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Underground Test Area Activity Sampling Technologies Evaluation Report, Nevada National Security Site, Nye County, Nevada

Revision No.: 0

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/s/ Joseph P. Johnston **09/30/2015**
Joseph P. Johnston, Navarro CO Date

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UNDERGROUND TEST AREA ACTIVITY SAMPLING TECHNOLOGIES EVALUATION REPORT, NEVADA NATIONAL SECURITY SITE, NYE COUNTY, NEVADA

Revision No.: 0
September 2015

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Approved by: Ken Rehfeldt Date: 9/30/2015

Ken Rehfeldt, UGTA Project Manager
Navarro

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LIST OF ACRONYMS AND ABBREVIATIONS

General Acronyms and Abbreviations

ALS	American Laboratory Service
ARS	American Radiological Service
CADD	Corrective action decision document
CAI	Corrective action investigation
CAP	Corrective action plan
CAU	Corrective action unit
COC	Contaminant of concern
COPC	Contaminant of potential concern
CR	Closure report
CS	Carbon steel
DRI	Desert Research Institute
EC	Electrical conductivity
EPS	Environmental Program Services
ES	Electric submersible
ft	Foot
gal	Gallon
gpm	Gallons per minute
HSU	Hydrostratigraphic unit
in.	Inch
ISPID	Integrated Sampling Plan Identification
L	Liter
LLNL	Lawrence Livermore National Laboratory
m	Meter
MDC	Minimum detectable concentration
mg/L	Milligrams per liter
M&O	Management and Operating
N/A	Not applicable
NAD	North American Datum
NNES	Navarro Nevada Environmental Services, LLC
NNSS	Nevada National Security Site
NSPC	Nevada State Plane Coordinate

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

NTU	Nephelometric turbidity unit
NWIS	National Water Information System
pCi/L	Picocuries per liter
PXD	Pressure transducer
RPM	Reservoir performance monitor
SD	Standard deviation
SDWA	*Safe Drinking Water Act*
SEC	Specific electrical conductivity
SNJV	Stoller-Navarro Joint Venture
SS	Stainless steel
SU	Standard unit
TFM	Thermal flowmeter
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WL	Water level
°C	Degrees Celsius
µmhos/cm	Micromhos per centimeter

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

AA	Alluvial aquifer
ATCU	Argillic tuff confining unit
BA	Benham aquifer
BFCU	Bullfrog confining unit
BLFA	Basalt lava flow aquifer
BRCU	Belted Range confining unit
CFCM	Crater Flat composite unit
CHCU	Calico Hills confining unit
CHZCM	Calico Hills zeolitic composite unit
CPA	Comb Peak aquifer
FCCM	Fortymile Canyon composite unit
FCCU	Fluorspar Canyon confining unit

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

LCA	Lower carbonate aquifer
LCA3	Lower carbonate aquifer-thrust plate
LCCU	Lower clastic confining unit
LPCU	Lower Paintbrush confining unit
LTCU	Lower tuff confining unit
LVTA	Lower vitric-tuff aquifer
MPCU	Middle Paintbrush confining unit
OAA	Older alluvium
OSBCU	Oak Spring Butte confining unit
PBPCU	Post-Benham Paintbrush confining unit
PLFA	Paintbrush lava-flow aquifer
RMWTA	Rainier Mesa welded-tuff aquifer
RVA	Redrock Valley aquifer
SPA	Scrugham Peak aquifer
TCA	Tiva Canyon aquifer
TCVA	Thirsty Canyon volcanic aquifer
THCM	Tannenbaum Hill composite unit
THLFA	Tannenbaum Hill lava-flow aquifer
Thp	Mafic-poor Calico Hills formation
Tmab	Bedded Ammonia Tanks tuff
Tmap	Mafic-poor Ammonia Tanks tuff
Tmar	Mafic-rich Ammonia Tanks tuff
Tmat	Rhyolite of Tannenbaum Hill
TMCM	Timber Mountain composite unit
Tml	Rhyolite of the Loop
TMLVTA	Timber Mountain lower vitric-tuff aquifer
Tmrf	Rhyolite of Fluorspar Canyon
Tmrp	Mafic-rich Rainier Mesa tuff
Tmrr	Mafic-rich Rainier Mesa tuff
TMWTA	Timber Mountain welded-tuff aquifer
Tp	Paintbrush group, undivided
Tpb	Rhyolite of Benham
Tpcm	Pahute Mesa lobe of Tiva Canyon tuff

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

Tpcy	Tuff of Pinyon Pass
Tps	Rhyolite of Scrugham Peak
Tptm	Pahute Mesa lobe of Topopah Spring tuff
Tpw	Rhyolite of Windy Wash
TSA	Topopah Spring aquifer
UCCU	Upper clastic confining unit
UPCU	Upper Paintbrush confining unit

Elements and Compounds

Br	Bromide
C	Carbon
Ca	Calcium
Cl	Chloride
DO	Dissolved oxygen
F	Fluoride
K	Potassium
Mg	Magnesium
Na	Sodium
SO_4	Sulfate

1.0 BACKGROUND

The Underground Test Area (UGTA) Activity Topical Committee on Well Development and Sampling evaluated several methods for collecting representative groundwater samples, including currently used methods and some existing alternative technologies that may be used once aquifer testing and evaluations are performed. The purpose of the evaluation was to identify more cost-effective methods for collecting groundwater samples from UGTA wells. Consideration was given to the cost of sampling existing UGTA multiple-completion wells because of the time and expense required to reconfigure the wells for independent purging of completion intervals. Criteria for evaluating alternative technologies included the ability to deploy the sampling apparatus within existing completion casing and smaller-diameter access tubing or piezometer tubes; and the withdrawal of groundwater from depths of 600 meters (m) or more.

Alternative technologies the committee evaluated included the jack pump, BESST Blatypus (air/gas operated), and MagLift (prototype wireline deployed electric pump) systems. A summary of the Topical Committee’s recommendations is presented in *Background Information for the Nevada National Security Site Integrated Sampling Plan* (N-I, 2014a). In general, the following determinations were made:

- The submersible pump is the only technology that can be used in the deeper intervals of a multiple-completion well if piezometers and appropriate annular seals are absent in the annular space and if access tubes have not been installed in the primary casing along with seals to isolate the intervals.
- The jack pump is the technology of choice for piezometers with a 2 7/8 inch (in.) or less diameter, as long as water-level measurements are not desired from the well in which the jack pump will be used. The jack pump should not be considered as a mobile technology. A cost-benefit analysis of the jack pump versus the submersible pump is needed to determine which technology is more cost effective.
- The bailer is the technology of choice for wells where limited sample volumes are to be collected if ambient flow is known to occur in the well in the zone of interest, and it has been characterized to a degree such that defensibly purged samples can be obtained.
- The BESST Blatypus pump was the mobile technology of choice when purging is required. The technology is easily deployed, can purge a well (albeit at low rates), can lift water from

the depth of interest, and does not strongly impact the sample's water quality. The reliability of the unit has to be established; and the efficacy of the modifications, in terms of long-term economical pumping, needs to be determined. The BESST Blatypus system should undergo field testing to determine whether it is the optimal choice for mobile technologies that can effectively purge wells/piezometers.

This report presents the results of the next stage of sampling technology evaluations as described in *Underground Test Area Activity Sampling Technologies Methods Plan* (N-I, 2014b). Testing of the BESST Blatypus system was originally planned; however, communications with the vendor indicated it is premature for the UGTA Activity to field test this technology. The system currently uses latex tubing and nitrogen gas to push the water to the surface. The large amount of nitrogen gas needed due to the depths of the UGTA wells makes this unfeasible. Also, the latex tubing will likely not hold up in steel tubing. Instead, three technologies were evaluated: depth-discrete bailer, jack pump, and submersible pump. Each of these is a proven technology for certain conditions. The evaluation includes logistical and operational data collected during the purging of the well or completion interval and groundwater sampling at three wells. These techniques are described as follows:

- **Depth-Discrete Bailer.** Depth-discrete bailer samples are routinely collected for the UGTA Activity during drilling and well development and testing. These samples are used primarily for screening and fluid management purposes only and have not been considered representative of groundwater in the formation. The depth-discrete bailer can be deployed quickly and is useful for collecting small sample quantities. The sample collection depth is typically based on flow or temperature logging during drilling and testing. A depth-discrete bailer is not typically used to purge a well because most bailers provide less than 2-liter (L) volumes.

- **Jack Pump.** The jack pump can be deployed in a small-diameter tubing such as a piezometer, which is typically less than 3 in. in diameter. The jack pump requires rods and a pump to be installed in the well, so it is somewhat resource intensive to deploy. The pump and rods can either be left in place or removed; however, if left in place, water levels cannot be collected. If removed, the rods and pump can be decontaminated and used in another well, although it is inefficient timewise and costly to do so. The quality of the samples collected from the jack pump is expected to be consistent with the submersible pump because both are capable of purging the well to achieve stable water-quality parameters.

- **Submersible Pump.** The submersible pump has been the primary method of sample collection for the UGTA Activity. Typically, an electric submersible pump is installed in a well for sampling after development and testing. Samples are collected after purging the well and achieving stable water-quality parameters; consequently, the submersible pump is considered the standard against which other technologies are compared. In multiple-completion wells, the pump is placed in the uppermost completion zone with the lower zones isolated using bridge plugs. Once the pump is installed, it is labor intensive to sample other zones.

ER-EC-11, ER-20-8, and ER-20-8 #2, located on Pahute Mesa (Figure 1-1), were selected for testing because of their construction and proximity to known tritium contamination. These wells were recently completed as large-diameter wells with accessible piezometer strings during the Phase II characterization of the Pahute Mesa corrective action units (CAUs). ER-EC-11 and ER-20-8 have zones that were sealed off during drilling after encountering tritium, and these zones have not been developed or sampled since installation. The accessible zones are isolated from each other with bridge plugs and have been sampled, so some historic data are available for comparisons, although the lower two zones in ER-EC-11 were sampled together before a bridge plug was installed. Also, all three wells are identified in the *Nevada National Security Site Integrated Sampling Plan* as characterization wells requiring periodic (2 to 3 years) sampling for a robust set of analytes (NNSA/NFO, 2014). More information regarding these wells is as follows:

- **ER-EC-11** is constructed with four piezometers and two main completion zones (see Figure A-1 in Appendix A). The shallow piezometer zone (ER-EC-11_p4) is located at the water table in the Timber Mountain welded tuff aquifer (TMWTA). There is no corresponding main completion zone. The upper piezometer (ER-EC-11_p3) intersects the Benham aquifer (BA) and the Fluorspar Canyon confining unit (FCCU) hydrostratigraphic units (HSUs), and was sealed off from the main completion during drilling because elevated tritium was encountered; consequently, there is no corresponding main completion zone. This zone had not been developed nor sampled. The intermediate piezometer (ER EC-11_p2) intercepts the Lower Paintbrush confining unit (LPCU), Tiva Canyon aquifer (TCA), and Middle Paintbrush confining unit (MPCU) HSUs, and the deep piezometer (ER-EC-11_p1) intercepts the Topopah Spring aquifer (TSA) and the Calico Hills zeolitic composite unit (CHZCM) HSUs; there are corresponding main completion zones (ER-EC-11_m2 and ER-EC-11_m1) for the intermediate and deep piezometers. A dedicated submersible pump is installed in the main upper completion zone (ER-EC-11_m2).

- **ER-20-8** is constructed with three piezometers and two main completion zones (see Figure A-2 in Appendix A). The shallow piezometer (ER-20-8_p3) was sealed off from the main completion during drilling because elevated tritium was observed; consequently, there is no corresponding main completion zone. This zone had not been sampled nor developed. The shallow piezometer intersects the Upper Paintbrush confining unit (UPCU) and Scrugham Peak aquifer (SPA) HSUs. The intermediate piezometer zone (ER-20-8_p2) intercepts the LPCU, TCA, and MPCU HSUs. There is a corresponding main completion zone (ER-20-8_m2) with a dedicated submersible pump installed. The deep piezometer (ER-20-8_p1) and corresponding main completion zone (ER-20-8_m1) intercept the LPCU, TSA, and CHZCM HSUs. Both main completion zones have been developed and sampled.

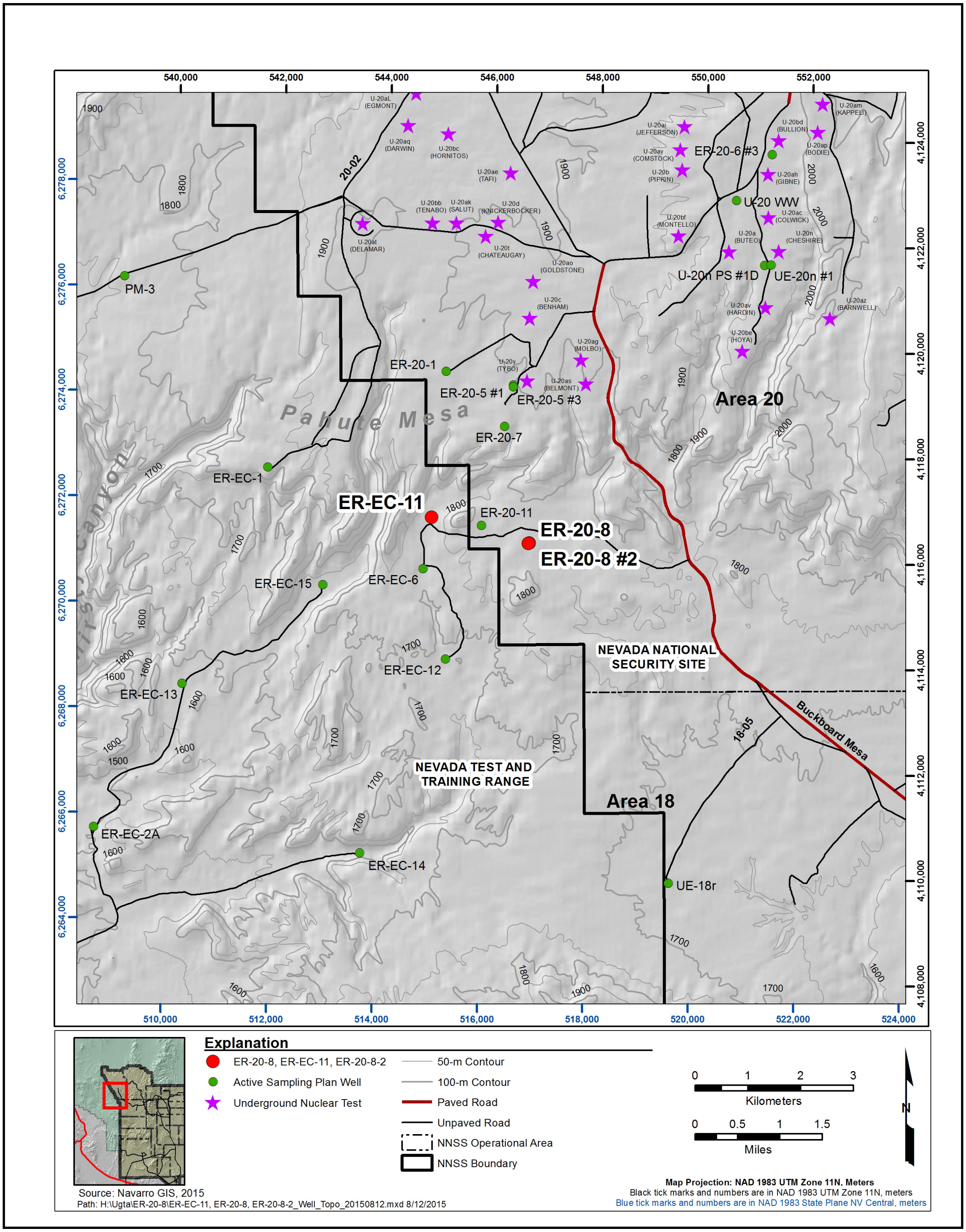

Figure 1-1
ER-EC-11, ER-20-8, and ER-20-8 #2 Locations

- **ER-20-8 #2** is constructed with one piezometer (ER-20-8-2_p1) and a corresponding main completion zone (ER-20-8-2_m1) (see Figure A-3 in Appendix A). Well ER-20-8 #2 is approximately 50 feet (ft) away from ER-20-8 and was constructed to access the BA and SPA HSUs. The main completion zone has a dedicated submersible pump installed, and the zone has been developed and sampled.

2.0 PURPOSE AND OBJECTIVES

The purpose of this report is to identify the sampling methods for each active well identified in the Integrated Sampling Plan (NNSA/NFO, 2014) and in *Underground Test Area (UGTA) Closure Report for Corrective Action Unit 98: Frenchman Flat Nevada National Security Site, Nevada* (NNSA/NFO, 2015). The sampling method will be based on the construction of the well, the objectives for each well type (characterization, source/plume, early detection, distal, and community), and the UGTA Strategy stage (Corrective Action Investigation [CAI], Corrective Action Decision Document [CADD]/Corrective Action Plan [CAP], or Closure Report [CR] stages). In addition, this report will help determine purging criteria for future sampling.

In order to identify sampling methods and purging criteria, this report had the following specific objectives:

- Determine the relative cost of the three sampling technologies: depth-discrete bailer, jack pump, and dedicated electric submersible pump. Costs included deploying, operating, and maintaining each technology.
- Identify and assess the conditions and limitations for use of each technology on the UGTA Activity, including usability and portability.
- Identify potential improvements for each technology to reduce costs, obtain more accurate results, and reduce risks.
- Compare analytical results from a depth-discrete bailer sample to “pumped” samples for various tritium levels.
- Evaluate the correlation between the volume of water purged and water-quality parameters and tritium activities.
- Compare tritium activities in samples collected from undeveloped zones to activities in samples collected after the zone has been developed.
- Recommend a plan for testing and deploying additional technologies.

3.0 DATA COLLECTION ACTIVITIES

All samples were collected in accordance with the *Field Instruction for the Underground Test Area Activity Well Development, Hydraulic Testing and Groundwater Sampling* (N-I, 2012). Sampling information for the technologies evaluated at each piezometer and main completion are presented in Table 3-1. Samples were collected using a bailer from all piezometers except the shallow ER-EC-11 piezometer (ER-EC-11_p4). The jack pump was used to collect samples in ER-EC-11 (ER-EC-11_p1, ER-EC-11_p2, and ER-EC-11_p3) and ER-20-8 #2 (ER-20-8-2_p1) piezometers; and the electric submersible pump was used to collect samples from ER-20-8 #2 (ER-20-8-2_m1) and ER-20-8 (ER-20-8_m2) main completions. This section describes the criteria established for collecting samples for this report, including selection of the depths for bailing and the purging requirements for pumping. In addition, the analytes and associated methods and the samples collected at each location are presented.

Table 3-1
Technology Evaluation Information
(Page 1 of 2)

Sampling Location	Bailer		Jack Pump or Submersible Pump					
	Sampling Date	Sampling Depth (ft)	Date	Intake Depth (ft)	Borehole Volume (gal)	Purge Volume (gal)	Rate (gpm)	Pump Type
ER-EC-11								
ER-EC-11_p1	07/16/2014	3,860	07/24/2014 07/25/2014	1,564	3,416	13,123 16,302	2.7	Jack Pump
ER-EC-11_p2	07/31/2014	3,350	08/11/2014	1,488	1,744	14,453	2.5	Jack Pump
ER-EC-11_p3	08/14/2014	2,750	08/25/2014	1,566	9,157	23,966	2.5	Jack Pump
ER-20-8								
ER-20-8_p1	09/03/2014 09/04/2014	3,170	--	--	--	--	--	--
ER-20-8_p2	10/21/2014	2,800	--	--	--	--	--	--
ER-20-8_p3	09/10/2014 09/15/2014	1,717	--	--	--	--	--	--
ER-20-8_m2	--	--	03/07/2015 03/08/2015	1,762	2,506	77,684 108,931 [a]	25.3	ES Pump

Table 3-1
Technology Evaluation Information
(Page 2 of 2)

Sampling Location	Bailer		Jack Pump or Submersible Pump					
	Sampling Date	Sampling Depth (ft)	Date	Intake Depth (ft)	Borehole Volume (gal)	Purge Volume (gal)	Rate (gpm)	Pump Type
ER-20-8 #2								
ER-20-8-2_p1	09/17/2014	2,100	10/06/2014	1,692	4,150	26,360	2.3	Jack Pump
ER-20-8-2_m1	--	--	10/16/2014	1,751	4,150	67,147	27	ES Pump

[a] Sample was analyzed by LLNL.

ES = Electric submersible
gal = Gallon
gpm = Gallons per minute

-- = Technology was not tested for this completion zone.

3.1 Sampling Requirements

Criteria for the amount of purging required before samples could be collected and the depth of sample collection for bailed sampling for each piezometer are presented in the following subsections.

3.1.1 Jack Pump and Submersible Pump Sample Collection

Samples were collected for laboratory analysis when appropriate purge volumes were reached and when water-quality parameters stabilized. During purging operations, the total discharge was monitored and water-quality parameters were determined on an hourly or bi-hourly basis. The well completion zone is considered adequately developed once a minimum of one effective well volume is produced and the water-quality parameters meet the stability criteria. Adequate purge volume was determined when the following criteria were met:

- Turbidity below 10 nephelometric turbidity units (NTUs)
- pH remains constant within 0.1 standard unit (SU)
- Specific electrical conductivity (SEC), dissolved oxygen (DO), and temperature vary no more than 10 percent for at least three consecutive readings.

If the stability criteria were not met, additional well volumes were purged to attain water-quality parameter stability. Water levels were continuously monitored in the isolated adjacent completion zones during pumping to determine whether a response to pumping was induced. Tritium samples were collected and analyzed from the initial discharge and at approximately every quarter well volume to determine development progress.

3.1.2 Depth-Discrete Bailer Sample Collection

Sampling depths were selected based on analysis of hydrophysical and hydrochemical logs run by Desert Research Institute (DRI) and Baker Atlas under ambient and stressed conditions. Information supporting depth selection for each piezometer sampled using a bailer is as follows:

- **ER-EC-11_p1**. An active flow zone centered at about 3,860 ft suggests collection of samples at this depth. Thermal flowmeter (TFM) logs run under both ambient and stressed conditions indicate downward and upward flow converges near this depth, and the ambient chemical indicators are stable. An inflection on the Baker Atlas temperature log during pumping is shown at about this same depth, although their spinner log indicates more active flow above.

- **ER-EC-11_p2**. A target depth of 3,300 ft takes advantage of converging vertical flow and an active flow zone. The ambient log indicates downward flow from 3,180 to about 3,310 ft, and ambient DO concentrations are highest in this zone. The other chemical indicators are nearly stable through this zone under ambient conditions, although temperature and conductivity logs suggest a possible discrete flow interval at about 3,330 ft. In addition, the Baker Atlas temperature log during pumping indicates a strong inflection point at 3,300 ft.

- **ER-EC-11_p3**. This piezometer was neither developed nor logged. The screen is about 314 ft long and without logging results, sampling at 2,750 ft, about 80 ft above the midpoint, is considered reasonable.

- **ER-20-8-2_p1.** Entry of groundwater into this piezometer below a depth of about 2,080 ft is indicated by chemistry logs run under ambient conditions that clearly show increased DO and redox potential, and lower electrical conductivity (EC) and temperature below this depth. This flow appears to be directed across the borehole rather than vertical because the TFM logs under ambient conditions show only very low rates of vertical flow (down in the main well, up in the piezometer). Baker Atlas's spinner and reservoir performance monitor (RPM) logs suggest increasing flow with increasing elevation in the well at 2,070 and 2,120 ft, although these are under pumping conditions.

- **ER-20-8_p1.** A target depth of about 3,170 ft takes advantage of upward vertical flow in the most active flow zone noted on the TFM log run under stressed conditions. In addition, a sample has previously been bailed from this depth, so a direct comparison of water chemistry over time can be made. The Baker Atlas logs run during pumping suggest that most inflow to the well occurs from this depth down to about 3,226 ft.

- **ER-20-8_p2.** Ambient DO concentrations are higher at lower depths in the screen, indicating a higher degree of natural flow in this interval. The TFM log run under ambient conditions suggests upward flow below about 2,100 ft. The Baker Atlas spinner and RPM logs run during pumping are consistent with flow under stressed conditions increasing upward from about 2,830 ft. A target depth of 2,800 takes advantage of this flow and corresponds to the depth of a bailed sample in the main well in 2011.

- **ER-20-8_p3.** This piezometer was neither developed nor logged. However, the screen is only 30 ft long, and selection of the sampling depth at the midpoint of 2,100 ft depth is considered reasonable. For sampling with a non-depth-discrete bailer, collection took place at a depth of 1,717 ft, which is just below the water table.

3.2 Sample Collection and Laboratory Analysis

Samples were collected for major cations (calcium [Ca^{+2}], magnesium [Mg^{+2}], potassium [K^{+}], and sodium [Na^{+}]); major anions (chloride [Cl^{-}], fluoride [F^{-}], and sulfate [SO_4^{-2}]); and tritium. Anion samples were filtered using a 0.45-micrometer filter; cation and tritium samples were not filtered. Samples were analyzed by a commercial laboratory, American Laboratory Service (ALS) Laboratory Group, using the procedures shown in Table 3-2. Samples with tritium concentrations less than 300 picocuries per liter (pCi/L) were analyzed by American Radiological Service (ARS) using a tritium enrichment process. Daily tritium and water-quality samples were also collected during depth-discrete bailer and purging activities.

Table 3-2
Analytical Procedures

Analytes	Procedure
Calcium Magnesium Potassium Sodium	SW-846-6010 [a]
Bromide Chloride Fluoride Sulfate	EPA 300.1 [b]
Tritium	EPA 906.0 [c]

[a] EPA, 2015
[b] EPA, 1997
[a] EPA, 1980

Additional samples were collected for the groundwater characterization suite of analytes to support the Integrated Sampling Plan (NNSA/NFO, 2014). These samples were analyzed by the commercial laboratories and by DRI, Lawrence Livermore National Laboratory (LLNL), and the U.S. Geological Survey (USGS). These results do not support this evaluation and therefore will be not be presented or discussed within this report. The groundwater characterization samples will instead be reported in the Annual Sampling Report.

3.2.1 ER-EC-11

A sample and a duplicate were collected using a depth-discrete bailer followed by a jack pump from the three piezometers in ER-EC-11: ER-EC-11_p1, ER-EC-11_p2, and ER-EC-11_p3. Depth-discrete bailer samples were collected before purging the well. After depth-discrete bailer samples were collected, the rod pump was installed and the jack pump surface unit was positioned to drive the pump, and the respective zones were pumped to purge the well and establish stable water-quality parameters. During purging, discharge samples were collected starting with initial discharge then approximately at each quarter well volume and analyzed for tritium. Once the well was purged, a sample was collected and analyzed for the groundwater characterization suite. Pumping was continuous through the purging and sampling process without any interruption in production.

3.2.2 ER-20-8

A sample and a duplicate were collected using the depth-discrete bailer from two piezometers: ER-20-8_p1 and ER-20-8_p2. ER-20-8_p3 was sampled using a non-depth-discrete bailer; a duplicate sample was collected for tritium analysis. Because of the small (1.6 in.) diameter of ER-20-8_p3, only non-depth-discrete bailing was possible. ER-20-8_p3 had not been developed before this sampling and could not be pumped even with the jack pump. Groundwater samples were also collected from the shallow zone of the main completion (ER-20-8_m2) using an electric submersible pump.

3.2.3 ER-20-8 #2

A sample and duplicate were collected using the depth-discrete bailer from ER-20-8-2_p1 before pumping. A sample and a duplicate were also collected from the main completion zone (ER-20-8-2_m1) using the electric submersible pump and from the piezometer (ER-20-8-2-p1) using the jack pump. The main completion, ER-20-8-2_m1, was purged using a jack pump and an electric submersible pump. After purging criteria were satisfied, groundwater characterization samples were collected from the wellhead manifold sampling port for both technologies.

Initially, the jack pump seal failed to seat or became unseated after the pump was started. The pump was visually inspected before the initial installation but was not disassembled or serviced. During the installation, several attempts were made to seat the seal. The pump was removed from the piezometer and upon inspection, it was noted that the ball valves and pump barrel were full of fine scale. The pump was replaced. The new pump also did not function properly and was pulled and cleaned before pumping could be initiated. Once pumping was initiated, it was uninterrupted through sampling.

3.3 Technology Cost

Two contractors participated in groundwater sampling field operations. The Environmental Program Services (EPS) contractor provided site supervision, environmental and safety compliance and support, and sample collection. Construction services and support were provided by the Management and Operating (M&O) contractor. The cost associated with deploying and operating each technology was estimated based on labor costs incurred by both organizations. The number of labor hours required to setup, operate, and demobilize each technology varied from site to site, and the average costs per technology were estimated. The maintenance costs are considered negligible over this evaluation period and were therefore not included in the estimates. Labor hours were therefore used as a surrogate for estimating cost.

4.0 RESULTS

The optimal sampling technology for each active Sampling Plan well depends on multiple factors. First, viable options must consider the well construction. For instance, multiple-completion wells must be reconfigured to purge and sample each zone independently if the electric submersible pump is to be used for sampling. This has proven to be cost prohibitive for routine sampling, which limits the viability of the submersible pump in these wells unless sampling a single zone is all that is required. Several multiple-completion wells also have piezometer strings that access the formations of interest, but sampling the piezometers requires a technology capable of sampling narrow diameter tubing. Next, identification of the optimal sampling technology must consider the objectives for each well type (characterization, source/plume, early detection, distal, and community). For instance, characterization wells require a large sample volume to support a large analyte set, whereas other well types require a much reduced analyte set. Early detection, distal, and community wells require only tritium samples. In addition, characterization well sampling requires collection of representative samples for these analytes and likely requires that the well is purged before sample collection. Finally, the hydrologic system being sampled must also be considered. Sampling discrete flow zones are particularly important as they may reflect faster flow paths within an aquifer and thus require lower purge volumes.

This report was designed to address these factors. Different combinations of the three tested technologies were applied at the three wells; samples were collected and analyzed for tritium and major ions. In addition, tritium and water-quality parameter samples were collected over the purging period to determine whether the purging criteria ensured representative tritium samples.

4.1 Purging Impact on Water Quality and Tritium Activities

One objective of this report is to evaluate the correlation between the purge volume and tritium activities. During purging with the jack pump and electrical submersible pump, time-series discharge samples were collected starting at initial discharge then approximately every quarter borehole volume. Samples were collected for water-quality parameters (see Appendix B) and tritium (see Appendix C). The minimum, maximum, mean, and standard deviation (SD) for the time-series tritium data for each piezometer and main completion zone are presented in Table 4-1. In most cases, the first sample (collected after purging 10 to 30 gal) was observed as an outlier and not included in the statistics (Table 4-1). These data are also shown in Figures 4-1 through 4-5 and described in the following subsections.

Table 4-1
Tritium Results (pCi/L) Summary

Sampling Location	Primary HSU	Bailer	Time Series [a]				Final Pumped Sample [b]	Previous Sample	
		Mean	Min	Max	Mean	SD	Mean	Mean	Date
ER-EC-11									
ER-EC-11_p1	TSA	6.51	5.48	8.22	6.89	0.96	7.00	31 [d]	05/18/2010
ER-EC-11_p2	TCA	11.6	3.28 [c]	8.16	5.53	1.40	11.5		
ER-EC-11_p3	BA	12,400 [e]	15,700	16,800	16,258	337	16,289	10,295 [e, f] 10,247 [e, f]	10/09/2009 10/10/2009
ER-20-8									
ER-20-8_p1	TSA	121.5	--	--	--	--	--	<320 [f]	07/22/2011
ER-20-8_p2	TCA	8,500	--	--	--	--	--	2,090 [f]	05/26/2011
ER-20-8_p3	SPA	1,705	--	--	--	--	--	--	--
ER-20-8_m2	TCA	--	5,500	8,200	6,693	714	4,575	2,835	06/27/2011
ER-20-8 #2									
ER-20-8-2_p1	BA/SPA	2,555	2,100	2,720	2,420	176	2,567	805 [e, f]	12/03/2009
ER-20-8-2_m1	BA/SPA	--	2,060	3,170	2,744	246	2,555	960 [b]	12/18/2009

[a] First samples (collected after 10 to 30 gal purged) were not included in statistics.
[b] Mean of two pumped duplicate samples collected after water-quality parameter stabilization. Sample was collected several borehole volumes after the last tritium time-series sample was collected for ER-EC-11_p2, ER-20-8 and ER-20-8 #2.
[c] Tritium value is considered a non-detect (less than the MDC plus error).
[d] Tritium result from LLNL for sample pumped from ER-EC-11_m1-2.
[e] Sample collected before development.
[f] Results are for bailed sample.

MDC = Minimum detectable concentration

-- = Sample was not collected using this technology.

4.1.1 ER-EC-11

The deep (ER-EC-11_p1), intermediate (ER-EC-11_p2), and shallow (ER_EC-11_p3) piezometer tritium and water-quality results are provided in Figures 4-1 and 4-2, respectively. The tritium activity for the first ER-EC-11_p2 sample was considerably higher (29 pCi/L) and the first ER-EC-11_p3 sample was considerably lower (8,400 pCi/L) than subsequent samples (Figure 4-1). With the

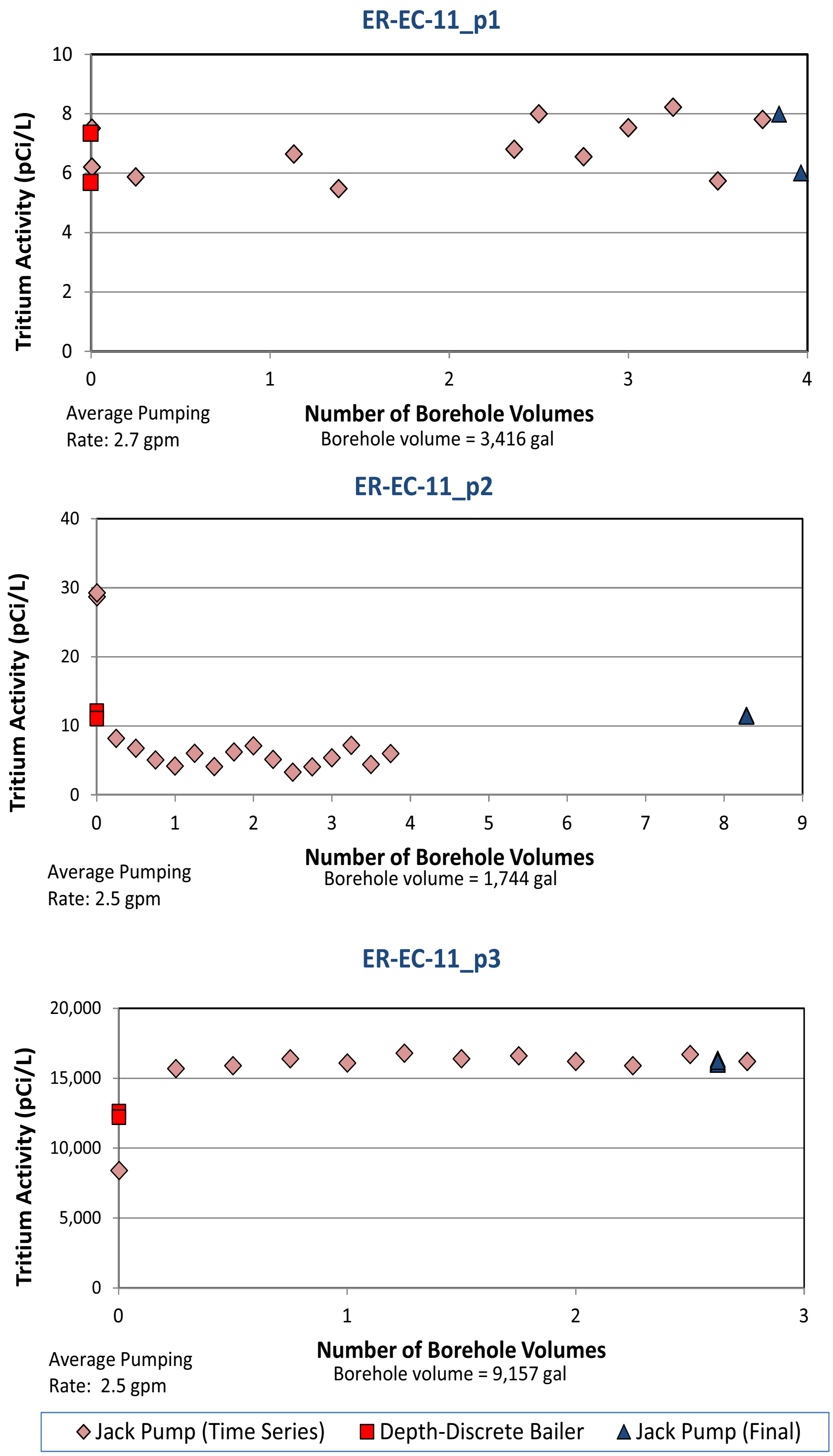

Figure 4-1
ER-EC-11 Tritium Results

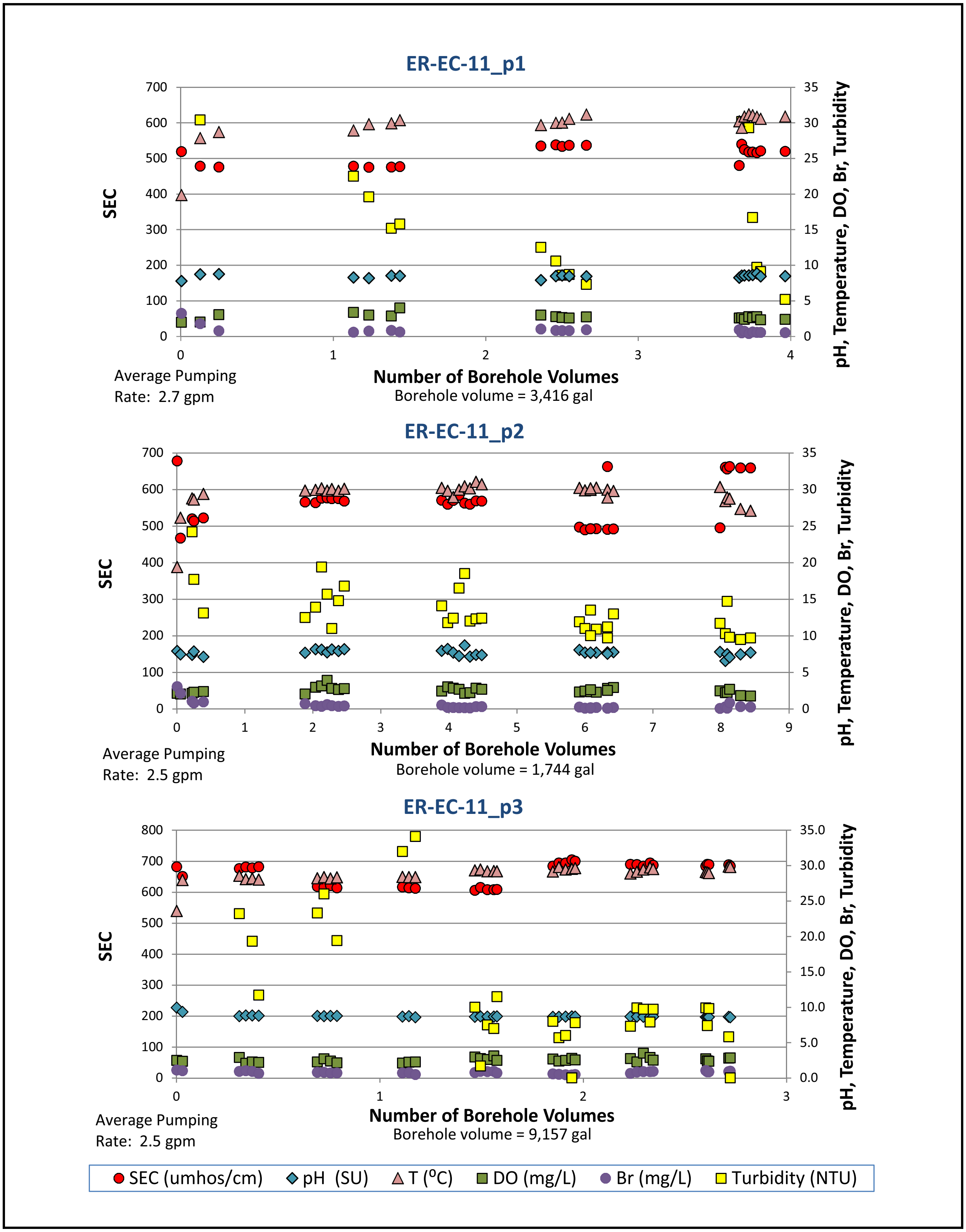

Figure 4-2
ER-EC-11 Water-Quality Parameter Results

exception of these samples, the time-series tritium activities range from 5.48 to 8.22 pCi/L for ER-EC-11_p1, from 3.28 to 8.16 pCi/L for ER-EC-11_p2, and from 15,700 to 16,800 pCi/L for ER-EC-11_p3, no trend in time-series tritium activity with respect to the purge volume is observed (Figure 4-1). In fact, the SD of the time-series data (Table 4-1) are within the error of the individual measurements (see Table C-1 in Appendix C). For ER-EC-11_p2, the final tritium sample, after pumping an additional 8,000 gal (11.5 pCi/L) was greater than the maximum time-series result (8.16 pCi/L) by 40 percent. It is important to note that tritium stabilization was reached while purging a single borehole volume, even though this zone had not been developed.

With the exception of turbidity and bromide, a similar lack of trend is observed for the water-quality parameters for the ER-EC-11 piezometers (Figure 4-2). Although there is a relatively high variability in some parameters, no visual trend is observed. Three consecutive measurements within 10 percent were observed for temperature and SEC after the first borehole volume was purged at all ER-EC-11 piezometers. Three borehole volumes were purged before pH and DO criteria were met for ER-EC-11_p1, and one bore volume was purged before pH and DO criteria were met for ER-EC-11_p3. While other water-quality parameters stabilized after one borehole volume was purged from ER-EC-11_p2, stabilization of pH required more than six borehole volumes to be purged. Turbidity required pumping 8,540, 10,610, and 13,433 gal to reach the 10 NTU stabilization criteria at ER-EC-11_p1, ER-EC-11_p2, and ER-EC-11_p3 (see Table B-1 in Appendix B), respectively. While purge criteria may have been satisfied after purging a few borehole volumes, subsequent samples often fluctuated above the criteria.

4.1.2 ER-20-8

Time-series water-quality and tritium data for samples collected using the electric submersible pump (25 gpm) at ER-20-8_m2 are presented in Figure 4-3. The tritium activities for the first ER-20-8_m2 samples were considerably lower (400 and 490 pCi/L for duplicate samples) than subsequent samples (see Table C-2 in Appendix C). Tritium activities increased from 400 to 8,200 pCi/L during initial pumping (1,300 gal). Following this increase, a steady decrease was observed until tritium stabilized at 6,100 to 6,300 pCi/L after pumping approximately 9,000 gal (two borehole volumes). With the exception of turbidity, water-quality parameters stabilized (i.e., met the established criteria) within three borehole volumes. A general increasing trend in turbidity was observed over this period.

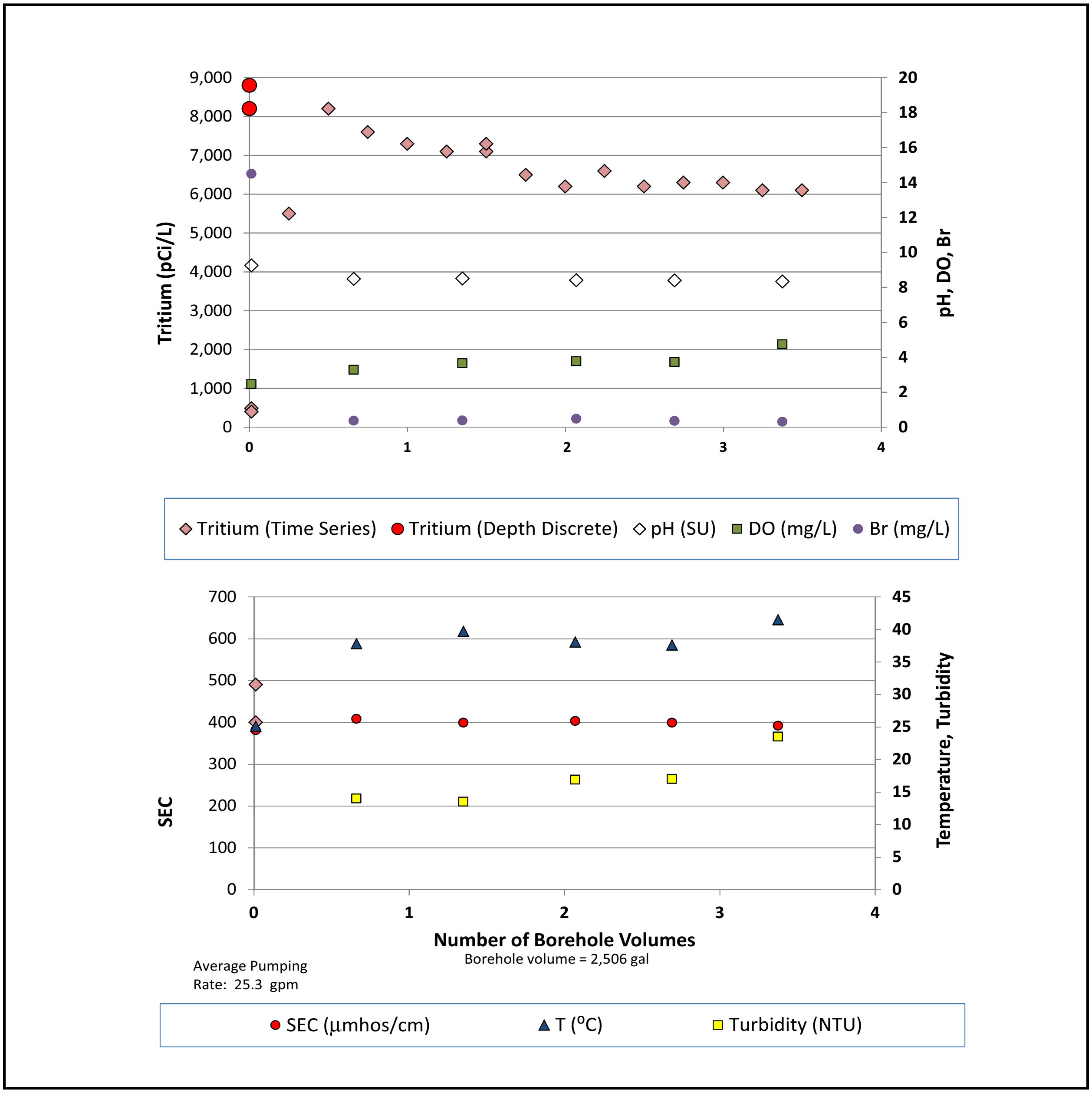

Figure 4-3
ER-20-8_m2 (Electric Submersible Pump) Water-Quality and Tritium Time-Series and ER-20-8_p2 (Depth-Discrete Bailer) Tritium Results

Figure 4-4 presents the tritium and water-quality data collected over the entire pumping period. While water quality appeared to stabilize within the first few borehole volumes, considerable variability was observed as pumping continued. Tritium samples and duplicates were collected after pumping almost 78,000 gal (4,560 ± 760 pCi/L and 4,590 ± 770 pCi/L) and 109,000 gal (4,019 ± 180 pCi/L and 4,056 ± 103 pCi/L) of groundwater from ER-20-8_m2 (Figure 4-4). A significant decrease in tritium

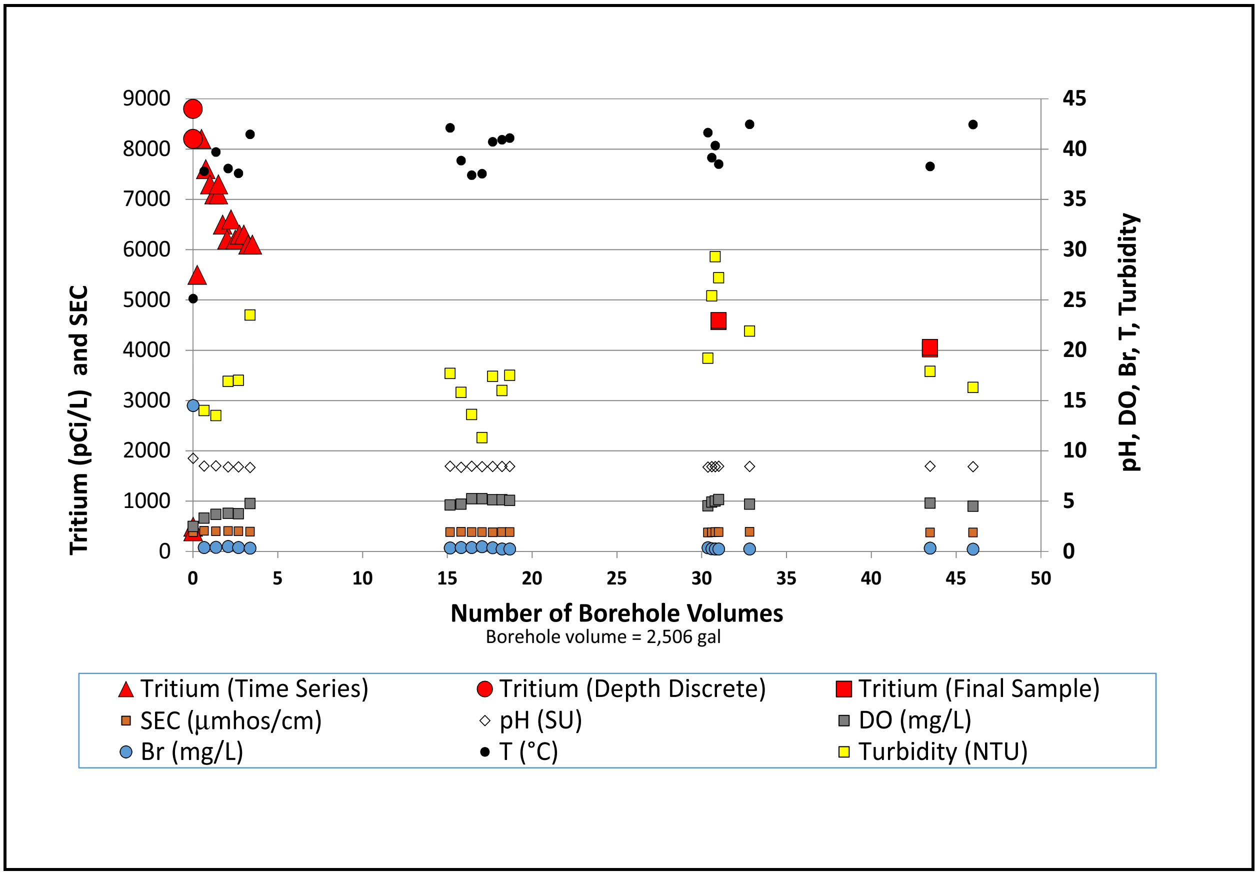

Figure 4-4
ER-20-8_m2 (Electric Submersible Pump) Water-Quality and Tritium and ER-20-8_p2 (Depth-Discrete Bailer) Tritium Results

was observed in these samples when compared to the pumped and bailed samples collected earlier. The turbidity did not reach the 10 NTU criteria over the entire 115,283 gal pumping period (Figure 4-4).

4.1.3 ER-20-8 #2

The water-quality and tritium results for the jack pump, submersible pump, and depth-discrete bailer samples from ER-20-8 #2 are presented in Figure 4-5. The time-series tritium and water-quality samples were not collected at similar time intervals using the electric submersible pump. While multiple tritium samples were collected during purging the first four borehole volumes, only two water-quality samples were collected at comparable times. The first two tritium samples (collected after purging 15 and 1,037 gal) were lower (1,080 and 2,060 pCi/L, respectively) than subsequent samples.

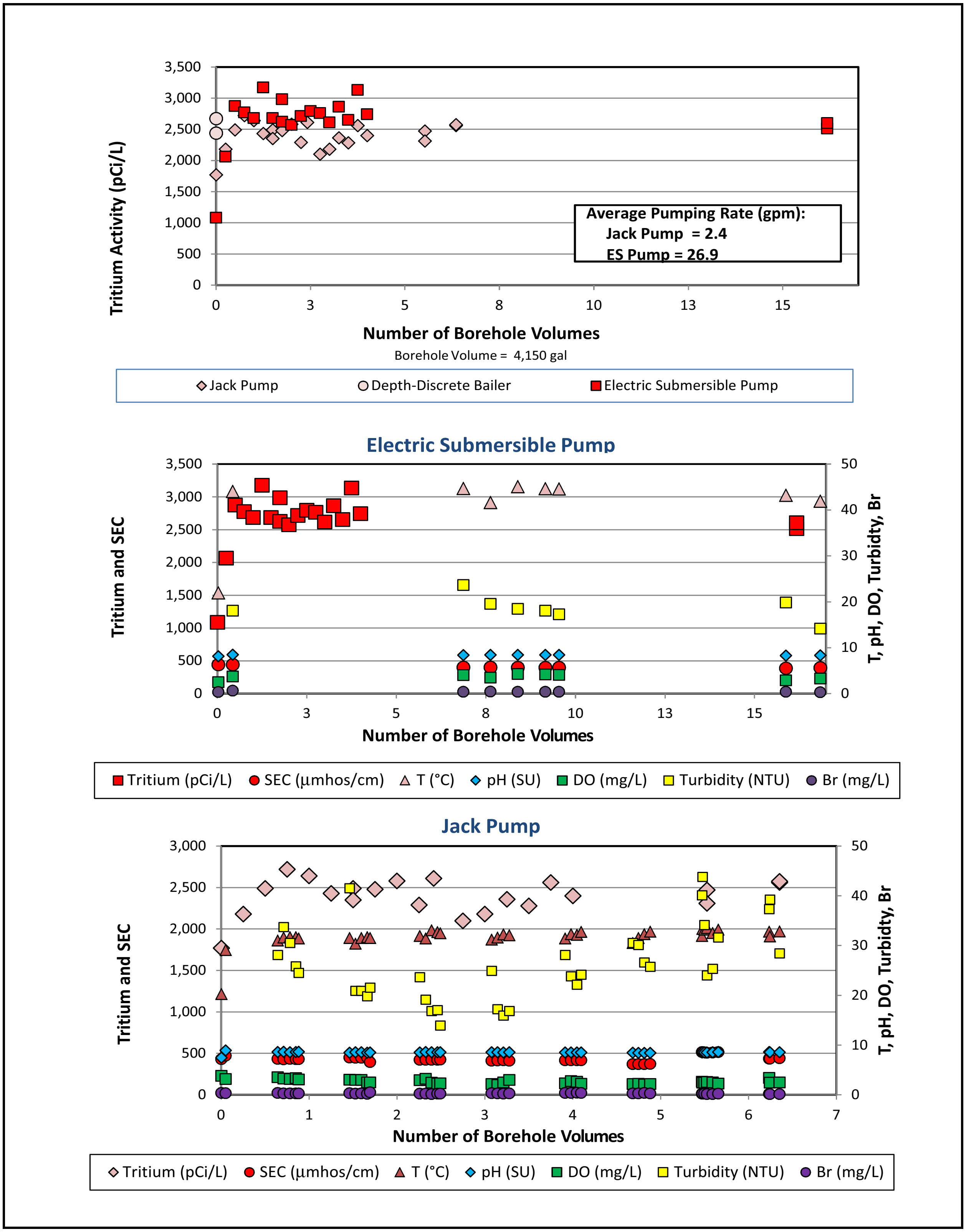

Figure 4-5
ER-20-8 #2 Water-Quality and Tritium Results

The first sample, collected after purging 10 gal with the jack pump, was lower (1,770 pCi/L) than all subsequent samples. Tritium activities for the remaining samples ranged from 2,100 to 2,720 pCi/g during the 16,600 gal (approximately four borehole volumes) pumping period. The tritium variability for these time-series results are within the error of the individual measurements. The majority of the water-quality parameters stabilized while pumping the first borehole volume (less than 4,000 gal). Turbidity did not reach the 10 NTU criteria over the nearly 17,000-gal pumping period.

4.2 Technology Results Comparison

To assess the applicability of each of the tested techniques, three objectives of this evaluation were established as follows:

1. Compare analytical results from a depth-discrete bailer sample to pumped samples for various tritium levels.
2. Evaluate the correlation between the volume of water purged and water-quality parameters and tritium activities.
3. Compare tritium activities in samples collected from undeveloped zones to activities in samples collected after the well is developed

These objectives will be discussed in the following subsections. To meet these objectives, samples collected using the various technologies were analyzed for tritium and major ions. Tritium is the contaminant of concern and is a required analyte for all Sampling Plan wells. Tritium is therefore the primary target for these evaluations.

Major ions are only analyzed for in groundwater samples from characterization wells. While the major-ion results are not representative of all analytes measured for characterization wells, their analysis is intended to support decisions regarding sampling technologies for these wells. Bromide and magnesium concentrations are near their analytical detection limits and therefore are not included in this analysis (see Table F-1 in Appendix F). The remaining major ions are presented in Figure 4-6. To allow comparison of each ion on the same scale plot, the data were standardized by dividing each ion concentration by the mean for that ion for each well (ER-EC-11, ER-20-8, ER-20-8 #2). In general, the bailed and pumped samples are quite similar with respect to the major ions (Figure 4-6). The exceptions are Ca and K, which tend to be greater in the bailed samples. In some cases, the total Ca was much greater than the dissolved when compared to earlier (ER-EC-11_p1 and ER-20-8_p1)

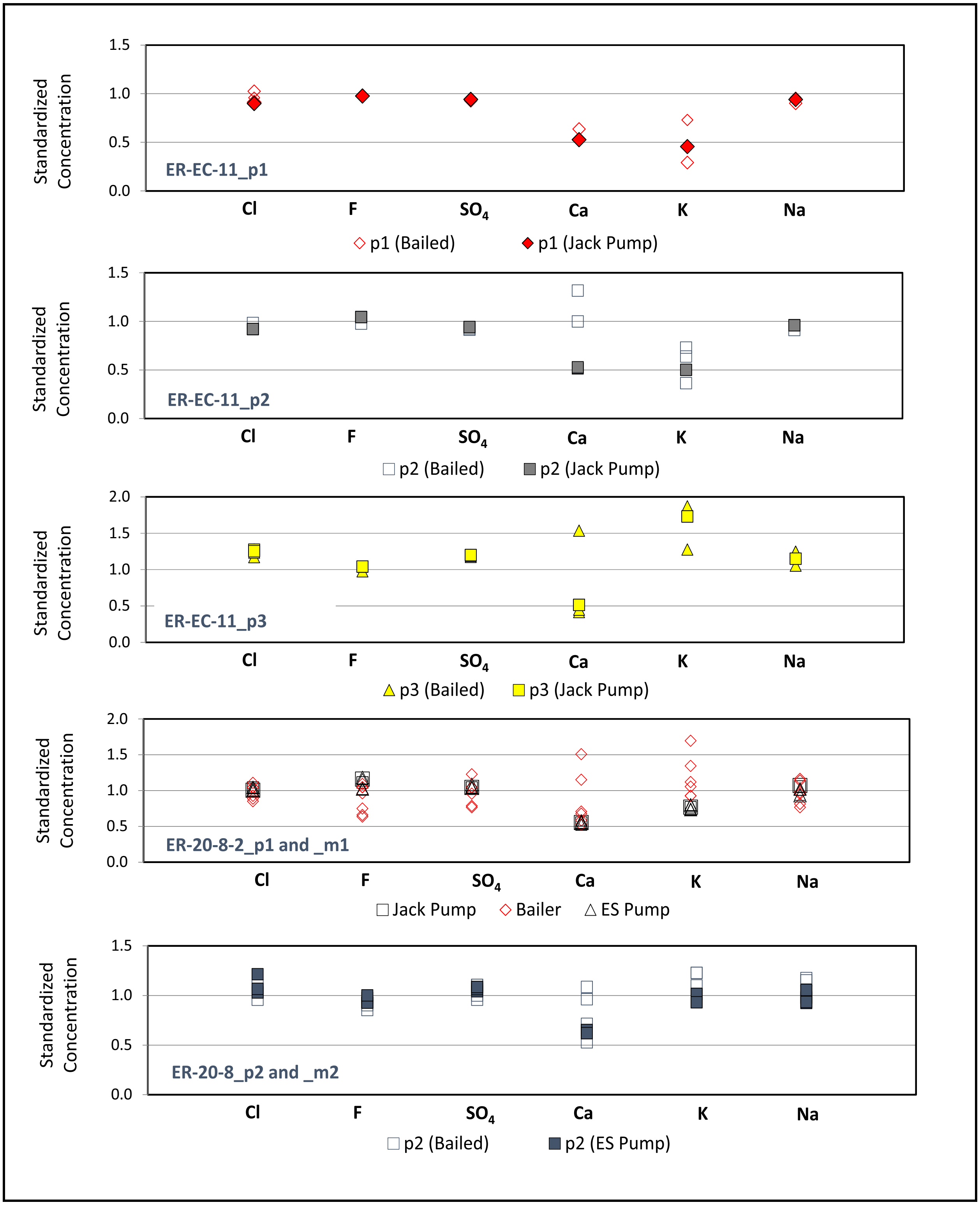

Figure 4-6
Standardized Major-Ion Concentrations

Note: Standardized concentration equals major-ion concentration for the individual sample divided by the mean concentration for the well (i.e., ER-20-8, ER-20-8#2, and ER-EC-11). A Ca outlier for ER-EC-11_p2 bailer (3.3), a K outlier for ER-EC-11_p3 bailer (2.5), and two Ca outliers for ER-20-8-2_p1 bailer (2.7 and 3.0) are not shown.

or samples collected at the same time (ER-EC-11_p3 and ER-20-8_p3). This suggests that bailer samples may not be desirable when characterizing the formation groundwater and purging is necessary.

Statistical determinations cannot be made because of the low sample numbers representing each technology. Instead visual comparisons are presented. Data collected during this evaluation are also compared to results from earlier samples from these wells.

4.2.1 Bailed Versus Pumped Samples

Samples were collected from the ER-EC-11 piezometers and ER-20-8-2_p1 using the jack pump and a depth-discrete bailer. Samples were collected from ER-20-8_m2 and ER-20-8-2_m1 using the electric submersible pump and can be compared to bailed samples collected from ER-20-8_p2 and ER-20-8-2_p1. Tritium results for ER-EC-11, ER-20-8, and ER-20-8-2_p1 are presented in Figures 4-1, 4-4, and 4-5, respectively, and are summarized in Table 4-1. Major-ion results are shown in Figure 4-6 and Table F-1 in Appendix F. A summary of these data is as follows:

- With the exception of the first sample collected using the jack pump, the variability in tritium activities over the pumping period was within the variability of the individual measurements (i.e., 2 sigma error associated with analysis).
- The ER-EC-11_p1 and ER-20-8-2_p1 tritium activities for each sampling method were nearly identical regardless of whether the sample was pumped or bailed.
- The ER-EC-11_p2 tritium activities for the bailed samples (11.6 pCi/L) were nearly identical to the final pumped samples (11.5 pCi/L).
- The ER-EC-11_p3 tritium activities for the bailed sample were approximately 25 percent less than the final pumped samples and slightly greater (approximately 20 percent) than the bailed sample collected in 2009. This piezometer was not developed before the bailed samples were collected.
- The ER-20-8 #2 tritium samples tended to be greater when collected using the electric submersible pump compared to the jack pump while pumping the first five borehole volumes. Average tritium activities in final samples collected using the electric submersible pump (2,555 pCi/L) and jack pump (2,567 pCi/L) and using the depth-discrete bailer (2,555 pCi/L) were remarkably similar (Table 4-1).
- In general, the bailed and pumped samples are quite similar with respect to the major ions. The exceptions are Ca and K, which tend to be greater in the bailed samples. In some cases, the total Ca was much greater than the dissolved when compared to earlier samples

(ER-EC-11_p1 and ER-20-8_p1) or samples collected at the same time (ER-EC-11_p3 and ER-20-8_p3). While this does not reflect issues with bailing tritium samples, it does suggest that other analytes used to characterize the formation groundwater should not be analyzed from a bailed sample, or at least the formation should be purged and developed before characterization sampling.

- Tritium activities for samples collected at ER-20-8_p2 using the bailer (8,500 pCi/L) were substantially greater than those collected with the electric submersible pump (4,575 pCi/L).
- Although apparent tritium stabilization was observed after purging three to four borehole volumes from ER-20-8_m2, the tritium activity reduced by approximately 25 percent over the rest of the pumping period (from approximately 6,000 to 4,000 pCi/L). This is similarly the case for ER-EC-11_p2; the final tritium sample, after pumping an additional 8,000 gal (11.5 pCi/L), was greater than the maximum time-series result (8.16 pCi/L) by 40 percent.
- Initial tritium activities are generally quite different than subsequent results for both the jack pump and the electric submersible, and do not appear to depend on pumping rates.

4.3 Relative Labor Hours

The three sampling methodologies are considerably different with respect to their deployment and operation. For the purposes of this report, only labor hours expended to complete the methodology testing and sampling were considered, and include (but are not limited to) preparation and coordination, mobilization and demobilization, purging and sampling, and decontamination. The labor hours expended by the contractors were estimated daily based on Daily Morning Reports (see Appendix G).

The jack pump requires installation and removal from the piezometer strings accessing the specific completion intervals. Installation requires equipment (i.e., crane, support truck, jack pump surface unit, and electric submersible pump) and technical support personnel (EPS and M&O contractors). Jack pump purging and sampling is a multiple contractor effort requiring M&O contractor's support for installation and removal of the rod pump and jack pump surface unit before pumping and after sampling has been completed. Operation of the electric submersible pump also requires support from the M&O contractor. The M&O contractor is required for initial operations and for demobilization. The EPS contractor provides technical oversight, reporting, and site supervision for application of all sampling technologies. This includes monitoring pump production, flow rates, and water-quality parameters; and collecting groundwater samples. The bailer can be operated exclusively by the EPS contractor or other contractors. An estimate of the labor hours required for each technology is presented in Table 4-2.

Table 4-2
Estimated Labor Hours for Sampling Technologies

Activity	Days	M&O	EPS	Total Hours [a]
		Persons		
Submersible Pump				
Mobilization/Setup	1	5	2	130
	1	2	2	
Purging/Sampling	2	0	3	90
Demobilization	1	5	2	80
	1	2	2	50
Total	**6**	**14**	**11**	**350**
Jack Pump				
Mobilization/Setup	1	10	2	130
	1	6	2	90
Purging/Sampling	4	0	2	120
Demobilization	1	10	2	130
	1	6	2	90
Total	**8**	**32**	**10**	**560**
Bailer				
Mobilization/Sampling/ Demobilization	3	0	2	90
Total	**3**	**0**	**2**	**90**

[a] Total hours based on 10 and 15 hours per day for the M&O and EPS contractor, respectively.

4.3.1 ER-EC-11

Bailer sample collection within both deep and intermediate piezometers required two operational days, respectively. Bailer sampling in the shallow piezometer required one day. Installation of the rod pump and the jack lift surface unit for the sampling of the deep piezometer (ER-EC-11_p1) was completed in a single day.

Pumping the deep piezometer was initiated several days later to ensure that the appropriate water-quality and time-series tritium samples could be collected. Once purging was initiated, the piezometer was pumped continuously and supported solely by the EPS contractor. Purging and groundwater sampling of the well occurred over a five-day period. The pump was allowed to continue pumping unattended for an additional two days after the characterization samples were collected until an M&O contractor was available to turn off the pump. The removal of the rod pump and repositioning the jack pump surface unit required one day to complete. The purging and sampling of ER-EC-11_p1 required a total of seven operational days, which included the pump installation, purging, characterization sample collection, and rod pump removal. However, this does not include non-operational days when the site was not staffed.

4.3.2 ER-20-8

Two days were required for mobilization and trailer set up. Bailer sample collection required three operational days for the deep piezometer (ER-20-8_p3), eight operational days for the shallow piezometer (ER-20-8_p1), and two operational days for the intermediate piezometer (ER-20-8_p2). Mobilization and set up required one day of labor before pumping could be initiated. Once purging was initiated, ER-20-8_m2 was pumped continuously and supported solely by the EPS contractor. Purging and groundwater sampling of the well occurred over a four-day period. Demobilization required one day.

4.3.3 ER-20-8 #2

Bailer sample collection required two operational days. The equipment was set up and tested on the first day, and sampling took place on the second day. As described in Section 3.2.3, the jack pump was not functioning properly and needed to be pulled and cleaned. In addition, the pump became detached from the crane and fell to the ground. Mobilization, installation, servicing, and evaluations required six days of labor before pumping could be initiated. Once purging was initiated, the piezometer was pumped continuously and supported solely by the EPS contractor. Purging and groundwater sampling of the well occurred over an eight-day period. The removal of the rod pump and repositioning the jack pump surface unit required one day to complete.

ER-20-8-2_m1 purging and sampling using the electric submersible pump required a total of five operational days, which included the pump installation, purging, and characterization sample.

4.4 Technology Limitations

The following subsections are focused on identifying and assessing the conditions and limitations for use of each technology on the UGTA Activity, including usability and portability.

4.4.1 Depth-Discrete Bailer

The depth-discrete bailer can be deployed quickly and is useful for collecting small quantities of sample. The depth of sample collection is typically based on flow or temperature logging during drilling and testing. A depth-discrete bailer is not typically used to purge a well because most bailers provide less than 2-L samples. The depth-discrete bailer is highly mobile and can be deployed quickly. Bailed tritium appears to be representative of the average pumped value.

Logistical and operational use of a wireline deployed bailer is relatively straightforward and allows for simple mobilization and set up at the well head. The technique is limited in terms of the volume of water that may be withdrawn from the well in a single run due to the small diameter of the piezometer tubing (e.g. 2.375 in.) and the lack of purging capability. At ER-EC-11, a 1-L bailer was used for all sampling and worked satisfactorily for collecting the smaller volumes required for the analysis of tritium and major ions in approximately two days. However, if larger volumes are required (e.g., groundwater characterization suite), the depth-discrete bailer would require considerable more time to obtain sufficient sample volumes required for analysis.

4.4.2 Jack Pump

The jack pump is resource-intensive to deploy, operate, and maintain. The jack pump was successfully deployed in several piezometers but had technical difficulties in a few cases. Jack pump installation requires rods and a pump to be installed and sealed in the well. The pump and rods can either be left in place or removed. The most efficient use of the jack pump requires leaving the rods in each well. However, if left in place, water levels cannot be collected. If removed, the rods and pump can be decontaminated and used in another well. The jack lift pump allows groundwater to be pumped from the depths required and may be deployed in piezometer strings used in UGTA well constructions. The pump may be installed in 2.375-in. and 2.875-in. piezometer strings. The downhole rod pump as driven by the surface jack pump provided expected performance from both ER-EC-11_p1 and ER-EC-11_p2. Rates of production ranged from 2.5 to 3.5 gpm, respectively. The production was steady and uninterrupted throughout the purging and groundwater sampling cycle. In the simplest case, tubing configurations where the slotted portion of the tubing lies very near or above the static water level requires that the jack lift rod pump be designed with an extension barrel to allow the pump to draw and pump water to a point above the screened portion of the tubing.

This jack pump configuration was successfully used at PM-3-2 and again in ER-EC-11_p2, and it proved to be effective in this type of tubing configuration. The second piezometer tubing arrangement uses two different tubing diameters. Many of the piezometer strings installed in recent UGTA wells are designed and installed with a 2.375-in. carbon steel (CS) tubing located above the water table and 2.875-in. stainless steel (SS) tubing extending below to a slotted interval within the 2.875-in tubing. In piezometers where the connection between the 2.375-in CS tubing is located more than approximately 40 ft above the static water table the pump must be set in the larger 2.875-in. tubing. This unique configuration with respect to the tubing and the static water level requires a pack-off assembly that is small enough to enter the 2.375-in. CS tubing and is also capable of expanding to set the pump in the larger 2.875-in. SS tubing. A pump assembly and packer were used for testing in ER-EC-11_p2, but were not available at the time of pump installation at ER-20-8.

4.5 Electric Submersible Pump

The submersible pump has been the primary method of sample collection for the UGTA Activity. Typically, an electric submersible pump is installed in a well for sampling after development and testing. Samples are collected after purging the well and achieving stable water-quality parameters; consequently, the submersible pump is considered the standard against which other technologies are compared. In multiple-completion wells, the pump is placed in the uppermost completion zone with the lower zones isolated using bridge plugs. Once the pump is installed, it is labor intensive to try to sample other zones.

5.0 CONCLUSIONS

Determination of cost-effective groundwater monitoring technologies is a complex problem. To collect a high-quality sample, pumping is typically required to purge the well bore from stagnant water that is not representative of the formation. The number of well volumes to be pumped from a monitoring well before a water sample is collected is dependent on multiple factors, including the hydraulic conductivity of the well and presence or absence of ambient intra-borehole flow; the purpose for the sample (e.g., evaluate trends, characterize the system); and the analytes of interest. Well purging strategies should be established by calculating reasonable purging requirements, pumping rates, and volumes based on these factors.

As stated in Yeskis and Zavala (2002), "stabilization of the water-quality-indicator parameters is the criterion for sample collection. But if stabilization is not occurring and the procedure has been strictly followed, then sample collection can take place once three (minimum) to six (maximum) casing volumes have been removed" (Schuller et al., 1981; EPA, 1986; Wilde et al., 1998; Gibs and Imbrigiotta, 1990). The results of this evaluation indicate that stabilization of the water-quality-indicator parameters often requires greater purge volumes than that required for tritium stabilization. In most cases, time-series tritium results stabilized in less than one borehole volume. With the exception of turbidity and DO, water-quality parameters also often stabilized after purging a single borehole volume. Depth-discrete bailer tritium analytical results are comparable to purged analytical results when samples are collected from developed intervals and the sample is collected near an active flow zone.

Depth-discrete bailer sampling may be used for sampling early detection and distal wells where the objective is to determine the presence or absence of tritium. The jack pump is an alternative method to collect samples in characterization wells. Relative cost (labor) of the jack pump is much greater than the bailer because of the required time and resources to set up and purge the interval. However, the labor cost of moving the electric submersible pump in a multiple-completion well is more than the operational cost of the jack pump.

5.1 Recommended Sampling Technologies

The purpose of this report is to identify the sampling methods for each active well identified in the Integrated Sampling Plan (NNSA/NFO, 2014). The sampling method will be based on the construction of the well; the objectives for each well type (characterization, source/plume, early detection, distal, and community); and the UGTA Strategy stage (CAI, CADD/CAP, and CR stages). Characterization wells should be sampled after sufficient purging in order to obtain samples representative of the formation water. Once a baseline is established, characterization wells are recategorized as either a source/plume well or an early detection based on the tritium activity. If the well will be identified as a source/plume well, then installing a pump should be considered depending on the need to accurately quantify contaminants of potential concern. If recategorized as an early detection well, then bailing may be the preferred technology.

Table 5-1 lists the objectives, technology requirements, and viable sampling technologies for each of the Sampling Plan well types. The following subsections present the recommendations for the wells within each UGTA CAU. Table H-1 in Appendix H provides a list of active wells in the Sampling Plan along with information to support selection of the appropriate sampling technology.

5.1.1 Frenchman Flat

Frenchman Flat sampling will be compliant with the CR, which requires six wells (ER-5-3, ER-5-3 #2, ER-5-5, UE-5n, RNM-2S, and ER-11-2) to be sampled annually for the first five years of CR stage monitoring (NNSA/NFO, 2015). Closure monitoring wells include ER-11-2, which is currently an inactive well with respect to the Sampling Plan, but not RNM-1, which is identified as a source/plume well in the Sampling Plan (see Table H-1 in Appendix H). The majority of the sampling locations have electric submersible pumps installed, and the two remaining (ER-11-2_m1 and ER-5-3_p2) require sampling through narrow diameter (2.875 in.) tubing that precludes the submersible pump as an option (see Table H-1 in Appendix H). The wells with electric submersible pumps should be sampled using this technology, but purging criteria must be established to minimize plume migration. ER-5-3_p2 is a characterization well and therefore should be sampled using the jack pump. ER-11-2_m1 is sampled to demonstrate the lack of tritium transport (i.e., sampled only for low-level tritium analysis) and therefore can be sampled using a depth-discrete bailer.

Table 5-1
Sampling Technologies for Integrated Sampling Plan Well Types

Location Type	Objective	Technology Requirements	Viable Sampling Technology
Characterization	• Support flow and transport model development and/or evaluation. • Identify groundwater flow paths. • Establish the presence or absence of groundwater COCs and COPCs. • Estimate travel time of contaminants. • To be reclassified and sampled according to its new type when above objectives are met.	• Capable of sampling large sample volumes (up to 20 L per sample depending on required analytes). • Purging capability (samples must represent formation waters). • Optimal technology dependent on borehole diameter.	Jack Pump or ES Pump
Source/Plume	• Support flow and transport model development and/or evaluation. • Identify COCs for downgradient wells. • Monitor contaminant migration. • Monitor natural attenuation.	• Capable of sampling large sample volumes (up to 20 L per sample depending on required analytes). • Purging capability (samples must represent formation waters).	Jack Pump or ES Pump
Early Detection	• Support flow and transport model development and/or evaluation. • Detect and monitor plume edge.	• Sampling for low-level tritium only (3 L per sample). • Ambient flow in the zone of interest is preferred. • Detect initial presence of tritium. • Optimal technology dependent on borehole diameter.	Depth-Discrete Bailer, Jack Pump, or ES Pump
Distal and Community	• Monitor tritium (COC) below 1,000-pCi/L SDWA required detection limit [a]. • Support flow and transport model development and/or evaluation.	• Sampling for standard tritium analysis only (1.25 L per sample). • Ambient flow in the zone of interest is preferred. • Detect tritium below 1,000 pCi/L.	Depth-Discrete Bailer, Jack Pump, or ES Pump
Inactive	• Defined as needed.	• Defined as needed.	Depth-Discrete Bailer, Jack Pump, or ES Pump

[a] CFR, 2015

COC = Contaminant of concern
COPC = Contaminant of potential concern
SDWA = *Safe Drinking Water Act*

5.1.2 Pahute Mesa

Twenty-one Pahute Mesa locations are characterization wells, and the majority of these are accessible through piezometer strings (see Table H-1 in Appendix H). As stated in Table 5-1, characterization wells are best sampled using the jack pump or electric submersible pump. The electric submersible pump will continue to be used for those zones with currently installed pumps; otherwise, the jack pump will be used. The only exception is ER-20-8_p3, which as stated in Section 3.2.2 cannot be sampled using either pump and therefore must be bailed. The optimal sampling technology may change depending on its new type (i.e., following recategorization from a characterization well).

Five sampling locations are categorized as early detection wells. The results of this evaluation indicate that early detection wells can be sampled using a pump or depth-discrete bailer. Because characterization is emphasized for Pahute Mesa, use of the jack pump is recommended for the three offsite locations with detected tritium (ER-EC-6, PM-3_p1, and PM-3_p2) to ensure a representative sample is collected. Use of the depth-discrete bailer is recommended for the other two (ER-20-1 and U-20WW) until tritium is detected. Once tritium is detected, the need to purge the well before sampling may be reevaluated depending on the levels detected and consistency with the current conceptual contaminant transport model.

Sampling of the 11 distal and community wells will use the electric submersible pump when one is already installed; others will be sampled using a bailer. A scooper/dipper will be used for spring sampling.

5.1.3 Rainier Mesa/Shoshone Mountain

Rainier Mesa/Shoshone Mountain CAU is in the later part of the CAI stage with sampling primarily focused on establishing baselines in support of monitoring plan development. Eight locations are characterization wells. Electric submersible pumps are installed in two locations, and four locations are accessible through piezometer strings. The electric submersible pump will continue to be used for those zones with currently installed pumps; otherwise, the jack pump will be used.

The two source/plume locations sample from vent holes and require a bailer. The two early detection locations can also be sampled with a bailer. Three of the distal locations are sampled using a dedicated electric submersible pump. The fourth distal location, TW-1, may be bailed.

5.1.4 Yucca Flat/Climax Mine

Yucca Flat/Climax Mine CAU is in the later part of the CAI stage with sampling primarily focused on specific objectives related to model evaluation and to establish baselines in support of monitoring plan development. Seven locations are characterization wells. Electric submersible pumps are installed in three locations. The electric submersible pump will continue to be used for those zones with currently installed pumps; otherwise, the jack pump will be used. The characterization wells will likely be recategorized as either source/plume or early detection wells once a baseline has been established. The optimal sampling technology may change depending on its new categorization.

Five sampling locations are categorized as source/plume. Either a jack pump or electric submersible pump should be used for collecting samples from these wells. Electric submersible pumps are installed in three of these locations, but the pump status is unknown. Five sampling locations are categorized as early detection wells, and one location is categorized as a distal well. Sampling of the distal and community wells will use the electric submersible pump in those cases where one is already installed; others will use a bailer.

5.2 Recommended Purge Criteria Guidelines

Several recommendation with respect to purging criteria and sampling technology result from this study:

- Early detection, distal, and community wells can be bailed or pumped.
- If using a pump for sampling, one well volume should be purged before samples are collected for early detection, distal, and community wells.
- Hydrophysical logs should be collected and analyzed to determine optimal sampling points for bailed wells.
- Turbidity or DO should not be included as a stabilization criteria.
- Pumping should be limited to a maximum of three well volumes for characterization and source term wells, even if water-quality parameters have not stabilized.

5.3 Recommended Future Studies and Technology Improvements

Another objective of this report is to identify potential improvements for each technology to reduce costs, obtain more accurate results, and reduce risks; and to recommend a plan for testing/deploying additional technologies. The following recommended actions or studies address this objective:

- Permanently install jack pump rods in ER-5-3_p2 and determine the cost associated with annual sampling over the next five years. First year will require purchase and installation of the rods, but subsequent years should be greatly reduced costs for sampling two additional years of characterization suite and subsequent years for tritium only (after recategorization as an early detection well).

- Identify piezometers that can be removed from the water-level monitoring program so that rods may be permanently installed. This will eliminate the future high cost associated with repeated rod installation.

- Collect time-series tritium and COC (a subset of tritium) samples during purging at RNM-2S and UE-5n to determine purging requirements for sampling the alluvial aquifer (AA) in Frenchman Flat.

- Determine whether progress has been made toward mobile sampling technique development including the BESST Blatypus pump, which may be used to sample piezometer strings.

- Determine sampling depths for depth-discrete bailers for sampling characterization wells that will likely be recategorized as early detection or distal wells.

- Evaluate historical results for samples collected from Nevada National Security Site (NNSS) wells that employed both a pump and a bailer. Compare analytical results with respect to the sampling technology and the aquifer sampled.

6.0 REFERENCES

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Appendix A

Well Completion Diagrams

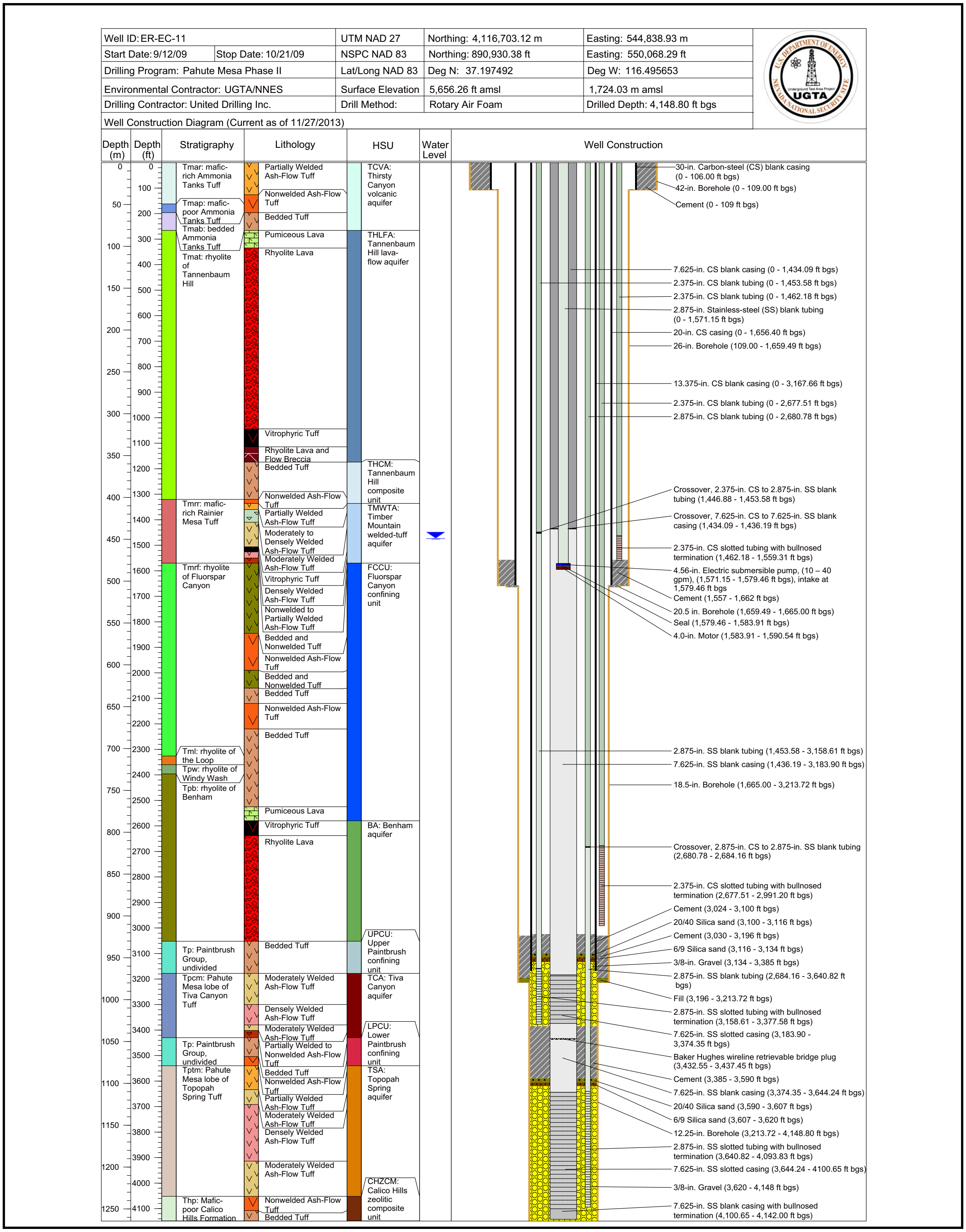

Figure A-1
Well Completion Diagram for Well ER-EC-11

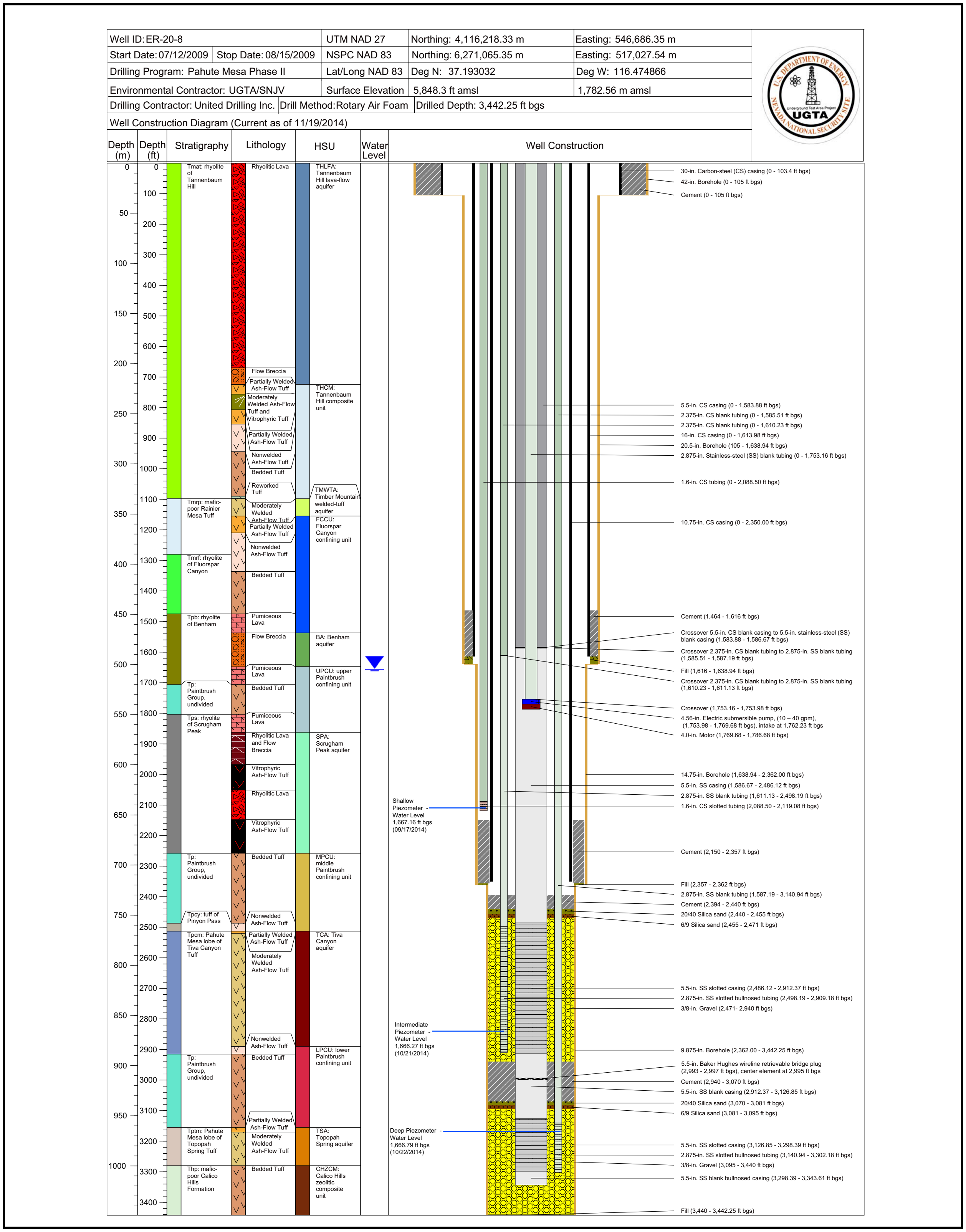

Figure A-2
Well Completion Diagram for Well ER-20-8

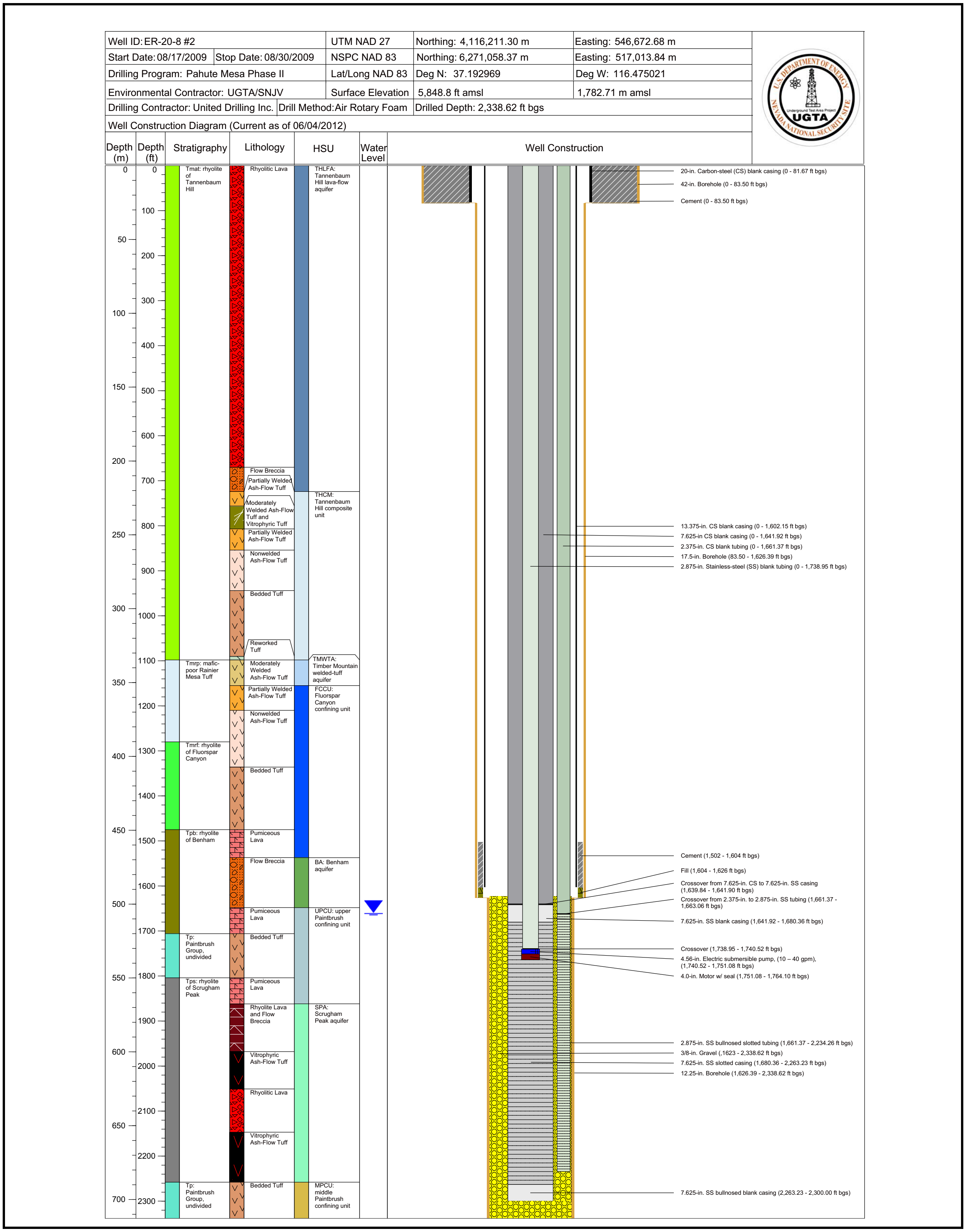

Figure A-3
Well Completion Diagram for Well ER-20-8 #2

Appendix B

Water-Quality Parameters

Table B-1
ER-EC-11 Piezometer Water-Quality Results Using the Depth-Discrete Bailer and Jack Pump
(Page 1 of 5)

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal)
Depth-Discrete Bailer ER-EC-11_p1 (3,860 ft bgs)									
07/15/2014	15:05	31.48	525	8.20	6.81	2,000	N/A	N/A	N/A
07/16/2014	14:48	26.17	516	8.41	6.20	205	1.03	25.4	N/A
Jack Pump ER-EC-11_p1									
07/21/2014	11:25	19.84	519	7.79	1.98	105	3.25	24.5	15
07/21/2014	13:30	27.86	478	8.72	2.01	30.4	1.81	24.2	434
07/21/2014	15:54	28.70	476	8.76	3.05	66.8	0.80	25.5	854
07/22/2014	09:30	28.91	478	8.30	3.36	22.5	0.613	23.9	3,870
07/22/2014	11:30	29.81	475	8.18	2.98	19.6	0.746	24.3	4,213
07/22/2014	14:25	29.93	476	8.54	2.87	15.2	0.855	25.3	4,720
07/22/2014	15:30	30.37	477	8.52	4.01	15.8	0.623	25.5	4,909
07/23/2014	09:37	29.68	535	7.92	2.98	12.5	1.05	24.6	8,069
07/23/2014	11:30	29.98	538	8.49	2.78	10.6	0.84	26.0	8,400
07/23/2014	12:22	30.04	534	8.56	2.65	8.6	0.83	24.6	8,540
07/23/2014	13:30	30.57	537	8.47	2.59	8.7	0.81	25.3	8,700
07/23/2014	15:30	31.15	537	8.45	2.75	7.3	0.93	25.9	9,084
07/24/2014	10:45	30.21	480	8.24	2.59	39.1	0.94	23.4	12,512
07/24/2014	11:05	29.30	540	8.53	2.62	30.2	0.50	25.6	12,567
07/24/2014	11:25	30.87	525	8.58	2.39	37.6	0.73	25.6	12,627
07/24/2014	12:00	31.19	518	8.58	2.77	29.3	0.40	26.1	12,724
07/24/2014	12:30	31.08	518	8.62	2.63	16.7	0.63	25.8	12,811
07/24/2014	13:00	30.84	516	8.84	2.78	9.7	0.58	25.9	12,903
07/24/2014	13:30	30.56	521	8.46	2.32	9.1	0.56	25.5	12,992
07/24/2014	16:55	30.89	520	8.47	2.41	5.2	0.54	25.7	13,541

Table B-1
ER-EC-11 Piezometer Water-Quality Results Using the Depth-Discrete Bailer and Jack Pump
(Page 2 of 5)

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal)
Jack Pump ER-EC-11_p1 (continued)									
07/25/2014	08:44	30.33	500	8.26	1.87	9.9	N/A	N/A	16,190
07/25/2014	09:06	30.28	485	8.46	1.97	8.4	0.45	258	16,251
07/25/2014	09:25	30.30	485	8.56	1.90	6.9	0.42	25.1	16,302
07/25/2014	10:57	30.89	488	8.43	2.24	7.8	0.59	25.7	17,514
Depth-Discrete Bailer ER-EC-11_p2 (3,350 ft bgs)									
07/30/2014	11:10	30.38	552	8.25	6.23	286	1.05	24.5	N/A
07/30/2014	15:30	30.19	546	8.29	6.01	122	0.71	24.6	N/A
07/31/2014	10:00	30.00	509	7.94	6.60	79.7	0.66	24.4	N/A
07/31/2014	14:30	30.01	511	8.30	5.26	95.5	0.43	25.9	N/A
Jack Pump ER-EC-11_p2									
08/07/2014	10:48	19.40	678	7.91	2.12	126	3.05	23.9	10
08/07/2014	11:30	26.15	467	7.46	2.04	42.9	2.12	24.6	96
08/07/2014	13:30	28.77	520	7.39	2.14	24.2	1.04	25.3	390
08/07/2014	13:40	28.63	514	7.87	2.28	17.7	0.824	25.7	436
08/07/2014	15:30	29.40	522	7.14	2.38	13.1	0.973	24.9	682
08/08/2014	09:10	29.85	566	7.68	2.04	12.5	0.714	25.3	3,291
08/08/2014	11:00	29.95	564	8.17	2.95	13.9	0.433	25.6	3,559
08/08/2014	12:00	30.16	576	8.10	3.13	19.4	0.349	25.7	3,711
08/08/2014	13:00	29.86	577	7.74	3.90	15.7	0.592	25.4	3,853
08/08/2014	14:00	30.06	575	8.15	2.81	11.0	0.435	24.5	3,977
08/08/2014	15:00	29.82	575	7.92	2.65	14.8	0.361	25.0	4,148
08/08/2014	16:00	30.11	568	8.17	2.77	16.8	0.425	25.3	4,296
08/09/2014	09:00	30.23	571	7.95	2.44	14.1	0.526	25.8	6,792

Table B-1
ER-EC-11 Piezometer Water-Quality Results Using the Depth-Discrete Bailer and Jack Pump
(Page 3 of 5)

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal)
Jack Pump ER-EC-11_p2 (continued)									
08/09/2014	10:00	29.83	560	8.20	3.01	11.8	0.203	24.8	6,944
08/09/2014	11:00	28.97	570	7.70	2.84	12.4	0.200	25.6	7,087
08/09/2014	12:00	29.98	584	7.25	2.69	16.5	0.177	24.8	7,237
08/09/2014	13:00	30.45	563	8.70	2.13	18.5	0.176	25.3	7,378
08/09/2014	14:00	30.17	560	7.17	2.21	12.0	0.148	25.3	7,520
08/09/2014	15:00	31.05	569	7.41	2.84	12.3	0.331	25.2	7,670
08/09/2014	16:00	30.73	568	7.36	2.67	12.4	0.323	25.3	7,821
08/10/2014	09:00	30.24	497	8.09	2.32	11.9	0.250	26.2	10,322
08/10/2014	10:00	29.88	490	7.71	2.43	11.0	0.089	25.8	10,465
08/10/2014	11:00	29.94	493	7.69	2.34	13.5	0.092	25.5	10,610
08/10/2014	12:00	30.25	493	7.70	2.27	10.9	0.207	25.4	10,758
08/10/2014	13:00	30.15	493	7.70	2.61	10.0	0.176	25.5	10,610
08/10/2014	14:00	29.98	491	7.74	2.80	11.2	0.090	25.6	11,045
08/10/2014	15:00	29.81	492	7.77	2.93	13.0	0.187	25.5	11,200
08/10/2014	16:00	30.34	495	7.80	2.48	11.7	0.087	26.0	13,926
08/11/2014	09:45	28.90	663	7.55	2.53	9.7	0.118	26.0	11,045
08/11/2014	10:42	28.43	661	6.58	2.22	10.3	0.282	25.1	14,063
08/11/2014	11:00	28.93	656	7.49	2.24	14.7	0.104	25.3	14,109
08/11/2014	11:30	28.74	663	7.08	2.67	9.8	0.843	24.9	14,177
08/11/2014	13:30	27.34	659	7.47	1.81	9.5	0.310	24.5	14,453
08/11/2014	15:18	27.11	659	7.70	1.77	9.7	0.246	24.8	14,713
08/12/2014	09:40	29.00	465	7.97	1.88	11.2	0.088	26.1	17,363
08/12/2014	09:50	29.10	471	7.70	1.73	11.7	0.158	25.2	17,389

Table B-1
ER-EC-11 Piezometer Water-Quality Results Using the Depth-Discrete Bailer and Jack Pump
(Page 4 of 5)

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal)
Jack Pump ER-EC-11_p2 (continued)									
08/12/2014	11:30	29.55	464	7.26	2.02	8.0	0.160	25.6	17,617
08/12/2014	13:30	29.34	472	7.69	1.74	9.3	0.238	25.6	17,904
08/13/2014	08:45	29.53	554	7.79	2.53	12.4	0.107	25.1	20,661
Depth-Discrete Bailer ER-EC-11_p3 (2,750 ft bgs)									
08/14/2014	09:56	27.88	653	7.46	0.93	5,999	1.28	25.3	N/A
08/14/2014	15:30	30.96	678	7.39	7.10	344	1.01	24.8	N/A
Jack Pump ER-EC-11_p3									
08/18/2014	13:38	23.59	682	9.92	2.50	312	1.14	24.5	10
08/18/2014	15:30	27.95	651	9.34	2.36	103	1.02	25.6	273
08/19/2014	09:00	28.56	676	8.74	2.89	23.2	0.925	24.8	2,830
08/19/2014	11:00	28.10	681	8.82	2.07	58.7	1.04	24.6	3,121
08/19/2014	13:00	28.19	678	8.81	2.28	19.3	0.926	24.9	3,414
08/19/2014	15:00	28.03	682	8.78	2.19	11.7	0.660	24.8	3,705
08/20/2014	09:00	28.23	618	8.77	2.26	23.3	0.801	25.7	6,348
08/20/2014	11:00	28.38	616	8.73	2.70	26.0	0.804	24.7	6,641
08/20/2014	13:00	28.19	621	8.77	2.38	60.6	0.706	25.8	6,935
08/20/2014	15:00	28.33	614	8.76	2.14	19.4	0.724	25.8	7,228
08/21/2014	11:00	28.40	617	8.67	2.10	32.0	0.699	25.5	10,175
08/21/2014	13:00	28.36	614	8.73	2.23	58.1	0.752	25.7	10,468
08/21/2014	15:00	28.38	612	8.57	2.25	34.1	0.478	25.4	10,761
08/22/2014	09:10	29.31	606	8.64	2.97	10.0	0.769	25.9	13,433
08/22/2014	11:00	29.44	615	8.69	2.75	1.7	0.920	25.0	13,692
08/22/2014	13:00	29.20	608	8.66	2.62	7.5	0.905	25.1	13,995

Table B-1
ER-EC-11 Piezometer Water-Quality Results Using the Depth-Discrete Bailer and Jack Pump
(Page 5 of 5)

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal)
Jack Pump ER-EC-11_p3 (continued)									
08/22/2014	15:00	29.23	608	8.68	3.11	7.0	0.920	24.9	14,285
08/22/2014	16:00	29.21	609	8.69	2.50	11.5	0.705	25.3	14,433
08/23/2014	09:00	29.18	684	8.62	2.68	8.0	0.571	25.5	16,950
08/23/2014	11:00	29.80	694	8.64	2.40	5.7	0.515	25.7	17,221
08/23/2014	13:00	29.44	694	8.66	2.49	6.0	0.444	25.8	17,515
08/23/2014	15:00	29.54	704	8.69	2.77	0.0	0.414	25.4	17,802
08/23/2014	16:00	29.63	700	8.66	2.54	7.8	0.504	25.5	17,953
08/24/2014	09:00	28.89	690	8.65	2.74	7.3	0.646	26.0	20,436
08/24/2014	11:00	29.12	689	8.66	2.27	9.9	0.855	24.9	20,727
08/24/2014	13:00	29.44	684	8.64	3.50	9.7	0.889	24.8	21,022
08/24/2014	15:00	29.72	694	8.64	2.90	7.9	0.895	25.5	21,318
08/24/2014	16:00	29.52	687	8.65	2.53	9.7	0.921	24.5	21,460
08/25/2014	08:15	29.10	684	8.61	2.72	9.9	1.06	24.7	23,834
08/25/2014	08:45	29.04	690	8.59	2.41	7.4	0.871	25.1	23,899
08/25/2014	09:10	28.94	689	8.60	2.37	9.8	0.866	21.5	23,966
08/25/2014	15:35	29.86	688	8.63	2.81	5.8	0.901	25.8	24,861
08/25/2014	16:04	29.80	684	8.57	2.85	0.0	0.959	25.1	24,931

Source: N-I, 2015

[a] Reported temperatures do not reflect formation fluid temperature or discharge fluid temperature.

bgs = Below ground surface
°C = Degrees Celsius
mg/L = Milligrams per liter
N/A = Not applicable
µmhos/cm = Micromhos per centimeter

Table B-2
ER-20-8 Piezometer Water-Quality Results Using a Bailer

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal)
Depth-Discrete Bailer ER-20-8_p1 (3,170 ft bgs)									
09/03/2014	13:00	35.65	388	7.74	5.35	241	0.262	25.0	N/A
09/03/2014	16:50	35.39	389	7.99	5.66	427	0.228	25.2	N/A
09/04/2014	09:40	35.10	393	8.02	5.34	314	0.312	25.4	N/A
09/04/2014	12:30	34.60	388	8.05	6.27	136	0.235	25.4	N/A
Non-Depth-Discrete Bailer ER-20-8_p3 (1,717 ft bgs)									
09/11/2014	10:30	32.50	376	7.34	5.19	189	0.999	24.8	N/A
09/12/2014	12:50	30.79	367	7.41	5.08	168	2.56	25.8	N/A
09/15/2014	13:40	32.46	361	7.26	5.31	189	2.96	25.3	N/A
09/16/2014	13:50	27.17	355	7.52	5.44	173	1.90	24.2	N/A
Depth-Discrete Bailer ER-20-8_p2 (2,800 ft bgs)									
10/21/2014	11:20	33.13	316	8.58	5.71	83.1	0.546	25.9	N/A

Source: Modified from Navarro, 2015a

[a] Reported temperatures do not reflect formation fluid temperature or discharge fluid temperature.

Table B-3
ER-20-8_m2 Water-Quality Results Using the Electric Submersible Pump

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal) [b]
03/05/2015	10:17	25.13	381	9.26	2.48	109	14.5	24.6	30
03/05/2015	11:15	37.79	408	8.49	3.30	14	0.375	25.9	1,655
03/05/2015	12:15	39.71	399	8.51	3.67	13.5	0.393	26.4	3,381
03/05/2015	13:15	38.06	403	8.41	3.78	16.9	0.490	26.2	5,186
03/05/2015	14:15	37.59	399	8.40	3.74	17.0	0.374	24.6	6,746
03/15/2015	15:15	41.47	392	8.34	4.75	23.5	0.322	26.2	8,456
03/06/2015	09:25	42.11	381	8.47	4.60	17.7	0.339	25.2	37,996
03/06/2015	10:25	38.86	386	8.37	4.70	15.8	0.379	26.5	39,640
03/06/2015	11:25	37.41	383	8.46	5.23	13.6	0.389	27.3	41,195
03/06/2015	12:25	37.54	381	8.43	5.24	11.3	0.472	27.0	42,730
03/06/2015	13:25	40.72	380	8.44	5.12	17.4	0.360	26.8	44,285
03/06/2015	14:15	40.92	381	8.44	5.13	16.0	0.242	26.1	45,665
03/06/2015	15:00	41.10	382	8.44	5.06	17.5	0.226	25.3	46,805
03/07/2015	10:00	41.64	375	8.38	4.52	19.2	0.354	26.0	76,085
03/07/2015	10:25	39.15	380	8.42	4.89	25.4	0.256	26.1	76,664
03/07/2015	10:45	40.35	385	8.42	5.01	29.3	0.235	25.5	77,193
03/07/2015	11:05	38.50	381	8.46	5.15	27.2	0.240	25.8	77,684
03/07/2015	14:08	42.47	387	8.45	4.69	21.9	0.245	25.2	82,252
03/08/2015	09:00	38.28	376	8.46	4.80	17.9	0.319	25.8	108,931
03/08/2015	13:15	42.43	375	8.43	4.48	16.3	0.217	26.0	115,283

Source: Navarro, 2015b

[a] Reported temperatures do not reflect formation fluid temperature or discharge fluid temperature.
[b] Groundwater samples were collected at the wellhead manifold sampling port.

Table B-4
ER-20-8 #2 Water-Quality Results Using a Depth-Discrete Bailer, Jack Pump, and Electric Submersible Pump
(Page 1 of 3)

Date	Time	Temperature (°C) [a]	SEC (µmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal) [b]
Depth-Discrete Bailer ER-20-8-2_p1 (2,100 ft bgs)									
09/17/2014	09:35	34.04	471	8.67	6.30	162	0.524	24.3	N/A
09/17/2014	14:05	38.30	450	8.70	5.89	430	0.363	25.4	N/A
Jack Pump ER-20-8-2_p1									
09/29/2014	14:36	20.23	428	7.46	3.79	137	0.371	25.0	10
09/29/2014	16:00	29.09	471	8.92	3.12	116	0.326	25.5	212
09/30/2014	09:00	31.00	431	8.61	3.50	28.1	0.355	25.6	2,671
09/30/2014	11:00	31.61	427	8.67	3.21	33.7	0.256	25.3	2,949
09/30/2014	13:05	31.70	431	8.57	3.13	30.5	0.257	25.3	3,251
09/30/2014	15:03	31.71	429	8.63	3.33	25.8	0.257	24.1	3,527
09/30/2014	16:00	31.41	430	8.64	3.05	24.5	0.257	25.4	3,662
10/01/2014	09:00	31.50	447	8.47	2.98	41.5	0.328	25.0	6,065
10/01/2014	11:00	30.35	444	8.57	2.94	20.9	0.213	25.0	6,338
10/01/2014	13:00	31.51	445	8.57	2.93	20.9	0.267	25.4	6,616
10/01/2014	15:00	31.69	447	8.48	2.47	19.8	0.174	24.1	6,892
10/01/2014	16:00	31.52	392	8.54	2.43	21.5	0.497	25.3	7,033
10/02/2014	09:00	31.90	422	8.50	2.89	23.6	0.215	24.3	9,380
10/02/2014	11:00	31.44	421	8.62	3.17	19.1	0.231	25.7	9,655
10/02/2014	13:00	33.04	420	8.57	2.39	16.8	0.115	26.2	9,930
10/02/2014	15:00	32.71	420	8.55	2.22	17.0	0.222	25.9	10,206
10/02/2014	16:00	32.45	423	8.55	2.28	13.9	0.202	25.0	10,342
10/03/2014	09:30	31.19	410	8.57	2.11	24.9	0.295	25.1	12,772
10/03/2014	11:30	31.61	413	8.55	1.96	17.2	0.250	25.8	13,046

Table B-4
ER-20-8 #2 Water-Quality Results Using a Depth-Discrete Bailer, Jack Pump, and Electric Submersible Pump
(Page 2 of 3)

Date	Time	Temperature (°C) [a]	SEC (μmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal) [b]
Jack Pump ER-20-8-2_p1 (continued)									
10/03/2014	13:30	32.22	414	8.51	2.47	15.9	0.203	25.6	13,324
10/03/2014	15:30	32.04	411	8.56	2.94	16.8	0.254	25.5	13,600
10/04/2014	10:30	31.44	416	8.53	2.27	28.1	0.330	25.6	16,239
10/04/2014	12:30	32.29	416	8.50	2.72	23.8	0.345	25.3	16,515
10/04/2014	14:30	32.16	415	8.52	2.57	22.1	0.379	24.5	16,793
10/04/2014	16:00	32.72	415	8.51	2.17	24.1	0.358	25.9	16,999
10/05/2014	09:30	30.53	370	8.45	2.14	30.5	0.282	25.3	19,425
10/05/2014	11:30	31.50	370	8.44	2.18	30.1	0.274	25.8	19,701
10/05/2014	13:30	32.29	370	8.43	2.06	26.6	0.339	25.3	19,978
10/05/2014	15:30	32.78	371	8.41	2.15	25.7	0.262	25.9	20,254
10/06/2014	09:05	31.91	515	8.54	2.60	40.1	0.234	25.7	22,696
10/06/2014	09:20	33.34	515	8.55	2.41	43.8	0.215	25.5	22,720
10/06/2014	10:00	33.18	510	8.54	2.42	34.1	0.203	25.9	22,810
10/06/2014	11:00	33.52	505	8.54	2.52	24.0	0.135	26.2	22,938
10/06/2014	13:00	32.53	508	8.57	2.45	25.3	0.139	25.9	23,201
10/06/2014	15:00	33.22	513	8.59	2.23	31.6	0.216	25.8	23,469
10/07/2014	08:45	32.80	434	8.62	3.36	37.3	0.154	25.7	25,871
10/07/2014	09:00	31.81	434	8.56	2.41	39.2	0.133	25.9	25,903
10/07/2014	12:30	32.82	439	8.57	2.44	28.4	0.111	25.6	26,365

Table B-4
ER-20-8 #2 Water-Quality Results Using a Depth-Discrete Bailer, Jack Pump, and Electric Submersible Pump
(Page 3 of 3)

Date	Time	Temperature (°C) [a]	SEC (μmhos/cm)	pH (SU)	DO (mg/L)	Turbidity (NTU)	Bromide (mg/L)	Bromide Temperature (°C) [a]	Total Purged (gal) [b]
Electric Submersible Pump ER-20-8-2_m1									
10/14/2014	13:36	21.93	440	8.10	2.46	208	0.289	24.3	115
10/14/2014	16:30	44.01	439	8.45	3.68	18.0	0.633	25.6	1,778
10/15/2014	09:00	44.68	400	8.35	3.95	23.6	0.355	26.0	28,500
10/15/2014	11:00	41.60	399	8.40	3.42	19.5	0.395	25.9	31,643
10/15/2014	13:00	45.05	397	8.40	4.20	18.4	0.349	25.4	34,819
10/15/2014	15:00	44.59	397	8.40	4.11	18.0	0.380	25.6	38,005
10/15/2014	16:00	44.57	397	8.41	4.02	17.2	0.370	25.9	39,587
10/16/2014	08:40	43.17	386	8.25	2.82	19.8	0.358	26.1	65,889
10/16/2014	11:10	41.87	392	8.31	3.24	14.1	0.256	24.5	69,867
10/16/2014	14:05	44.64	389	8.32	4.00	10.3	0.350	25.8	74,366
10/16/2014	15:55	44.79	388	8.34	4.11	12.7	0.315	25.7	77,180
10/17/2014	09:00	44.15	380	8.27	4.10	14.1	0.29	25.3	103,641
10/17/2014	11:00	44.68	375	8.28	3.87	13.1	0.31	25.4	106,708
10/17/2014	13:45	45.31	377	8.31	4.34	18.0	0.06	24.7	110,936

Source: Modified from Navarro, 2015b

[a] Reported temperatures do not reflect formation fluid temperature or discharge fluid temperature.
[b] Groundwater samples were collected at the wellhead manifold sampling port.

B.1.0 REFERENCES

N-I, see Navarro-Intera, LLC.

Navarro. 2015a. Written communication. Subject: *Well ER-20-8 Groundwater Sampling Data Report*. Las Vegas, NV.

Navarro. 2015b. Written communication. Subject: *Well ER-20-8 #2 Groundwater Sampling Data Report*. Las Vegas, NV.

Navarro-Intera, LLC. 2015. Written communication. Subject: *Well ER-EC-11 Groundwater Sampling Data Report*. Las Vegas, NV.

Appendix C

Time-Series Tritium Results

Table C-1
ER-EC-11 Time-Series Tritium Results Using a Jack Pump
(Page 1 of 2)

Sample Number	Purge Volume (gal)	MDC (pCi/L)	Tritium (pCi/L)	Error [a] (pCi/L)
ER-EC-11_p1				
116-072114-1	15	2.00	J 7.52	2.64
116-072114-2 (Duplicate)	15	1.98	J 6.21	2.29
116-072114-3	854	2.09	J 5.88	2.24
116-072214-4	3,870	2.06	J 6.65	2.43
116-072214-5	4,720	2.17	J 5.48	2.18
116-072314-6	8,069	1.85	J 6.81	2.40
116-072314-7	8,540	2.08	J 8.00	2.79
116-072314-8	9,394	2.11	J 6.56	2.42
116-072314-9	10,248	2.07	J 7.53	2.66
116-072414-10	11,102	2.10	J 8.22	2.85
116-072414-11	11,956	1.91	J 5.74	2.14
116-072414-12	12,810	1.95	J 7.81	2.70
ER-EC-11_p2				
116-080714-1	10	2.44	J 28.71	8.76
116-080714-2 (Duplicate)	10	2.43	J 29.28	8.92
116-080714-3	436	2.45	J 8.16	2.95
116-080714-4	872	2.45	J 6.75	2.60
116-080714-5	1,308	2.46	J 5.04	2.19
116-080714-6	1,744	2.46	UJ 4.15	2.00
116-080814-7	2,180	2.47	J 6.02	2.42
116-080814-8	2,616	2.47	UJ 4.08	1.99
116-080814-9	3,052	2.41	J 6.22	2.45
116-080814-10	3,488	2.44	J 7.11	2.68
116-080814-11	3,924	2.45	J 5.15	2.21
116-080814-12	4,360	2.42	UJ 3.28	1.81
116-080814-13	4,796	2.50	UJ 4.06	2.00
116-080814-14	5,232	2.45	J 5.37	2.26
116-080914-15	5,664	2.42	J 7.19	2.69
116-080914-16	6,104	2.47	UJ 4.38	2.05
116-080914-17	6,540	2.48	J 5.97	2.42

Table C-1
ER-EC-11 Time-Series Tritium Results Using a Jack Pump
(Page 2 of 2)

Sample Number	Purge Volume (gal)	MDC (pCi/L)	Tritium (pCi/L)	Error [a] (pCi/L)
ER-EC-11_p3				
116-081814-1	10	300	8,400	1,300
116-081914-2	2,289	300	15,700	2,400
116-081914-3	4,579	300	15,900	2,500
116-082014-4	6,868	300	16,400	2,500
116-082114-5	9,156	300	16,100	2,500
116-082114-6	11,446	300	16,800	2,600
116-082214-7	13,736	300	16,400	2,500
116-082314-8	16,025	300	16,600	2,600
116-082314-9	18,314	300	16,200	2,500
116-082414-10	20,603	300	15,900	2,500
116-082514-11	22,893	300	16,700	2,600
116-082514-12	25,181	300	16,200	2,500
116-082514-13 (Duplicate)	25,181	300	16,200	2,500

Source: N-I, 2015

[a] Error is 2 SD.

J = Estimated value. Values are considered estimated because the matrix spike recovery exceeded control limits (for ER-EC-11_p1) or because the duplicate precision analysis exceeded control limits (ER-EC-11_p2).
UJ = Compound was non-detect, but result is biased low.

Table C-2
ER-20-8_m2 Time-Series Tritium Results Using an Electric Submersible Pump

Sample Number	Purged Volume (gal)	MDC (pCi/L)	Tritium (pCi/L)	Error [a] (pCi/L)
112-030515-1	30	370	490	250
112-030515-2 (Duplicate)	30	370	400	240
112-030515-3	626	370	5,500	910
112-030515-4	1,252	400	8,200	1,300
112-030515-5	1,878	400	7,600	1,200
112-030515-6	2,504	400	7,300	1,200
112-030515-7	3,130	400	7,100	1,100
112-030515-8	3,756	400	7,100	1,100
112-030515-9 (Duplicate)	3,756	400	7,300	1,200
112-030515-10	4,382	400	6,500	1,100
112-030515-11	5,008	400	6,200	1,000
112-030515-12	5,634	400	6,600	1,100
112-030515-13	6,260	400	6,200	1,000
112-030515-14	6,886	400	6,300	1,000
112-030515-15	7,512	400	6,300	1,000
112-030515-16	8,138	400	6,100	1,000
112-030515-17	8,764	400	6,100	1,000

Source: Navarro, 2015a

[a] Error is 2 SD.

Table C-3
ER-20-8 #2 Time-Series Tritium Results
Using a Jack Pump and Electric Submersible Pump
(Page 1 of 2)

Sample Number	Purged Volume (gal) [a]	MDC (pCi/L)	Tritium (pCi/L)	Error [b] (pCi/L)
Jack Pump ER-20-8-2_p1				
113-092914-1	10	370	1,770	380
113-092914-2	1,038	370	2,180	440
113-093014-3	2,075	380	2,490	480
113-093014-4	3,113	370	2,720	510
113-093014-5	4,150	370	2,640	500
113-100114-6	5,188	370	2,430	470
113-100114-7	6,225	370	2,490	480
113-100114-8 (Duplicate)	6,225	380	2,350	460
113-100114-9	7,263	370	2,480	480
113-100214-10	8,300	370	2,580	490
113-100214-11	9,338	370	2,290	450
113-100214-12	10,035	370	2,610	490
113-100214-13	11,413	370	2,100	430
113-100314-14	12,450	370	2,180	440
113-100314-15	13,488	370	2,360	460
113-100314-16	14,525	370	2,280	450
113-100414-17	15,563	370	2,560	490
113-100414-18	16,600	390	2,400	470
Electric Submersible Pump ER-20-8-2_m1				
113-100814-1	15	320	1,080	270
113-101414-2	1,037	330	2,060	400
113-101414-3	2,075	330	2,870	510
113-101414-4	3,113	330	2,770	500
113-101414-5	4,150	330	2,680	490
113-101414-6	5,188	330	3,170	560
113-101414-7	6,225	330	2,680	490
113-101414-8	7,263	330	2,620	480
113-101414-9 (Duplicate)	7,263	360	2,980	540
113-101414-10	8,300	360	2,570	490
113-101414-11	9,338	360	2,710	500

Table C-3
ER-20-8 #2 Time-Series Tritium Results
Using a Jack Pump and Electric Submersible Pump
(Page 2 of 2)

Sample Number	Purged Volume (gal) [a]	MDC (pCi/L)	Tritium (pCi/L)	Error [b] (pCi/L)
Electric Submersible Pump ER-20-8-2_m1 (continued)				
113-101414-12	10,375	360	2,790	520
113-101414-13	11,413	360	2,760	510
113-101414-14	12,450	360	2,610	490
113-101414-15	13,488	360	2,860	530
113-101514-16	14,525	360	2,650	500
113-101514-17	15,563	360	3,130	560
113-101514-18	16,600	360	2,740	510

Source: Navarro, 2015b

[a] Samples were collected by an auto sampler approximately every 1,000 gal, and therefore purge volumes are calculated.
[b] Error is 2 SD.

C.1.0 REFERENCES

N-I, see Navarro-Intera, LLC.

Navarro. 2015a. Written communication. Subject: *Well ER-20-8 Groundwater Sampling Data Report*. Las Vegas, NV.

Navarro. 2015b. Written communication. Subject: *Well ER-20-8 #2 Groundwater Sampling Data Report*. Las Vegas, NV.

Navarro-Intera, LLC. 2015. Written communication. Subject: *Well ER-EC-11 Groundwater Sampling Data Report*. Las Vegas, NV.

Appendix D

Depth-Discrete Bailer Sample Analytical Results

Table D-1
ER-EC-11 Laboratory Results for Bailer Samples

Analyte	Detection Limit	ER-EC-11_p1–TSA (3,860 ft bgs)		ER-EC-11_p2–TCA (3,350 ft bgs)		ER-EC-11_p3–BA (2,750 ft bgs)	
		116-071514-1 [a] 116-071614-1(F) [b]	116-071514-1 [a] 116-071614-2(F) [b]	1116-073014-1 [a] 116-073114-1(F) [b]	116-073014-1 [a] 116-073114-2(F) [b]	116-081414-1(F) [b]	116-081414-2(F) [b]
Major Anions (mg/L)							
Calcium	1	51	69	9.1	12	53	14
Magnesium	1	2.9	5.6	<1	1.3	<1	<1
Potassium	1	1.3	1.6	1.4	1.6	5.4	4.1
Sodium	1	100	100	100	100	130	130
Bromide	0.2	J 0.18	J 0.19	0.25	0.26	0.28	0.31
Chloride	1	43	43	44	44	61	59
Fluoride	0.1	2.9	2.9	3.1	3.1	3.1	3.1
Sulfate	1	68	69	68	67	87	88
Tritium (pCi/L)							
Tritium	2.07, 2.02, 2.62, 2.21, 300, 300 [c]	J 5.68 ± 2.19	J 7.34 ± 2.60	12.14 ± 4.08	11.07 ± 3.67	12,600 ± 2,000	12,200 ± 1,900

Source: N-I, 2015

[a] Sample analyzed by ARS for low-level tritium.
[b] Filtered samples designated 116-071614-1F, 116-071614-2F, 116-073114-1F, 116-073114-2F, 116-081414-1F, and 116-081414-2F.
[c] Detection limits apply to the samples in the order presented.

J = Result is estimated.

Table D-2
ER-20-8 Laboratory Results for Bailer Samples

Analyte	Detection Limit	ER-20-8_p1 Depth-Discrete (3,170 ft bgs)		ER-20-8_p2 Depth-Discrete (2,800 ft bgs)		ER-20-8_p3 Non-Depth-Discrete	
		112-090314-1 [a] 112-090414-1(F) [b]	112-090314-2 [a] 112-090414-2(F) [b]	112-102114-1(F) [b]	112-102114-2(F) [b]	112-091014-1 112-091514-1(F) [b]	112-091014-2
Major Ions (mg/L)							
Calcium	1	28	35	3.1	3.5	13	--
Magnesium	1	2.1	3.7	0.87	1.1	0.44	--
Potassium	1	J 3.0	J 2.6	2.9	2.9	J 3.6	--
Sodium	1	84	87	96	98	87	--
Bromide	0.2	J 0.16	J 0.14	J 0.16	J 0.18	J 0.14	--
Chloride	1	25	24	29	30	29	--
Fluoride	0.1	4.4	4.5	3.8	3.8	5.4	--
Sulfate	1	43	44	52	52	44	--
Tritium (pCi/L)							
Tritium	4.37, 4.59, 400, 400, 410, 410 [c]	128.22 ± 38.14	114.72 ±34.21	8,200 ± 1,300	8,800 ± 1,400	1,770 ± 400	1,640 ± 380

Source: Navarro, 2015a

[a] Sample analyzed by ARS for low-level tritium.
[b] Filtered samples designated 112-090414-1F, 112-090414-2F, 112-102114-1F, 112-102114-1F, 112-102114-2F, and 112-091514-1F.
[c] Detection limits apply to the samples in the order presented.

J = Result is estimated.
-- = No result

Table D-3
ER-20-8 #2 Laboratory Results for Depth-Discrete Bailer (2,100 ft bgs) Samples

Analyte	Detection Limit	113-091714-1(F) [a]	113-091714-2(F) [a]
Major Ions (mg/L)			
Calcium	1	9.6	8.8
Magnesium	1	7.1	7.6
Potassium	1	4.1	4.2
Sodium	1	98	98
Bromide	0.2	J 0.13	J 0.12
Chloride	1	27	27
Fluoride	0.1	4.8	4.8
Sulfate	1	49	49
Tritium (pCi/L)			
Tritium	420, 410 [b]	2,670 ± 520	2,440 ± 490

Source: Navarro, 2015b

[a] Filtered samples designated 113-091714-1F and 113-091714-2F.
[b] Detection limit applies to the samples in the order presented.

J = Result is estimated.

D.1.0 REFERENCES

N-I, see Navarro-Intera, LLC.

Navarro. 2015a. Written communication. Subject: *Well ER-20-8 Groundwater Sampling Data Report*. Las Vegas, NV.

Navarro. 2015b. Written communication. Subject: *Well ER-20-8 #2 Groundwater Sampling Data Report*. Las Vegas, NV.

Navarro-Intera, LLC. 2015. Written communication. Subject: *Well ER-EC-11 Groundwater Sampling Data Report*. Las Vegas, NV.

Appendix E

Electric Submersible Pump and Jack Pump Sample Laboratory Results

Table E-1
ER-EC-11 Laboratory Results for Jack Pump Samples

Analyte	Reporting Limit	ER-EC-11_p1		ER-EC-11_p2		ER-EC-11_p3	
		116-072414-1(F) [a] 116-072414-3 [b]	116-072414-2(F) [a] 116-072414-4 [b]	116-081114-1(F) [a] 116-081114-3 [b]	116-081114-2(F) [a] 116-081114-4 [b]	116-082514-1(F) [a]	116-082514-2(F) [a]
Major Ions (mg/L)							
Calcium	1	5.0 | 4.8	4.9 | 4.8	4.8 | 4.7	4.7 | 4.8	25 | 4.7	7.9 | 4.7
Magnesium	1	U 1 | U 1	U 1 | U 1	U 1 | U 1	U 1 | U 1	U 1 | U 1	U 1 | U 1
Potassium	1	1.0 | U 1	U 1 | U 1	1.2 | 1.1	1.1 | 1.1	4.1 | 3.8	4.0 | 3.8
Sodium	1	99 | 98	99 | 99	100 | 100	100 | 100	120 | 120	130 | 120
Bromide	0.2	J 0.19	J 0.18	0.22	0.21	0.25	0.26
Chloride	1	43	43	44	44	61	60
Fluoride	0.1	2.9	2.9	3.1	3.1	3.1	3.1
Sulfate	1	69	69	69	69	88	88
Tritium (pCi/L)							
Tritium	1.81, 1.97, 2.38, 2.32, 300, 300 [c]	J 7.99 ± 2.71	J 6.01 ± 2.23	11.53 ± 3.85	11.41 ± 3.8	16,100 ± 2,500	16,000 ± 2,500

Source: Navarro, 2015

[a] Filtered samples designated 116-072414-1F, 116-072414-2F, 116-081114-1F, 116-081114-2F, 116-082514-1F, and 116-082514-2F.
[b] Sample analyzed by ARS for low-level tritium.
[c] Reporting limits apply to the samples in the order presented.

J = Result is estimated.
U = Value is a nondetect.

Note: Results reported with a "|" represent Unfiltered | Filtered sample results.

Table E-2
ER-20-8_m2 Laboratory Results for Electric Submersible Pump Samples

Analyte	Reporting Limit	112-030715-1(F) [a]	112-030715-2(F) [a]
Major Ions (mg/L)			
Calcium	1	2 | 2	2 | 2
Magnesium	1	J 0.025 | U 1	< 0.013 | J 0.021
Potassium	1	2.2 | 2.2	2.2 | 2.2
Sodium	1	86 | 87	87 | 288
Bromide	0.2	J 0.15	J 0.14
Chloride	1	28	29
Fluoride	0.1	4.0	4.1
Sulfate	1	51	51
Tritium (pCi/L)			
Tritium	350, 360 [b]	4,560 ± 760	4,590 ± 770

Source: Navarro, 2015

[a] Filtered sample designated 112-030715-1F and 112-030715-2F.
[b] Reporting limits apply to the samples in the order presented.

J = Result is estimated.
U = Value is a nondetect.

Note: Results reported with a "|" represent Unfiltered | Filtered sample results.

Table E-3
ER-20-8 #2 Laboratory Results for Jack Pump and Electric Submersible Pump Samples

Analyte	Reporting Limit	Jack Pump (ER-20-8-2_p1)		Submersible Pump (ER-20-8-2_m1)	
		113-100614-1(F) [a]	113-100614-2(F) [a]	113-101614-1(F) [a]	113-101614-2(F) [a]
Major Ions (mg/)					
Calcium	1	1.9 | 1.8	1.8 | 1.8	J 1.8 | J 1.7	J 1.8 | J 1.8
Magnesium	1	U 1 | U 1	U 1 | < 0.03	U 1 | U 1	U 1 | U 1
Potassium	1	2.3 | 2.4	2.4 | 2.4	2.2 | 2.3	2.2 | 2.3
Sodium	1	91 | 91	92 | 92	86 | 87	86 | 88
Bromide	0.2	J 0.15	J 0.16	J 0.14	J 0.16
Chloride	1	27	26	27	27
Fluoride	0.1	4.9	5.1	J+ 5.1	J+ 5.2
Sulfate	1	49	49	49	51
Tritium (pCi/L)					
Tritium	370, 370, 360, 360 [b]	2,470 ± 470	2,310 ± 450	2,600 ± 490	2,510 ± 480

Source: Navarro, 2015

[a] Filtered samples designated 113-100614-1F, 113-100614-2F, 113-101614-1F, and 113-101614-2F.
[b] Reporting limits apply to the samples in the order presented.

J = Result is estimated.
J+ = Results is estimated; bias is high.
U = Value is a nondetect.

Note: Results reported with a “|” represent Unfiltered | Filtered sample results.

E.1.0 References

Navarro. 2015. Written communication. Subject: "UGTA Chemistry Database (UCDB)," UGTA Technical Data Repository Database Identification Number UGTA-4-1197. Las Vegas, NV. As accessed on 14 May.

Appendix F

Major-Ion Results

Table F-1
Major-Ion Concentrations
(Page 1 of 3)

Date	Br	Cl	F	SO_4	Ca	K	Mg	Na
	(mg/L)							
ER-EC-11								
ER-EC-11_m1-2								
05/18/2010	0.21	43	3.1	70	4.0	J- 0.75	< 0.013	95
05/18/2010	< 0.023	42	3.0	70	3.9	J- 0.68	< 0.013	95
ER-EC-11_p1 (Depth-Discrete Bailer at 3,750 and 3,860 ft)								
05/02/2010	J 0.17	49	2.9	68	5.8	J- 0.64	J- 0.098	94
05/02/2010	J 0.17	42	2.9	66	7.3	J- 0.65	J- 0.2	95
07/16/2014	J 0.18	43	2.9	68	51 [a]	1.3 [a]	2.9 [a]	100 [a]
07/16/2014	J 0.19	43	2.9	69	69 [a]	1.6 [a]	5.6 [a]	100 [a]
ER-EC-11_p1 (Jack Pump)								
07/24/2014	J 0.19	43	2.9	69	4.8 | 5.0 [a]	U 1 | 1 [a]	U 1 | U 1 [a]	98 | 99 [a]
07/24/2014	J 0.18	43	2.9	69	4.8 | 4.9 [a]	U 1 | U 1 [a]	U 1 | U 1 [a]	99 | 99 [a]
ER-EC-11_p2 (Depth-Discrete Bailer at 3,300 and 3,350 ft)								
05/02/2010	J 0.17	47	2.9	67	30	J- 0.8	1.8	95
07/31/2014	0.25	44	3.1	68	9.1 [a]	1.4 [a]	U 1 [a]	100 [a]
07/31/2014	0.26	44	3.1	67	12 [a]	1.6 [a]	1.3 [a]	100 [a]
ER-EC-11_p2								
08/11/2014	0.22	44	3.1	69	4.7 | 4.8 [a]	1.1 | 1.2 [a]	U 1 | U 1 [a]	100 | 100 [a]
08/11/2014	0.21	44	3.1	69	4.8 | 4.7 [a]	1.1 | 1.1 [a]	U 1 | U 1 [a]	100 | 100 [a]
ER-EC-11_p3 (Depth-Discrete Bailer at 2,750 ft)								
08/14/2014	0.28	61	3.1	87	53 [a]	5.4 [a]	U 1 [a]	130 [a]
08/14/2014	0.31	59	3.1	88	14 [a]	4.1 [a]	U 1 [a]	130 [a]
ER-EC-11_p3 (Jack Pump)								
08/25/2014	0.25	61	3.1	88	4.7 | 25 [a]	3.8 | 4.1 [a]	U 1 | U 1 [a]	120 | 120 [a]
08/25/2014	0.26	60	3.1	88	4.7 | 7.9 [a]	3.8 | 4.0 [a]	U 1 | U 1 [a]	120 | 130 [a]
ER-EC-11_o1 (Depth-Discrete Bailer at 2,450, 2,750, and 3,150 ft)								
10/09/2009	0.78	56	3.6	86	2.4 | 2.4 [a]	3.9 | 4.0 [a]	J- 0.02 | J- 0.039 [a]	110 | 110 [a]
10/10/2009	0.94	56	2.9	86	3.8 | 3.8 [a]	2.8 | 2.9 [a]	< 0.0066 | J- 0.012 [a]	110 | 110 [a]
10/10/2009	1.1	57	2.7	83	4.1 | 3.9 [a]	2.2 | 2.4 [a]	< 0.0066 | < 0.0066 [a]	110 | 110 [a]

Table F-1
Major-Ion Concentrations
(Page 2 of 3)

Date	Br	Cl	F	SO_4	Ca	K	Mg	Na
	(mg/L)							
ER-20-8								
ER-20-8_p1 (Depth-Discrete Bailer at 3,170 ft)								
07/22/2011	J 0.081	24	J 4.2	44	4.4	1.8	U 1	77
09/04/2014	J 0.16	25	4.4	43	28 [a]	J 3.0 [a]	2.1 [a]	84 [a]
09/04/2014	J 0.14	24	4.5	44	35 [a]	J 2.6 [a]	3.7 [a]	87 [a]
ER-20-8_m1 (Electric Submersible Pump)								
08/08/2011	J 0.081	23	4.2	43	3.4 | 3.4 [a]	1.8 | 1.8 [a]	U 1 | J- 0.027 [a]	J 79 | J 79 [a]
08/08/2011	J 0.081	24	4.1	42	3.3 | 3.4 [a]	1.7 | 1.7 [a]	< 0.013 | < 0.013 [a]	J 78 | J 78 [a]
ER-20-8_p2 (Depth-Discrete Bailer at 2,800 ft)								
05/26/2011	J 0.10	26	3.7	47	2.3	2.6	J- 0.54	81
05/26/2011	J 0.11	28	3.5	45	1.7	2.4	< 0.013	82
10/21/2014	J 0.16	29	3.8	52	3.1 [a]	2.9 [a]	0.87 [a]	96 [a]
10/21/2014	J 0.18	30	3.8	52	3.5 [a]	2.9 [a]	1.1 [a]	98 [a]
ER-20-8_m2								
06/27/2011	J 0.098	33	3.8	49	2.1 | 2.1 [a]	2.4 | 2.4 [a]	U 1 | U 1 [a]	J 77 | J 79 [a]
06/27/2011	J 0.11	28	3.8	50	2.1 | 2.1 [a]	2.4 | 2.4 [a]	U 1 | U 1 [a]	J 78 | J 77 [a]
03/07/2015	J 0.15	28	4.0	51	2.0 | 2.0 [a]	2.2 | 2.2 [a]	U 1 | J 0.025 [a]	87 | 86 [a]
03/07/2015	J 0.14	29	4.1	51	2.0 | 2.0 [a]	2.2 | 2.2 [a]	J 0.021 | < 0.013 [a]	88 | 87 [a]
ER-20-8_p3 (Depth-Discrete Bailer at 1,717 ft)								
09/15–16/2014	J 0.14	29	5.4	44	13 [a]	J 3.6 [a]	0.44 [a]	87 [a]

Table F-1
Major-Ion Concentrations
(Page 3 of 3)

Date	Br	Cl	F	SO_4	Ca	K	Mg	Na
	(mg/L)							
ER-20-8 #2								
ER-20-8-2_m1 (Electric Submersible Pump)								
12/18/2009	J 0.12	26	4.5	49	1.8	2.5	< 0.0067	80
12/18/2009	J 0.12	26	4.5	49	1.9 | 1.8 [a]	2.5 | 2.5 [a]	J- 0.011 | <0.0067 [a]	81 | 80 [a]
10/16/2014	J 0.14	27	J+ 5.1	49	J 1.7 | J 1.8 [a]	2.3 | 2.2 [a]	U 1 | U 1 [a]	87 | 86 [a]
10/16/2014	J 0.16	27	J+ 5.2	51	J 1.8 | J 1.8 [a]	2.3 | 2.2 [a]	U 1 | U 1 [a]	88 | 86 [a]
ER-20-8-2_o1 (Depth-Discrete Bailer at 1,710 and 2,200 ft)								
08/31/2009	0.92	23	2.8	36	1.9	3.5	J- 0.024	66
08/31/2009	0.95	22	2.9	37	1.7	3.3	J- 0.023	70
08/31/2009	4.0	24	3.3	45	4.9 | 5.3 [a]	5.3 | 6.4 [a]	J- 0.24 | 0.37 [a]	100 | 100 [a]
ER-20-8-2_p1 (Depth-Discrete Bailer at 2,100 ft)								
12/03/2009	J 0.12	27	4.6	49	2.2 | 2.5 [a]	2.9 | 2.8 [a]	< 0.0067 | J- 0.12 [a]	82 | 82 [a]
12/03/2009	J 0.12	27	4.6	49	2.3 | 2.7 [a]	2.9 | 2.9 [a]	< 0.0067 | J- 0.18 [a]	84 | 82 [a]
09/17/2014	J 0.13	27	4.8	49	9.6 [a]	4.1 [a]	7.1 [a]	98 [a]
09/17/2014	J 0.12	27	4.8	49	8.8 [a]	4.2 [a]	7.6 [a]	98 [a]
ER-20-8-2_p1 (Jack Pump)								
10/06/2014	J 0.15	27	4.9	49	1.8 | 1.9 [a]	2.4 | 2.3 [a]	U 1 | U 1 [a]	91 | 91 [a]
10/06/2014	J 0.16	26	5.1	49	1.8 | 1.8 [a]	2.4 | 2.4 [a]	< 0.03 | U 1 [a]	92 | 92 [a]

Source: Navarro, 2015

[a] Sample was not filtered.

J = Estimated value.
J- = Estimated value with a negative bias.
U = Compound was non-detect.

F.1.0 REFERENCES

Navarro. 2015. Written communication. Subject: "UGTA Chemistry Database (UCDB)," UGTA Technical Data Repository Database Identification Number UGTA-4-1197. Las Vegas, NV. As accessed on 14 May.

Appendix G

ER-EC-11 and ER-20-8 #2 Chronological Summaries

Table G-1
Chronological Summary of Well ER-EC-11 Sampling Activities
(Page 1 of 2)

Date	M&O Hours [a]	EPS Hours [b]	Cumulative Hours [c]	Activities
07/10/2014	0	30	30	Begin mobilization. Drop off laboratory trailer and miscellaneous equipment and supplies. Two EPS contractors.
07/11 to 07/15/2014	0	0	0	No activity.
07/16/2014	0	45	45	Removed PXD from the deep piezometer and begin depth-discrete bailer sampling in deep piezometer. Three EPS contractors.
07/17/2014	0	45	45	Complete depth-discrete bailer sampling. Three EPS contractors.
07/18/2014	140	30	170	M&O contractor installs jack pump, deep piezometer. Two EPS contractors and M&O crew.
07/19 to 07/21/2014	0	0	0	No activity.
07/22/2014	40	30	70	Begin pumping deep piezometer. Two EPS contractors and M&O contractor support.
07/23/2014	0	30	30	Pumping deep piezometer. Two EPS contractors.
07/24/2014	0	30	30	Pumping deep piezometer. Two EPS contractors.
07/25/2014	0	30	30	Pumping deep piezometer. Begin groundwater sampling. Two EPS contractors.
07/26/2014	0	30	30	Pumping deep piezometer. Completed groundwater sampling. Two EPS contractors.
07/27 to 07/28/2014	0	0	0	No activity.
07/29/2014	80	30	110	Shut-off pump and remove from deep piezometer. Two EPS contractors and M&O contractor support.
07/30/2014	10	30	40	Reinstalled PXD in deep piezometer and removed PXD from intermediate piezometer. Two EPS contractors.
07/31/2014	0	30	30	Depth-discrete bailer sampling in intermediate piezometer. Two EPS contractors.
08/01/2014	0	30	30	Complete depth-discrete bailer sampling. Two EPS contractors.
08/02 to 08/06/2014	0	0	0	No activity.
08/07/2014	140	30	170	Install rod pump in intermediate piezometer and function test. Two EPS contractors and M&O contractor support.
08/08/2014	20	30	50	Begin pumping intermediate piezometer. Two EPS contractors and M&O contractor support to start pump.

Table G-1
Chronological Summary of Well ER-EC-11 Sampling Activities
(Page 2 of 2)

Date	M&O Hours [a]	EPS Hours [b]	Cumulative Hours [c]	Activities
08/09/2014	0	30	30	Pumping intermediate piezometer. Two EPS contractors.
08/10/2014	0	30	30	Pumping intermediate piezometer. Two EPS contractors.
08/11/2014	0	30	30	Pumping intermediate piezometer. Two EPS contractors.
08/12/2014	0	45	45	Pumping intermediate piezometer, begin groundwater sampling. Three EPS contractors.
08/13/2014	0	45	45	Pumping intermediate piezometer, completed groundwater sampling. Three EPS contractors. Pump shut down.
08/14/2014	130	30	160	M&O contractor removed pump from intermediate zone. EPS contractors installed PXD in intermediate piezometer and removed PXD from shallow piezometer. Two EPS contractors and M&O contractor support.
08/15/2014	0	30	30	EPS contractors conduct depth-discrete bailer sampling in shallow piezometer. Two EPS contractors.
08/16 to 08/18/2014	0	0	0	No activity.
08/19/2014	90	30	120	M&O contractor installs pump in shallow piezometer and begins pumping. Two EPS contractors and M&O contractor support.
08/20/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
08/21/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
08/22/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
08/23/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
08/24/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
08/25/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
08/26/2014	0	45	45	Pumping shallow piezometer. Completed groundwater sampling. Three EPS contractors.
Total	650	975	1,625	

[a] M&O contractor hours are estimated, 10 hours used for each person.
[b] EPS contractor hours are estimated, 15 hours per day for each person.
[c] EPS and M&O contractor estimated hours combined.

PXD = Pressure transducer

Table G-2
Chronological Summary of Well ER-20-8 #2 Sampling Activities
(Page 1 of 2)

Date	M&O Hours [a]	EPS Hours [b]	Cumulative Hours [c]	Activities
09/16/2014	0	30	30	Begin mobilization. Two EPS contractors.
09/17/2014	0	60	60	Measured water-level then installed PXD. Begin bailer operations and groundwater sampling. Four EPS contractors.
09/18/2014	140	30	170	M&O contractor lowered the rod pump into the piezometer and inspected jack pump surface unit set up at wellhead. Started jack pump and shut it down after 15 minutes. Two EPS and four M&O contractors.
09/19/2014	10	30	40	Started pump. Problem with flow line; seal was not set. Shut down pump. Two EPS and one M&O contractors.
09/20 to 09/21/2014	0	0	0	No activity.
09/22/2014	140	30	170	M&O contractors tripped out pump string and conducted inspection. Tripped in the pump and sucker rods but unable to set the polishing rod. Tripped out sucker rods, secured the pump in the boot; and equipment. Two EPS contractors and M&O support crew.
09/23/2014	80	30	170	M&O contractors lowered the pump into the boot. Rod pump became detached from the 2-ft rod pup in the crane elevator and fell to the ground. Work suspended. Two EPS contractors. Two M&O supervisors and support crew.
09/24/2014	0	30	30	Work suspended. Two EPS contractors.
09/25/2014	140	30	170	Work suspended. The EPS contractor collected depth-discrete bailer samples. M&O removed the rod pump from the damaged pump and secured site. Two EPS contractors. Two M&O supervisors and support crew.
09/26/ to 09/28/2014	0	0	0	No activity.
09/29/2014	80	30	170	Begin pumping. Two EPS contractors. Two M&O supervisors and support crew.
09/30/2014	10	30	40	Pumping continues. Two EPS contractors and M&O support crew.
10/01/2014	10	30	40	Pumping continues. Two EPS contractors and M&O support crew.
10/02/2014	0	30	30	Pumping continues. Two EPS contractors.
10/03/2014	0	45	45	Pumping shallow piezometer. Removed deep piezometer PXD and measured water level. Three EPS contractors.

Table G-2
Chronological Summary of Well ER-20-8 #2 Sampling Activities
(Page 2 of 2)

Date	M&O Hours [a]	EPS Hours [b]	Cumulative Hours [c]	Activities
10/04/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
10/05/2014	0	30	30	Pumping shallow piezometer. Two EPS contractors.
10/06/2014	0	45	45	Pumping continues. Begin groundwater sampling. Three EPS contractors.
10/07/2014	10	45	55	Pumping continues. Completed groundwater sampling. Three EPS contractors and M&O contractors support.
10/08/2014	140	30	170	The M&O contractor shut down jack pump, moved surface unit, and measured water level. Started electric submersible pump, and conducted function test. Begin groundwater sampling. Shut down pump after sampling and purging. Two EPS contractors and M&O contractor support crew.
10/09/ to 10/13/2014	0	0	0	No activity.
10/14/2014	0	45	45	The EPS contractor measured water level, installed PXD then started electric submersible pump. Three EPS contractors.
10/15/2014	0	30	30	Pumping main completion. Two EPS contractors.
10/16/2014	0	45	45	Pumping main completion. Begin groundwater sampling. Three EPS contractors.
10/17/2014	10	30	40	Completed groundwater sampling. Shut down the pump. Two EPS contractors and M&O contractor support crew.
Total	730	765	1,495	

[a] M&O contractor hours are estimated, 10 hours used for each person.
[b] EPS contractor hours are estimated, 15 hours per day for each person.
[c] EPS and M&O contractor estimated hours combined.

Appendix H

NNSS Integrated Sampling Plan Well Information and Recommended Technology

Table H-1
Frenchman Flat Well Information

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1}) [a]	Technology
Characterization															
5149	ER-5-3	ER-5-3_p2	No	No	No	N/A	Yes	2.875	927	1,012	Yes	N/A	BLFA/OAA	1	Jack Pump
5150	ER-5-3-2	ER-5-3-2_m1	Yes	Yes	Yes	5.5	No	N/A	4,674	5,683	Yes	N/A	LCA	1	ES Pump
9713	ER-5-5	ER-5-5_m1	Yes	Yes	Yes	6.63	Yes	2.38	WL	1,041	Yes	N/A	BLFA/OAA	1	ES Pump
Source/Plume															
1920	RNM-1	RMN-1_m5	No	Yes	Yes	5.5	No	N/A	WL	1,002	No	9.875	AA	4	ES Pump
1922	RNM-2S	RNM-2S_m1	Yes	Yes	Yes	9.6	Yes	1.9	WL	1,120	Yes	N/A	AA	1	ES Pump
1919	UE-5n	UE-5n_m1	--	Yes	--	9.9	No	N/A	WL	1,687	No	15	AA	1	ES Pump
Inactive															
9714	ER-11-2 [b]	ER-11-2_m1	No	No	No	N/A	Yes	2.375	WL	1,304	Yes	N/A	LTCU	1	Bailer

[a] Annual sampling is required or the first five years of the CR stage.
[b] ER-11-2 is a closure monitoring well and will be sampled annually for the first five years of the CR stage.

-- = Not available
N/A = Not applicable

AA = Alluvial aquifer
BLFA = Basalt lava flow aquifer
ES = Electric submersible pump
LCA = Lower carbonate aquifer
LTCU = Lower tuff confining unit
OAA = Older alluvial aquifer
ISPID = Integrated Sampling Plan Identification
WL = Water level

Table H-2
Pahute Mesa Well Information
(Page 1 of 4)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Characterization															
5151	ER-EC-2A [a]	ER-EC-2A_m3	Yes	Yes	Yes	5.5	No	N/A	2,587	2,730	Yes	N/A	FCCM	3	ES Pump
4103	ER-EC-5	ER-EC-5_m1-3	Yes	Yes	Yes	5.5	No	N/A	1,187 1,885 2,223	1,443 2,146 2,480	Yes	N/A	TMCM	3	ES Pump
4104	ER-EC-8	ER-EC-8_m1-3	Yes	Yes	Yes	5.5	No	N/A	662 1,428 1,660	1,050 1,558 1,990	Yes	N/A	FCCM/TMCM	3	ES Pump
6770	ER-EC-11	ER-EC-11_p1	No	Yes	No	7.6	Yes	2.88	3,620	4,148	Yes	N/A	TSA/CHCU	3	Jack Pump
		ER-EC-11_m2	Yes	Yes	Yes	7.6	Yes	2.38	3,134	3,385	Yes	N/A	UPCU/TCA	3	ES Pump
		ER-EC-11_p3	No	No	No	N/A	Yes	2.38	1,662	3,024	No	18.50	FCCU/BA	3	Jack Pump
6772	ER-EC-12	ER-EC-12_m1	No	Yes	No	6.6	Yes	2.38	3,231	3,770	Yes	N/A	TSA/CHCU	3	Jack Pump
		ER-EC-12_m2	Yes	Yes	Yes	6.6	Yes	2.38	1,893	2,744	Yes	N/A	THCM/TCA/ LPCU	3	ES Pump
6773	ER-EC-13	ER-EC-13_p1	No	Yes	No	5.5	Yes	2.38	2,263	2,680	Yes	N/A	FCCM	3	Jack Pump
		ER-EC-13_m2	Yes	Yes	Yes	6.6	Yes	2.38	1,916	2,136	Yes	N/A	FCCM	3	ES Pump
6774	ER-EC-14	ER-EC-14_p1	No	Yes	No	6.6	Yes	2.38	1,920	2,372	Yes	N/A	RMWTA	3	Jack Pump
		ER-EC-14_m2	Yes	Yes	Yes	6.6	Yes	2.38	1,328	1,704	Yes	N/A	RMWTA	3	ES Pump
6775	ER-EC-15	ER-EC-15_p1	No	Yes	No	5.5	Yes	2.38	2,784	3,189	Yes	N/A	TSA/CHCU	3	Jack Pump
		ER-EC-15_p2	No	Yes	No	5.5	Yes	2.38	2,139	2,427	Yes	N/A	TCA/LPCU	3	Jack Pump
		ER-EC-15_m3	Yes	Yes	Yes	7.6	Yes	2.38	1,191	1,769	Yes	N/A	FCCU/CPA/ PBPCU	3	ES Pump
6769	ER-20-7	ER-20-7_m1	Yes	Yes	Yes	7.6	No	N/A	2,332	2,924	Yes	N/A	LPCU/TSA/ CHZCM	3	ES Pump

Table H-2
Pahute Mesa Well Information
(Page 2 of 4)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Characterization (continued)															
6771	ER-20-8	ER-20-8_p1	No	Yes	No	5.5	Yes	2.38	3,095	3,440	Yes	N/A	LPCU/TSA/ CHZCM	3	Jack Pump
		ER-20-8_m2	Yes	Yes	Yes	5.5	Yes	2.38	2,471	2,940	Yes	N/A	MPCU/TCA/ LPCU	3	ES Pump
		ER-20-8_p3	No	No	No	N/A	Yes	1.60	WL	2,150	No	14.75	UPCU/SPA	3	Bailer
6963	ER-20-8-2	ER-20-8-2_m1	Yes	Yes	Yes	7.6	Yes	2.38	1,623	2,339	Yes	N/A	BA/UPCU/ SPA/MPCU	3	ES Pump
9712	ER-20-11	ER-20-11_m1	Yes	Yes	Yes	6.6	Yes	2.38	2,591	3,004	Yes	N/A	FCCU/BA/ UPCU	3	ES Pump
Source/Plume															
16	ER-20-5-1	ER-20-5-1_p1	Yes	Yes	Yes	5.5	Yes	2.88	2,278	2,655	Yes	N/A	TSA/CHZCM	4	ES Pump
21	ER-20-5-3	ER-20-5-3_m1	Yes	Yes	Yes	5.5	No	N/A	3,393	3,954	Yes	N/A	CHZCM	4	ES Pump
18	ER-20-6-1	ER-20-6-1_p1	No	Yes	No	5.5	Yes	2.88	2,437	2,947	Yes	N/A	CHZCM	4	Jack Pump
19	ER-20-6-2	ER-20-6-2_p1	No	Yes	No	5.5	Yes	2.88	2,414	2,945	Yes	N/A	CHZCM	4	Jack Pump
20	ER-20-6-3	ER-20-6-3_p1	No	Yes	Yes	5.5	Yes	2.88	2,480	2,807	Yes	N/A	CHZCM	4	Jack Pump
3534	UE-20n1	UE-20n 1_o2	Yes	Open	Yes	N/A	Yes	2.38	2,323	2,824	No	8.50	CHZCM	4	ES Pump
5454	U-19ad PS1A [b]	U-19ad PS 1A_m1	Yes	Yes	Yes	5.5	No	N/A	WL	2,579	No	--	PLFA	4	ES Pump
3390	U-19q PS 1D [c]	U-19q PS 1D_m1	--	--	--	9.6	--	--	3,665	4,304	--	--	--	4	ES Pump [a] or Jack Pump
3399	U-19v PS 1D	U-19v PS1D_m1	No	Yes	--	6.6	No	N/A	3,960	4,113	--	--	BFCU	4	Jack Pump
3533	U-20n PS1 DDh	U-20n PS 1DDh	Yes [a]	Yes	--	5.5	No	N/A	2,417	4,285	Yes	N/A	CHZCM	4	ES Pump [a] or Jack Pump

Table H-2
Pahute Mesa Well Information
(Page 3 of 4)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Early Detection															
4180	ER-EC-6	ER-EC-6_m4	No	Yes	No	5.5	No	N/A	1,608	1,948	Yes	N/A	FCCU/BA	2	Jack Pump or Bailer
3468	ER-20-1	ER-20-1_o1	No	Open	Yes	N/A	No	N/A	WL	2,065	No	20.50	TMLVTA/ PBPCU/BA/ UPCU/TCA	2	Bailer
3645	PM-3	PM-3_p1	No	No	No	N/A	Yes	2.88	1,901	2,192	Yes	N/A	TCA/LPCU	2	Jack Pump or Bailer
		PM-3_p2	No	No	No	N/A	Yes	2.88	1,428	1,687	Yes	N/A	UPCU	2	
3647	U-20 WW	U-20 WW_m1	No	Yes	Yes	13.4	No	N/A	WL	3,268	No	18	CHZCM	2	Bailer
Distal															
4178	ER-EC-1	ER-EC-1_m1-3	Yes	Yes	Yes	5.5	No	N/A	2,284 3,318 4,433	2,867 3,776 4,840	Yes	N/A	CPA/UPCU/ TCA/LPCU/ TSA/CHCU/ CFCM	5	ES Pump [e]
3309	UE-18r	UE-18r_o1	No	Open	Yes	10.8	No	N/A	1,636	4,930	No	9.88	TMCM	5	Bailer
Community															
4917	Ash-B	Ash-B_p1	No	Yes	--	5.6	No	N/A	1,062	1,185	Yes	N/A	Volcanic rocks	5	Bailer
		Ash-B_p2	No	Yes	--	5.6	No	N/A	362	428	Yes	N/A	Valley fill	5	
7067	Peacock Ranch	Peacock Ranch_s1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--	5	Scoop/Dipper
6531	Revert Springs	Revert Springs_s1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--	5	Scoop/Dipper
9521	Spicer Ranch	Spicer Ranch_s1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--	5	Scoop/Dipper
4936	U.S. Ecology	U.S. Ecology_m1	--	Yes	--	8.0	No	N/A	453	573	--	--	--	5	ES Pump

Table H-2
Pahute Mesa Well Information
(Page 4 of 4)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Community (continued)															
6768	Amargosa Valley RV Park	Amargosa Valley RV Park_m1	N/A	Yes	Yes	8.6	No	N/A	300	1,280	Yes	N/A	--	5	ES Pump
4908	Cind-R-Lite Mine	Cind-R-Lite Mine_m1	Yes	Yes	Yes	8.9	No	N/A	320	460	Yes	N/A	Valley Fill	5	ES Pump
9715	EW-4 [d]	EW-4_m1	Yes	--	Yes	--	--	--	--	--	--	--	--	5	ES Pump

[a] Pump installed but is not functioning.
[b] Slant hole (about 22 degrees).
[c] Reported that the hole is obstructed at 3,690 ft bgs.
[d] No Redbook (RSN, 1991) or NWIS data (USGS and DOE, 2015) are available.
[e] ES Pump installed, but a bailer is sufficient for sampling a distal well.

-- = Not available
N/A = Not applicable

NWIS = National Water Information System

BA = Benham aquifer
BFCU = Bullfrog confining unit
CFCM = Crater Flat composite unit
CHCU = Calico Hills confining unit
CHZCM = Calico Hills zeolitic composite unit
CPA = Comb Peak aquifer
FCCM = Fortymile Canyon composite unit
FCCU = Fluorspar Canyon confining unit
LPCU = Lower Paintbrush confining unit
MPCU = Middle Paintbrush confining unit
PBPCU = Post-Benham Paintbrush confining unit
PLFA = Paintbrush lava-flow aquifer
RMWTA = Rainier Mesa welded-tuff aquifer
SPA = Scrugham Peak aquifer
TCA = Tiva Canyon aquifer
THCM = Tannenbaum Hill composite unit
TMCM = Timber Mountain composite unit
TMLVTA = Timber Mountain lower vitric-tuff aquifer
TSA = Topopah Spring aquifer
UPCU = Upper Paintbrush confining unit

Table H-3
Rainier Mesa/Shoshone Mountain Well Information
(Page 1 of 2)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Characterization															
3809	ER-30-1	ER-30-1_p1	Yes	No	No	N/A	Yes	2.875	712	790	Yes	N/A	FCCM	3	Jack Pump
3117	UE-12t-6 [a]	UE-12t-6_o1	No	Yes	--	4.5	No	N/A	WL	1,461	--	3.94	LTCU/OSBCU/ LCCU	3	Jack Pump
5452	ER-12-3	ER-12-3_m1	Yes	Yes	Yes	5.5	No	N/A	WL	4,903	No	12.25	LCA3	3	ES Pump
		ER-12-3_p1	No	No	No	N/A	Yes	2.38	WL	2,210	No	18.50	LTCU/OSBCU/ ATCU	3	Jack Pump
5453	ER-12-4	ER-12-4_m1	No	Yes	Yes	5.5	No	N/A	WL	3,715	No	12.25	LCA3	3	ES Pump
		ER-12-4_p1	No	No	No	--	Yes	2.38	WL	1,988	No	18.50	LVTA/BRCU/ LTCU/OSBCU	3	Jack Pump
3311	UE-18t	UE-18t_p1	No	Yes	No	3.5	Yes	2.38	--	2,600	Yes	2.98	TMCM	3	Jack Pump
5276	ER-16-1	ER-16-1_m1	No	Yes	Yes	5.5	No	N/A	WL	3,832	No	12.25	LCA	3	ES Pump
Source/Plume															
3069	U-12n Vent Hole 2 [b]	U-12n Vent Hole_2_m1	--	Open	--	--	No	N/A	20	--	No	13.75	LTCU	4	Bailer
3043	U-12n.10 Vent Hole [c]	U-12n.10 Vent Hole_m1	--	Yes	--	4.5	No	N/A	1,238	--	Yes	N/A	LTCU	4	Bailer
Early Detection															
3317	ER-19-1	ER-19-1_p1	Yes	Yes	No	2.9	Yes	1.90	2,577	2,738	Yes	N/A	RVA/ATCU	5	Bailer
		ER-19-1_p2	Yes	Yes	No	2.9	Yes	1.90	1,331	1,422	Yes	N/A	OSBCU	5	Bailer

Table H-3
Rainier Mesa/Shoshone Mountain Well Information
(Page 2 of 2)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Distal															
2876	ER-12-1	ER-12-1_m5	Yes	Yes	Yes	5.5	No	N/A	1,641	1,846	Yes	N/A	UCCU	5	ES Pump [d]
3237	TW-1	TW-1_m1	--	Open	--	8.0	No	N/A	1,840	4,206	No	7.625	OSBCU/RVA/ LTCU/ATCU/ LCA3	5	Bailer
3235	UE-16d WW	UE-16d WW_m1	Yes	Open	Yes	7.0	No	N/A	WL	1,944	No	10.00	UCCU	5	ES Pump [d]
3316	WW-8	WW-8_m22	Yes	Open	Yes	7.6	No	N/A	2,031	5,490	Yes	N/A	OSBCU/RVA/ LTCU/ATCU	5	ES Pump [d]

[a] Obstruction encountered at 149.96 m bgs (492 ft bgs) on 08/09/2006, with 3.75-in. diameter tool.
[b] Hole is probably open to the full extent of N-Tunnel. Diameter of the hole into the tunnel is probably 13.75 in., although in Redbook borehole segment (RSN, 1991), data are unclear.
[c] Vent hole into N-Tunnel looks like two strings of 4.5-in. casing inside a single string of 30-in. casing down to the tunnel adit. Unknown whether 4.5-in. casing is cemented to 30-in. casing. Bottom probably open to the rest of the tunnel complex.
[d] ES Pump installed, but a bailer is sufficient for sampling an early detection and distal well.

-- = Not available
N/A = Not applicable

ATCU = Argillic tuff confining unit
BRCU = Belted Range confining unit
LCA3 = Lower carbonate aquifer-thrust plate
LCCU = Lower clastic confining unit
LVTA = Lower vitric-tuff aquifer
OSBCU = Oak Spring Butte confining unit
RVA = Redrock Valley aquifer
UCCU = Upper clastic confining unit

Table H-4
Yucca Flat/Climax Mine Well Information
(Page 1 of 2)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Characterization															
5204	ER-2-1	ER-2-1_m1	Yes	Yes	Yes	7.0	No	N/A	1,700	2,177	No	12.25	TMWTA/ TMLVTA/LTCU	3	ES Pump
5203	ER-6-1-2	ER-6-1-2_m1	No	Open	Yes	N/A	No	N/A	1,834	3,200	No	12.25	LCA	3	Jack Pump
5199	ER-7-1	ER-7-1_m1	Yes	Yes	Yes	7.0	No	N/A	WL	2,500	No	12.25	LCA	3	ES Pump
1747	TW-7	TW-7_m1	No	Open	Yes	N/A	No	N/A	WL	2,272	No	10.63	LTCU	3	Jack Pump
2719	UE-10j [a]	UE-10j_m3	Yes	Yes	Yes	5.5	No	N/A	2,232	2,297	Yes	N/A	LCA	3	ES Pump [b] or Jack Pump
69	UE-1h	UE-1h_o1	No	Open	Yes	N/A	No	N/A	2,134	3,358	No	8.75	LCA	3	Jack Pump
1971	WW-3	WW-3_m1	No	Yes	Yes	6.0	No	N/A	WL	1,800	No	8.00	AA	3	Jack Pump
Source/Plume															
1018	U-3cn PS 2 [c]	U-3cn PS 2_m1	Yes	Yes	Yes	4.5	No	N/A	WL	2,603	No	9.00	LTCU	4	ES Pump [b] or Jack Pump
1838	U-4u PS 2A	U-4u PS 2A_p1	No	Yes	No	2.4	No	N/A	1,602	2,280	Yes	N/A	LTCU	4	ES Pump [b] or Jack Pump
319	UE-2ce [d]	UE-2ce_m1	Yes	Yes	Yes	8.6	No	N/A	WL	1,650	Yes	N/A	LCA3	4	ES Pump [e]
2059	UE-7nS [f]	UE-7nS_m1	No	Yes	Yes	7.6	No	N/A	1,707	2,205	Yes	N/A	LCA	4	Jack Pump or Bailer
1745	WW-A	WW-A_m1	Yes	Yes	No	10.8	No	N/A	WL	1,870	Yes	N/A	AA	4	ES Pump [b] or Jack Pump

Table H-4
Yucca Flat/Climax Mine Well Information
(Page 2 of 2)

ID	Sampling Location	ISPID	Dedicated Sampling Pump Installed?	Cased Completion?	Cased Completion Immediately Accessible for Sampling?	Casing Diameter (in.)	Piezometer to Access Completion Interval?	Piezometer Tubing Inside Diameter (in.)	Open Top (ft)	Open Bottom (ft)	Annulus filled?	Open Hole Diameter	HSU	Sampling Frequency (year^{-1})	Technology
Early Detection															
549	WW-2 [g]	WW-2_m1	Yes	Yes	Yes	6.6	No	N/A	2,940	3,422	Yes	N/A	LCA	5	ES Pump [e]
1892	TW-D [h]	TW-D_m1	--	Open	--	10	No	N/A	1,700	1,950	--	12	ATCU/LCA	5	Bailer
22	UE-1q	UE-1q_o1	No	Open	Yes	N/A	No	N/A	2,470	2,600	No	6.75	LCA	5	Bailer
1970	WW-C-1	WW C-1_m1	Yes	Yes	Yes	16.6	No	N/A	WL	1,650	No	18.63	LCA	5	Bailer
1015	U-3cn 5 [i]	U-3cn 5_o1	Yes	Open	Yes	6.6	Yes	2.38	2,832	3,030	No	5.75	LCA	5	ES Pump [e]
Distal															
3648	Army 1 WW	Army 1 WW_m1	--	Yes	--	12.3	No	N/A	611	1,931	Yes	6.75	LCA	5	ES Pump [e]

[a] Sampling will require sliding sleeve to be opened. Assumption made that Monyo pump installed is still functioning.
[b] Pump installed but is not functioning.
[c] Pump was run for 140 hours in 1997. Packer set in 4.5-in. casing at 1,842 ft bgs. This casing is collapsed and pinched at 1,926 ft bgs. Perforations in the 4.5-in. casing from 1,680 to 1,729 ft bgs.
[d] USGS diagram (Elliott and Moreo, 2011) shows two access tubes into the perforated casing.
[e] ES Pump installed, but a bailer is sufficient for sampling an early detection and distal well.
[f] Redbook (RSN, 1991) notes 7.63-in. casing to 2,199 ft bgs. NWIS (USGS and DOE, 2015) states 3-in. casing at depth.
[g] Borehole Index (Navarro, 2015) states that an electric submersible pump was installed in the well in July 2006. Two primary zones of perforations are separated in the annulus by cement. The two zones could be separated by a packer and sampled separately if so desired. Further divisions of the upper zone might be possible.
[h] NWIS (USGS and DOE, 2015) states five open intervals between 1,780 and 1,950 ft bgs.
[i] Open hole 2,835 to 3,030 ft bgs. 2.375-in. access tube and Centerlift tandem pump assembly in hole as of 01/23/1997. 55-gal drum samples acquired on 03/29/2011.

-- = Not available
N/A = Not applicable

TMWTA = Timber Mountain welded-tuff aquifer

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