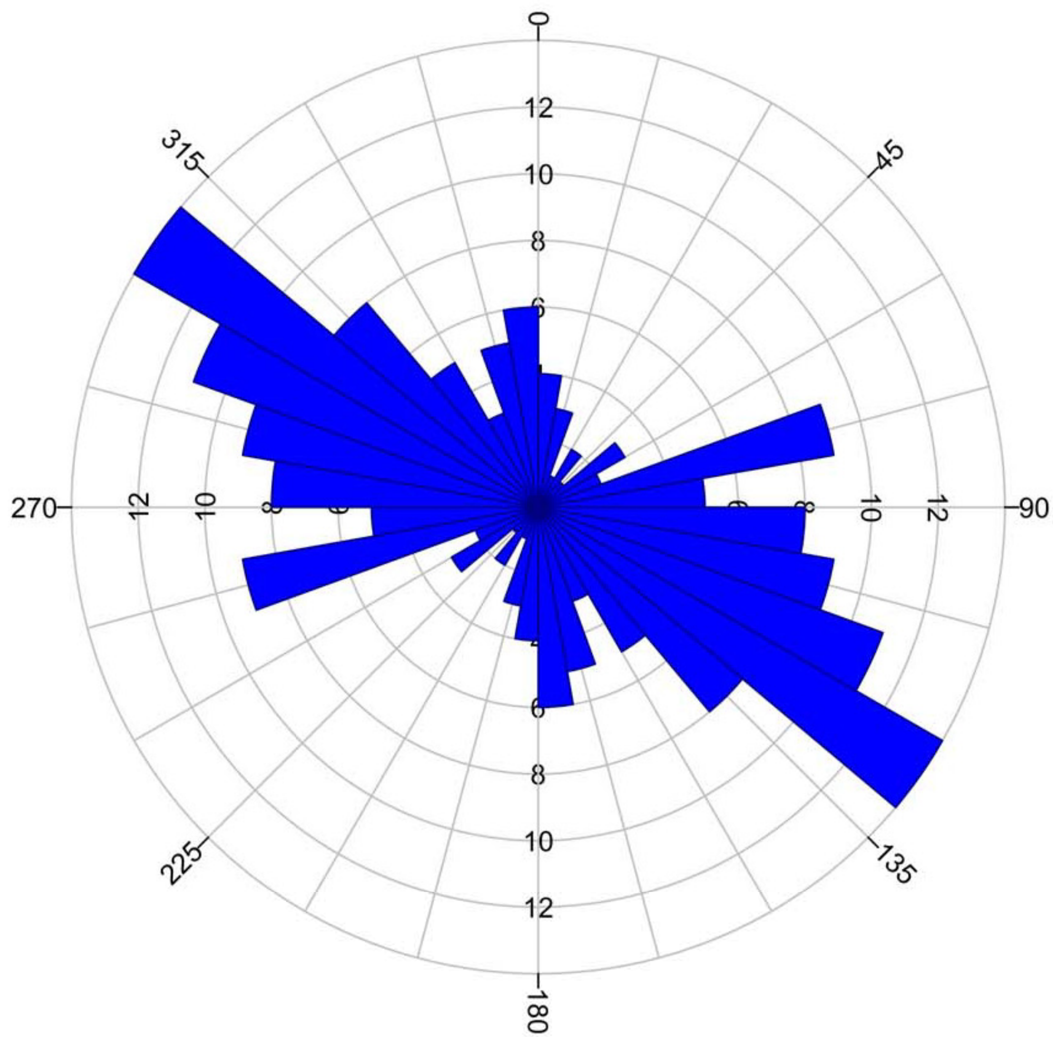


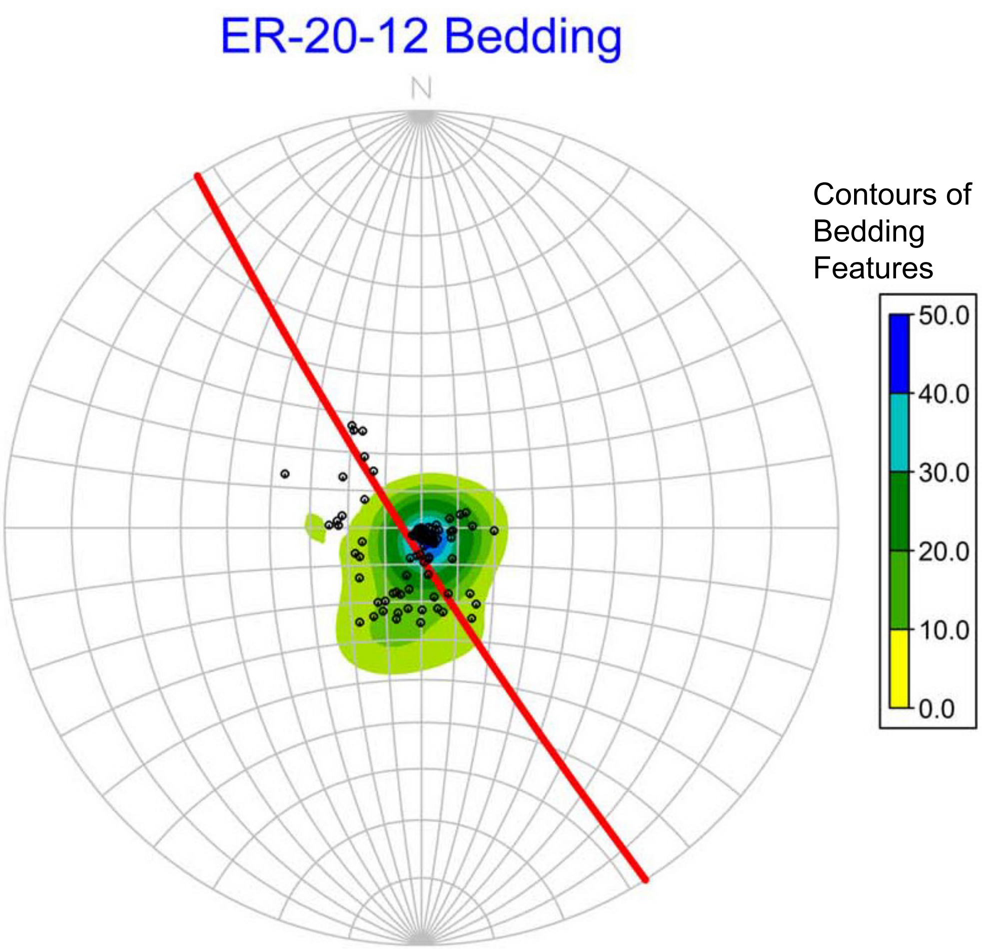
Figure G-1
Stereonet of Fractures and Joints in ER-20-12



Rose Diagram - Fracture/Joints for ER-20-12

Statistical Summary	
Calculation Method:	Frequency
Class Interval:	10.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Bidirectional
Population:	99
Total Length of All Lineations:	198.0
Maximum Bin Population:	14.0
Mean Bin Population:	5.5
Standard Deviation of Bin Population:	3.6
Maximum Bin Population (%):	7.07
Mean Bin Population (%):	2.78
Standard Deviation of Bin Population (%):	1.82
Maximum Bin Length:	14.0
Mean Bin Length:	5.5
Standard Deviation of Bin Lengths:	3.6
Maximum Bin Length (%):	7.07
Mean Bin Length (%):	2.78
Standard Deviation of Bin Lengths (%):	1.82
Vector Mean:	116.8 Degrees
	296.85 Degrees
Confidence Interval:	20.3 Degrees
	(95 Percent)
R-mag:	0.38

Figure G-2
Rose Diagram of Fractures/Joints in ER-20-12



Statistical Summary	
Projection:	Wulff (Equal Angle)
Number of Sample Points:	98
Mean Lineation Azimuth:	200.1
Mean Lineation Plunge:	84.5
Great Circle Azimuth:	147.5
Great Circle Plunge:	85.6
1st Eigenvalue:	0.939
2nd Eigenvalue:	0.038
3rd Eigenvalue:	0.023
LN (E1 / E2):	3.195
LN (E2 / E3):	0.527
(LN(E1/E2)] / (LN(E2/E3)):	6.063
Spherical Variance:	0.0321
Rbar:	0.9679

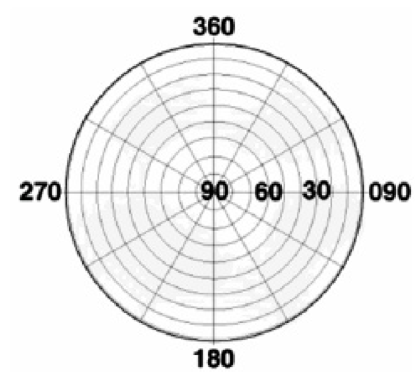
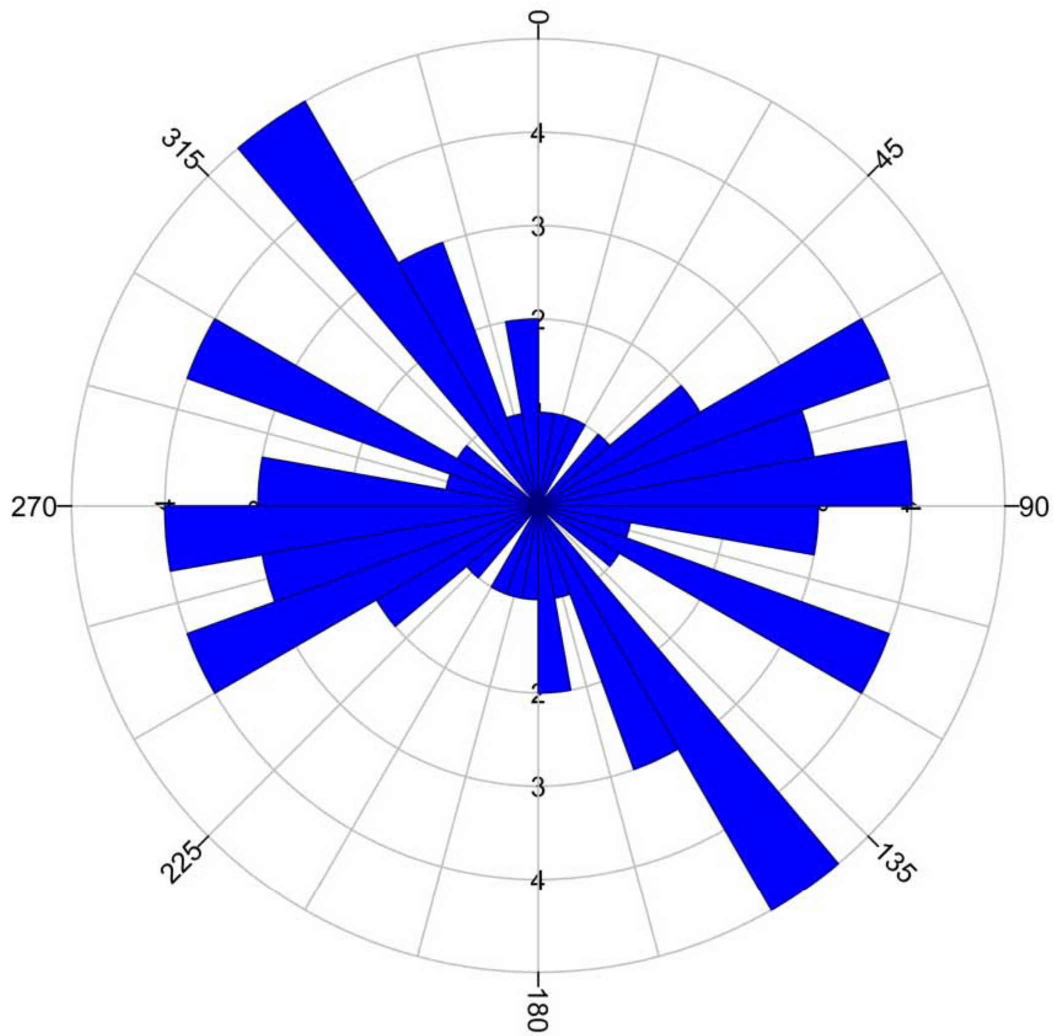


Figure G-3
Stereonet of Bedding Features in ER-20-12



Rose Diagram - Flow Features for ER-20-12

Statistical Summary	
Calculation Method:	Frequency
Class Interval:	10.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Bidirectional
Population:	37
Total Length of All Lineations:	74.0
Maximum Bin Population:	5.0
Mean Bin Population:	2.31
Standard Deviation of Bin Population:	1.38
Maximum Bin Population (%):	6.76
Mean Bin Population (%):	3.13
Standard Deviation of Bin Population (%):	1.86
Maximum Bin Length:	5.0
Mean Bin Length:	2.31
Standard Deviation of Bin Lengths:	1.38
Maximum Bin Length (%):	6.76
Mean Bin Length (%):	3.13
Standard Deviation of Bin Lengths (%):	1.86
Vector Mean:	102.3 Degrees
	282.26 Degrees
Confidence Interval:	53.9 Degrees
	(95 Percent)
R-mag:	0.24

Figure G-4
Rose Diagram of Bedding Features in ER-20-12

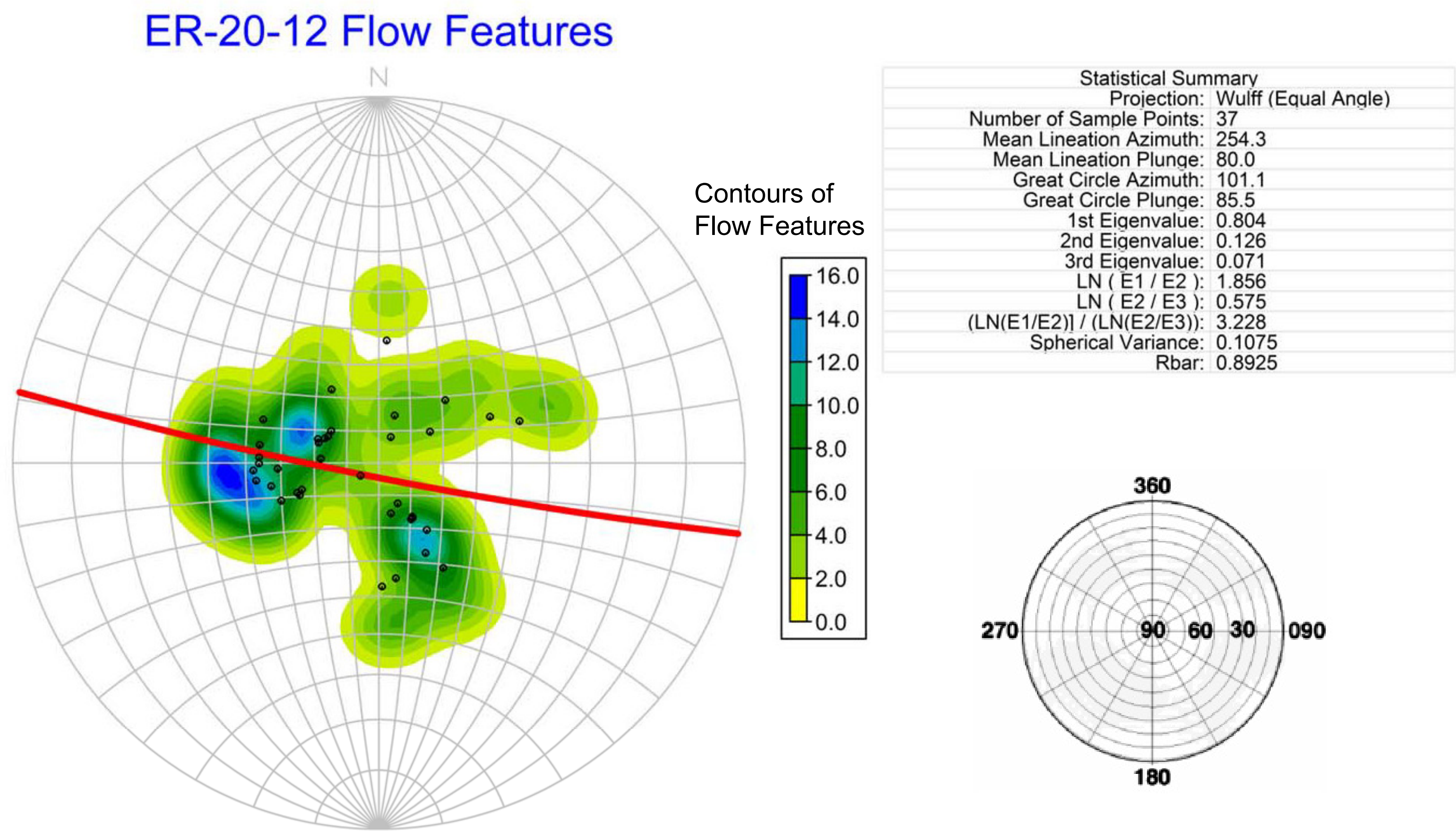
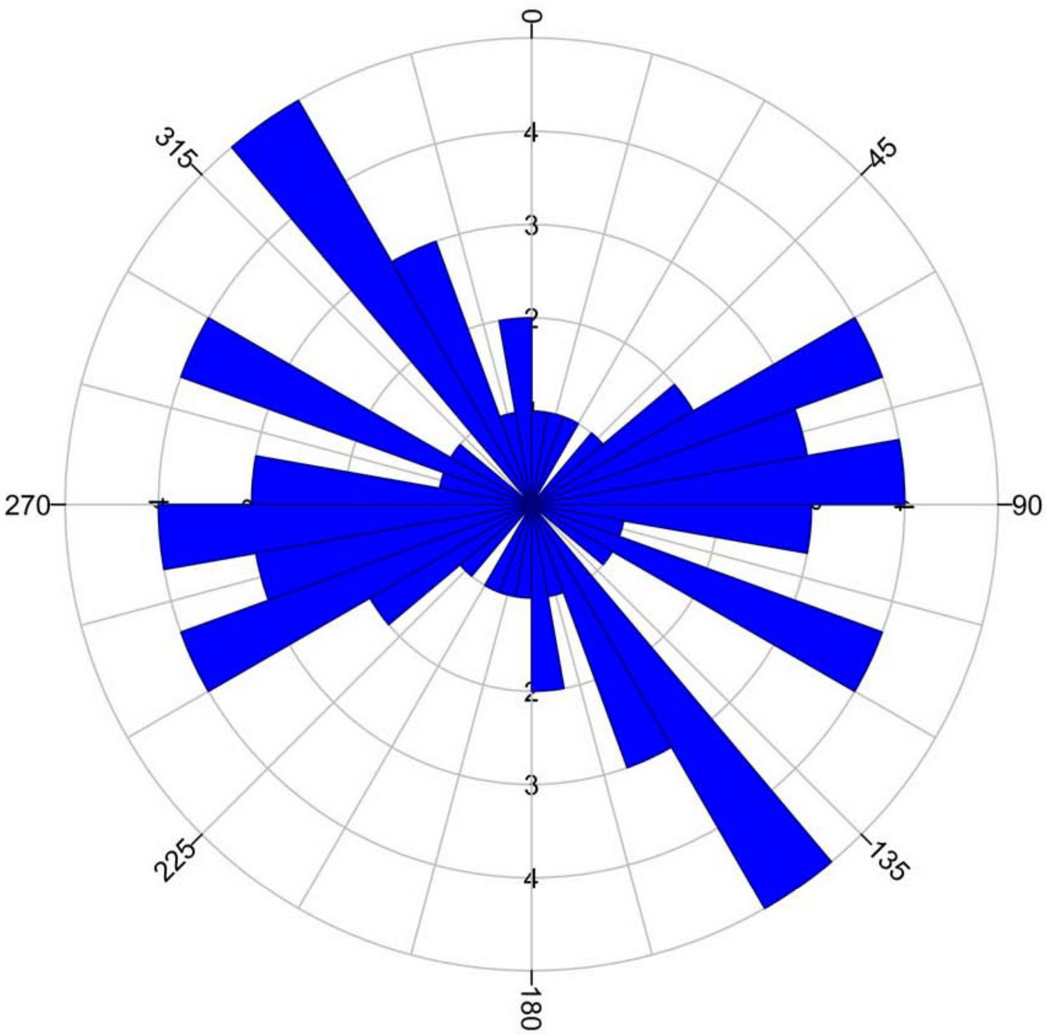


Figure G-5
Stereonet of Flow Features in ER-20-12



Rose Diagram - Flow Features for ER-20-12

Statistical Summary	
Calculation Method:	Frequency
Class Interval:	10.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Bidirectional
Population:	37
Total Length of All Lineations:	74.0
Maximum Bin Population:	5.0
Mean Bin Population:	2.31
Standard Deviation of Bin Population:	1.38
Maximum Bin Population (%):	6.76
Mean Bin Population (%):	3.13
Standard Deviation of Bin Population (%):	1.86
Maximum Bin Length:	5.0
Mean Bin Length:	2.31
Standard Deviation of Bin Lengths:	1.38
Maximum Bin Length (%):	6.76
Mean Bin Length (%):	3.13
Standard Deviation of Bin Lengths (%):	1.86
Vector Mean:	102.3 Degrees
	282.26 Degrees
Confidence Interval:	53.9 Degrees
	(95 Percent)
R-mag:	0.24

Figure G-6
Rose Diagram of Flow Features in ER-20-12

Appendix H

LANL Final Mineralogical and Geochemical Data Report for Samples of Lava and Tuff Cuttings from Well ER-20-12

(15 Pages)

Mineralogical and Geochemical Data Report for Samples of lava and tuff cuttings from Well ER-20-12

Giday WoldeGabriel, Hongwu Xu, and Emily Kluk
Earth Environmental Sciences Division
Los Alamos National Laboratory
Los Alamos, NM 87545

Introduction

Well ER-20-12 was drilled and completed on Western Pahute Mesa on the Nevada National Security Site between October, 2015 and January, 2016. A goal of the well was to obtain detailed hydrogeological information to reduce uncertainties in the hydrostratigraphic framework model (HFM) and improve subsequent groundwater flow and transport modeling for Western Pahute Mesa. XRD and XRF analyses were performed on cuttings from the well to determine sample mineralogy and geochemistry, which was subsequently used to determine the lithology and stratigraphic units of the samples. This report presents the results of the mineralogical and geochemical analyses. Results of this analysis are input for the Well ER-20-12 completion report and ultimately to the HFM.

More than 20 samples of partially to totally altered tuff and lava fragments were selected and screened for XRD and XRF analyses using a binocular microscope to remove contaminants from the dominant fractions of the ER-20-12 drill hole cuttings. Most of the cuttings are coarse sand-sized and contain variable amounts of other rock fragments mixed during sample recovery and drilling. The lava and tuff samples exhibit differences in physical features such as color, grain size, texture, crystal contents, hardness, welding, degree of alteration, etc. The samples are briefly described in descending stratigraphic order to highlight the similarities and differences based on the physical features (Appendix 1). The uppermost two samples (400-410 ft and 710-720 ft below ground surface (bgs)) represent more than 300 ft of similar lava flow. The lava fragments exhibit minor color variation. Both samples are porphyritic and contain quartz, coarse and fractured feldspars, and minor partially altered mafic minerals. The next three samples (840-850 ft, 870-880 ft, and 1050-1060 ft bgs) were also collected from a lava flow that is more than 300 ft thick. The light brown to brownish gray lava fragments are fine grained and crystal-rich and contain coarse and fractured feldspar, quartz, and partially altered mafic minerals. A light brownish gray tuff (1240-1250 ft bgs) was intersected more than 200 ft below the lava sequence. The crystal-rich tuff contains quartz, coarse and fractured feldspars, and partially altered mafic minerals. The dominant tuff fragments are contaminated with minor fractions of other rock types.

A pale red tuffaceous sample (1610-1620 ft bgs) was encountered about 400 ft below the overlying tuff. The unit contains significant amounts of coarse and fractured quartz and feldspars and partially altered biotite grains. The sample is less contaminated with other rock fragments. The next two samples (1830-1840 ft and 1880-1890 ft bgs) are tuffaceous and glassy and were collected more than 200 ft below the overlying tuff. The upper unit (1830-1840 ft bgs) is dark gray vitrophyre-like, whereas the lower tuff (1880-1890 ft bgs) is grayish to medium pinkish orange. Both samples contain similar types and amounts of quartz, feldspars, and biotite and possibly other mafic minerals. More glassy tuffs that appear fairly different from the overlying tuff were encountered down section. The very pale orange tuff samples (2000-2010 ft and 2280-2290 ft bgs) are thick and less porphyritic compared with the previous tuff. Quartz, feldspars, and biotite grains are embedded in a fine-grained matrix. Some pumice fragments were noted within the cuttings. The next sample is yellowish gray tuff (2450-2460 ft bgs) and platy unlike the overlying tuff samples. It is crystal-poor and homogeneous with insignificant amounts of other rock fragments. More tuff samples (2780-2790 ft, 2890-2900 ft, and 3180-3190 ft bgs) that are generally similar to each other were encountered more than 300 ft below the overlying tuff. The uppermost of these samples (2780-2790 ft) is a sparsely porphyritic and pale reddish brown vitrophyre. The underlying two samples are grayish pink, and more porphyritic with more quartz, feldspars, and biotite grains. Minor fractions of other rock fragments were noted in the samples.

Fine-grained lava (3530-3540 ft bgs) was encountered below the tuff sequence. The dark reddish brown fragments are porphyritic and partially altered. A pale olive, platy, and perlite–like (3640-3650 ft bgs) occurs down below the lava flow. The cuttings are sparsely porphyritic and are mixed with minor amounts of brown rock fragments. Additional tuff units were encountered in the lowermost part of the ER-20-12 well. A dark reddish brown tuff (3760-3770 ft bgs), partially contaminated with perlite-like fragments from the overlying unit and grayish pink clasts was intersected above a light to medium gray porphyritic silicic lava (3990-4000 ft bgs). The silicic lava cuttings contain abundant quartz, feldspars and biotite. More tuff samples (4210-4220 ft and 4530-4540 ft bgs) were intersected below the silicic lava flow in the lowermost part of the well. The upper unit (4210-4220 ft bgs) is pale reddish brown, porphyritic and mixed with minor contents of pale olive and grayish pink rock fragments. The lower unit (4530-4540 ft) is very pale orange tuff and appears more crystal-rich than the overlying tuff. Abundant quartz, feldspars, biotite, and possibly hornblende were noted. The cuttings are contaminated by dark gray lava fragments and rounded exotic quartz pebbles. The dominant fractions from each of the samples briefly described above were handpicked and processed for the mineralogical and chemical analyses using the XRD and XRF methods, respectively.

Analytical Methods: Mineralogical Analysis

The powder X-ray diffraction method uses an internal standard and full-pattern fitting for quantitative mineral analysis. Details of this method are available in Chipera and Bish (2002). The full-pattern (FULLPAT) quantitative analysis program for X-ray powder diffraction uses measured and calculated patterns (J. Applied Crystallography, **35**, 744-749). The implementation for the UGTA program is outlined in the standard operating procedures (SOP) listed below.

1. UGTA-LANL-SOP-3.01, Rev. 5: X-ray Diffraction Analyses
2. UGTA-LANL-SOP-3.02, Rev. 5: X-ray Diffraction Data Reduction

The measuring and Test Equipment (M&TE) are listed below

1. Siemens D500 X-Ray Powder Diffractometer, PN 487066 [1A].
2. Siemens D500 X-Ray Powder Diffractometer, PN 743467 [2B].
3. Mettler AE-100 Analytical Balance, PN 620505.

The XRD data are processed and reduced using the following software.

1. MDI Data Scan Version 5.3.7: Instrument operation and data collection software package.
2. MDI JADE Version 9: XRD data analysis software package.

In addition to the equipment and software listed above, an automated Retsch Mill/grinder marketed in the USA by Brinkmann Incorporated was used to grind and homogenize samples for preparation for quantitative X-ray diffraction (QXRD) analyses. Samples to be analyzed are prepared as outlined in the FULLPAT manual, which includes addition of a corundum internal standard and grinding in an automated agate mortar to ensure appropriate fine grain size and homogeneity. Sample preparation data are included below (Table 1). There are no requirements for special measures in shipping or handling of samples. There are no required environmental controls.

Parameters for QXRD analyses acceptance are outlined in the FULLPAT User's Manual. Typically, an analysis is rejected if the total significantly deviates (~5-10%) from 100%. It is up to the analyst to determine whether the analysis is acceptable for the work being conducted. Routine sources of error are outlined in the FULLPAT users' manual.

An approximately 1.3 gram aliquot of each sample was mixed with an internal standard of 1.0 μm corundum using the Mettler AE100 balance PN 620505 in a ratio of approximately 80% sample to 20% corundum. Original entries for weighing are located in the XRDLAB sample-weighing logbook. Samples were ground for a time of approximately 10 minutes under acetone in the Brinkmann automated grinder to reduce the particle size and homogenize the sample and internal standard.

Table 1. ER-20-12 well samples submitted for XRD analyses.

Sample Label	Grams Sample	Grams Al_2O_3	Ratio	Mix Date
ER-20-12-400-410	1.3006/.0008	.3249/.0000	80:20	5/12/2016
ER-20-12-710-720	1.3009/.0019	.3258/.0012	80:20	5/12/2016
ER-20-12-840-850	1.3006/.0020	.3256/.0000	80:20	5/12/2016
ER-20-12-870-880	1.3009/.0023	.3252/.0010	80:20	5/12/2016
ER-20-12-1050-1060	1.3007/.0027	.3259/.0000	80:20	5/12/2016
ER-20-12-1240-1250	1.3005/.0028	.3258/.0000	80:20	5/12/2016
ER-20-12-1610-1620	1.3005/.0017	.3259/.0004	80:20	5/12/2016
ER-20-12-1830-1840	1.3009/.0020	.3257/.0002	80:20	5/12/2016
ER-20-12-1880-1890	1.3007/.0027	.3259/.0000	80:20	5/12/2016
ER-20-12-2000-2010	1.3002/.0020	.3256/.0000	80:20	5/12/2016
ER-20-12-2290-2300	1.3008/.0021	.3254/.0000	80:20	5/12/2016
ER-20-12-2450-2460	1.3007/.0025	.3252/.0000	80:20	5/12/2016
ER-20-12-2780-2790	1.3004/.0020	.3253/.0001	80:20	5/12/2016
ER-20-12-2890-2900	1.3006/.0024	.3250/.0005	80:20	5/12/2016
ER-20-12-3180-3190	1.3004/.0011	.3251/.0000	80:20	5/12/2016
ER-20-12-3530-3540	1.3005/.0015	.3250/.0003	80:20	5/12/2016
ER-20-12-3640-3650	1.3008/.0018	.3251/.0000	80:20	5/12/2016
ER-20-12-3760-3770	1.3003/.0011	.3258/.0003	80:20	5/12/2016
ER-20-12-3990-4000	1.3008/.0013	.3254/.0006	80:20	5/12/2016
ER-20-12-4210-4220	1.3008/.0019	.3257/.0000	80:20	5/12/2016
ER-20-12-4530-4540	1.3004/.0024	.3253/.0000	80:20	5/12/2016

Calibration of the diffractometer

A sample of NIST SRM 640b (Si Powder) was loaded into a cavity in a glass sample mount and run from "~18° 2θ to ~150° 2θ using 0.01-0.02°-2θ steps and counting for at least 1.0 second per step," which is written in our procedures for the various programs for which we conduct work (e.g., UGTA). Using the JADE software program, the peak profiles are fit (using a split-Pearson VII function) to obtain accurate 2θ positions. These values are then compared to the certified values to assess the magnitude of the 2θ errors. For work we conducted for the Yucca Mountain project many years ago, alignment within 0.1°2θ was deemed acceptable. Typically, we keep our diffractometers within 0.02°2θ and will conduct an alignment if we deviate from this control. The QXRD results are given in Table 2.

Analytical Methods: Chemical Analysis

Major and trace element compositions of the unknown samples were determined using an automated Rigaku wavelength-dispersive X-ray fluorescence (XRF) spectrometer. Samples were first crushed and homogenized in 5-10 gram portions in a tungsten-carbide ball mill. Sample splits were heated at 110°C for 4 hours, and then allowed to equilibrate at ambient laboratory conditions for 12 hrs. To obtain the fusion disks, 1.25-gram splits were mixed with 8.75 grams of lithium metaborate-tetraborate flux and heated in a muffle furnace for 45 minutes at 1050°C. Additional one-gram splits were heated at 1000°C to obtain the Loss on Ignition (LOI) measurements to be used in the data reduction program. Elemental concentrations were calculated by comparing x-ray intensities for the samples to those for 19 standards of known composition using "consensus values" from Govindaraju (1994). Intensities were reduced using the de Jongh model empirical method to calculate theoretical matrix correction coefficients (Rigaku, 2009).

Mineralogical Results

The binocular microscope examinations of the ER-20-12 drill hole cuttings provided qualitative information about the various rock types intersected in the well. The qualitative physical features, which include color, texture, hardness, mineral contents, grain size, degree of alteration, etc., were used in the selection of samples for subsequent laboratory analysis. The QXRD method is a fundamental analytical tool that is commonly used to determine the types and abundances of crystalline and non-crystalline compositions of unknown solid materials. Moreover, the QXRD results provide information about the different types and intensities of physical and chemical processes that impacted the rocks in the depositional environment. Based on the quantitative mineralogical results, the various rock types were differentiated and assigned to their respective rock types and stratigraphic units. Moreover, the secondary mineral contents are used to determine the types and intensities of alteration processes that impacted the various volcanic rocks intersected in the ER-20-12 well.

The ER-20-12 samples are clearly differentiated according to their primary (phenocrysts) and secondary mineral contents (Table 2). For example, the uppermost five samples 400 to 1060 ft bgs) are crystal-rich and contain abundant plagioclase (32-57 wt.%) and K-feldspars (0-33.7 wt.%) phenocrysts. The amount of quartz in these samples is <5wt.%, suggesting that these rocks are mafic in composition. This is also consistent with the elevated hematite content (>1 wt.%). The secondary mineral contents (e.g., smectite, mica/illite, opal/CT, and cristobalite) of the lava flows are variable. One of the samples contains significant amount of smectite (870-880 ft). The mica/illite content is misleading because the rocks contain biotite, which is a primary volcanic mineral. The opal/CT and cristobalite contents are also much higher. The tuff sample below the lava sequence is also crystal-rich and contains abundant quartz and feldspars, making it more silicic than the lava flows in the upper part of the well. The silicic rock (1610-1620 ft bgs) contains greater than three times more feldspars (74.3 wt.%) compared with the amount of quartz (21.6 wt.%). Glass shards (24.6-74.6 wt.%) dominate most of the tuffs (1830 ft -2790 ft bgs) from the middle part of the ER-20-12 well and the crystal contents are variable but not as crystal-rich as the lava flows in the uppermost part of the well. Like the lava flows, plagioclase is the most abundant followed by quartz and by K-feldspar in the tuffs. The hematite content is significantly reduced. Based on the secondary mineral contents, the tuff units were subjected to intense alteration processes because the glass shards in some of the tuffs are totally replaced by zeolites and other alteration minerals. For example, the amount of Opal/CT in the tuffs is much higher, whereas the cristobalite content is significantly reduced compared with the lava flows. Moreover, the altered tuffs contain more zeolite, mica/illite, and smectite.

Table 2. Quantitative mineralogical results of the ER-20-12 samples

Sample	Analcime	Smectite	Mica/Illite	Clinoptilolite	Mordenite	Hematite	Opal-C / CT	Cristobalite	Quartz	K-Feldspar	Plagioclase	Hornblende	Glass	Total
ER-20-12-400-410	---	---	5.9	---	---	1.0	4.2	5.2	3.4	31.7	47.9	0.5	---	99.8
ER-20-12-710-720	---	---	12.0	---	---	1.1	6.4	3.9	4.1	31.0	43.0	0.6	---	102.1
ER-20-12-840-850	---	1.0	11.5	---	---	1.5	2.3	5.5	0.8	29.8	47.6	---	---	100.0
ER-20-12-870-880	---	5.2	---	---	---	1.1	3.2	3.6	---	29.8	57.1	---	---	100.0
ER-20-12-1050-1060	---	0.6	16.2	---	---	1.3	0.1	5.6	1.7	24.5	50.0	0.1	---	101.1
ER-20-12-1240-1250	---	---	5.9	---	---	0.6	4.2	20.0	3.3	33.7	32.3	---	---	100.0
ER-20-12-1610-1620	---	---	3.7	---	---	0.4	---	---	21.6	36.0	38.3	---	---	100.0
ER-20-12-1830-1840	---	---	0.3	---	---	---	8.8	3.4	6.9	6.1	13.9	---	60.5	99.9
ER-20-12-1880-1890	---	5.1	1.6	---	---	0.2	13.2	1.1	3.6	3.2	14.2	---	57.9	100.1
ER-20-12-2000-2010	---	---	4.6	3.8	---	0.3	7.8	---	4.9	4.3	8.4	---	66.0	100.1
ER-20-12-2290-2300	---	1.8	6.8	16.2	---	0.3	8.1	---	4.6	5.4	6.1	---	48.6	97.9
ER-20-12-2450-2460	---	1.7	12.5	47.8	---	0.2	6.4	1.3	0.9	0.9	3.6	---	24.6	99.9
ER-20-12-2780-2790	---	---	6.1	3.4	---	---	10.6	---	1.8	1.0	2.4	---	74.6	99.9
ER-20-12-2890-2900	---	---	8.5	40.3	15.5	0.3	7.9	2.9	4.4	10.5	9.6	---	---	99.9
ER-20-12-3180-3190	---	0.9	10.8	49.7	---	0.2	10.5	3.8	5.3	12.4	6.4	---	---	100.0
ER-20-12-3530-3540	---	---	---	---	---	0.7	---	---	30.1	30.7	38.5	---	---	100.0
ER-20-12-3640-3650	---	7.8	7.8	24.5	---	0.2	9.9	---	1.0	3.2	6.7	---	38.9	100.0
ER-20-12-3760-3770	---	---	10.7	1.3	---	0.8	6.6	18.6	5.4	30.1	26.4	---	---	99.9
ER-20-12-3990-4000	---	3.9	9.1	1.5	---	0.7	---	---	38.3	26.4	19.8	---	---	99.7
ER-20-12-4210-4220	---	10.2	18.0	30.9	---	1.0	2.1	---	16.2	7.8	14.1	---	---	100.2
ER-20-12-4530-4540	2.6	15.5	12.3	7.4	---	0.4	---	---	25.1	17.4	18.3	---	---	99.0

Clinoptilolite and mordenite are the dominant zeolites and along with opal/CT significantly decrease with depth unlike smectite and mica/illite. The lava and tuff units in the lowermost part of the ER-20-12 well contain abundant primary minerals (i.e., quartz, K-feldspar, and plagioclase) like the uppermost lavas. However, most of the rocks are dominated by K-feldspar and quartz instead of plagioclase except for one of the samples (3760-3770 ft bgs), which is similar to the lavas in its primary and secondary mineral contents. They are mostly silicic in composition. The lava flow (3990-400 ft bgs) at the base of the section contains twice as much quartz than K-feldspar and plagioclase combined. It also contains considerable amounts of mica/illite and smectite, but the clinoptilolite content is insignificant. The two tuffs (4210-4230 and 4530-4540 ft bgs) at the base of the ER-20-12 well are crystal-rich compared with the other tuffs from the upper parts of the well and contain slightly elevated quartz compared with K-feldspar and plagioclase contents. The alteration mineral contents are also higher. The smectite and mica/illite fractions are much higher than any of the samples described above. Abundant clinoptilolite is present in the upper sample (4210-4220 ft bgs), whereas the lowermost tuff contains fairly abundant analcime, which was not encountered in the rest of the section.

Geochemical Results

Like the mineralogical data of the ER-20-12 samples, the chemical compositions from the XRF analyses clearly discriminate the various lava flows and tuff deposits into their respective units (Table 3). Even though the upper six samples yielded similar mineralogical results, the major and trace element compositions clearly indicate that the samples represent two types of rock formations. The upper two samples (400-410 ft and 710-720 ft bgs) contain slightly higher SiO_2, lower Fe_2O_3, and CaO compared with the underlying three lava flows (840-1060 ft bgs), which have the opposite trend. The lava flows are trachydacite (mafic) in composition and represent two distinct units. The trace element contents of the mafic lava flows are generally similar to each other except for minor differences. The lower lavas (850-1060 ft bgs) have higher Sr and slightly lower Zr and Ba (Table 3).

The upper silicic tuff sample (1240-1250 ft bgs) has slightly higher major (Fe_2O_3, Al_2O_3, CaO, and K_2O) and trace (Ba, Zr, Sr, and lower Rb) element contents compared with the underlying tuffs and probably represents a different unit (Table 3). The next group of tuffs (1620-2290 ft bgs) has generally similar major and trace element contents. Except for minor scattering in the SiO_2 content, the least mobile elements (i.e., Fe_2O_3, Al_2O_3, CaO, TiO_2) and including the alkalis, show very similar compositions. This is also true with the trace element contents.

The next tuff unit (2450-2460 ft bgs) is chemically distinct from the overlying tuff units. It is more mafic (i.e., low SiO_2) and higher in Fe_2O_3, CaO, Sr, Zr, and Ba (Table 3). The underlying three tuffs (2780-3190 ft bgs) belong to the same unit because they have very similar major and trace element compositions. A chemically distinct lava flow (3530-3540 ft bgs) occurs more than 300 ft below the three tuffs described above. It has higher SiO_2, Fe_2O_3, Zn, Y, Nb, Rb, and Zr and the lowest Al_2O_3, CaO, Sr, and Ba contents (Table 3). A low-SiO_2 and -Al_2O_3 and high-CaO tuff (3640-3650 ft bgs) occurs down deep below the high-SiO_2 tuff (3530-3540 ft bgs) described above. However, it has similar trace element contents to the underlying tuff (3760-3770 ft bgs) and lava flow (3990-4000 ft bgs). Despite minor differences in SiO_2, TiO_2, Al_2O_3, and Fe_2O_3 but similar in MgO, and CaO compositions in the lowermost tuffs at the base of the ER-20-12 well, the trace element compositions of the two samples are generally similar.

Discussion and Conclusion

The brief qualitative visual descriptions of the lithologic units intersected in the ER-20-12 well are consistent with the chemical and mineralogical results of the samples (Tables 2 and 3, Appendix 1). Based on the chemical results given in Table 3, at least nine lithologic units with distinct major and trace element compositions are identified. These classifications are also consistent with the mineralogical results except for minor inconsistencies in the lower most part of the sequence. For example, the mineralogical and chemical results of the shallow lavas (410-720 ft bgs) are consistent with each other and represent the same unit. The mineralogical results for the next samples of lavas and tuffs (850-1620 ft bgs) indicate very similar primary mineral (phenocrysts) contents (Table 2). However, the major and trace element results and the lithologic descriptions were helpful to differentiate the samples to their respective stratigraphic units (Tables 3 and 4). The next group of tuffs (2780-3190 ft bgs) yielded correlative chemical and mineralogical results that are consistent to the Calico Hills mafic-rich tuff based on the high Zr and Ba contents compared with the other Calico Hills tuff units. The Grouse Canyon Tuff (3530-3540 ft bgs) is also consistent with the chemical and mineralogical results. The major and trace element compositions are consistent with published data.

Table 3. Major and trace element compositions of the ER-20-12 samples. The major and trace element contents are given in wt.% and ppm, respectively.

Samples	**SiO2**	**TiO2**	**Al2O3**	**Fe2O3**	**MgO**	**MnO**	**CaO**	**Na2O**	**K2O**	**P2O5**	**Total**	**LOI**
ER-20-12-410	67.10	0.72	15.25	4.21	0.64	0.155	1.18	4.91	5.45	0.164	99.77	0.33
ER-20-12-720	66.23	0.66	16.34	4.26	0.59	0.172	1.25	5.28	5.50	0.153	100.43	0.32
ER-20-12-850	64.09	0.80	16.10	5.88	0.66	0.181	1.80	4.98	5.35	0.226	100.06	0.70
ER-20-12-880	63.39	0.75	16.15	5.74	0.85	0.110	2.06	5.07	5.26	0.231	99.60	1.10
ER-20-12-1060	64.35	0.73	16.16	5.66	0.65	0.166	1.87	5.06	5.11	0.228	99.99	0.46
ER-20-12-1250	76.27	0.21	12.95	1.18	0.13	0.051	0.58	3.52	5.42	0.022	100.33	0.27
ER-20-12-1620	77.16	0.15	12.94	0.93	0.19	0.049	0.49	3.39	5.27	0.013	100.58	0.46
ER-20-12-1840	76.36	0.12	12.54	0.81	0.12	0.054	0.51	3.64	4.59	0.011	98.75	2.22
ER-20-12-1890	74.75	0.12	13.16	0.85	0.54	0.068	0.73	3.20	4.46	0.009	97.89	2.59
ER-20-12-2010	75.16	0.11	12.34	0.77	0.12	0.062	0.69	2.90	4.51	0.007	96.67	4.33
ER-20-12-2300	73.50	0.12	12.15	0.82	0.28	0.046	0.81	2.66	4.42	0.010	94.82	6.37
ER-20-12-2460	71.10	0.11	12.06	1.13	0.25	0.050	1.13	2.89	4.02	0.008	92.77	8.26
ER-20-12-2790	74.30	0.12	12.30	1.13	0.10	0.053	0.74	2.91	5.17	0.014	96.84	3.95
ER-20-12-2900	72.27	0.13	12.31	1.21	0.14	0.045	1.58	2.02	5.04	0.017	94.75	4.85
ER-20-12-3190	73.01	0.14	12.39	1.33	0.26	0.024	1.64	1.65	5.01	0.019	95.47	5.01
ER-20-12-3540	78.61	0.12	11.24	1.81	0.01	0.017	0.03	3.74	4.75	0.007	100.33	0.56
ER-20-12-3650	71.94	0.14	11.84	1.28	0.12	0.047	1.79	2.48	3.04	0.023	92.70	8.33
ER-20-12-3770	77.05	0.13	12.43	1.26	0.09	0.040	0.49	3.32	5.29	0.019	100.11	0.76
ER-20-12-4000	77.45	0.17	11.43	1.50	0.18	0.058	0.87	2.63	4.34	0.034	98.66	1.45
ER-20-12-4220	72.97	0.22	12.63	1.80	0.39	0.025	2.04	2.19	3.10	0.049	95.41	5.44
ER-20-12-4540	71.42	0.32	14.51	2.35	0.52	0.044	1.81	2.49	4.32	0.079	97.87	3.03

Samples	V	Cr	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
ER-20-12-410	15	10	4	1	115	161	103	60	822	64	840	9
ER-20-12-720	13	6	2	0	112	128	136	48	832	45	1339	11
ER-20-12-850	18	6	3	0	132	141	199	58	856	56	1099	9
ER-20-12-880	16	7	1	1	121	130	238	54	798	53	1293	10
ER-20-12-1060	14	5	2	1	97	121	221	55	785	54	1242	0
ER-20-12-1250	8	2	6	0	31	135	40	20	169	23	156	13
ER-20-12-1620	8	4	6	0	28	187	21	23	115	28	65	12
ER-20-12-1840	8	4	6	3	32	216	13	26	101	34	39	13
ER-20-12-1890	7	7	5	1	29	238	16	33	104	30	38	12
ER-20-12-2010	6	4	6	3	28	235	48	28	95	31	43	12
ER-20-12-2300	6	6	6	1	29	180	52	26	104	23	90	15
ER-20-12-2460	8	8	8	4	37	161	86	22	128	21	166	16
ER-20-12-2790	6	6	6	2	33	192	75	22	121	21	358	19
ER-20-12-2900	7	7	6	2	31	170	84	32	126	19	429	25
ER-20-12-3190	7	5	6	2	37	163	109	16	154	20	513	13
ER-20-12-3540	7	9	9	2	115	216	0	58	469	42	5	13
ER-20-12-3650	9	6	5	2	44	214	76	19	166	28	239	12
ER-20-12-3770	7	6	6	0	41	176	46	39	177	35	182	16
ER-20-12-4000	10	8	4	1	51	159	63	31	186	30	229	14
ER-20-12-4220	13	8	6	3	52	110	478	29	233	26	602	8
ER-20-12-4540	20	7	6	1	54	134	356	28	284	25	922	11

The tuffs (3640-3650 ft and 3760-3770 ft bgs) and lava (3990-400 ft bgs) yielded variable mineralogical compositions that are consistent with the major element contents especially with regard to SiO_2, Al_2O_3, CaO, Fe_2O_3, and the alkalis (Table 3). However, the trace element compositions of the three samples are very similar to each other. Based on major and trace element results, the three samples are assigned to the Tunnel Beds – Tn3BC, which are similar to published chemical results. Published Tbq data show that the unit has high Fe2O3 (1.29-2.76 wt.%), variable CaO (-0.11-5.23 wt .%), low Ba (-52-119 ppm) and high Zr (298-1344 ppm). The mineralogical results of the lowermost two samples (4210-4220 ft and 4530-4540 ft bgs) in the ER-20-12 well are generally similar to each other but SiO_2, Al_2O_3, and Fe_2O_3 exhibit minor inconsistencies. Slight variations are also noted in the Ba and ZR contents. Based on comparison of the major and trace element contents with published data, the two samples appear to correlate with Ton2 instead of Tqj (Rhyolite of Handley). The published SiO_2, MgO, TiO_2, and Fe_2O_3 contents of the Ton2 results are more similar to the ER-20-12 samples than to the Tqj data.

Table 4. Preliminary stratigraphic assignments of the ER-20-12 well lithologic units

ER-20-12-410 ER-20-12-720	Ttc – Comendite of Ribbon Cliff
ER-20-12-850 ER-20-12-880 ER-20-12-1060	Tmar – Timber Mountain Ammonia Tanks mafic-rich lava
ER-20-12-1250	Tmrr – Timber Mountain Rainer Mesa mafic-rich tuff
ER-20-12-1620 ER-20-12-1840 ER-20-12-1890 ER-20-12-2010 ER-20-12-2300	Tmrp – Timber Mountain Rainer Mesa mafic-poor tuff
ER-20-12-2460	Tp – Paintbrush Group nonwelded tuff
ER-20-12-2790 ER-20-12-2900 ER-20-12-3190	Thr – Calico Hills mafic-rich tuff
ER-20-12-3540	Tbg – Grouse Canyon Tuff
ER-20-12-3650 ER-20-12-3770 ER-20-12-4000	Tn3BC- Tunnel Beds
ER-20-12 4220 ER-20-12 4540	Ton2

Acknowledgement

The UGTA program funded the investigation.

References

Chipera, S.J., and Bish, D.L., 2002, FULLPAT: A full-pattern quantitative analysis program for X-ray powder diffraction using measured and calculated patterns. J. Applied Crystallography, 35, 744-749.

Govindaraju, K., 1994, 1994 compilation of working values and sample description for 383 geostandards, Geostandards Newsletter, 18, 15-35.

MDI Data Scan Version 5.3.7 (1995-2014) An Automated Control and Data Acquisition System for X-Ray Diffractometers, USERS MANUAL, copyright 1995-2014, Material Data, 1224 Concannon Blvd., Livermore, CA 94550.

MDI JADE Version 9 (2013), XRD data analysis software package Materials Data, Inc. (2013) Jade XRD Pattern Processing, Users Manual. Materials Data Inc., 1224 Concannon Blvd., Livermore, CA, 94550. TIC 254786.

Rigaku Corporation, 2009, ZSX Primus Series Instruction Manual.

Siemens D500/501 Operating Instructions, C72000-B3463-A42, Siemens Corporation, Cherry Hill, New Jersey.

ZSX Primus Series Instruction Manual, Rigaku Corporation, 2009.

Appendix 1. Simplified ER-20-12 Well Sample Lithologic Descriptions

Sample Interval (ft bgs)	**Lithologic Description**
400-410	Medium light gray lava fragments. Drill cuttings are porphyritic, containing quartz, partially altered mafic minerals, and coarse and fractured feldspar. Rock fragments are partially altered and/or oxidized.
710-720	Light brownish gray lava fragments are porphyritic and granular. Quartz, coarse and fractured feldspar and partially weathered mafic minerals noted. Cuttings contaminated with less abundant other fragments.
840-850	Brownish gray, fine grained with microcrystalline matrix and abundant phenocrysts. Cuttings are contaminated with other lithic fragments.
870-880	Light brown cuttings are similar to previous sample. Coarse and fractured feldspar, quartz and partially altered mafic minerals are commonly noted. The cuttings are contaminated with other rock fragments.
1050-1060	The sample has two types of rock fragments. Both light and brownish gray fractions contain fractured and partially altered felsic and mafic minerals.
1240-1250	Light brownish gray, porphyritic tuff fragments, containing coarse and fractured feldspars, quartz, and partially altered mafic minerals. Contains minor contents of other rock fragments.
1610-1620	The pale red cuttings are tuffaceous and are less contaminated by other fragments. The cuttings are porphyritic containing abundant coarse and fractured feldspar, quartz and partially altered biotite grains.
1830-1840	The cuttings are medium gray to dark gray vitrophyre-like fragments. Phenocrysts of coarse and fractured quartz, feldspar, and biotite are commonly noted.
1880-1890	The rock fragments are grayish to medium orangish pink tuff and are porphyritic. Abundant quartz and feldspar with minor mafic minerals of biotite and possibly pyroxene noted. Other rock fragments represent a minor fraction.
2000-2010	The very pale orange tuff fragments are porphyritic with less abundant quartz, feldspar, and biotite grains in a microcrystalline matrix. Few collapsed and stretched pumice clasts are present. Minor contents of other fragments are present.
2280-2290	The cuttings are very pale orange similar to previous sample but less porphyritic. More other rock fragments are present.

2450-2460	The rock fragments are yellowish gray tuff, sparsely porphyritic, platy, and contains very few other rock fragments.
2780-2790	Medium gray and pale reddish brown vitrophyric rock fragments. The fragments appear glassy and are sparsely porphyritic.
2890-2900	Grayish orange to grayish pink tuff fragments. Cuttings are porphyritic, nonwelded, and contain biotite, quartz, and feldspar grins. Few other rock fragments are present.
3180-3190	The cuttings are nonwelded grayish orange to grayish pink tuff fragments. Phenocrysts of quartz, feldspar, and biotite noted. Minor dark brown rock fragments are present.
3530-3540	Fine-grained dark reddish brown lava fragments are sparsely porphyritic. Minor grayish lithic fragments are mixed with the cuttings.
3640-3650	Pale olive, platy, perlite-like rock fragments. They are sparsely porphyritic. Minor brown rock fragments are mixed with the dominant fraction.
3760-3770	The drill cuttings consist of abundant dark reddish brown fragments mixed with minor pale olive and grayish pink fractions. The dark brown fraction is fine-grained and porphyritic.
3990-4000	The cuttings are light to medium gray and porphyritic lava. Quartz, feldspar, and biotite are the dominant phenocrysts. Minor fractions of dark brown and pale olive perlite are mixed with the dominant fraction.
4210-4220	Abundant pale reddish brown fragments are mixed with minor pale olive and grayish pink fractions. The pale reddish brown tuff fragments are porphyritic.
4530-4540	The very pale orange tuff fragments contains abundant felsic and mafic minerals. Quartz, feldspar, biotite, and hornblende were noted. Fairly abundant dark gray lava and exotic quartz pebbles and other clasts were also noted.

Library Distribution List

	Copies
U.S. Department of Energy Office of Scientific and Technical Information P.O. Box 62 Oak Ridge, TN 37831-0062	1 (Uncontrolled, electronic copy)
Southern Nevada Public Reading Facility c/o Nuclear Testing Archive P.O. Box 98521, M/S 400 Las Vegas, NV 89193-8521	2 (Uncontrolled, electronic copies)
Manager, Northern Nevada FFACO Public Reading Facility c/o Nevada State Library & Archives 100 N. Stewart Street Carson City, NV 89701-4285	1 (Uncontrolled, electronic copy)