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Background Information for the Nevada National Security Site Integrated Sampling Plan

Navarro-Intera

Revision No.: 0

December 2014

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Joseph P. Johnston **12/04/2014**
Joseph P. Johnston, N-I CO Date

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Navarro-Intera

BACKGROUND INFORMATION FOR THE NEVADA NATIONAL SECURITY SITE INTEGRATED SAMPLING PLAN

Revision No.: 0
December 2014
Navarro-Intera, LLC
c/o U.S. DOE
P.O. Box 98952
Las Vegas, NV 89193-8952

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Approved by: /s/ Sam Marutzky Date: 12-9-14

Sam Marutzky, UGTA Project Manager
Navarro-Intera, LLC

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LIST OF ACRONYMS AND ABBREVIATIONS

General Acronyms and Abbreviations

AMS	Accelerator mass spectrometer
bgs	Below ground surface
Bq/L	Becquerels per liter
CADD	Corrective action decision document
CAI	Corrective action investigation
CAIP	Corrective action investigation plan
CAMS	Center for Accelerator Mass Spectrometry
CAP	Corrective action plan
CAS	Corrective action site
CAU	Corrective action unit
CD-ROM	Compact disc read-only memory
CEMP	Community Environmental Monitoring Program
CFR	*Code of Federal Regulations*
cfs	Cubic feet per second
CG	Characterization group
COC	Contaminant of concern
COPC	Contaminant of potential concern
CR	Closure report
DOE	U.S. Department of Energy
DRI	Desert Research Institute
EPA	U.S. Environmental Protection Agency
FFACO	*Federal Facility Agreement and Consent Order*
ft	Foot
F&T	Flow and transport
FY	Fiscal year
HFM	Hydrostratigraphic framework model
HSU	Hydrostratigraphic unit
in.	Inch
ID	Identification
K_d	Distribution coefficient
L	Liter

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
m	Meter
MCL	Maximum contaminant level
MDA	Minimum detectable amount
MDC	Minimum detectable concentration
MDL	Method detection limit
mg/L	Milligrams per liter
mi	Mile
M&O	Management and operating
mrem/yr	Millirem per year
MWAT	Multiple-well aquifer test
N/A	Not applicable
NAD	North American Datum
NDEP	Nevada Division of Environmental Protection
N-I	Navarro-Intera, LLC
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NSSAB	Nevada Site Specific Advisory Board
NSTec	National Security Technologies, LLC
NWIS	National Water Information System
pCi/L	Picocuries per liter
PM	Pahute Mesa
PS	Post-shot
QAP	Quality Assurance Plan
RM/SM	Rainier Mesa/Shoshone Mountain
RN	Radionuclide
RNM	Radionuclide migration experiment
RREMP	Routine Radiological Environmental Monitoring Plan
SDWA	*Safe Drinking Water Act*
TFM	Thermal flowmeter
UGT	Underground test
UGTA	Underground test area

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WL	Water level
wrt	With regards to
WW	Water Well
YF/CM	Yucca Flat/Climax Mine
°C	Degrees Celsius
µg/L	Micrograms per liter

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

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

AA	Alluvial aquifer
AA2	Alluvial aquifer 2
AA3	Alluvial aquifer 3
ATCU	Argillic tuff confining unit
BFCU	Bullfrog confining unit
BA	Benham aquifer
BLFA	Basalt lava-flow aquifer
BRCU	Belted Range confining unit
CFCM	Crater Flat composite unit
CFCU	Crater Flat confining unit
CHCU	Calico Hills confining unit
CHZCM	Calico Hills zeolitized composite unit
CPA	Comb Peak aquifer
FCCM	Fortymile Canyon composite unit
FCCU	Fortymile Canyon confining unit
LCA	Lower carbonate aquifer
LCA3	Lower carbonate aquifer-thrust plate
LCCU	Lower clastic confining unit
LCCU1	Lower clastic confining unit 1
LPCU	Lower Paintbrush confining unit
LTCU	Lower tuff confining unit
LTCU 1	Lower tuff confining unit 1
LVTA1	Lower vitric-tuff aquifer 1
MGCU	Mesozoic granite confining unit
MPCU	Middle Paintbrush confining unit
OAA	Older alluvium
OAA1	Older alluvium 1
OSBCU	Oak Spring Butte confining unit
PBPCU	Post-Benham Paintbrush confining unit
PLFA	Paintbrush lava-flow aquifer

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

RM-WTA	Rainier Mesa welded-tuff aquifer
RVA	Redrock Valley aquifer
TCA	Tiva Canyon aquifer
TCU	Tuff confining unit
TM-LVTA	Timber Mountain lower vitric-tuff aquifer
TM-WTA	Timber Mountain welded-tuff aquifer
TSA	Topopah Spring aquifer
UCA	Upper carbonate aquifer
UCCU	Upper clastic confining unit

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

Elements and Compounds

C	Carbon
Ca	Calcium
Cl	Chlorine
Cs	Cesium
DOC	Dissolved organic carbon
^{3}H	Tritium
He	Helium
I	Iodine
Kr	Krypton
Np	Neptunium
Pu	Plutonium
Ra	Radium
SO_4	Sulfate
Sr	Strontium
Tc	Technetium
U	Uranium

1.0 INTRODUCTION

This document describes the process followed to develop the Nevada National Security Site (NNSS) Integrated Sampling Plan (referred to herein as the Plan). It provides the Plan's purpose and objectives, and briefly describes the Underground Test Area (UGTA) Activity, including the conceptual model and regulatory requirements as they pertain to groundwater sampling.

Background information on other NNSS groundwater monitoring programs—the Routine Radiological Environmental Monitoring Plan (RREMP) and Community Environmental Monitoring Program (CEMP)—and their integration with the Plan are presented. Descriptions of the evaluations, comments, and responses of two Sampling Plan topical committees are also included.

1.1 Sampling Plan Purpose and Objectives

The Plan was developed to provide a comprehensive, integrated approach for collecting and analyzing groundwater samples to meet the needs and objectives of the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) UGTA Activity. Its implementation will provide high-quality data required by the UGTA Activity for ensuring public protection in an efficient and cost-effective manner. The Plan provides a basis of estimate for the life-cycle baseline and will support a successful transition to long-term monitoring by ensuring that appropriate analytical data are available as each corrective action unit (CAU) enters the Closure Report (CR) stage. The Plan is designed to ensure compliance with the UGTA Quality Assurance Plan (QAP) (NNSA/NSO, 2012); *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended); and DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE, 2013).

The objectives of the Plan are to (1) classify sampling locations relevant to assessing contamination from underground nuclear testing based on their objectives; (2) identify monitoring locations to support the community component of the Plan; (3) define specific sampling and analysis methodologies by CAU and well type; (4) define data collection criteria such as well purging requirements, detection levels, sampling frequency, chemical and isotopic analytes, and accuracy requirements; (5) standardize processes and procedures for collecting and analyzing water samples;

(6) define reporting and data management requirements; and (7) provide a process to ensure sampling activity (e.g., collection, analysis, and reporting) coordination for sampling locations of interest to UGTA that are already being performed.

Groundwater sampling performed for the Plan satisfy DOE environmental regulations and occur within the context of the UGTA mission to achieve CAU closure. The conceptual model of groundwater flow and radionuclide (RN) transport is central to the activities conducted for the UGTA Activity. Through implementation of the Plan, the conceptual model will serve as the basis for evaluating compliance with DOE environmental regulations.

1.2 UGTA Activity

Underground nuclear weapons testing was conducted at the NNSS, formerly the Nevada Test Site, from 1951 until 1992. As a consequence, RNs were released into the subsurface and have impacted groundwater quality in some areas. The purpose of the UGTA Activity is to complete environmental corrective action activities at sites associated with underground nuclear tests that have resulted or might result in impacts to groundwater resources. The 878 individual corrective action sites (CASs) (associated with 907 underground nuclear detonations) were originally grouped into five CAUs based on NNSS geographic testing areas; two of these have been combined because of their similarity. The UGTA CAUs are as follows (Figure 1-1):

- **Yucca Flat/Climax Mine (CAU 97)** with 717 CASs in Areas 1, 2, 3, 4, 6, 7, 8, 9, 10 (Yucca Flat), and 3 CASs in Area 15 (Climax Mine). The Yucca Flat detonations occurred in vertical emplacement holes in alluvium and volcanic and carbonate rock with most of them above the regional water table (76 detonations were below the water table), whereas the Climax Mine detonations occurred in tunnels in fractured granite. About 39 percent of the total RN inventory is within the Yucca Flat/Climax Mine CAU (Bowen et al., 2001).

- **Frenchman Flat (CAU 98)** with 10 CASs in the northern part of Area 5 and southern part of Area 11 within the Frenchman Flat topographic basin. These detonations were conducted in both vertical emplacement holes and shafts primarily in basin-fill alluvium in a localized aquifer that is well above the regional aquifer. Less than 1 percent of the total RN inventory is within the Frenchman Flat CAU (Bowen et al., 2001).

- **Rainier Mesa/Shoshone Mountain (CAU 99)** with 60 CASs on Rainier Mesa in Area 12 and 6 CASs on Shoshone Mountain in Area 16. The large majority of these tests occurred in tunnels constructed in volcanic rock, above the regional water table. Less than 1 percent of the total RN inventory is within the Rainier Mesa/Shoshone Mountain CAU (Bowen et al., 2001).

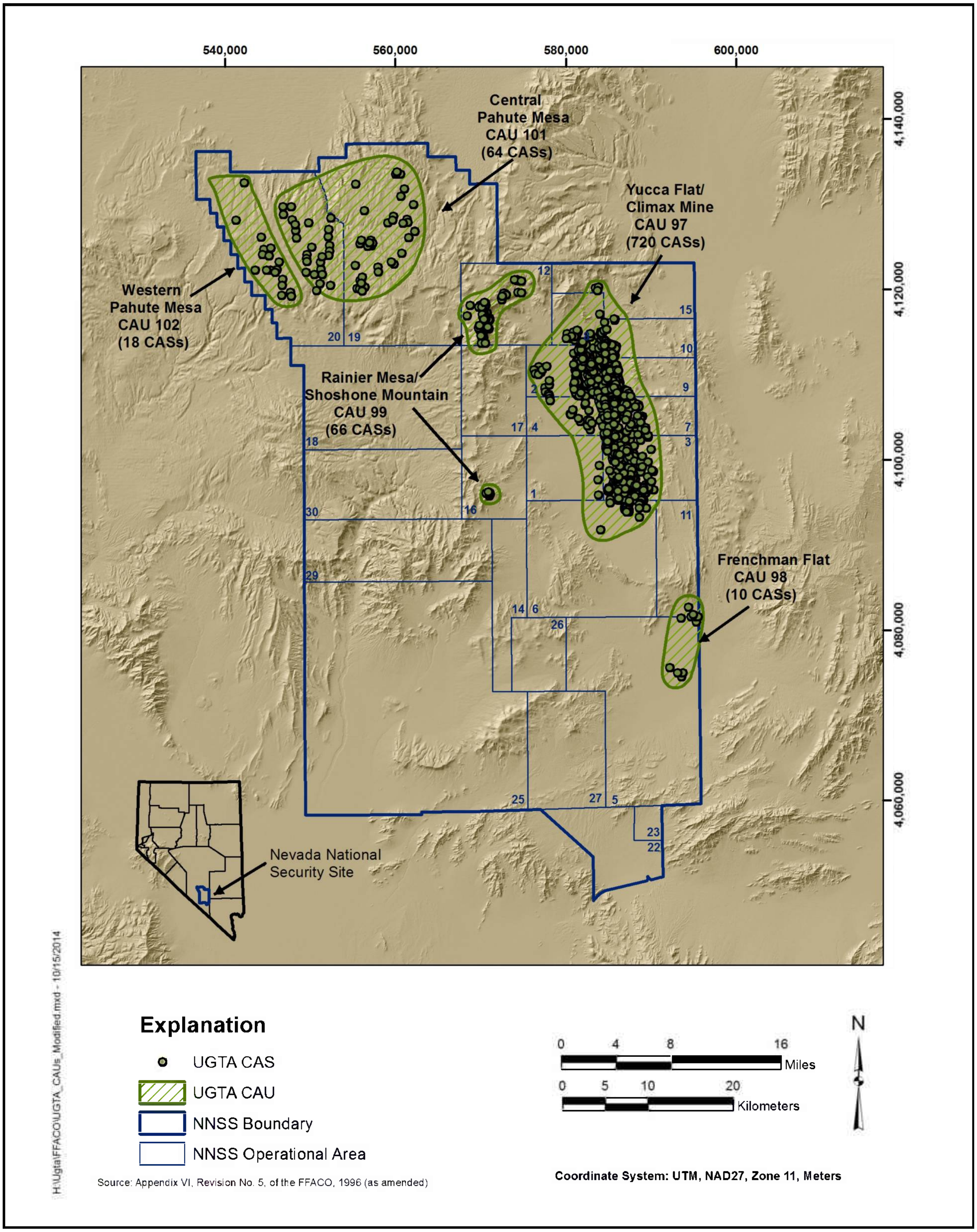

Figure 1-1
UGTA CAUs

- **Central Pahute Mesa (CAU 101)** and **Western Pahute Mesa (CAU 102)** with a total of 82 CASs in Areas 19 and 20 on Pahute Mesa. These tests were conducted in vertical emplacement holes in volcanic rocks. Some of the higher yield tests were conducted on Pahute Mesa, a majority at or below the water table. Approximately 61 percent of the total RN inventory is within Central and Western Pahute Mesa CAUs (Bowen et al., 2001). These two CAUs are referred to as the Pahute Mesa CAU throughout this document.

The anticipated corrective action for each CAU is closure in place with monitoring and institutional controls because there is no reasonable method to remove or stabilize the RNs remaining from an underground nuclear test, and potential risks from these RNs are only realized with access to the groundwater. The corrective action strategy for all UGTA CAUs except Rainier Mesa/Shoshone Mountain is fulfilled in four stages: the Corrective Action Investigation Plan (CAIP), the Corrective Action Investigation (CAI), the Corrective Action Decision Document (CADD)/Corrective Action Plan (CAP), and Closure Report (CR) stages. A revised strategy has been proposed for Rainier Mesa/Shoshone Mountain that is fulfilled in three stages: CAIP, CAI, and CR stages (NNSA/NFO, 2013).

With the exception of Rainier Mesa/Shoshone Mountain, the primary UGTA objective for each CAU is to define a perimeter boundary around areas that may potentially exceed the *Safe Drinking Water Act* (SDWA) radiologic standards (CFR, 2014) within 1,000 years. The primary objective for Rainier Mesa/Shoshone Mountain is to demonstrate that institutional control will not be challenged by RNs emanating from underground tests conducted within the CAU for 1,000 years. This objective is met through an iterative process of (1) data collection, (2) groundwater flow and RN transport modeling, (3) conceptual and/or numerical model evaluation, (4) monitoring, and (5) institutional controls.

Groundwater sampling is an integral part of the UGTA Activity providing data to characterize the CAUs and to develop conceptual and numerical models. The chemical and isotopic character of groundwater provides information on groundwater movement, and on the potential for and actual extent of contaminant transport.

1.3 Conceptual Model for RN Migration from the UGTA CAUs

The conceptual model of groundwater flow and RN transport is central to the development of the Plan. This conceptual model includes the processes that occur at the time of detonation and extends through transport of the resulting RNs entered into the groundwater system. The energy of a nuclear explosion initially vaporizes surrounding rock, creating a conceptually spherical cavity. The rock, fission products, and device components vaporized by the heat and pressure of the nuclear reaction quickly condense and coalesce into nuclear melt glass in the lower portion of the cavity. RNs incorporated into the melt glass must be leached in order to be transported by groundwater. As the pressure drops, the overlying rock collapses into the cavity and forms a chimney of rubble, which in some cases extends to land surface forming a collapse crater. RNs with lower boiling points can migrate throughout voids in the spherical volume that contains the immediate extent of radioactive contamination around the detonation (the exchange volume) as well as the chimney. The RNs eventually deposit on rock surfaces where they are more susceptible to release in groundwater than those in the melt glass. RN transport is then governed by the characteristics of the groundwater system.

Aquifers beneath the NNSS are part of the Death Valley regional flow system (Belcher et al., 2004) and can be grossly divided into three types: regional aquifers developed in fractured carbonate rock, aquifers in alluvium that are mostly restricted to individual topographic basins, and aquifers in volcanic rocks that range from local to regional in extent. Flow directions are dominantly south–southwest in a regional sense, though there are local deviations (Figure 1-2) (Fenelon et al., 2010). Vertical hydraulic gradients are downward in most areas, though the volume of flow between the overlying alluvial and volcanic aquifers into the underlying carbonate aquifer is restricted by intervening low-permeability confining units.

As RNs migrate with groundwater, they are subject to a variety of processes, most of which serve to slow their movement relative to the water velocity. Important among these processes are sorption (the tendency of some RNs to attach to solid particles) and matrix diffusion (movement out of fractures into stagnant water in the pores space of adjacent rock). Radioactive decay is an ongoing natural process that systematically reduces RN concentrations with the passage of time.

The general conceptual model discussed above is refined and specialized for each CAU during the UGTA CAI stage. Samples and measurements from wells are a critical part of the investigation. The chemical and hydraulic data provide independent information for interpreting groundwater flow paths, calculating groundwater velocities, and estimating transport properties.

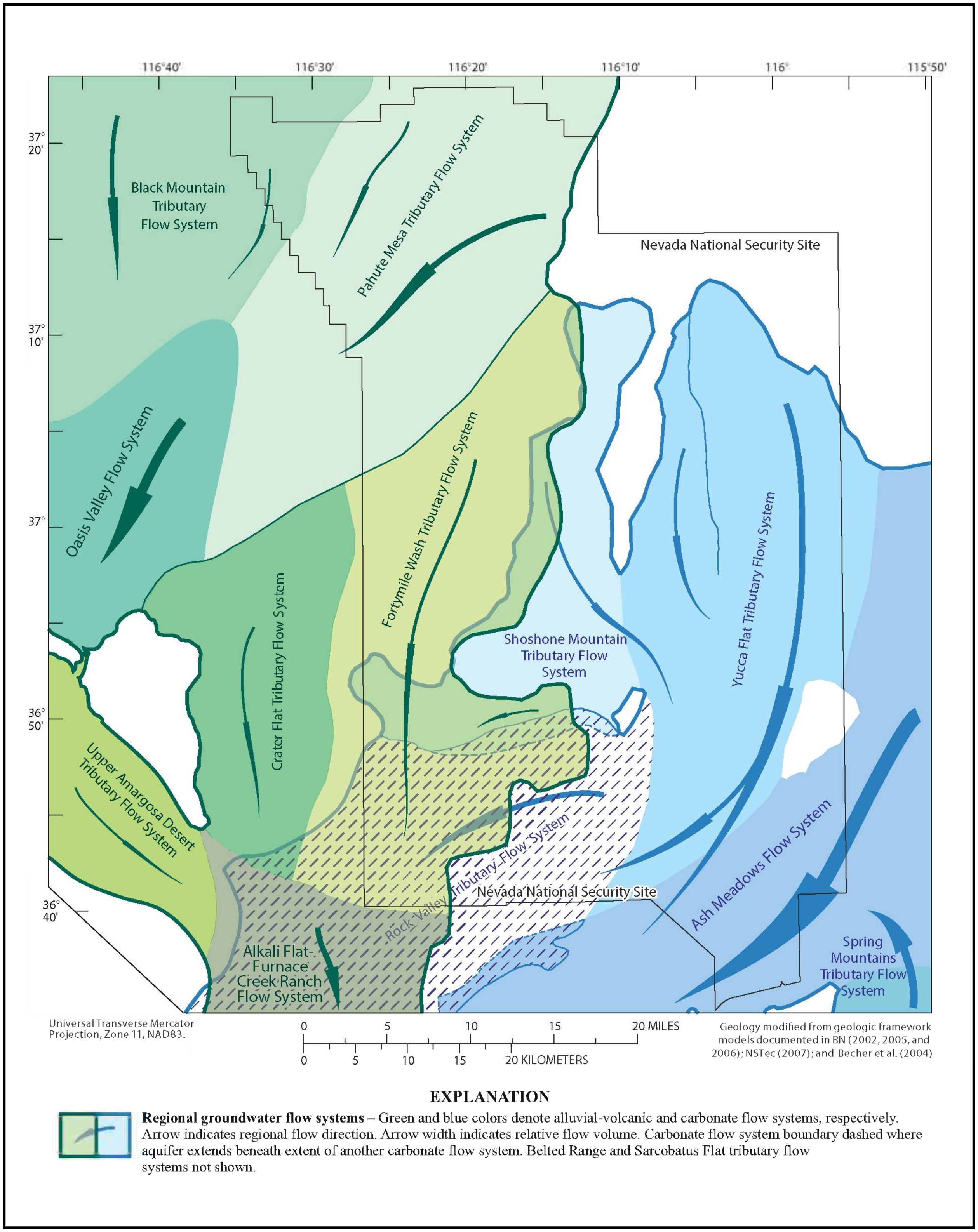

Figure 1-2
Major Groundwater Flow Systems of the Regional Alluvial-Volcanic and Carbonate Aquifers
Source: Modified from Fenelon et al., 2010

1.4 Regulatory Requirements

The UGTA Activity is conducted in compliance with the FFACO (1996, as amended). In turn, the FFACO is regulated based on the SDWA radiological standards (CFR, 2014). The SDWA includes RNs because of the concern that radiation could increase the risk of cancers or harmful genetic effects as a result of long-term exposure through drinking water. The probability of a radiation-caused cancer or genetic effect is related to the total amount of exposure to radiation accumulated by the individual. The SDWA seeks to limit that exposure. The Radionuclide Rule of the SDWA specifies maximum contaminant levels (MCLs) for four categories of RNs, as presented in Table 1-1.

Table 1-1
Maximum Contaminant Levels

RN Category	MCL
Beta and photon emitters (combined)	4 mrem/yr
Gross alpha particles [a]	15 pCi/L
Ra-226/228 (combined)	5 pCi/L
Uranium	30 µg/L

[a] Gross alpha MCL includes Ra-226 but excludes radon and uranium

mrem/yr = Millirem per year
pCi/L = Picocuries per liter
Ra = Radium
µg/L = Micrograms per liter

The total RN inventory was composed of 86 (Rainier Mesa/Climax Mine CAU) to 96 (Pahute Mesa CAUs) percent tritium (^3H) activity in 1992. Many of the NNSS inventory RNs presented in Bowen et al. (2001) are relatively immobile because portions of their inventory are bound within the melt glass produced during nuclear detonation and have chemical properties that cause them to bind strongly to solid particles in the aquifer. A smaller set of RNs that are most mobile in groundwater and present in high abundance has the greatest potential for impacting groundwater quality.

For all CAUs except Rainier Mesa/Shoshone Mountain, ^3H is the only RN included in the inventory known to have exceeded the MCL in sampling locations away from the exchange volume associated with a nuclear test (i.e., in sampling locations other than cavity or post-shot [PS] wells) (N-I, 2014c). Tritium has therefore been identified as the contaminant of concern (COC) for all CAUs. Although plutonium (Pu) has been reported above its MCL in T-Tunnel located in Rainier Mesa (Zavarin, 2009), it has not been detected in downgradient wells at concentrations above 10 percent of its 15 pCi/L MCL. Pu has therefore been identified as a contaminant of potential concern (COPC) for the Rainier Mesa/Shoshone Mountain CAU.

Modeling completed for the Frenchman Flat CAU has identified ^{3}H, carbon-14 (^{14}C), chlorine-36 (^{36}Cl), iodine-129 (^{129}I), and technetium-99 (^{99}Tc) as the major contributors to the contaminant boundary (NNES, 2010). Short-lived mobile RNs that initiate in the lower carbonate aquifer (LCA)—such as strontium-90 (^{90}Sr), cesium-137 (^{137}Cs), and ^{3}H—contribute most to the Yucca Flat/Climax Mine contaminant boundary. After a few hundred years, these RNs decay to concentrations that are insignificant relative to the SDWA MCLs (CFR, 2014). The longer-lived RNs—such as ^{14}C, ^{36}Cl, ^{129}I, and ^{99}Tc—are generally at concentrations that do not significantly contribute to the Yucca Flat/Climax Mine contaminant boundary (N-I, 2013).

Although contaminant boundaries will not be established for the Rainier Mesa/Shoshone Mountain CAU, results from smaller-scale models of E-Tunnel, N-Tunnel, T-Tunnel, CLEARWATER, and WINESKIN demonstrate the potential for MCL exceedances for ^{3}H, ^{14}C, ^{36}Cl, ^{90}Sr, ^{99}Tc, ^{129}I, and Pu (Russell, 2012). The groundwater flow and transport models for Pahute Mesa are still in the development stage.

A list of COPCs was developed based on the Bowen et al. (2001) inventory, previous sampling and analysis data, and modeling results. This list was primarily established based on modeling results for all CAUs except Pahute Mesa. For Pahute Mesa, the list is established based on the understanding of relative mobility of the inventory RNs, and previous analytical results from sampling contaminated groundwater near or in nuclear test cavities.

2.0 NNSS MONITORING PROGRAMS

Sampling and analysis by UGTA, RREMP, and CEMP have historically been implemented independently and have served different objectives. UGTA is driven by the strategy described in FFACO Appendix VI (1996, as amended). The RREMP water monitoring design and implementing program, apart from NNSS state-issued permits, addresses compliance primarily with DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE, 2013). Independent NNSS environmental monitoring is provided by CEMP, whose mission is to monitor and communicate environmental data relevant to the safety and well-being of participating communities and their surrounding areas. CEMP is an independent, community outreach program with no regulatory basis.

2.1 UGTA Corrective Action Strategy

The UGTA strategy presented in the FFACO Appendix VI (1996, as amended) is general in its discussion of data requirements and thus includes no specific sampling criteria. A long-term monitoring program is required as part of the CAU closure process, but the details for the monitoring program are left for specification in the CR. Appendix VI has no specific criteria or requirements for long-term monitoring and sampling, other than calling for periodic evaluation. Evaluation of the long-term closure monitoring must check for the following (FFACO, 1996; as amended):

1. Consistency with the CAU conceptual models of flow and transport
2. Consistency with contaminant boundary forecasts
3. Adherence to the use-restriction and regulatory boundaries
4. Consistency with the corrective action decision
5. Protectiveness of institutional controls for human health and the environment.

Contaminant boundaries will not be developed for Rainier Mesa/Shoshone Mountain, and therefore item two above does not apply (NNSA/NFO, 2013). While these requirements are not specific in terms of sampling measurements, they do require a monitoring program that provides data meaningful for evaluating models, boundaries, and institutional controls used for CAU closure. The Plan serves to ensure that appropriate data, including sample collection technology evaluations, are available to support long-term monitoring and the associated regulatory review of the protectiveness of the closure decision. This includes data collected throughout each stage of the UGTA Strategy.

2.2 Routine Radiologic Monitoring Plan

NNSA/NFO monitors water under RREMP in the interest of stakeholders residing in the NNSS vicinity and to comply with DOE directives and applicable state and federal water-quality and water-protection regulations. Surface and groundwater including natural springs, drinking water wells, nonpotable groundwater wells, and water discharged into domestic and wastewater systems on the NNSS are routinely monitored (Figure 2-1). In addition to the NNSA/NFO annual onsite monitoring, the Nevada State Health Division's Bureau of Health Care Quality and Compliance is allowed access to the NNSS to independently sample onsite water-supply wells at its discretion.

The RREMP identifies requirements for radiological monitoring at NNSA/NFO facilities, primarily the NNSS, which ensure that the public and the environment are protected, compliance is achieved, and that good land stewardship is practiced (BN, 2003). A decision-based approach is used to ensure that data generated for various media (i.e., air, water, biota, soils, direct radiation) are defensible. RREMP data are reported in annual site environmental reports available to the public at libraries and on the internet.

Water sources sampled under RREMP have historically included 89 wells and 15 surface locations shown in Figure 2-1. Water sources have been sampled at three-month to three-year frequencies for specified radiological and water-chemistry parameters. Surface water monitoring is primarily conducted to demonstrate that RN concentrations comply with human and/or biota dose limits and to determine whether NNSS facilities are in compliance with permit discharge limits.

Tritium monitoring is routinely performed to detection limits of approximately 30 pCi/L (onsite public water system) and 300 pCi/L (onsite and offsite aquifer monitoring), both well below the U.S. Environmental Protection Agency's (EPA's) SDWA required detection limit specified by 40 *Code of Federal Regulations* (CFR) 141.25 as 1,000 pCi/L (CFR, 2014).

Groundwater monitoring is conducted to (1) determine whether water-supply wells (on and off the NNSS) are impacted from RNs originating from the NNSS, (2) demonstrate compliance with DOE dose limit requirements for the public and the environment, (3) assess whether groundwater at the NNSS and its vicinity is impacted from RNs associated with the underground test areas, and (4) evaluate whether there are groundwater impacts from NNSS surface and shallow vadose zone RN sources (waste disposal facilities).

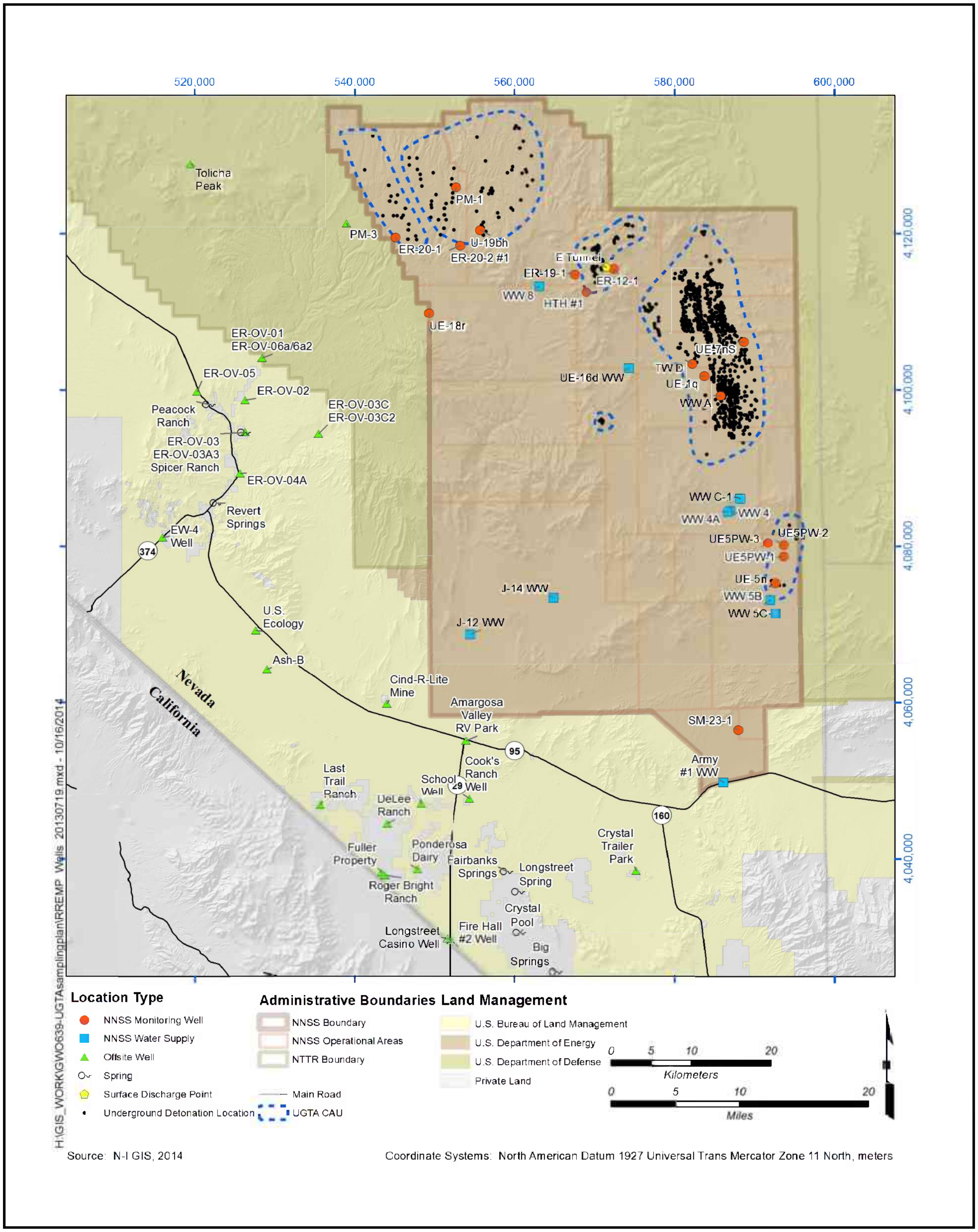

Figure 2-1
Wells Monitored by RREMP

The RREMP aquifer monitoring network is designed as an interim program until the CAU-specific post-closure monitoring networks are designed and implemented (BN, 2003). With the development of the Plan, considering the information gained to date by the UGTA Activity, it was deemed an appropriate time to integrate both water sampling programs under one plan while ensuring objectives of both are met.

2.2.1 Community Environmental Monitoring Program

CEMP, established by NNSA/NFO, monitors springs and water-supply systems in communities surrounding the NNSS in the interest of stakeholders. The monitoring network encompasses a much larger area and includes communities located much further from the NNSS than boundaries established in RREMP. CEMP is a nonregulatory public information and outreach program. It provides the public with data regarding the presence of man-made RNs that could be the result of current operations or past nuclear testing on the NNSS. CEMP monitors groundwater wells, surface waters, and springs used for water supplies in areas surrounding the NNSS. Water samples are collected by Desert Research Institute (DRI) personnel and analyzed for ^{3}H.

Sample locations are selected based upon input from environmental monitors representing their local communities. As an example, DRI sampled 4 springs, 21 wells, and 3 surface water bodies either directly or through municipal water-supply systems in 2012 (Figure 2-2). As forecasted by the UGTA Activity, the wells and water-supply systems within the CEMP monitoring network continue to show no evidence of ^{3}H contamination from past NNSS underground nuclear testing. ^{3}H has been detected at a few CEMP water monitoring locations that are either upgradient of the NNSS or that sample groundwater from a separate groundwater flow system (i.e., not part of the Death Valley regional flow system). The origin of this ^{3}H is thought to be modern recharge (less than 60 years) that contains some combination of ^{3}H from atmospheric testing along with natural production of ^{3}H in the upper atmosphere. CEMP data are available on the DRI website (http://www.cemp.dri.edu/cemp) as well as published in the annual site environmental reports.

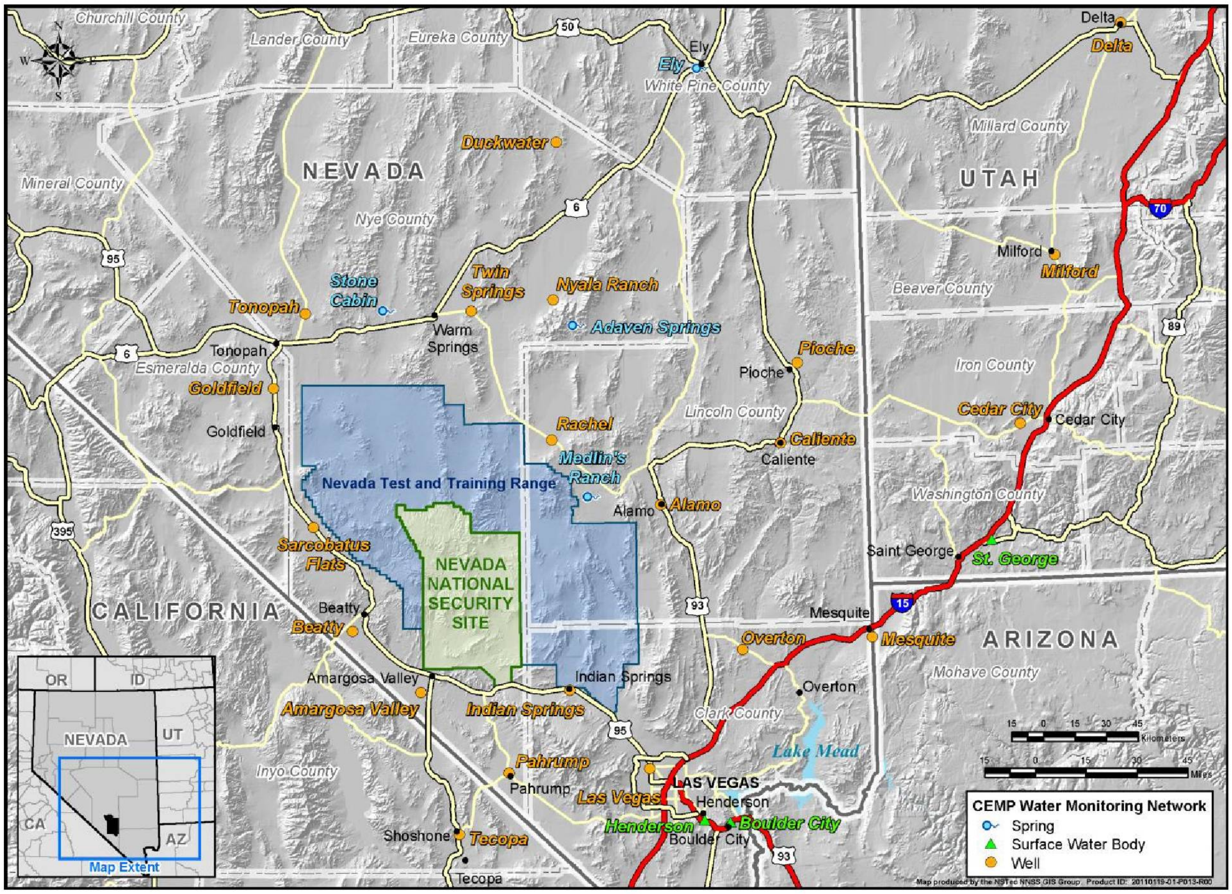

Figure 2-2
CEMP Water Monitoring Network

3.0 PLAN DEVELOPMENT

To meet the Plan objectives, CAU investigation teams, pertinent UGTA Activity topical committees, RREMP and CEMP representatives, and the Nevada Site Specific Advisory Board (NSSAB) provided input during the Plan's development. Two topical committees provided input to the Plan: one (the Sampling Plan Committee) supported the overall Plan, and the other (the Well Development and Sampling Committee) assessed and made recommendations regarding available sample collection technologies. These committees included representatives from NNSA/NFO; DRI; Navarro-Intera, LLC (N-I), Lawrence Livermore National Laboratory (LLNL); Los Alamos National Laboratory (LANL); National Security Technologies, LLC (NSTec); and the U.S. Geological Survey (USGS). Involvement occurred through formal presentations, committee meetings, recommendations from the technical leads for each CAU (i.e., CAU Leads), and Draft Plan review.

Table 3-1lists the CAU Leads and their respective organizations.

Table 3-1
CAU Leads by Organization and CAU

Name	Organization	CAU
Ed Kwicklis	LANL	Yucca Flat/Climax Mine
Greg Ruskauff	N-I	Frenchman Flat
Chuck Russell	DRI	Rainier Mesa/Shoshone Mountain
Greg Ruskauff	N-I	Central and Western Pahute Mesa

Table 3-3 lists the members of the UGTA topical committees. A discussion of the Sampling Plan committee activities is provided in Section 3.1. The evaluation, evaluation results and recommendations of the Well Development and Sampling committee are presented in Appendix C.

3.1 Sampling Plan Committee

The Sampling Plan Committee requested that CAU Leads recommend sampling locations that should be included in the Plan based on their potential for assessing RN transport from NNSS underground nuclear tests. They were also asked to provide recommendations regarding well categorization,

Table 3-2
UGTA Activity Topical Committee Members

Name	Organization
Sampling Plan Committee	
Jenny Chapman	DRI
Dave Finnegan	LANL
Dan Levitt	LANL
Mavrik Zavarin	LLNL
Irene Farnham, Chair	N-I
Kathryn Knapp	NNSA/NFO
Sig Drellack	NSTec
Ted Redding	NSTec
Joe Fenelon	USGS
Jim Paces	USGS
Well Development and Sampling Committee	
Chuck Russell, Chair	DRI
Dan Levitt	LANL
Mavrik Zavarin	LLNL
Jeff Sanchez	N-I
Jeff Wurtz	N-I
Kathryn Knapp	NNSA/NFO
Ken Ortego	NSTec
Terry Sonnenburg	NSTec
Robert Graves	USGS

analytes, and sampling frequencies based on recommendations regarding well categorization, analytes, and sampling frequencies based on Table 3-3. The recommendations were based on available data and the current conceptual and numerical models of groundwater flow and transport; and focused on locations that may eventually (over the 1,000-year compliance period) have detectable RNs from NNSS underground nuclear testing. The CAU Lead recommendations are provided in Appendix A. The Sampling Plan Committee reviewed the CAU Lead recommendations and provided their comments and recommendations to the DOE representative and CAU Leads. Appendix B summarizes the Sampling Plan Committee comments and the DOE representative and CAU Lead responses.

Table 3-3
Template Provided to CAU Leads To Guide Recommendations (December 2012)

Well Type	Definition	Analytes (MDL)	Purpose	Sampling Frequency[a]
Characterization	Located in study area and used to characterize system or model evaluation.	• Dependent on characterization objective but may include major ions, environmental isotopes, and radioisotopes.	• Identify groundwater flow paths. • Evaluate contaminant migration. • Estimate travel time estimates. • Evaluate model. • Monitor well.	As needed
Source-Term Investigation[a]	Located within, near, and/or immediately downgradient of underground detonation and $^3H \geq$ 10,000 pCi/L.	• ^3H (>300 pCi/L). • Select radioisotopes (low MDLs).	• Characterize source term. • Monitor natural attenuation. • Identify potential COC.	4 years (1/3 ^3H $T_{1/2}$)[b]
Early Detection	Located immediately downgradient of an underground detonation and ^3H <10,000 pCi/L.	• ^3H (based on baseline concentrations). • Potential COCs identified by source-term investigation wells (low MDLs).	• Detect plume front. • If investigation level[c] is not triggered or contamination is not confirmed, this may serve as a monitoring location.	2 year
Distal	Outside the early detection boundary but on government land. ^3H <300 pCi/L.	• ^3H ($\leq$ 300 pCi/L). • Potential COCs identified by early detection wells (MDL < MCL).	• Verify COCs (i.e., currently ^3H) do not exceed the MCL. • This may serve to support the regulatory boundary[d].	4 years
Point of Use	Used as private or public water-supply source.	• ^3H ($\leq$ 300 pCi/L). • Potential COCs identified by early detection and distal wells (MDL < MCL). • Consider whether to monitor for SDWA analytes not included in source term.	• Verify COCs (i.e., currently ^3H) do not exceed the MCL. • Verification of COC concentrations in the distal wells may necessitate actions at these locations.	To be determined

[a]"Source-term investigation" wells and "source/plume" wells are the same. Well type names changed over the course of Sampling Plan development.
[b]Tritium half-life ($T_{1/2}$) = 12.32 years
[c]Investigation level is reached when the RN deviates from a previously established trend and/or the conceptual model. The investigation will evaluate the reason for the deviation. The evaluation will begin with measurement verification, and may include additional sample collection and analysis of additional radioisotopes.
[d]The regulatory boundary provides protection for the public and the environment from the effects of migration of radioactive contaminants (FFACO, 1996 as amended).

MDL = Method detection limit

3.2 Integration of RREMP and CEMP

To ensure appropriate integration, the following sampling locations monitored under RREMP or CEMP were added to the locations recommended by the CAU Leads:

- Peacock Ranch
- Spicer Ranch
- Revert Springs
- EW-4
- U.S. Ecology
- Ash-B
- Cind-R-Lite Mine
- Amargosa Valley RV Park

These locations are potentially downgradient of NNSS underground nuclear tests, are (in general) the first public locations encountered along the flow paths, and surround the west and southwest NNSS boundaries. These locations are included in the Plan to ensure continued monitoring of public water sources for COCs from NNSS underground nuclear testing (e.g., 20,000 pCi/L ^{3}H MCL) (CFR, 2014) and to demonstrate DOE's continued commitment to stakeholders.

The Plan establishes the technical basis for sampling the locations presented in Figure 3-1. The basis for location selection is presented in Tables A-3 through A-5. The Plan does not address or support permit compliance for NNSS wells included herein that are also included in an NNSS permit (e.g., WW-8). Compliance activities involving those wells are addressed by RREMP independently of the Plan.

Notably, a number of locations RREMP previously sampled are not included in Figure 3-1. For instance, sampling the ER-OV wells located southwest of Pahute Mesa has been discontinued under the Plan. Sampling has instead been established for the ER-EC wells located closer downgradient of the Pahute Mesa underground nuclear tests. This is similarly the case for wells located in the southern portion of the NNSS (e.g., J-12 WW and J-14 WW) and in Amargosa Valley. These sampling locations, along with others located on the NNSS and its vicinity that may be considered for future monitoring were placed on an Inactive List (N-I, 2014b). This list will be periodically evaluated to determine whether a given location should be added to the Plan or sampled at a later time.

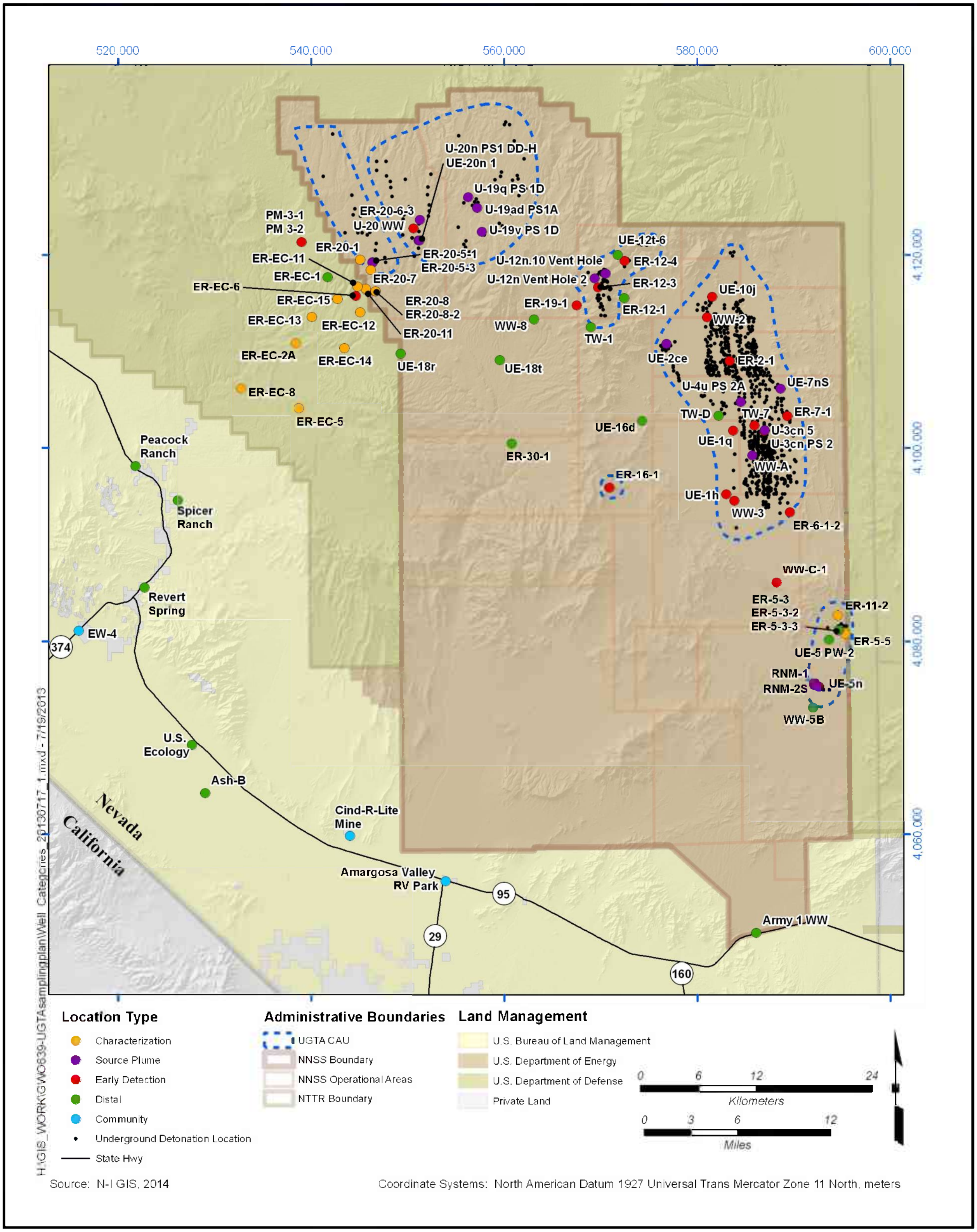

Figure 3-1
NNSS Integrated Sampling Plan Well Network

3.3 NSSAB Presentation

The Plan was presented to the NSSAB on April 17, 2013. The NSSAB was asked to provide their input on some key parameters with respect to distal and point-of-use wells. In particular, they were asked whether DOE should do the following:

- Eliminate sampling upgradient wells.
- Increase laboratory detection level for ^3H.
- Reduce the list of RNs to be analyzed.
- Increase the laboratory detection level.
- Reduce the frequency of sampling.
- Change well types to reclassify wells as inactive as UGTA progresses.

The NSSAB recommendations were addressed and incorporated in the Sampling Plan.

3.4 Other Presentations

The Plan was presented at several UGTA Manager and CAU Lead meetings throughout 2012 through 2014. A presentation was given at the 2013 Waste Management Conference, and a poster was presented at the 2013 Devils Hole and 2013 UGTA Technical Information Exchange meetings. These presentations gave opportunity for feedback from a large audience.

3.5 Plan Revisions and Reviews

The development of the Plan continued through an iterative series of Plan reviews and revisions by the Sampling Plan Committee, CAU Leads, DOE, and UGTA Contract Managers. These reviews are provided in the UGTA Technical Data Repository. A final Draft document was submitted to the Nevada Division of Environmental Protection (NDEP) on July 25, 2013. NDEP stated that they considered the Plan an internal document that is not subject to their approval.

The Plan was then finalized after incorporating informal NDEP and DOE comments. One major revision to the Plan was to remove the background information and decision discussion and instead provide the information within this document. Because the Plan will not be approved by NDEP, text was added regarding referencing the Plan in FFACO documents that do require NDEP approval.

CAU Leads were also asked for final recommendations. One large change resulted from the new ability to purge and sample piezometer strings using the jack pump allowing access to sampling zones, primarily in Pahute Mesa, that were not accessible earlier. Also, the recent completion of Frenchman Flat Model Evaluation provided additional information with respect to groundwater flow directions and velocities (N-I, 2014a). For Frenchman Flat, wells not directly on flow paths associated with UGTA CAS locations were removed (i.e., ER-11-2, UE-5 PW-2, and WW-5B). These wells are not anywhere near the Frenchman Flat contaminant boundaries and therefore are not considered in the Plan categories. In addition, the ER-5-3 shallow piezometer was added. This piezometer provides very distal monitoring for DERRINGER. ER-5-3-3 was also placed on the inactive list. For Pahute Mesa, ER-EC-11 and ER-20-8 shallow piezometers and the BULLION tracer-test wells were added as characterization locations. Other changes—including required analyses, well characterization names (e.g., point of use to community), and specific categorizations for given wells—occurred as a result of the multiple reviews and discussions. These recommendations have been incorporated into the Final Plan (October, 2, 2014). Documentation of the reviews, recommendations, meetings, and presentations is provided as a record in the UGTA Technical Data Repository (UGTA-4-1280).

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Appendix A

CAU Lead Recommendations

(December 2012)

A.1.0 YUCCA FLAT/CLIMAX MINE

A.1.1 Introduction

As described in N-I (2013), 747 underground nuclear detonations were expended in the Yucca Flat/Climax Mine CAU between 1957 and 1992. Most (668) of the detonations expended in Yucca Flat proper (744) were conducted above the water table and 76 were conducted below the water table. A number of wells have been drilled and sampled in order to characterize the extent and magnitude of groundwater contamination in Yucca Flat, both in close proximity to nuclear detonations, and well beyond the so-called exchange volume (usually 1 to 3 cavity radii in extent) within which RNs are initially distributed following a detonation. A succinct summary of groundwater RN sampling and characterization in both near-field and far-field wells in Yucca Flat is given in N-I (2013, Appendix D). Table A-1 is reproduced from Appendix D of N-I (2013). Generally, RN concentrations beyond the exchange volume are well below their MCLs as specified in the SDWA (CFR, 2014), except for ^{3}H at UE-2ce, which samples groundwater contamination from the NASH detonation in the lower carbonate aquifer-thrust plate (LCA3).

USGS makes routine measurements of water levels in and around the NNSS (Figure A-1). Based on their summary of the wells at and near the NNSS where access to the water table is possible, a number of possible sampling locations exist where groundwater sampling would aid in either characterizing the groundwater flow system (characterization wells) or better understanding the evolution of the RN source term (source-term wells); or serve as early detection, distal, or point-of-use monitoring wells (Figure A-1 and Table A-2). Sampling requirements at these different types of wells are described in the following subsections.

A.1.2 Characterization Wells

The proposed characterization wells include ER-8-1, TW-7, UE-1h, and WW-3. Well ER-8-1 is completed in granite (MGCU) in northernmost Yucca Flat. Although numerous head data have been collected since the well was recompleted in 2007 (Fenelon et al., 2010), the well has not been sampled for general geochemical and isotopic data that could be useful for characterizing inflow through the northern margin of Yucca Flat and tracing its persistence at downgradient locations.

Table A-1
Sampling Dates and Radioisotopes for Sampled Observations Wells in Yucca Flat
(Page 1 of 5)

Well	NNSS Area	HSU Open to Well	Sample Dates	Radioisotopes Analyzed and Corresponding Results
ER-2-1	2	TM-WTA, TM-LVTA, LTCU	09/03/2003 (pumped), 09/05/2003 (564 m bgs bailed)	• For the 09/03/2003 sample, ^{3}H was reported as 228 pCi/L, ^{14}C as 0.04 pCi/L, and ^{36}Cl as 1.0E-04 pCi/L; ^{137}Cs, ^{90}Sr, ^{129}I, and Pu were below the MDL; ^{99}Tc was reported as 12 ± 4 pCi/L and 8 ± 4 pCi/L for duplicates (these values are near the 6 pCi/L MDL and considered highly uncertain). • For the 09/05/2003 sample, ^{3}H, ^{14}C, ^{137}Cs, and Pu were reported below the MDL.
ER-3-1	3	LCA	1995, 1996 (pumped)	• ^{3}H was reported below the MDL (181 to 283 pCi/L) for both samples. • Pu was analyzed in both samples, and ^{137}Cs was analyzed in the 11/09/1995 sample. Reported results were below the MDL. • For the 11/09/1995 sample, ^{90}Sr and ^{99}Tc were reported below the MDL (0.6 and 25 pCi/L, respectively), and as 0.27 ± 0.13 and 3.2 ± 1.4 pCi/L, respectively for the 10/16/1996 sample; values are near the MDLs (0.2 and 2.2 pCi/L, respectively) and considered highly uncertain.
ER-3-2	3	AA	1995, 1999, 2000 (451 and 774 m bgs bailed)	• ^{3}H was reported below the MDL (10 to 164 pCi/L) for all samples. • Pu was analyzed only in the 02/25/1999 sample and was reported below the MDL (0.05 pCi/L).
ER-6-1	6	LCA	10/09/1992, 11/23/1992, 1999 to 2004 (bailed annually), 01/28/2004 (pumped)	• ^{3}H was reported below the MDL (0.96 to 360 pCi/L) for all samples. • ^{14}C, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, and Pu were reported below the MDL throughout the sampling period; these RNs were not analyzed in all samples. • ^{36}Cl was reported as 1.3E-04 pCi/L for the 11/23/1992 sample.
ER-6-1-2	6	LCA	2003 (pumped), 2004 (701 m bgs bailed)	• For the 2003 sample, ^{3}H was reported as ≤30.8 pCi/L, ^{14}C as 7.4E-03 pCi/L, ^{36}Cl as 1.4E-04 pCi/L; and ^{99}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, ^{237}Np, and Pu were reported below the MDL. • For the 2004 sample, ^{3}H, ^{14}C, ^{137}Cs, and Pu were reported below the MDL.
ER-6-2	6	LCA3	07/20/2004 (823 m bgs bailed), 08/04/2004 (pumped)	• For the 07/20/2004 sample, ^{3}H, ^{14}C, ^{137}Cs, and Pu were reported below the MDL. • For the 08/04/2004 sample, ^{3}H was reported as 92 pCi/L, ^{14}C as 8.1E-03 pCi/L, and ^{36}Cl as 1.6E-04 pCi/L; ^{99}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, and Pu were reported below the MDL.
ER-7-1	7	LCA	07/02/2003 (719 m bgs bailed), 07/17/2003 (pumped)	• For the 07/02/2003 sample, ^{3}H, ^{14}C, ^{137}Cs, and Pu were reported below the MDL. • For the 7/17/2003 sample, ^{3}H was reported as ≤117 pCi/L, ^{14}C as 1.6E-02 pCi/L and ^{36}Cl as 1.2E-04 pCi/L; ^{99}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, and Pu were reported below the MDL.
ER-8-1	8	MGCU	None	• A sample was not collected because fill within the borehole obstructed access to the water table.
HTH 2	8	LCA	1962, 1989 to 2006 (monthly to annually)	• For a 2006 sample, ^{3}H and ^{36}Cl were reported as <1 and 1.5E-04 pCi/L, respectively. • Gamma emitters, ^{3}H, ^{14}C, ^{99}Sr, ^{99}Tc, and Pu were reported below or near the MDL (values reported near the MDL are likely to be nondetects). Samples were primarily analyzed for ^{3}H; other RNs were analyzed less frequently. The ^{3}H MDLs ranged from 1 to 900 pCi/L.
TW B	6	TSA	1963, 1965, bailed monthly from 1976 to 1987, 1990, 1993, 1998	• ^{90}Sr was reported below the MDL (0.4 pCi/L) for the 1963 sample, and ^{3}H was reported as a nondetect for the 1965 sample. • ^{3}H was reported to decrease from 260 pCi/L to 158 pCi/L for the monthly samples, and was reported as 109 and 44 pCi/L for the 1990 and 1998 samples, respectively. • For the 1993 sample, ^{36}Cl, ^{99}Tc, and ^{137}Cs were reported as 6.8E-04, <5, and <0.7 pCi/L, respectively.

Table A-1
Sampling Dates and Radioisotopes for Sampled Observations Wells in Yucca Flat
(Page 2 of 5)

Well	NNSS Area	HSU Open to Well	Sample Dates	Radioisotopes Analyzed and Corresponding Results
TW D	4	LCA	1965, bailed 1973 to 1987 (biannually) and 1993 to 2010 (annually)	• ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc, ^{90}Sr, ^{137}Cs, and Pu were reported below or near the MDL (values reported near the MDL are likely to be nondetects). Samples were primarily analyzed for ^{3}H; other RNs were analyzed much less frequently. • For a 1993 sample, ^{3}H was reported as 3.8±1.3 pCi/L, and ^{99}Tc was reported as <5.
U-2gg PSE3A	2	TM-LVTA	09/21/1994 (597 m bgs bailed), 09/22/1994 (587 m bgs bailed) (see Section D.2.5 of N-I [2013] for more details)	• For the 09/21/1994 sample, ^{3}H was reported as 5.4E+03 and 7.6E+03 pCi/L,^{14}C as 6.0E+03 pCi/L, ^{137}Cs as 2.7 pCi/L, and Pu as <2.7E-03 pCi/L. • For the 09/22/1994 sample, ^{3}H was reported as 6,490 pCi/L, ^{14}C as 19,900 pCi/L, ^{137}Cs as 0.9 pCi/L, and Pu as <3.1E-03 pCi/L.
U-3cn 5	3	LCA	Samples were collected frequently during 1965 to 1973 hydraulic testing; additional sampling in 1980, 1981, 1997, 1998, 2000, 2011 (see Section D.3.1 of N-I [2013] for more details)	• During 1965 to 1973 hydraulic tests, ^{3}H ranged from less than 1.3E+03 to 1.3E+08 pCi/L (671 to 727 m); 1.6E+06 to 3.2E+06 pCi/L (604 to 655 m); 1.6E+06 to 8.5E+06 pCi/L (560 to 604 m); and <1.3E+03 to 9.4E+04 pCi/L (863 to 893 m). • ^{3}H was reported below the MDL (10.9 to 1,200 pCi/L) for most samples following the hydraulic tests; ^{3}H was reported as 2.9 pCi/L for the 1980 sample and as 10.4 pCi/L for the 1981 sample. ^{137}Cs was reported as 0.003 pCi/L for the 1980 sample and below the MDL (0.001 to 101 pCi/L) for subsequent samples (1981 to 2000); ^{90}Sr was reported as 7.0E-04 pCi/L for the 1980 sample, as 4.6E-04 pCi/L for the 1981 sample, and below the MDL (0.29 and 0.59 pCi/L, respectively) for 1997 and 2000 samples; ^{99}Tc was reported below the MDL (2.1 pCi/L) for the 1997 sample; and Pu was reported as 2.3E-04 pCi/L for the 1980 sample and below the MDL (0.07 and 0.01 pCi/L, respectively) for the 1997 and 2000 samples. • For the 2011 sample, ^{3}H was reported below the MDL (192 pCi/L), ^{14}C as 0.033 pCi/L, ^{129}I as 1.1E-06 pCi/L, and ^{137}Cs as <0.04 pCi/L.
U-3cn PS 2	3	OSBCU	Samples were collected frequently during 1964 to 1966 hydraulic testing, 1977, 1981, 1982, 1983, 1985, 1997, 2001, 2004, and 2007 (see Section D.3.1 of N-I [2013] for more details)	• During 1964 to 1966 hydraulic tests, ^{3}H ranged from 2.1E+08 to 2.7E+08 pCi/L, ^{99}Sr was reported as 0.4 pCi/L, and ^{137}Cs ranged from 3 to 5 pCi/L at 579 to 792 m; ^{3}H ranged from 9.8E+05 to 9.5E+07 pCi/L at 512 to 527 m (no ^{137}Cs or ^{99}Sr results were reported for this sampling interval). • ^{3}H in subsequent samples ranged from 7.7E+06 pCi/L (2007) to 4.6E+07 pCi/L (1981), ^{14}C from 171 pCi/L (1997) to 372 pCi/L (2004), ^{36}Cl from 0.3 pCi/L (1997) to 63 pCi/L (2004), ^{90}Sr from 0.06 pCi/L (1983) to 2.4 pCi/L (1997), ^{99}Tc from 36 pCi/L (2007) to 80 pCi/L (1997), ^{129}I from 0.2 pCi/L (2007) to 0.5 pCi/L (1997), ^{137}Cs from 1.1 pCi/L (1997) to 3.7 pCi/L (1977), and Pu from 2E-03 pCi/L (1985) to 6E-02 pCi/L (2007).
U-4t PS 3A	7	LTCU	1993 and 2008 (bailed; see Section D.2.4 of N-I [2013] for more details)	• For the 1993 samples (311 and 322 m), a high variability in ^{3}H (1.1E+03 to 6.7E+04 pCi/L) was observed. • For the 2008 sample, ^{3}H was reported as 3.0E+03 pCi/L, ^{14}C as 0.87 pCi/L, ^{36}Cl as <4.9E-03 pCi/L, ^{129}I as 2.5E-04, and Pu as <1.5E-03 pCi/L.

Table A-1
Sampling Dates and Radioisotopes for Sampled Observations Wells in Yucca Flat
(Page 3 of 5)

Well	NNSS Area	HSU Open to Well	Sample Dates	Radioisotopes Analyzed and Corresponding Results
U-4u PS 2A	7	LTCU	1992, 1993, 1997, 1998, 1999, 2003, 2008 (bailed at 472-, 484-, and 504-m depths; see Section D.2.3 of N-I [2013] for more details)	• For the 1992 samples, ^{3}H was reported as 5.8E+07 pCi/L (504 m). • For the 1993 samples, ^{3}H ranged from 4.9E+07 pCi/L (533 m) to 5.3E+07 pCi/L (484 m), ^{137}Cs from 2.0 pCi/L (533 m) to 600 pCi/L (504 m), and Pu was 0.14 pCi/L (533 m). • For the 1997 samples, ^{3}H was reported as 1.6E+07 pCi/L (472, 484, and 512 m); ^{14}C was reported as 47 pCi/L, ^{90}Sr as 3.1 pCi/L, ^{137}Cs as 66 pCi/L, and $^{239/240}Pu$ as 0.2 pCi/L for samples collected at 512 m. • For the 1998 samples, ^{3}H was reported as 1.5E+07 to 2.2E+07 pCi/L, ^{14}C as 238 pCi/L, ^{36}Cl as 8.5 pCi/L, ^{99}Tc as 16 pCi/L,^{137}Cs as 43 to 75 pCi/L, and $^{239/240}Pu$ as 0.12 pCi/L. • For the 1999 samples, ^{3}H was reported as 1.6E+07 pCi/L,^{14}C as 229 pCi/L, ^{36}Cl as 8.5 pCi/L, and $^{239/240}Pu$ as 1.2 pCi/L. • For the 2003 samples, ^{3}H was reported as 2.7E+07 pCi/L, ^{14}C as 326 pCi/L, ^{36}Cl as 29 pCi/L, ^{129}I as 0.13 pCi/L, ^{99}Tc as 35 pCi/L, and $^{239/240}Pu$ as 0.32 pCi/L. • For the 2008 samples, ^{3}H was reported as 2.4E+07 pCi/L, ^{14}C as 402 pCi/L, ^{36}Cl as 19 pCi/L, ^{129}I as 0.15 pCi/L, ^{99}Tc as 26 pCi/L, and $^{239/240}Pu$ as 0.44 pCi/L.
U-7ba PS 1AS	7	LTCU	07/19/1995 (bailed at 366-, 427-, 488-, 549-, and 584-m depths; see Section D.2.2 of N-I [2013] for more details)	• ^{3}H increased with depth (5.5E+06 pCi/L to 4.3E+07 pCi/L). • ^{137}Cs was reported as 65 pCi/L (366 m), 4.7E+04 pCi/L (427 m), 6.9E+04 pCi/L (488 m), 3.4E+04 pCi/L (549 m), and 1.3E+05 pCi/L (584 m).
UE-10j	10	LCA	05/25/1965 (bailed 728 m), 04/30/1993 (680 to 796 m), 03/17/1997 (760 to 796 m; Zone 1), 03/20/1997 (721 to 741 m; Zone 2), 03/24/1997 (680 to 700 m; Zone 3)	• For the 1965 sample, ^{99}Sr was reported below the MDL (0.3 pCi/L). • For the 1993 sample, ^{3}H, ^{99}Sr, ^{99}Tc, and ^{137}Cs were reported below MDLs (2, 0.5, 4.5, and 0.6 pCi/L, respectively); and ^{36}Cl was reported as 2E-04 pCi/L. • For the 1997 samples, ^{3}H and ^{137}Cs were reported below MDLs (90 to 190 and 6.8 pCi/L, respectively.)
UE-1q	1	LCA	1992 and bailed annually from 1999 to present	• ^{3}H was reported near or below the MDL (1 to 34 pCi/L) for all samples indicating its absence (values reported near the MDL are likely to be nondetects). • Gamma emitters, ^{14}C, ^{99}Sr, ^{99}Tc, and Pu were reported below the MDL throughout the sampling period; these RNs were not analyzed in all samples. • ^{36}Cl was reported as 1.4E-04 pCi/L in 1992 samples.
UE-2ce	2	LCA3	Frequent pumped samples between 1977 to 1984; bailed in 1993, 2001, 2005; pumped in 2008 (see Section D.3.3 of N-I [2013] for more details)	• ^{3}H ranged from 1.6E+04 to 3.4E+07 pCi/L, ^{99}Sr ranged from 0.08 to 5.1 pCi/L, and ^{137}Cs ranged from <4.5E-03 to 1.7 pCi/L in early samples (1977 to 1984). • ^{3}H ranged from 9.3E+04 to 1.5E+05 pCi/L, and Pu was below the MDL (0.04 to 0.09 pCi/L) in 1993, 2001, and 2005 bailed samples; ^{137}Cs was <0.3 pCi/L in 1993 sample; and ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I were 0.8, 0.4, <0.002, 0.02 pCi/L, respectively in the 2005 sample. • For the 2008 samples, ^{3}H ranged from 1.2E+5 to 2.7E+5 pCi/L; ^{14}C ranged from 0.88 to 1.11 pCi/L; and ^{36}Cl, ^{99}Tc, ^{129}I were 1.3, 0.002, 0.01 pCi/L, respectively.
UE-3e 4 P1	3	LTCU	1990, 1991, 1992, 1993, 1998, and 2009 (bailed; see Section D.2.1 of N-I [2013] for more details)	• ^{3}H ranged from 3.3E+05 to 1.8E+07 pCi/L. • For the 1993 samples, ^{14}C and $^{239,240}Pu$ were reported below the MDL (3,200 and 0.06 pCi/L, respectively). • For the 2009 samples, ^{14}C was reported as 1.3 pCi/L, ^{36}Cl as 0.73 pCi/L, ^{99}Tc as 2.1 pCi/L, ^{129}I as 6.8E-03 pCi/L, and $^{239,240}Pu$ as <3.1E-04 pCi/L.

Table A-1
Sampling Dates and Radioisotopes for Sampled Observations Wells in Yucca Flat
(Page 4 of 5)

Well	NNSS Area	HSU Open to Well	Sample Dates	Radioisotopes Analyzed and Corresponding Results
UE-3e 4 P2	3	LTCU	1990, 1991, 1992, 1993, 1998, and 2009 (bailed; see Section D.2.1 of N-I [2013] for more details)	• ^{3}H decreased from 3.3E+06 to 2.2E+03 pCi/L from 1990 to 2009. • For the 1993 sample, ^{14}C, ^{137}Cs, and $^{239,240}Pu$ were reported below the MDL (3,200, 0.28, and 0.08 pCi/L, respectively). • For the 2009 sample, ^{14}C was reported as 0.012 pCi/L, ^{36}Cl as 3.6E-04 pCi/L, ^{99}Tc as 1.9 pCi/L, and ^{129}I as 1.7E-04 pCi/L.
UE-3e 4 P3	3	TM-LVTA	1990, 1991, 1992, 1993, 1998, and 2009 (bailed; see Section D.2.1 of N-I [2013] for more details)	• ^{3}H decreased from 3.3E+06 to 1.4E+05 pCi/L from 1990 to 2009. • For the 1993 sample, ^{14}C was reported as 4.8E+03 pCi/L; and ^{137}Cs and $^{239,240}Pu$ were reported below the MDL (0.47 and 0.08 pCi/L, respectively). • For the 2009 samples, ^{14}C was reported as 0.11 pCi/L, ^{36}Cl as 6.6E-02 pCi/L, ^{129}I as 5.6E-04 pCi/L, and $^{239,240}Pu$ as <3.1E-04 pCi/L.
UE-4t 1	7	LTCU	1990, 1992, 2000, and 2008 (bailed; see Section D.2.4 of N-I [2013] for more details)	• ^{3}H was reported below or near MDLs (8.4 to 1,080 pCi/L) for the 1990, 1992, and 2000 samples. • For the 2008 sample, ^{3}H was reported as 68 pCi/L, ^{14}C as 0.097 pCi/L, ^{36}Cl as 2.7E-04 pCi/L, and ^{129}I as 3.4E-05 pCi/L.
UE-4t 2	7	LTCU	2000 and 2008 (bailed; see Section D.2.4 of N-I [2013] for more details)	• For the 2000 sample, ^{3}H activities was reported below the MDL (10.4 pCi/L). • For the 2008 sample, ^{3}H was reported as 1.7E+03 pCi/L, ^{14}C as 0.061 pCi/L, ^{36}Cl as 5.1E-04 pCi/L, and ^{129}I as 4.2E-04 pCi/L.
UE-7nS	7	LCA	Samples were collected between 1977 and 1984 at multiple depths (sampling information incomplete); samples were collected at 620 m bgs by RREMP annually between 1994 and 2010, and in 1993, 2001, and 2005 by LLNL and LANL (see Section D.3.2 of N-I [2013] for more details)	• A general increasing trend in ^{3}H activities (13 pCi/L to 2,850 pCi/L) was reported for samples collected between 1977 and 1984; sampling information including depth was not reported for the earliest samples. • RREMP analyses included ^{3}H, ^{14}C, ^{99}Sr, ^{99}Tc, ^{137}Cs, and Pu. ^{3}H decreased from 550 pCi/L in 1995 to 41 pCi/L in 2010. All other RNs were below the MDL. • For the 1993 samples, ^{3}H was reported as 457 pCi/L, ^{14}C as <3,200 pCi/L, ^{137}Cs as <0.2 pCi/L, and $^{239,240}Pu$ as <0.04 pCi/L. • For the 2001 samples, ^{3}H was reported as 4,600 pCi/L, ^{14}C as 0.14 pCi/L, ^{36}Cl as 1.4E-03 pCi/L, ^{129}I as 6.1E-04 pCi/L, and $^{239,240}Pu$ as <0.04 pCi/L by LLNL. LANL reported ^{3}H as 386 to 3,320 pCi/L. • For the 2005 samples, ^{3}H was reported as 132 pCi/L, ^{14}C as 0.14 pCi/L, ^{36}Cl as 2.4E-04 pCi/L, ^{99}Tc as <0.04 pCi/L, ^{129}I as 4.1E-05 pCi/L, and $^{239,240}Pu$ as <0.04 pCi/L.
WW 4	6	TM-WTA	1983 to 2010 (monthly to biannually) (pumped)	• For a 1993 sample, ^{3}H was reported as 0.96 pCi/L, ^{36}Cl as 3.1E-4 pCi/L, and ^{99}Tc as <5 pCi/L. • ^{3}H, ^{14}C, ^{99}Sr, ^{99}Tc, ^{137}Cs, and Pu were reported below or near the MDL (values reported near the MDL are likely to be nondetects). Samples were primarily analyzed for ^{3}H; other RNs were analyzed less frequently. The ^{3}H MDLs ranged from 10 to 900 pCi/L.
WW 4A	6	TM-WTA	1994, and 1995 to 2010 (quarterly) (pumped)	• ^{3}H, ^{14}C, ^{99}Sr, ^{99}Tc, ^{137}Cs, and Pu were reported below or near the MDL (values reported near the MDL are likely to be nondetects). Samples were primarily analyzed for ^{3}H; other RNs were analyzed less frequently. The ^{3}H MDLs ranged from 1.5 to 754 pCi/L.

Table A-1
Sampling Dates and Radioisotopes for Sampled Observations Wells in Yucca Flat
(Page 5 of 5)

Well	NNSS Area	HSU Open to Well	Sample Dates	Radioisotopes Analyzed and Corresponding Results
WW A	3	AA	1961, 1962, monthly between 1972 and 1987, 1990, and annually from 2000 to 2010	• For the 1961 and 1962 samples, ^{90}Sr was reported below the MDL (0.4 pCi/L). • ^{3}H was reported near or below the MDL for the majority of the monthly 1972 to 1987 samples. ^{3}H was reported as 37 pCi/L for the final 1987 sample and as 170 pCi/L for the 1990 sample. • ^{3}H decreased from 573 to 342 pCi/L between 2001 and 2010. Gamma emitters, ^{14}C, ^{90}Sr, ^{99}Tc, and ^{239,240}Pu were reported near or below the MDL indicating their absence (values reported near the MDL are likely to be nondetects).
WW C	6	LCA	1961, 1962, nearly monthly between 1972 and 1995 (pumped)	• For the 1961 and 1962 samples, ^{90}Sr was reported below the MDL (0.4 and 0.5 pCi/L, respectively). • ^{3}H ranged from approximately 100 pCi/L in 1972 to less than 50 pCi/L in 1987; the initial elevated ^{3}H was attributed to a 1964 tracer test (Lyles, 1990). • For the 1993 sample, ^{3}H was reported as 11.5 pCi/L, ^{36}Cl as 2.4E-04 to 2.6E-04 pCi/L, and ^{90}Tc as <5 pCi/L. • ^{90}Sr and Pu was reported below the MDL for samples collected between 1989 and 1995 (these RNs were not reported for earlier samples).
WW-C-1	6	LCA	1962, pumped 1973 to 1987 (biannually) and 1989 to 2010 (monthly)	• ^{3}H decreased from about 100 pCi/L in the 1973 samples to less than the MDL in the 1987 samples. Initial high ^{3}H was attributed to a ^{3}H tracer introduced into this well in the early 1960s (Lyles, 1990). ^{3}H was reported below MDLs (10 to 30 pCi/L) for subsequent analyses. • ^{14}C, ^{90}Sr, ^{90}Tc, ^{137}Cs, and Pu were reported below or near the MDL for samples collected between 1989 and present (values reported near the MDL are likely to be nondetects). • For the 1993 sample, ^{36}Cl was reported as 2.4E-04 pCi/L.

Source: Modified from N-I, 2013

AA = Alluvial aquifer
bgs = Below ground surface
HSU = Hydrostratigraphic unit
LTCU = Lower tuff confining unit
m = Meter
MGCU = Mesozoic granite confining unit
Np = Neptunium
OSBCU = Oak Spring Butte confining unit
TM-LVTA = Timber Mountain lower vitric-tuff aquifer
TM-WTA = Timber Mountain welded-tuff aquifer
TSA = Topopah Spring aquifer

Note: Concentrations reported with a "<" are less than the MDL (the MDL follows the "<").

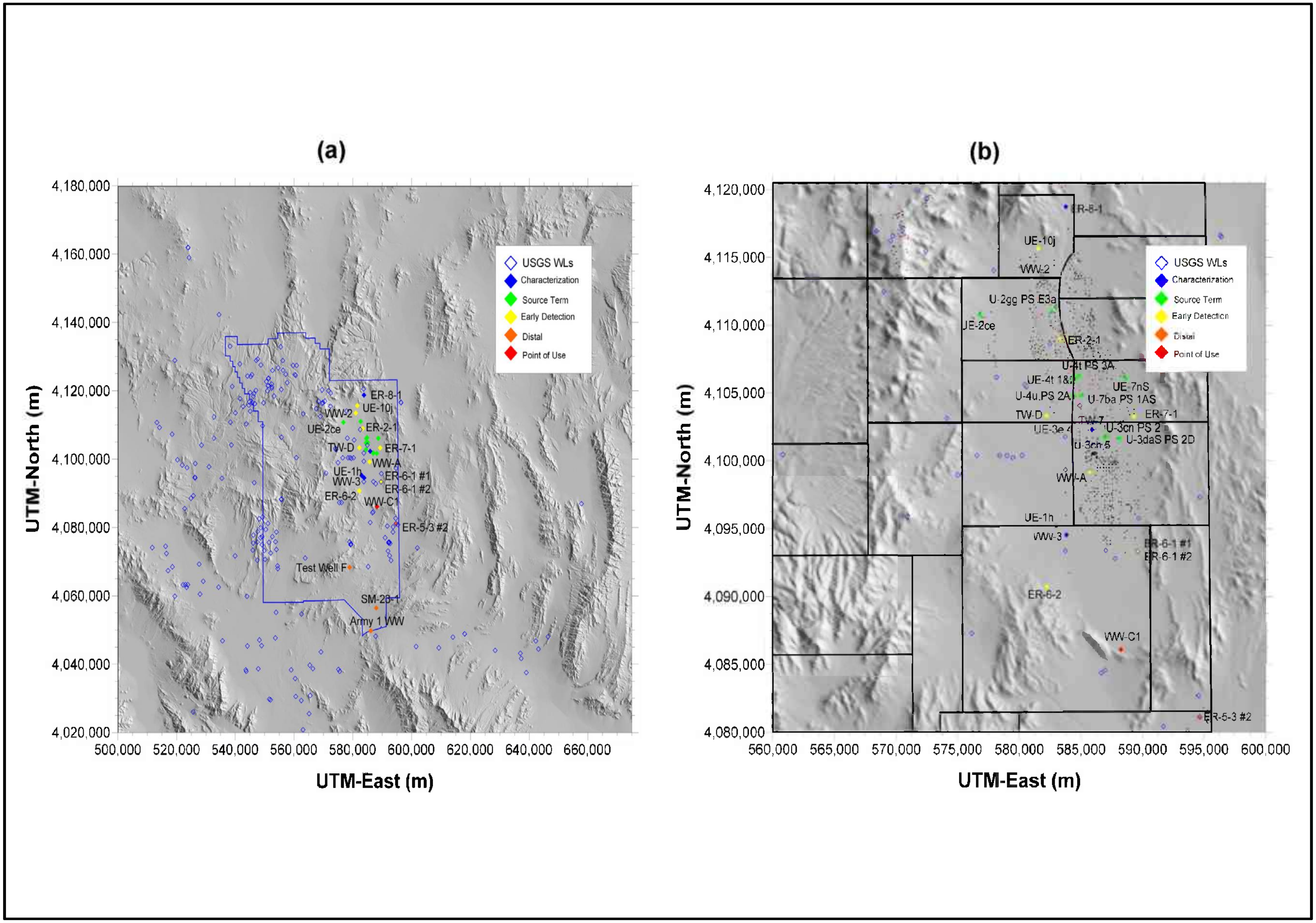


Figure A-1
USGS Water-Level Monitoring Wells in and Surrounding the NNSS, with Characterization, Source-Term Investigation, Early Detection, Distal, and Point-of-Use Wells for the Yucca Flat CAU: (a) Regional Scale and (b) Yucca Flat Area

Note: Black dots represent unsaturated-zone detonations; red dots represent saturated-zone detonations.

Table A-2
Possible Groundwater Sampling Locations in and Adjacent to Yucca Flat

Well	UTM-East (m)	UTM-North (m)	Well Type	HSU Open to Well
ER- 8-1 (recompleted)	583787.7	4118746.0	Characterization/Early Detection	MGCU
TW- 7	585901.0	4102301.2	Characterization	LTCU
UE- 1h	582983.1	4095223.6	Characterization	LCA
WW- 3 (1800 ft)	583827.5	4094554.8	Characterization	Sandstone/Conglom (AA3)
U - 2gg PS E3A	582657.5	4111010.0	Source-Term Investigation	TM-LVTA
U - 3cn 5	586921.7	4101714.4	Source-Term Investigation	LCA
U - 3cn PS 2	586973.5	4101819.1	Source-Term Investigation	OSBCU
U - 3daS PS 2D	588138.5	4101684.1	Source-Term Investigation	?
U - 4t PS 3A	584839.8	4106278.4	Source-Term Investigation	OSBCU
U - 4u PS 2A	584497.7	4104740.2	Source-Term Investigation	LTCU
U - 7ba PS 1A	585107.1	4104867.8	Source-Term Investigation	LTCU
UE- 2ce	576804.1	4110773.4	Source-Term Investigation	LCA3
UE- 3e 4-1 (2181 ft)	584480.9	4102812.7	Source-Term Investigation	LTCU
UE- 3e 4-2 (1919 ft)	584480.9	4102812.7	Source-Term Investigation	LTCU
UE- 3e 4-3 (1661 ft)	584481.2	4102812.7	Source-Term Investigation	TM-LVTA
UE- 4t 1 (1906-2010 ft)	584575.5	4106066.8	Source-Term Investigation	LTCU
UE- 4t 2 (1564-1754 ft)	584575.5	4106066.8	Source-Term Investigation	LTCU
UE- 7nS	588643.6	4106091.3	Source-Term Investigation	LCA
ER- 2-1 main (shallow)	583334.6	4108978.3	Early Detection	TM-WTA, TM-LVTA, LTCU
ER- 2-1 piezometer (deep)	583334.6	4108978.3	Early Detection	?
ER- 7-1	589315.0	4103275.4	Early Detection	LCA
WW- A (1870 ft)	585713.5	4099194.0	Early Detection	AA
WW- 2 (3422 ft)	581005.6	4113499.5	Early Detection	LCA
ER- 6-1 main (3206 ft)	589632.7	4093418.8	Early Detection	LCA
ER- 6-1-1	589635.8	4093403.7	Early Detection	LCA
ER- 6-1-2 main	589616.6	4093357.0	Early Detection	LCA
UE-10j (2232-2297 ft)	581526.5	4115644.9	Early Detection	LCA
ER- 6-2	582235.8	4090744.9	Early Detection	LCA3
ER- 5-3-2	594624.0	4081120.2	Distal	LCA
SM-23-1	587965.5	4056436.7	Distal	LCA
TW- F (3400 ft)	578858.1	4068348.0	Distal	LCA
Army 1 WW (MV-1)	586119.9	4049799.9	Distal	LCA
WW- C-1	588236.1	4086102.9	Point of Use/Early Detection	LCA

AA3 = Alluvial aquifer 3
ft = Foot
UTM = Universal Transverse Mercator

Although it is unlikely that water from this well will detect RNs from nuclear detonations done downgradient in Yucca Flat proper, it is broadly downgradient of the three nuclear detonations done in Climax Stock, and so it might also serve as an early detection well for RN migration from the Climax Mine detonations.

Water levels in zeolitic tuff confining units (LTCU) at well TW-7 have been monitored quarterly since 1987 and sporadically between 1958 and 1987 (Fenelon et al., 2010). Water-level measurement show that hydraulic heads have been periodically elevated as a result of nearby nuclear detonations. Thirty-eight nuclear tests, 22 near or below the water table, were detonated within 1 mile (mi) of TW-7. Three tests, detonated near or below the water table, were from 1,000 to 1,400 ft away. Despite numerous head measurements, no geochemical data exist to determine whether groundwater at TW-7 has been impacted by RNs introduced by nearby nuclear tests. Additionally, Fenelon et al. (2012) have analyzed pre-testing hydraulic heads in the context of the hydrostratigraphic framework model (HFM) for Yucca Flat and suggested that groundwater from the tuffs drains to the LCA in the vicinity of TW-7. Therefore, it would be useful to determine the background characteristics of that water and whether it has been contaminated from nuclear tests. From this point of view, TW-7 could also serve as an early detection well.

Well UE-1h taps the LCA and has exhibited a rise of several meters in water levels since the early 1980s similar to those exhibited at ER-6-2 (Fenelon et al., 2010). Neither well has had a nuclear test conducted within 1 mi of the well. The measured rise at UE-1h could be due to higher than average precipitation rates since the 1980s or the cessation of pumping from WW-3 in 1970, which taps sandstones and conglomerates at the base of the tuffs about 0.75 mi from UE-1h. Existing geochemical data from UE-1h indicate a relatively young (10,000 years old) ^{14}C age for UE-1h groundwater, but an oddly incongruous elevated Cl concentration (43 milligrams per liter [mg/L]) and low $^{36}Cl/Cl$ ratio (143×10^{-15}) indicative of the dissolution of ancient ^{36}Cl-free chloride from the Paleozoic LCA rock matrix. Geochemical data from WW-3 is limited to major ions, with no stable isotope data (including ^{14}C and ^{36}Cl) reported. Joint resampling of UE-1h and WW-3 for major ions and environmental isotopes could help to better define the relationship between shallow (AA) and deep (LCA) aquifers in an area where there appears to be hydraulic communication between the aquifers.

A.1.3 Source-Term Investigation Wells

As summarized in N-I (2013, Appendix D) and Table A-1, numerous near-field or “hot” wells exist near nuclear detonations in Yucca Flat to characterize RN abundances in and near nuclear detonations. These include (1) post-shot (PS) holes drilled back into the cavity/chimney system to diagnose test performance (e.g., U-7ba PS 1 AS, U-3cn PS 2, U-4u PS 2A, U-4t PS 3A); and (2) other wells drilled within several hundred meters of the working point to monitor lateral or vertical RN migration in either tuffs (UE-3e 4 P1, P2 and P3, UE-4t, U-2gg PSE 3A, ER-2-1) or the LCA (U-3cn 5, UE-7ns, UE-2ce [LCA3], and ER-7-1). Neither ER-2-1 nor ER-7-1 has of yet experienced any significant contamination, and so are considered as possible early detection rather than source-term wells. As indicated in Table A-1, generally only ^{3}H exceeds the MCLs established in the SDWA (CFR, 2014), even in relatively near-field wells (U-3cn 5, U-3cn PS 2, U-4t PS3A, UE-2ce, UE-3e 4 P1 and P2). Exceptions to this generalization include wells U-2gg PSE 3A and UE-3e 4 P3, where ^{14}C also exceeds the MCL; and wells U-4u PS 2A and U-7ba PS 1AS, where both ^{137}Cs and ^{3}H exceed the MCL.

The LCA constitutes the only groundwater pathway by which RNs can exit Yucca Flat. The primary value of continued monitoring in tuffs near tuff-hosted detonations would be to investigate the mobility of individual RN species from the near-field environment. If RN concentrations are unchanging with time except for radioactive decay, it could reflect the relative immobility of the RNs due to a combination of hydraulic and transport-related factors such as sorption. Conversely, a rapidly evolving source term would indicate the relatively high mobility of RNs in the near-field environment, and indicate that transport from the near-field is occurring. Because ^{3}H appears to be the major RN of concern for the tuff-hosted detonations, monitoring near-field wells every 4 years or so (3 times per ^{3}H half-life of 12.3 years) would be more than sufficient to distinguish ^{3}H changes due to decay from changes associated with transport.

Continued monitoring of near-field wells in the LCA (e.g., ER-7-1, U-3cn 5, and UE-7nS) would likely bring more substantial value to understanding the risk posed by the subset of nuclear tests that are estimated through modeling to have the greatest potential for long-range transport in Yucca Flat. ER-7-1 is only 200 m from the working point of TORRIDO; U-3cn 5 is 129 m from the working point of BILBY, one of the largest-yield tests (249 kt announced yield) conducted in Yucca Flat; and UE-7nS is 137 m from the working point of BOURBON, whose cavity intersects the LCA in the unsaturated zone. Of these wells, only U-3cn 5 has ever shown ^{3}H concentrations exceeding the

MCL, and that occurred only during a period of active hydraulic testing in the 1960s and 1970s. Since then, ^{3}H concentrations even at U-3cn 5 have not exceeded the MCL. This might point to the need to actively pump these wells (ER-7-1, U-3cn 5, and UE-7nS) in order to draw any nearby contamination into the well. Passive monitoring might not be sufficient to understand the extent of contamination near but not directly flowing into the wells.

A.1.4 Early Detection Wells

Potential early detection wells include relatively near-field wells ER-2-1 and ER-7-1 (discussed above); ER-8-1 (just south of the three Climax Mine tests); ER-6-1-1, ER-6-1-2, TW-D, and UE-10j (all of which are located in the LCA); ER-6-2 in the LCA3; and WW-A (located in the AA) (Table A-2). ER-6-1-2 was the pumping well during the 90-day multiple-well aquifer test (MWAT) (N-I, 2013) during which measurable draw downs were recorded in observation wells U-3cn 5, ER-7-1 and UE-7nS. North-striking normal faults in eastern Yucca Flat may have provided the hydraulic connection between pumping well ER-6-1-2 and monitoring wells U-3cn 5, ER-7-1, and UE-7nS. As discussed above, U-3cn 5, ER-7-1, and UE-7nS were drilled in proximity to the BILBY, TORRIDO, and BOURBON tests, respectively, so the same faults that provided the hydraulic connection between ER-6-1-2 and these wells could also serve as transport pathways for RN migration. Although RN concentrations at ER-6-1-1 and ER-6-1-2 are currently either very low or below detection (Table A-1), periodic pumping and sampling (every 1 to 5 years) for mobile RNs such as ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, and ^{129}I would provide confidence that RNs from detonations of concern were not being transported out of Yucca Flat basin along permeable faults in the eastern part of the basin.

Wells UE-10j and WW-2 tap the LCA in northern Yucca Flat. Because UE-10j is upgradient of most nuclear detonations in Yucca Flat proper, it is unlikely to detect RN migration from detonations done in Yucca Flat itself. However, UE-10j may be a suitable well for monitoring groundwater south of Climax Stock, where one unsaturated-zone and two saturated-zone detonations were conducted. Likewise, ER-8-1 is in the MGCU downgradient of the three Climax Stock detonations. Although previously mentioned as a characterization well, it would also serve as a suitable well for monitoring RN migration in the MGCU itself for the Climax Mine detonations.

Well TW-D is intersects the lower 5 ft of tuff and upper 110 ft of the LCA near the Carpetbag/Topgallant fault system (Fenelon et al., 2010). It has geochemical characteristics that indicate it receives significant contributions of water from the tuffaceous and alluvial aquifers (SNJV, 2007). Seven nuclear tests, six near or below the water table, were detonated within 1 mi of TW-D, with the closest test near or below the water table only 2,000 ft away. Sampling to date indicates no evidence for test-generated RN contamination (Table A-1). Nonetheless, TW-D should be sampled periodically (1 to 5 years) to confirm the continued absence of contamination.

Although binned as a point-of-use well, the location of WW-C-1 at the southern end of Yucca Flat downgradient of the termination of several major basin forming faults makes it ideally located to serve as an early detection well. The fact that it is also a water-supply well virtually guarantees convergent flow toward the well and a relatively wide capture zone compared with passively monitored wells.

Far less ideal is ER-6-2, which penetrates the LCA3 thrust plate above the CP thrust in the western part of the basin. Although in theory it could serve to monitor for RNs from tests in the western part of the basin, head gradients appear to have a northern component in the LCA3 (N-I, 2013, Section 5.0), and recent head measurements have indicated rising heads at ER-6-2 (Fenelon et al., 2010). Nonetheless, because of its location along the southern boundary of Yucca Flat, it should be periodically sampled (1 to 5 years) to confirm the absence of RNs.

A.1.5 Distal Wells

Because RN transport out of Yucca Flat is possible only through the LCA, sampling at distal wells focus on wells along the perimeter of Yucca Flat or beyond that tap the LCA. These wells include ER-5-3-2 in northern Frenchman Flat, Test Well F in southwestern Frenchman Flat, SM-23-1 Mercury, and Army 1 WW in northern Alkali Flat. None of these wells—with the possible exception of ER-5-3-2 in northern Frenchman Flat—is likely to be on a RN transport path. However, given that water levels at SM-23-1 (Army 1 WW) appeared to respond to the 2004 MWAT at ER-6-1-2 (Fenelon, 2012), public perception may demand that these wells be periodically monitored (every few years).

A.1.6 Point-of-Use Wells

Potential point-of-use wells include WW-C-1, which is currently the only active water-supply well in Yucca Flat. Other water-supply wells in Yucca Flat have since been retired: WW-3 (1952 to 1970), WW-A (1961 to 1988), WW-C (1961 to 1995), and WW-2 (1962 to 1990). Because of its location on the southern perimeter of Yucca Flat near the end of major basin-bounding faults, WW-C-1 could also be considered an early detection well (Section A.1.4).

A.2.0 FRENCHMAN FLAT

On December 18, 2012, a kickoff meeting was held for the development of the NNSS Integrated Sampling Plan (i.e., the Plan). An action item that came from the meeting was for the CAU Leads to preliminarily identify wells to be included and their classification (from Table 3-3) by January 11, 2013. This document satisfies this action item for Frenchman Flat.

Frenchman Flat is the first of the UGTA CAUs to complete the CADD/CAP process. The development of the Plan and a solid background water-quality database is an important step toward site closure as it provides the foundation for demonstrating that the monitoring system and institutional controls are properly designed and protective of human health and the environment.

The Plan for Frenchman Flat must consider the specific mechanisms of flow and transport processes within the Frenchman Flat Basin. Contaminant transport within the Frenchman Flat Basin tends to be shallow and limited in the saturated flow system (Table A-3). Groundwater moves very slowly in the basin, where velocities are no greater than 1 m per year and possibly almost an order of magnitude lower. Conservatively built groundwater models have most of the flow occurring laterally with limited vertical flow. These observations lead to two important criteria for a sampling plan:

1. Water-quality monitoring must not accelerate contaminant transport by withdrawals of significant volumes of water resulting in increased groundwater velocities to monitoring locations. Design of sampling methods and volumes will require simple calculations to look at capture zones and determine changes to mean groundwater velocities.

2. The sampling plan should be structured in such a way that shallow and near-source wells provide early detection.

Very few of the wells located within Frenchman Flat provide good-quality plume monitoring locations due to the very low groundwater velocities. As a consequence, wells have been selected to support establishment of use restrictions, institutional controls, and regulatory boundaries.

Sample locations, well type, frequency, analytes, and other applicable notes are provided in Table A-4.

Table A-3
Maximum Saturated-Zone Dimensions of Contaminant Boundary for Each Source

Test	Maximum (m)			Intersected HSUs
	Lateral Distance	Vertical Distance	Width	
Central Testing Area				
CAMBRIC	25	30	25	AA
CAMBRIC Ditch	2,860	110	1,110	AA
DILUTED WATERS	160	45	120	AA
WISHBONE	180	30	130	AA
Northern Testing Area				
DERRINGER	500	5	200	OAA, BLFA
DIAGONILE LINE	220	35	200	OAA, BLFA
DIANA MOON	150	30	190	OAA, BLFA
MILK SHAKE	1,650	60	625	OAA, BLFA
MINUTE STREAK	140	35	190	OAA
NEWPOINT	180	20	175	OAA
PIN STRIPE	1,610	15	350	TM-LVTA, TSA, OAA, LTCU

Source: Modified from NNES, 2010

BLFA = Basalt lava-flow aquifer
OAA = Older alluvium

Table A-4
Preliminary Frenchman Flat Sampling Locations and Types

Well ID (Completion HSU)	Well Type	Sampling Frequency [a]	Analytes and MDL	Objective	Notes/Conceptual Model
UE-5 PW-2 (OAA) ER-5-3 #3 (OAA) ER-11-2 (LTCU)	Distal	10 years	^{3}H ≤300 pCi/L	Safety measure to establish confidence that the plume migration has not been greater or with a different trajectory than anticipated.	Given the very slow groundwater velocities and calculated contaminant boundaries, these wells can be sampled at very long intervals for low levels of ^{3}H.
WW-5B (AA)	Point of Use	5 years	^{3}H ≤300 pCi/L	Safety measure to establish confidence that the plume migration has not been greater than anticipated.	This well is the only well in southern Frenchman Flat that is within the Rock Valley Fault block where the primary flow from the alluvial basin occurs.
ER-5-5 (OAA/BLFA) ER-5-3 shallow piezometer (OAA)	Early Detection	5 years	^{3}H ≤300 pCi/L	Establish groundwater breakthrough and travel times.	• ER-5-5 is within the contaminant boundary for MILK SHAKE, making it an obvious monitoring location. • ER-5-3 shallow piezometer is a water table monitoring point nearest to five other tests, providing a reasonable early detection location. • With sample collection this frequently, it is important to be very careful that sample volumes do not notably change the average groundwater velocity in the vicinity of tests.
RNM-1 UE-5n	Source-Term Investigation [b]	5 years	^{3}H ≥300 pCi/L ^{237}Np, ^{90}Sr, U, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I, ^{239}Pu less than MCLs	These wells monitor the stability of the plume. ^{14}C, ^{36}Cl, and ^{129}I may require AMS analysis to obtain meaningful detection levels.	• The suite of analytes was chosen based upon CAMBRIC modeling, drivers to the contaminant boundary, and continued data collection for the best transport example the project has for source-term characterization. • Sampling for RNM-1 is not a regulatory-focused sampling, but intended to provide ongoing characterization information for the UGTA Activity. • Sampling for UE-5n provides a long-term dataset with a limited set of analyses to monitor plume configuration. • Np and U were selected because these are the only contaminants that have concentrations that are measurable at 1,000 years based on the CAMBRIC modeling. • Sr was observed at RNM-2s and presents an opportunity to monitor low K_d transport. • Pu was observed during the CAMBRIC RNM and provides long-term data on Pu mobilization and transport.

[a] Different than proposed in annotated outline because groundwater velocities are very low.
[b] Or plume performance monitoring.

AMS = Accelerator mass spectrometer
ID = Identification
K_d = Distribution coefficient
RNM = Radionuclide migration experiment
U = Uranium

A.3.0 RAINIER MESA/SHOSHONE MOUNTAIN

A.3.1 Sampling Objectives for Rainier Mesa/Shoshone Mountain CAU

Sampling objectives for Rainier Mesa/Shoshone Mountain will be distinctly different relative to those of other UGTA CAUs. Negotiations between DOE and NDEP have resulted in concurrence to explore an alternative closure strategy not dependent upon establishing contaminant boundaries associated with 95th percentile confidence. The alternative strategy consists of institutional control and monitoring thereof.

A.3.1.1 Rationale for Not Pursuing the FFACO Strategy

The rationale for pursuing an alternative strategy follows:

- The Rainier Mesa/Shoshone Mountain CAU contains only 0.7 percent of the total UGTA RN inventory.
- The Rainier Mesa/Shoshone Mountain CAU is located in the north–central portion of the NNSS. Groundwater flow paths from this CAU are likely to the south and southwest. Distances to the closest NNSS downgradient boundaries are large with a minimum distance being 13 mi to the southwest and 40 mi to the south. Northerly flow is considered to be unlikely.
- Underground nuclear tests conducted in Rainier Mesa/Shoshone Mountain CAU were all located in the unsaturated zone above the water table. Unsaturated-zone flow will strongly attenuate RN transport.
- Unsaturated and CAU-scale saturated-zone flow and transport models have demonstrated that RN transport marginally exceeded the downgradient model boundary in only 1 of 24 simulations (a distance of 8 mi to the south). The sole RN was ^{3}H, and the MCL was exceeded by a factor of 2. Transport was entirely within the upper carbonate aquifer (LCA3). Simulations were parameterized in a way that tended to maximize transport. More probable realizations resulted in no transport to the model boundaries. None of the simulations resulted in transport that approached the boundaries of the NNSS.
- Potential exposure pathways do not exist within the modeled extent of RN transport.
- A large degree of uncertainty is associated with the nature of the LCA3 beneath Rainier Mesa. The LCA3 was modeled as a continuous laterally extensive unit, a scenario that tended to maximize transport. The likelier scenario is that the LCA3 is thrust faulted into discrete

structural blocks separated by intervening slivers of the upper clastic confining unit as observed in well ER-12-1. This latter scenario would greatly attenuate transport.

- Reducing some of the uncertainty associated with the nature and extent of the LCA3 is required to calculate 95th percentile contaminant boundaries that have not been purposely overestimated in order to compensate for existing uncertainties. Reduction of this uncertainty would require the drilling of multiple wells costing tens of millions of dollars. This investigation would almost certainly result in transport more limited than previously simulated.
- Reduction of uncertainty in order to calculate realistic contaminant boundaries is not warranted given the low inventory associated with the CAU, the lengthy flow paths, the lack of potential exposures, and the lack of transport to NNSS boundaries even when models biased toward overpredicting transport are used.

An alternative strategy for Rainier Mesa/Shoshone Mountain has been proposed. This alternative strategy consists of institutional control and the monitoring thereof. The strategy is predicated on the assumptions that the model results are sufficiently robust to give confidence that transport will not occur beyond the boundaries of the NNSS (albeit at less than 95 percent), the inventory and risk associated with Rainier Mesa/Shoshone Mountain are such that resources should not be spent on this CAU to increase confidence, and a sufficient amount of buffer exists between any simulated extent of transport and the boundaries of the NNSS such that the risk and ramifications of being wrong are negligible.

A.3.1.2 Sampling Objective Associated with an Alternative Strategy

The alternative strategy, if implemented, has the Rainier Mesa/Shoshone Mountain CAU leaving the CAI stage and proceeding directly toward the CR stage. Monitoring networks associated with the alternative strategy have the objective of determining whether RN transport from Rainier Mesa/Shoshone Mountain CAU is encroaching upon NNSS boundaries. Early discussions between DOE and NDEP have revealed that monitoring of the NNSS boundaries itself will not be an acceptable alternative to the State. As such, regulatory boundaries will be determined through negotiations between DOE and NDEP during the CR stage. Groundwater sampling and water-level monitoring in the interim should be conducted in a fashion that is consistent with the overall long-term. A cost-effective approach for achieving this objective would be to select existing wells that are potentially downgradient of predicted contaminant transport from Rainier Mesa/Shoshone Mountain CAU. The proposed interim monitoring wells for Rainier Mesa/Shoshone Mountain CAU are presented in Table A-5.

Table A-5
Proposed Interim Monitoring Wells for Rainier Mesa/Shoshone Mountain CAU
(Page 1 of 5)

Potential CAU Associated with Well	USGS NWIS Site ID	NWIS Well Name	Well Type	Sample Type (RN or WL) and Sampling Frequency	Sample Objective	Analyte Suite [a]
PM, RM/SM	371043116142101	ER-19-1-1 (deep)	Early Detection	WL (quarterly)	Water-level monitoring ensures hydrologic system is operating as parameterized in saturated-zone CAU-scale model.	N/A
PM, RM/SM	371043116142102	ER-19-1-2 (middle)	Early Detection	WL (quarterly), RN (every three years unless detected above background then annually)	Water-level monitoring ensures hydrologic system is operating as parameterized in saturated-zone CAU-scale model. Water samples collected from this piezometer are from the Red Rock Valley aquifer, the principle HSU for transport from WINESKIN and CLEARWATER. In addition, the piezometer is located at the distal edge of the expected maximum transport distance from these tests.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I (detection for ^{3}H should be 1 to 10 pCi/L for optimal detection). ^{3}He/^{4}He as well for long-term surrogate once ^{3}H decays to below detection.
PM, RM/SM	371043116142103	ER-19-1-3 (shallow)	Early Detection	WL (quarterly), RN (every five years unless detected above background then annually)	Water-level monitoring ensures hydrologic system is operating as parameterized in saturated-zone CAU-scale model. Water samples collected from this piezometer are from Tunnel Bed 2. Tunnel Bed 2 is a saturated tuffaceous unit located within the testing horizon. This piezometer is potentially downgradient from E-Tunnel if significant westward lateral flow occurs in these units from the testing areas. This conceptual model is unlikely given the permeability of the units and a shorter path that is vertically downward beneath the testing areas. Given the low probability of the event, sampling should occur relatively infrequently.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I (detection for ^{3}H should be 1 to 10 pCi/L for optimal detection). ^{3}He/^{4}He as well for long-term surrogate once ^{3}H decays to below detection.
PM, RM/SM	370301116185801	ER-30- 1-1 (deep)	Distal	WL (annually), RN (every five years unless detected above background then annually)	Water-level monitoring ensures general hydrologic system surrounding Rainier Mesa is operating as conceptualized on a regional scale. Water samples collected from the deeper interval at ER-30-1 is from a basaltic unit embedded within alluvium. Transport to this location from Rainier Mesa tests was not simulated by the models and is a remote possibility. However, if transport directions were incorrect on the southern part of the model and flow is more westward and moves upward stratigraphically as flow moves southward, then ER-30-1 represents a convenient pre-existing location to monitor what could conceivably be transported down the shallow portion of the Fortymile wash flow system. Sampling of this site would be relatively infrequent given the low probability of encountering contamination.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I. ^{3}He/^{4}He as well for long-term surrogate once ^{3}H decays to below detection.

Table A-5
Proposed Interim Monitoring Wells for Rainier Mesa/Shoshone Mountain CAU
(Page 2 of 5)

Potential CAU Associated with Well	USGS NWIS Site ID	NWIS Well Name	Well Type	Sample Type (RN or WL) and Sampling Frequency	Sample Objective	Analyte Suite [a]
PM, RM/SM	370741116194501	UE-18t	Distal	WL (annually), RN (every five years unless detected above background then annually)	Water-level monitoring ensures general hydrologic system surrounding Rainier Mesa is operating as conceptualized on a regional scale. Transport to UE-18t was not simulated. However, if transport from WINESKIN is more extensive than predicted and if that transport shallows stratigraphically as it flows to the southwest, then UE-18t offers a conveniently located preexisting monitoring point located intermediate to WW-8 and ER-30-1. Water samples collected from the well would be a composite sample of water discharging from the upper saturated portion of the volcanic section. Sampling of this site would be relatively infrequent given the low probability of encountering contamination.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I. $^{3}He/^{4}He$ as well for long-term surrogate once ^{3}H decays to below detection.
PM, RM/SM	370956116172101	WW- 8 (30-2031 ft)	Point of Use	WL (quarterly), RN (annually)	WW-8 is a potential stressor to the boundary conditions of the Rainier Mesa saturated-zone model. Its also the closest point of groundwater discharge downgradient of the expected extent of transport emanating from WINESKIN and CLEARWATER, although none of the simulations resulted in transport to the model boundaries adjacent to WW-8. Quarterly water-level monitoring is required to ensure drawdowns are consistent with historical values. Water-quality analysis is required in order to be compliant with SDWA (CFR, 2014) requirements and to ensure exposure to potential RNs never occurs.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I. $^{3}He/^{4}He$ as well for long-term surrogate once ^{3}H decays to below detection.
RM/SM	371106116110401	ER-12-1 (1641-1846 ft)	Distal	WL (annually), RN (every five years unless detected above background then annually)	Water-level monitoring ensures general hydrologic system surrounding Rainier Mesa is operating as conceptualized on a regional scale. Transport to ER-12-1 was not simulated. However, if transport from E-Tunnel pond is more extensive than predicted and if that transport occurs deeper into isolated fault blocks of the LCA3, then it may conceivably be detected at ER-12-1. Water samples should be collected only from the uppermost interval. Sampling of this site would be relatively infrequent given the low probability of encountering contamination.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I. $^{3}He/^{4}He$ as well for long-term surrogate once ^{3}H decays to below detection.

Table A-5
Proposed Interim Monitoring Wells for Rainier Mesa/Shoshone Mountain CAU
(Page 3 of 5)

Potential CAU Associated with Well	USGS NWIS Site ID	NWIS Well Name	Well Type	Sample Type (RN or WL) and Sampling Frequency	Sample Objective	Analyte Suite [a]
RM/SM	371142116125102	ER-12-3 main	Early Detection	WL (quarterly), RN (every three years unless detected above background then annually)	Water-level monitoring at ER-12-3 main ensures the hydrologic system is operating as parameterized in the saturated-zone CAU-scale model. ER-12-3 is located within the LCA3 downgradient of N-Tunnel and provides an optimal monitoring point for this portion of the flow system.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I (detection for ^{3}H should be 1 to 10 pCi/L for optimal detection). ^{3}He/^{4}He as well for long-term surrogate once ^{3}H decays to below detection.
RM/SM	371142116125101	ER-12-3 piezometer	Early Detection	WL (quarterly), RN (every three years unless detected above background then annually)	Water-level monitoring at ER-12-3 piezometer ensures the hydrologic system is operating as conceptualized within unsaturated zone. ER-12-3 piezometer is located at the base of the perched water interval immediately downgradient of N-Tunnel. As such, it provides an optimal monitoring point for this portion of the flow system.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I (detection for ^{3}H should be 1 to 10 pCi/L for optimal detection). ^{3}He/^{4}He as well for long-term surrogate once ^{3}H decays to below detection.
RM/SM	371311116105902	ER-12-4 main	Early Detection	WL (quarterly), RN (every three years unless detected above background then annually)	Water-level monitoring at ER-12-4 main ensures the hydrologic system is operating as parameterized in the saturated-zone CAU-scale model. ER-12-4 is located within the LCA3 downgradient of N-Tunnel and provides an optimal monitoring point for this portion of the flow system.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I (detection for ^{3}H should be 1 to 10 pCi/L for optimal detection). ^{3}He/^{4}He as well for long-term surrogate once ^{3}H decays to below detection.
RM/SM	371311116105901	ER-12-4 piezometer	Early Detection	WL (quarterly), RN (every three years unless detected above background then annually)	Water-level monitoring at ER-12-4 piezometer ensures the hydrologic system is operating as conceptualized within unsaturated zone. ER-12-4 piezometer is located at the base of the perched water interval immediately downgradient of N-Tunnel. As such, it provides an optimal monitoring point for this portion of the flow system.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I (detection for ^{3}H should be 1 to 10 pCi/L for optimal detection). ^{3}He/^{4}He as well for long-term surrogate once ^{3}H decays to below detection.

Table A-5
Proposed Interim Monitoring Wells for Rainier Mesa/Shoshone Mountain CAU
(Page 4 of 5)

Potential CAU Associated with Well	USGS NWIS Site ID	NWIS Well Name	Well Type	Sample Type (RN or WL) and Sampling Frequency	Sample Objective	Analyte Suite [a]
RM/SM	370929116132311	TW- 1 (1615-4206 ft)	Distal	WL (annually), RN (every three years unless detected above background then annually)	Water-level monitoring ensures general hydrologic system surrounding Rainier Mesa is operating as parameterized in the saturated-zone model. Transport to TW-1 was not simulated. However, if transport from E-Tunnel and N-Tunnel ponds is slightly more to the west than predicted, then TW-1 offers a potential monitoring point for the LCA3. Water levels tend to indicate that samples from this well may be most representative of the volcanic Redrock Valley aquifer (RVA), which is less than desirable. The well may need some recompletion to make it produce solely from the LCA3.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I. $^{3}He/^{4}He$ as well for long-term surrogate once ^{3}H decays to below detection.
RM/SM	371342116125102	U -12s (1480 ft)	Distal	WL (annually)	Water-level monitoring ensures hydrologic system is operating as parameterized in saturated-zone CAU-scale model.	N/A
RM/SM	371332116112802	UE-12t 6 (1461 ft)	Distal	WL (annually), RN (every five years unless detected above background then annually)	Water-level monitoring ensures hydrologic system is operating as parameterized in saturated-zone CAU-scale model. UE-12t #6 is completed in the LTCU northwest of T-Tunnel. There has been some concern of a localized northerly flow component from Rainier Mesa in the LCA3. This could also be expressed in the TCU north of Rainier Mesa. UE-12t #6 represents the only existing preexisting location for monitoring volcanics to the north of T-Tunnel. The sample point is not optimally located and transport is not likely, so infrequent sampling is preferred.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I. $^{3}He/^{4}He$ as well for long-term surrogate once ^{3}H decays to below detection.

Table A-5
Proposed Interim Monitoring Wells for Rainier Mesa/Shoshone Mountain CAU
(Page 5 of 5)

Potential CAU Associated with Well	USGS NWIS Site ID	NWIS Well Name	Well Type	Sample Type (RN or WL) and Sampling Frequency	Sample Objective	Analyte Suite [a]
RM/SM, YF/CM	370031116121103	ER-16-1 (recompleted)	Early Detection	WL (annually), RN (every five years unless detected above background, then annually)	ER-16-1 is located directly beneath U16a-Tunnel. As such, it is the only saturated-zone monitoring point available. Transport modeling results indicated transport to the saturated zone was a low probability. Sampling of this well should be relatively infrequent as a result.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I (detection for ^{3}H should be 1 to 10 pCi/L for optimal detection). $^{3}He/^{4}He$ as well for long-term surrogate once ^{3}H decays to below detection.
RM/SM, YF/CM	370412116095101	UE-16d WW	Point of Use	WL (quarterly), RN (annually)	UE-16d is a potential stressor to the boundary conditions of the Rainier Mesa saturated-zone model. Its also the closest point of groundwater discharge downgradient of the expected extent of transport emanating from U12n and E-Tunnel pond, although none of the simulations resulted in transport to the model boundaries adjacent to UE-16d. Quarterly water-level monitoring is required to ensure drawdowns are consistent with historical values. Water-quality analysis is required in order to be compliant with the SDWA (CFR, 2014) requirements and to ensure exposure to potential RNs never occurs.	^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I. $^{3}He/^{4}He$ as well for long-term surrogate once ^{3}H decays to below detection.

[a] Detection limits should ideally be 1/10th MCL in all cases) ^{3}H may be lower in some cases.

He = Helium
N/A = Not applicable
NWIS = National Water Information System
PM = Pahute Mesa
RM/SM = Rainier Mesa/Shoshone Mountain
TCU = Tuff confining unit
WL = Water level
YF/CM = Yucca Flat/Climax Mine

A.4.0 PAHUTE MESA

As described in Section A.2.0, an action item that came from the kickoff meeting for the Plan was for the CAU Leads to preliminarily identify wells to be included and their classification (from Table 3-3) by January 11, 2013. This document satisfies this action item for Pahute Mesa. Additionally, feedback on the proposed "Well Type" classification is included.

Monitoring systems have been a key element of environmental compliance for 30 years or more, so the CAU Lead for Pahute Mesa investigated how other agencies have developed guidance (Figure A-2 shows one example). Notice that while the source term—all groundwater contamination has a source term—is included, it does not get special treatment in well type.

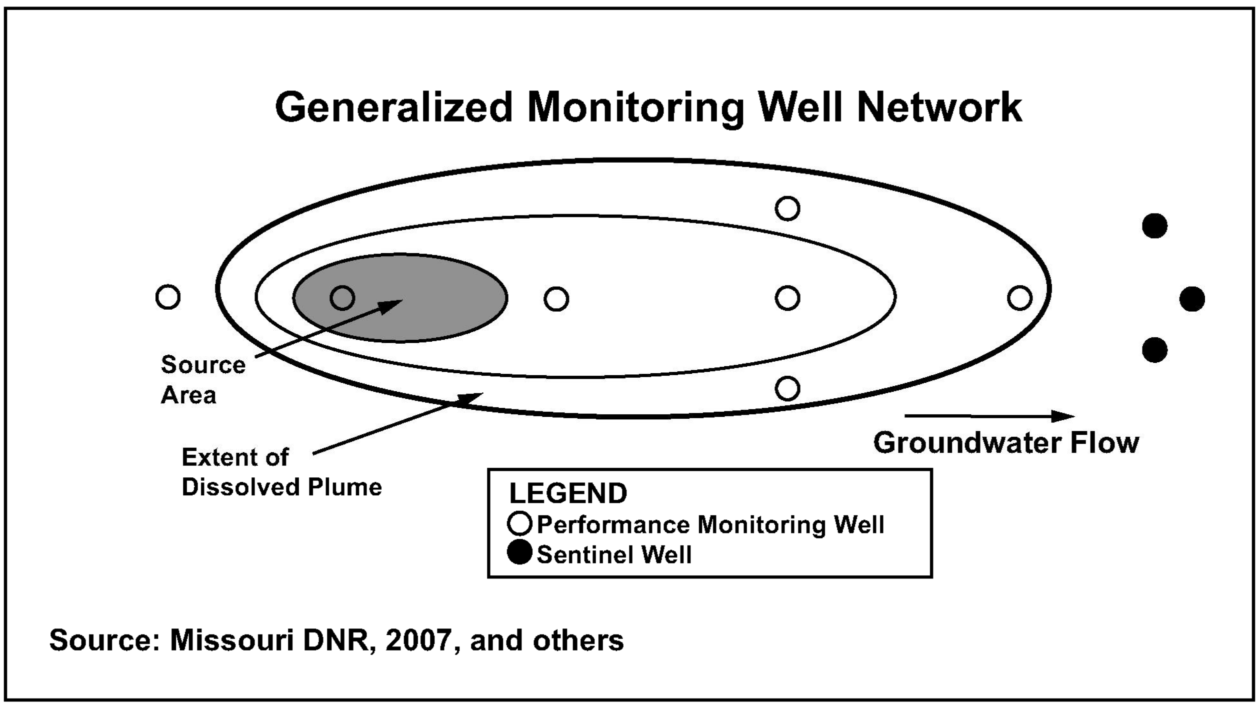


Figure A-2
Generalized Monitoring Well Network
Source: NJDEP, 2012

Note the sentinel wells along the expected path of plume migration start out uncontaminated but eventually may become contaminated. Rather than have source-term as a separate type, the CAU Lead suggests combining the source-term and characterization categories into something else; perhaps the more general "performance monitoring" category shown in Figure A-2. If desired, extra analytes can be periodically checked, but the analyte suite should focus on the contaminants most likely to be present. Recent data (N-I, 2012) confirm that ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, and ^{129}I are the primary mobile contaminants in Pahute Mesa groundwater—the latter four occurring at only a fraction of the MCL even as ^{3}H is thousands of times greater than MCL at ER-20-7 and the ER-20-5 cluster. At this time, it appears that the only way to get suitable detection levels for ^{14}C, ^{36}Cl, and ^{129}I is by AMS analysis. For instance, the contract laboratory used by N-I initially provided a method detection level of 10 pCi/L for ^{129}I (claimed to be 1 pCi/L currently); the MCL is 1 pCi/L. LLNL has been performing this analysis for UGTA at its Center for Accelerator Mass Spectrometry (CAMS) facility.

The basic conceptual model for RN release and migration is that a test will be the source of extensive groundwater contamination if the exchange volume (including chimney) for the test materially intersects laterally extensive transmissive formations. At Pahute Mesa, these rocks will be transmissive because of fracturing, resulting in higher groundwater velocities. UGTA wells are often completed in more than one zone that may or may not be a separate aquifer. Current data suggest that in southwest Area 20, all three aquifers proximal to underground nuclear tests are contaminated: (1) the lavas of Benham, Scrugham, and Comb Peak; (2) Tiva Canyon aquifer (TCA); and (3) Topopah Spring aquifer (TSA). The uppermost aquifer may be the most contaminated, with diminishing contamination with depth—current data are ambiguous. However, because these wells are relatively new (even the Phase I wells) and the understanding of plume dynamics is preliminary, it is proposed to monitor, as possible, all the zones in wells accessing contaminated groundwater. Table A-6 reflects these intervals, which when appropriate are indicated in parenthesis showing relevant HSU [e.g., "(BA, TCA)" is the Benham aquifer (BA) and TCA completions]. If no HSU data in parentheses are shown, there is only one possibility, or the choice is thought to be currently ambiguous. Figure A-3 shows the proposed locations.

Some wells, all accessing as yet uncontaminated groundwater, have more ambiguous completions that complicate sampling. Well UE-18r, for instance, is open to about 3,000 ft of volcanic rock. Gillespie (2005) indicates water enters the borehole just below the casing and again some distance below. Well ER-EC-2A has three screened intervals, two of which are nominally in TCUs

Table A-6
Preliminary Pahute Mesa Sampling Locations and Types

Well ID (Completion HSU)[a]	Well Type	Sampling Frequency	Analytes and MDL	Objective	Notes/Conceptual Model
ER-OV-* UE-18r ER-EC-1[b] ER-EC-2A ER-EC-5 ER-EC-8 ER-EC-12 (TCA, TSA) ER-EC-13 ER-EC-14 ER-EC-15 (CPA, TCA) PM-3 U-20 WW	Distal	6 years[c]	^{3}H $\geq$300 pCi/L	Safety measure to establish confidence that the plume has not grossly evaded the upstream monitoring network. Additionally define plume trajectory.	Longer sampling interval proposed because repeated nondetects have minimal value. Well ER-EC-1 has no ^{3}H detection even using noble-gas accumulation, and may not be on the main flow path. In the case of PM-3, it is the only well in position to detect possible migration from U-20p and U-20m.
ER-EC-11 (BA, TCA, TSA) ER-EC-6 (BA, TCA, TSA)	Early Detection	2 years	^{3}H $\leq$300 pCi/L	Trace ^{3}H has been detected at ER-EC-11 and ER-EC-6; presumably, the center of mass is following. These wells are completed in the three aquifers known to be contaminated in southwest Area 20. Establish groundwater breakthrough and travel times.	As ^{3}H becomes $\geq$300 pCi/L, these wells become source-term investigation[d] wells, and a new set of early detection wells is chosen/installed. By definition, this is a small set of wells. Depending on well location and groundwater velocity, at some point there may not be any wells situated so that a 2-year sampling interval makes sense. It seems like a rule to move an early detection well to distal needs to exist.
ER-20-6#3 UE-20n1 ER-20-5#1, #3 ER-20-7 ER-20-11 ER-20-8 (TCA, TSA) ER-20-8#2 U-20n PS1 DDh U-19ad PS1A U-19V PS#1D (3,090 ft)	Source-Term Investigation[d]	4 years	^{3}H $\geq$300 pCi/L ^{14}C, ^{36}Cl, ^{99}Tc, ^{129}I less than MCLs	These wells monitor the stability of the plume. Currently, ^{14}C, ^{36}Cl, and ^{129}I require AMS analysis to obtain meaningful detection levels. As breakthrough occurs at early detection wells, they become converted to this type of well.	The suite of analytes was chosen based upon Phase II data from ER-20-7 and ER-20-8 cluster (among others).

[a] Only for wells with multiple completions
[b] All completions open since 1999.
[c] Or plume performance monitoring.
[d] Different than proposed in annotated outline.
* = 01, 02, 03a, 03a3, 03c, 03c2, 04a, 05, 06a (e.g., ER-OV-01).

CPA = Comb Peak aquifer

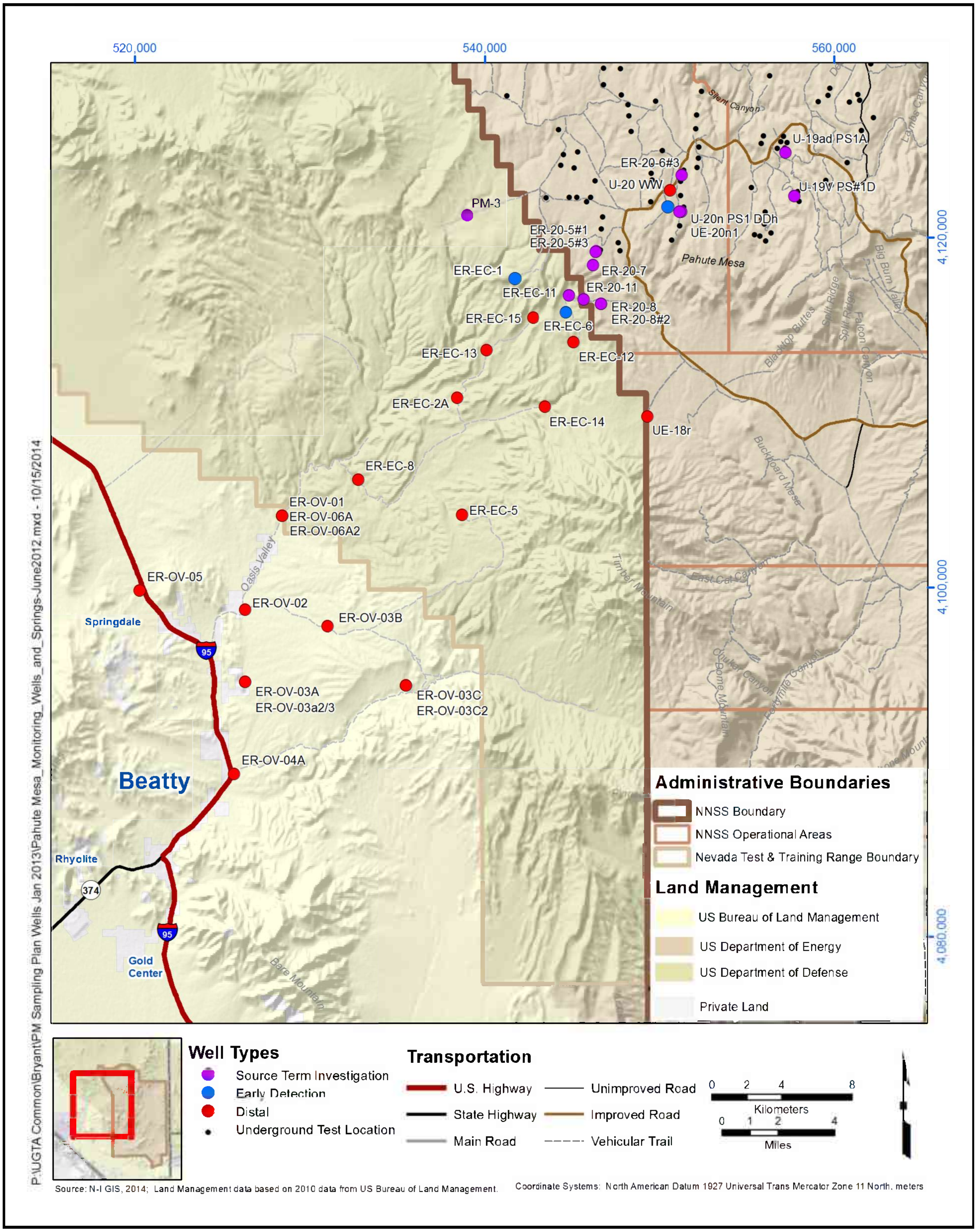


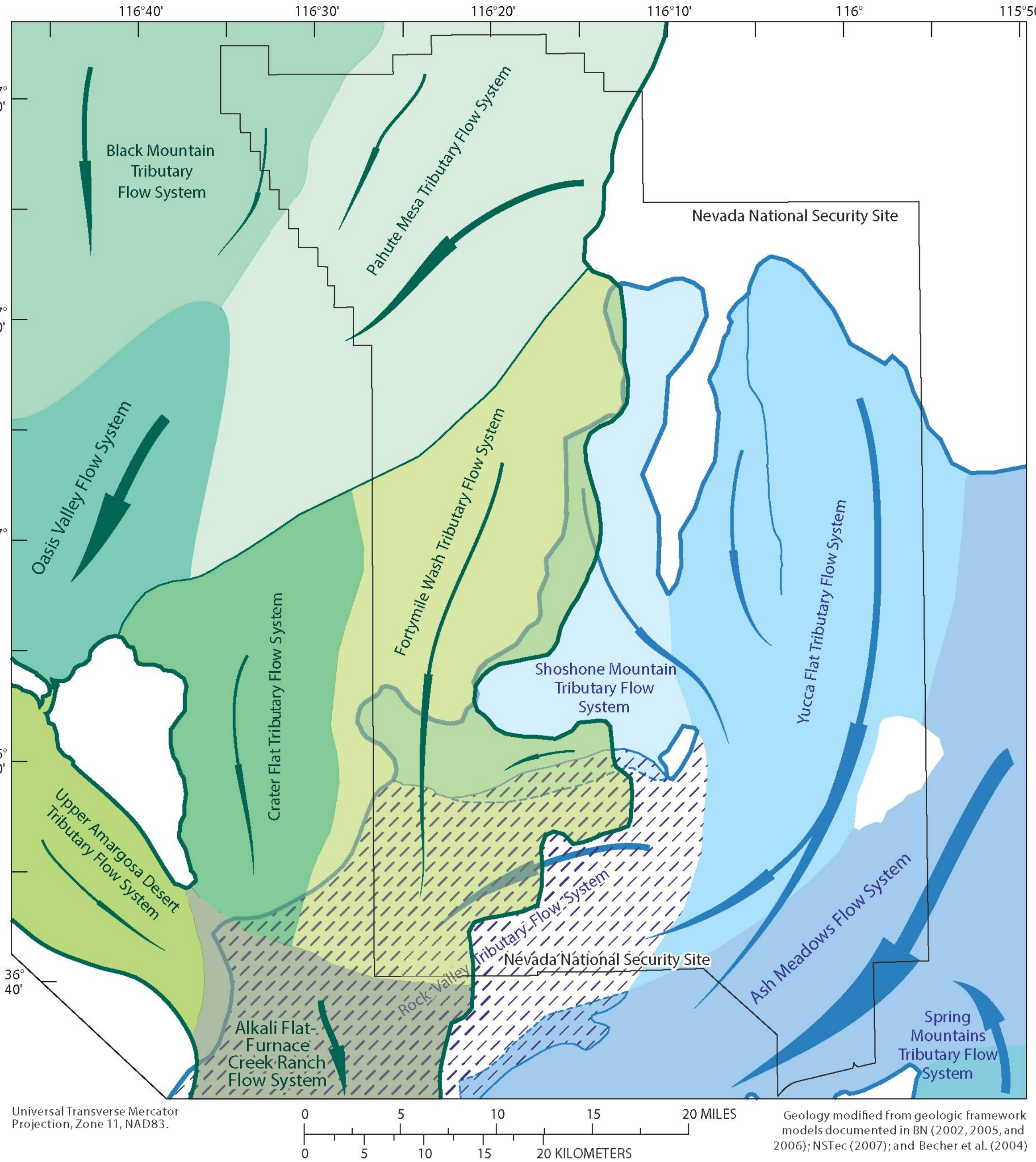
Figure A-3
Proposed Monitoring Well Network

(NNSA/NV, 2002), which by definition are unlikely to detect contaminants moving in the more transmissive parts of the aquifer system. In tension with this description is the production of up to 800 gallons per minute of water during drilling—fracturing is attributed as the cause of this discrepancy (NNSA/NV, 2002). Resolving such issues is considered beyond the scope of this initial outline.

Other wells have access to formations of interest, but only through 2 3/8-inch (in.) (or similar size) tubing, which at the well depths at Pahute Mesa is difficult to pump effectively. The BA interval at ER-EC-11 is an example of such an interval.

Wells ER-18-2, ER-EC-4, and ER-EC-7 are not included because they are not on the expected flow path of contaminated groundwater. Figures A-4 (from Fenelon et al., 2010) and A-5 (data from Fenelon et al., 2010) illustrate this point. Well ER-EC-5 is marginally located, but the scale of the contours may be a limiting factor and it is included nonetheless in the distal well category.
Well ER-20-1 is also omitted because water-level monitoring suggests it is not connected to the transmissive part of the formation. Point-of-use wells are not included.

Well PM-3 has been placed in the distal category, but it may need further consideration. Nominally, ^{3}H has been detected, but there appears to be some doubt about the analytical significance of the results. The conceptual model of the source of potential contamination is also unclear. Additional analysis and sampling is ongoing that may provide additional insight.



EXPLANATION

Regional groundwater flow systems – Green and blue colors denote alluvial-volcanic and carbonate flow systems, respectively. Arrow indicates regional flow direction. Arrow width indicates relative flow volume. Carbonate flow system boundary dashed where aquifer extends beneath extent of another carbonate flow system. Belted Range and Sarcobatus Flat tributary flow systems not shown.

Figure A-4
Major Groundwater Flow Systems of the Regional Alluvial-Volcanic and Carbonate Aquifers in the NNSS Area
Source: Modified from Fenelon et al., 2010

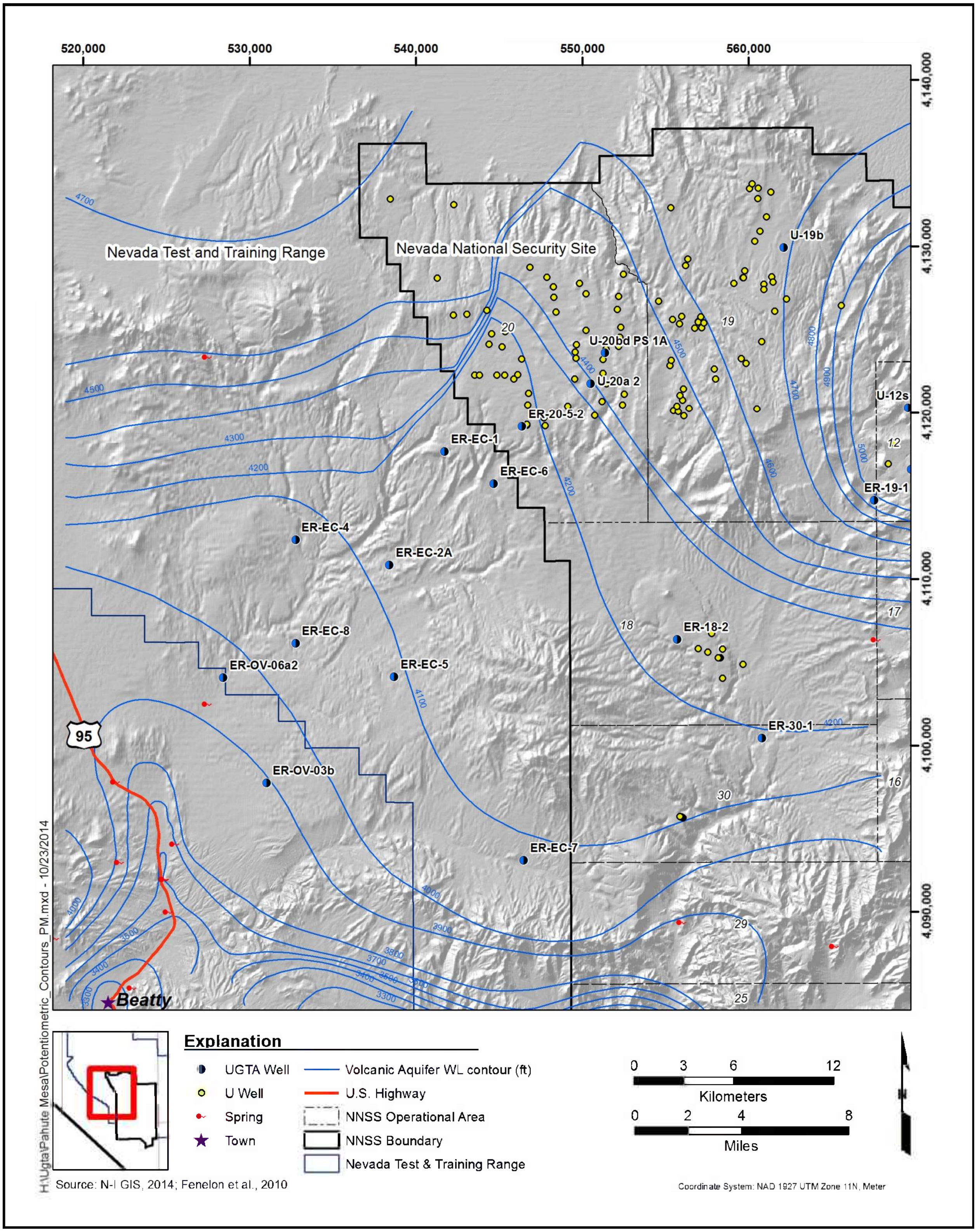


Figure A-5
Potentiometric Contours of Alluvial-Volcanic Aquifers from Fenelon et al. (2010) with Interpreted Flow Paths for ER-18-2, ER-EC-4, ER-EC-5, and ER-EC-7

A.5.0 REFERENCES

BN, see Bechtel Nevada.

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Appendix B

Sampling Plan Committee Comments

B.1.0 GENERAL COMMENTS AND RESPONSES

General comments from the Sampling Plan Committee and the responses from the NNSA/NFO representative are presented in Table B-1.

Note: "Source-term investigation" wells and "source/plume" wells are the same. Well type names changed over the course of Sampling Plan development.

B.2.0 YUCCA FLAT/CLIMAX MINE

Comments from the Sampling Plan Committee regarding the Yucca Flat/Climax Mine CAU and the responses from the CAU Lead are presented in Table B-2.

B.3.0 FRENCHMAN FLAT

Comments from the Sampling Plan Committee regarding the Frenchman Flat CAU and the responses from the CAU Lead are presented in Table B-3.

B.4.0 RAINIER MESA/SHOSHONE MOUNTAIN

Comments from the Sampling Plan Committee regarding the Rainier Mesa/Shoshone Mountain CAU and the responses from the CAU Lead are presented in Table B-4.

B.5.0 PAHUTE MESA

Comments from the Sampling Plan Committee regarding the Pahute Mesa CAU and the responses from the CAU Lead are presented in Table B-5.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
B.1.1 Wells	
1. I assume here that this sampling plan refers to long term sampling and is unrelated to any characterization work that might occur in anticipation of PM phase II modeling work (or when establishing new well in the various CAUs). I think this is a separate topic.	That was not the intent of the Sampling Plan. Revisions will be incorporated to reflect that wells begin as characterization wells and how they may later be categorized as another well type. This comment prompted us to relook at the categorization of the wells and change some of the well types to characterization wells.
2. Will we be committed to those in the list, and prohibited from monitoring at any not on the list? Might also consider a “potential wells of interest” table, or craft the Sampling Plan text along those lines.	The CAU Leads or other programs may choose to go beyond the list if there is a basis for increased monitoring. If the need is more than an exception or a case-by-case basis, the Sampling Plan may be revised accordingly.
3. Is ^{3}H at 300 pCi/L a reasonable concentration at which to re-categorize a well, which will involve additional effort (investigation, study, etc.)? Triggering the Investigation Level (>3 sigma increase over baseline) should replace the 300 pCi/L threshold for moving from Early Detection to Contaminant Migration categories.	Early detection wells are those directly downgradient of the underground test but where no COCs have been detected. Once ^{3}H is detected, an investigation is triggered to verify that tritium is in fact present and that it has resulted from an underground test. Once this has been verified, it will be identified as a source/plume monitoring well; otherwise, the CAU Lead, with consultation of other subject matter experts, will identify future sampling objectives for the well. The CAU Lead (with the consultation of a geochemistry/radiochemistry/ sampling committee) will then determine the suite of analytes and sampling frequency depending on the sampling objective.
4. It is unclear to me why the early detection wells differ from distal vs contaminated wells. I would recommend moving this into the “contaminated wells” category and reduce sampling to 5 year frequency. I understand that we want to establish baselines right now for the new wells.	See the response to Wells comment #3.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
***B.1.1 Wells** (continued)*	
5. Any wells that are not along plausible contamination flow paths (or contaminated already) should be eliminated.	The desire of DOE is to have the NNSS Sampling Plan be the umbrella for all sampling and for it to be entirely science based, concentrating on areas of potential contaminant transport. However, DOE feels that it is too premature to eliminate the "policy" or "public relation" bases addressed by RREMP and CEMP at this time. Therefore, it was decided by DOE prior to eliminating them that an established and agreed-upon process will be used to discontinue monitoring wells that do not have a scientific basis. For example, some point-of-use wells and distal wells that are monitored under the RREMP and CEMP will be phased out based on the Sampling Plan. It is the intent of the Sampling Plan to define parameters addressing when a well no longer needs to be monitored (i.e., after the completion of modeling and it is confirmed that the well is not along a plausible contamination flow path supported by monitoring data). Although continuous non-detects are of value, with time, if they are not in the expected pathway, continued monitoring may not be the best use of resources. This does run a risk for negative public perception. DOE presented this concept to the NSSAB for their feedback and recommendation on April 17, 2013, and the NSSAB input was considered during the development of the Sampling Plan. It should be noted that even if it is determined that if monitoring is no longer needed, wells that are not of interest will still be available, as the borehole plugging program is not active at this time.
6. A well could be rated differently for different aquifers (for each completion zone). Would the sampling plan be the same for all the aquifers of a multi-completion well? (I would say, not necessarily.) One well can be both a "distal" and "contaminated" well depending on the interval that is being sampled.	Yes, a well with multiple aquifers may be categorized as more than one well type and therefore could have a different monitoring plan.
7. Either treat the offsite monitoring locations the same as a distal well, applying whatever consistent constraints established for that set (e.g., sample tritium every five years), or continue what are probably annual sampling events. A case can be made for either approach. By aligning the off-site point-of-use with the distal wells, it affirms that the public wells are not in present danger and that other wells are "on the front line". Conversely, sampling and analysis of local supply wells is cost effective (given the necessary presence of pumps if the wells are in use) and may be extremely valuable in terms of allaying stakeholder concerns. DOE could lose any good-neighbor status it might have if it appears to be cutting costs and trading off public safety.	See the response to Wells comment #5.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
***B.1.1 Wells** (continued)*	
8. I really don't like the name "Contaminant Migration" for this group of wells. "Source monitoring" would be better.	As reflected in the meeting, the name has been changed to source/plume.
9. Every contaminant migration (Source Monitoring) well is unique in terms of what information is needed from it. There is no reason to force consistency and every reason to tailor activities to each specific well. Each CAU group should be allowed to identify the frequency, analytes and MDLs, though they need to make a good case for why the data are needed. It seems likely that some of these may decline in usefulness as time goes on because their notes suggest a primary interest for characterization and contaminant transport predictions. At some point, those types of investigations will decline and continued source monitoring will be of limited value (though natural attenuation monitoring will have value for a long time). It would be really good to be clear about that expected phasing out, both in the sampling plan proper and in the CAU-specific appendices, to try and avoid falling into the "once monitored, always monitored" trap. We could go back to the CAU leads and ask them to identify an anticipated timeframe over which each of these wells has value for monitoring	The Sampling Plan is intended to provide a consistent basis for monitoring for normal conditions while allowing flexibility for the CAU Leads and RREMP and CEMP Leads to go beyond what is required by the Sampling Plan. If the need is more than an exception or a case-by-case basis, the Sampling Plan may be revised accordingly. In addition, as noted in the response to Wells comment #5, the Sampling Plan will define parameters addressing when a well no longer needs to be monitored.
10. Concerning phasing out Point of Use Wells; this monitoring has no UGTA technical basis (based on historical data here and at Distal group, and UGTA models, we state PM groundwater contamination is not a credible pathway for public exposure), so Public Relations is the primary concern / objective. There would be a challenge in phasing this out - might be seen by the public that as the contamination gets closer, DOE is going to reduce and potentially cease monitoring.	See the response to Wells comment #5.
11. I don't know that this committee has authority to change the RREMP sampling and analysis plan. However, I would be in favor of lower sampling frequency and lower detection limits instead of the reverse.	Kathryn Knapp, DOE Program Manager of the RREMP and CEMP, and Ted Redding, NSTec RREMP Program Manager, are both on the committee and are receptive to integrating the outcome of the Sampling Plan into the respective programs. Also, as noted in the response to Wells comment #2, the CAU Leads or other programs may choose to go beyond the list if there is a basis for increased monitoring. If the need is more than an exception or a case-by-case basis, the Sampling Plan may be revised accordingly.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
B.1.2 Sampling Frequency	
1. The frequency for the distal and point of wells should be based on contamination detected in the early detection wells. Initially, they could be monitored at an agreed upon frequency (i.e., every 5 years). Then depending on lack of activity or stable activity in the Early Detection Wells, decrease frequency (i.e., every 10 years) OR cease monitoring until detection levels changes. If increased activity is detected in the early detection wells, increase monitoring frequency, first at the distal wells and then at the point of use as appropriate.	As noted in the response to Wells comment #5, the Sampling Plan will define parameters addressing when a well no longer needs to be monitored (i.e., after the completion of modeling and it is confirmed that the well is not along a plausible contamination flow path supported by monitoring data). Increasing or decreasing the frequency based on monitoring results should be addressed as well. This does run a risk for negative public perception. DOE presented this concept to the NSSAB for their feedback and recommendation on April 17, 2013, and the NSSAB input was considered during the development of the Sampling Plan.
2. Sampling Frequency. CAU leads varied in distal sampling frequency from 3 to 10 years. My general opinion is that if it is worth having in the sampling plan, it should have a frequency no longer than 5 years. Anything longer than that risks losing historical knowledge. Verifying the well, access, and land conditions are needed in that sort of timeframe anyway. Most contracts tend to go for 5 years, so aligning that frequency would ensure that most wells are sampled by each successive M&O contractor and thus records passed on to the next. Note my qualifier that the above applies to wells worth having in the plan. If no one thinks a well needs to be sampled at least every 5 years, I'd suggest that well is a good candidate for eliminating. It might be reasonable to gather those up and list them as triggered wells, ones that could be added into the sampling scheme if triggered by findings elsewhere.)	Agree; content of comment should be incorporated into the Sampling Plan. The first cut of a flowchart was developed (Figure B-1) suggesting a 2-year interval for characterization and early detection wells and a 5-year interval for source/plume and distal wells with the point-of-use wells in accordance with the RREMP/CEMP.
3. I recommend that sampling time intervals and radionuclides to be examined be consistent for all CAUs. Otherwise, one will have to make complex justifications for the differences (one exception in LCA aquifers in which the list of "mobile" radionuclides may differ from wells completed in tuff).	Agree, as described in the response to Wells comment #9, the Sampling Plan is intended to provide a consistent basis for monitoring for normal conditions while allowing flexibility for the CAU Leads and RREMP and CEMP Leads to go beyond what is required by the Sampling Plan. If the need is more than an exception or a case-by-case basis, the Sampling Plan may be revised accordingly. Also, a flow chart was prepared (Figure B-1) to include the different decision points for selecting analytes and sampling frequencies.
4. I agree with the five-year max sampling frequency.	See the response to Sampling Frequency comment #2.
5. Unless there is a sound reason and agreement on a specific frequency for a given well type and/or CAU, suggest we go with a range (e.g.; 1 – 5 years), and allow scheduling within that range.	See the response to Sampling Frequency comment #2.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
B.1.2 Sampling Frequency *(continued)*	
6. If we think the Early Detection and Contaminant Migration wells should be the same for all CAUs, I propose the frequency be every 2 years for early detection and every 4 years for Contaminant Migration.	See the response to Sampling Frequency comment #2.
7. I favor sampling more wells with a lower frequency. Any radionuclide migration will be quite slow (as we've seen historically) so frequent sampling should be avoided if possible.	See the response to Sampling Frequency comment #2.
8. All Distal, Early Detection, and Contaminated wells should be sampled on a 5 year cycle.	See the response to Sampling Frequency comment #2.
9. I think that variation (1 to 5 years) is fine for early detection wells because it is related to the hydrologic conditions of each well and proximity to cavities.	The first cut at the flowchart (Figure B-1) suggests a 2-year interval for early detection wells. Note, as reflected in the meeting minutes, once ^3H is detected in an early detection well, an investigation is triggered to verify that ^3H is in fact present and that it has resulted from an underground test. Once this has been verified, it will be identified as a source/plume monitoring well; otherwise, the CAU Lead, with consultation of other subject matter experts, will identify future sampling objectives for the well. The CAU Lead (with the consultation of a geochemistry/radiochemistry/sampling committee) will then determine the suite of analytes and sampling frequency depending on the sampling objective.
10. I wouldn't consider annual sampling for any wells except possibly point of use wells.	See the response to Sampling Frequency comment #2.
11. There ought to be criteria for frequency. I don't necessarily believe all early detection wells have to be the same frequency, but there should be a rationale for differences in sampling frequency. I don't think it would be difficult to go down the list and propose a frequency and justification for each well. Confining units, if they are sampled at all, should have low frequencies. Maybe we should just have some frequency ranges for each well type and assign a frequency for each well within this range. Ed does this for early detection wells in Yucca Flat. Using his criteria of 1-5 years, I might suggest a higher frequency for downgradient carbonate wells like WW-C-1 or ER-6-1 (2 years?) over wells like ER-2-1 main or WW-2 (5 years?).	See the responses to Wells comment #9 and Sampling Frequency comment #2.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
B.1.3 Analytes	
1. Should agree on the default analyte list (by well type, and across CAUs or CAU-specific, if reasonable), but not prohibit other analytes in any group. Are we restricting to the Bowen inventory (makes sense)? That is, we're not interested in Ra-226, Ra-228, which are SDWA analytes?	The analytes are restricted to the COC based on the Bowen Inventory (Bowen et al., 2001) and not the SDWA (CFR, 2004). The default list will be defined by well type across all CAUs. This is reflected in the newly developed flowchart (Figure B-1).
2. If for distal wells "…some enrichment method should apply" if not necessarily the Helium method, why would it be important to obtain/establish a $^{3}He/^{4}He$ ratio database?	The distal wells and point-of-use wells will be standard analytical methodology for ^{3}H, not the enrichment method. DOE feels this is sufficient in comparison to a regulatory level of 20,000-pCi/L MCL, and SDWA requires only a 1,000-pCi/L detection limit. Also, see the response to Analytes comment #3.
3. Not sure that you actually need to measure $^{3}He/^{4}He$.	The Sampling Plan Committee decided that it is not necessary to develop a $^{3}He/^{4}He$ baseline because ^{14}C, ^{36}Cl, and ^{129}I (actual COCs) can be used to provide the same information regarding plume extent.
4. For distal wells: I believe ^{3}H is sufficient, except that its daughter (as indicated by the $^{3}He/^{4}He$ ratio) and possibly some longer lived radionuclides should be included early on to establish baseline conditions because eventually ^{3}H will need to be supplanted by something else. It would be good to come to agreement on what other nuclide(s) should be transitioned in, so that the appropriate baseline data are consistently collected. Given that ^{3}H is likely the only radionuclide in the forefront of every plume, transitioning to helium makes the most sense. There is already a strong association between elevated ^{3}H and $^{3}He/^{4}He$, so the current baseline helium ratio is important to document. I think the models would suggest ^{14}C be included, but insight from Mavrik would be helpful, since I am not sure	See the response to Analytes comment #3.
5. It seems reasonable to analyze ^{3}H only for all non-contaminant migration wells. This assumes that if we detect low levels of ^{3}H in a well, we go back the next time and analyze for other parameters that help confirm the ^{3}H hit. For distal wells, there is no need to analyze for anything but ^{3}H.	For early detection, distal, and point-of-use wells, ^{3}H will be the only COC at this time.
6. I would focus on "mobile" species. In the LCA aquifers, this might include ^{137}Cs and ^{90}Sr as identified in models.	^{90}Sr and gamma emitters will be included in the analysis for characterization and depending on the results may be added for source/plume wells.
7. I believe there should be consistency in the analytes and MDLs for Early Detection Wells (though a well posed exception here or there is ok). ^{3}H needs to be on the list, and the detection should be low. If no other radionuclides are detected, then ^{3}H alone may suffice for routine monitoring.	See the response to Analytes comments #2 and #5.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
***B.1.3 Analytes** (continued)*	
8. It seems the analytes should be the same for all CAUs.	See the response to Analytes comment #1.
9. Distal, Point of Use, and Early Detection wells should be ^{3}H-only. The CAU Lead may decide on an as-needed basis to analyze for other isotopes even if they aren't included in the Sampling Plan. Are you planning on using enriched ^{3}H analysis? Otherwise what is the MDC for the standard method? I need some discussion on this one.	See the responses to Analytes comments #2 and #5.
B.1.4 Detection Limits	
1. Acronym MDL - we should decide on the use, or replacement (my vote) of the "MDL" acronym, and define whatever we go with. The UGTA QAP, revision 1 does not use any acronym relating to detection.	A decision on the use of the acronym (MDL or MDC) will be made and reflected in the next revision to the UGTA QAP.
2. Analytes and MDC (currently MDL) mention of "less than MCLs" 40 CFR 141.25(c) provides a detection limit definition and values. Depending on the Sampling Plan's relation to implementing SDWA requirements, these should be considered.	This decision will be addressed at a future meeting.
3. We should agree and be consistent in using "detect" - are we talking about the Critical Value (considers only Type I error, also called the Critical Level, Decision Level), the Minimum Detectable Concentration (MDC), (considers Type I and II errors, also called the Minimum Detectable Amount (MDA)), statistical trends, some other approach? Or if we're interested in quantification rather than detection, should we consider *minimum quantifiable concentration* or *minimum quantifiable value* (MARLAP Chapter 20, 20.2.7), defined as the concentration "…at which the measurement process gives results with a specified relative standard deviation" (usually 10%)?	This decision will be addressed at a future meeting.
4. Point of use. MDC (currently MDL) – this should be ≥ 300 pCi/L, since we're comparing against the 20,000 MCL, and SDWA requires only a 1000 pCi/L detection limit.	See the response to Analytes comment #2.
5. Distal Wells: I recommend a lower detection limit for ^{3}H (10 pCi/L) which would require enrichment.	See the response to Analytes comment #2.
6. For both on-site and off-site supply wells, if and when RREMP/CEMP is open for revision, the detection limit for tritium should be low, through an enrichment procedure. This is consistent with a good-faith effort by DOE to identify a plume early.	See the response to Analytes comment #2.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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Comment	Response
***B.1.4 Detection Limits** (continued)*	
7. For both on-site and off-site supply wells, if and when RREMP/CEMP is open for revision, the detection limit for tritium should be low, through an enrichment procedure. As discussed above, this is consistent with a good-faith effort by DOE to identify a plume early. Additionally, establishing the background of the eventual tritium replacement(s) is also needed for the supply wells, as discussed for the distal wells.	See the response to Analytes comment #2.
8. I would recommend point of use wells be tested for low level ^{3}H but nothing else.	See the response to Analytes comment #2.
9. Listing or at least having a list of possible “triggered” wells is a good idea. These standby wells might need to be maintained – or at least not lost. Do we have a well head protection plan/standards for such wells?	Maintaining a list of possible wells is a good suggestion. Note that even if it is determined that if monitoring is no longer needed, wells that are not of interest will still be available as the borehole plugging program is not active at this time.
10. Might word the Sampling Plan so additional analyses could be added if desired. However, once the Plan is in place will CAU leads be able to suggest spending unplanned funds on additional sampling/analyses?	Good suggestion.
11. I disagree with the comment that repeated non-detects have minimal value. They tell you where the plume is not, therefore yield some information about flow directions, velocity, etc.	See the response to Wells comment #5.
B.1.5 Characterization/Baseline	
1. We need to give some thought to monitoring for background. Staying on top of, and documenting, the natural background of ^{3}H and the helium ratio in areas upgradient of the NNSS testing areas is important. Cosmogenic ^{3}H and atmospheric-test derived ^{3}H occur in groundwater and springs, for example CEMP analyses have detectable ^{3}H at Adaven springs, the spring at Medlin’s Ranch, and the supply well for Caliente. If detected in Oasis Valley by UGTA sampling or sampling by some other group, comparison to trends in upgradient areas will be priceless.	See the response to Analytes comment #3.
2. It would be wise to get some assessment of natural backgrounds or analytical limits for relevant radionuclides so that a baseline can be established. We may already have sufficient data on this, but, might need to formally write that up.	A series of three samples will be analyzed for characterization wells, therefore providing this baseline for the characterization suite of analytes.
3. The note cautioning about affecting the groundwater system in Frenchman Flat by over pumping is good. But this potential issue is not acknowledged for Yucca Flat. Could it be a concern elsewhere?	This should be addressed by the Purging/Sampling Committee and mentioned in the Sampling Plan for all CAUs. See the response to Sampling Method comment #1.

Table B-1
General Comments from the Sampling Plan Committee and Responses from the NNSA/NFO Representative
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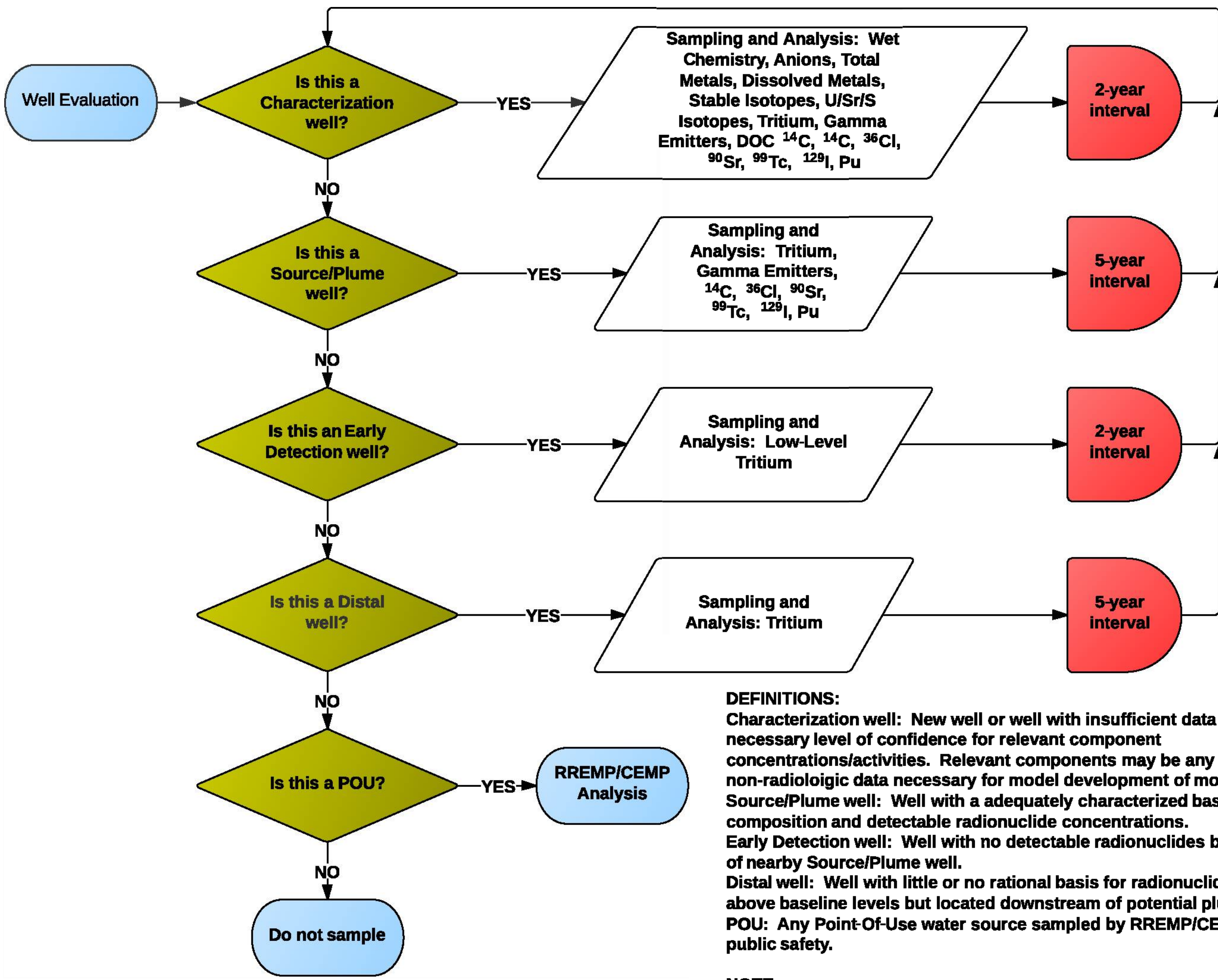
Comment	Response
***B.1.5 Characterization/Baseline** (continued)*	
4. However, once we are done with characterizing new wells (I would recommend sampling every year for three years during characterization phase), a 5 year schedule should suffice.	See the response to Sampling Frequency comment #2.
5. I assume here that this sampling plan refers to long term sampling and is unrelated to any characterization work that might occur in anticipation of PM phase II modeling work (or when establishing new well in the various CAUs). I think this is a separate topic.	See the response to Wells comment #3.
6. I define a "well characterization" phase which should last 3 to 5 years upon completion of a new well. During that time, sampling should occur on an annual basis to establish reproducibility and baseline. After that, the well can go into a standard sampling schedule.	See the response to Sampling Frequency comment #2.
7. But a solid baseline needs to be established for the ^{3}H daughter ($^{3}He/^{4}He$) and additional radionuclides, not only in the event longer?lived species are needed as ^{3}H fades out, but for this well group, a plume may overtake the well and knowing background for other likely contaminants is needed. Every early detection well needs a good background established for $^{3}He/^{4}He$, ^{14}C, ^{36}Cl, ^{99}Tc, and ^{129}I. Once those data are in hand, those analyses need not be run if the ^{3}H is nondetect (until ^{3}H expires).	See the response to Analytes comment #3.
8. Establishing the background of the eventual ^{3}H replacement(s) is also needed for the supply wells, as discussed for the distal wells.	See the response to Characterization/Baseline comment #2.
B.1.6 Sampling Method	
1. One question that I have is whether some criteria will be established regarding the sampling quality. In particular, will the sampling plan REQUIRE that samples be pumped and not bailed. Do we want to state that sampling shall occur from pumped wells? If they cannot be pumped, are they still worth sampling?	This is dependent on the outcome of the testing performed as recommended by the Topical Committee on Sampling and Purging. The committee recommendations are provided in Appendix C, and additional planning will take place in FY 2014 and FY 2015.



DEFINITIONS:
Characterization well: New well or well with insufficient data to yield necessary level of confidence for relevant component concentrations/activities. Relevant components may be any radiologic or non-radioloigic data necessary for model development of model evaluation.
Source/Plume well: Well with a adequately characterized baseline composition and detectable radionuclide concentrations.
Early Detection well: Well with no detectable radionuclides but downstream of nearby Source/Plume well.
Distal well: Well with little or no rational basis for radionuclide observation above baseline levels but located downstream of potential plumes.
POU: Any Point-Of-Use water source sampled by RREMP/CEMP to ensure public safety.

NOTE:
1. List of analytes in Characterization wells may be reduced depending on the specific purpose of that well.
2. List of analytes in Source/Plume wells may be reduced depending on baseline characterization of that well.
3. Methods and detection limits for analyses depend on the purpose and baseline characteristics of that well.

Figure B-1
Well Categorization Flow Chart

Table B-2
Yucca Flat Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 1 of 2)

Comment	Response
B.2.1 General Comments	
1. The number of wells in YF seems rather large when compared to others. It may be possible to reduce the number of wells by not sampling those well that are “upstream” of contamination areas and/or very far from receptors (i.e. do we need to monitor wells located in the northern end of YF if contamination must be moving southward? Maybe the focus should be on southern wells and wells in LCA?).	Agreed. Will drop ER-8-1, ER-6-1, ER-6-2, ER-6-1-1, ER-2-1 (piezometer), either Army #1 or SM-23-1, and approximately half of the source-term evaluations wells.
2. Any wells that are not along plausible contamination flowpaths (or contaminated already) should be eliminated (I did not look at each well specifically). Again, I would focus on “mobile” species. In the LCA aquifers, this might include ^{137}Cs and ^{90}Sr as identified in models.	Agreed. Will focus on potential flowpaths.
B.2.2 Point-of-Use Wells	
1. RREMP wells WW-4, WW-4A and WW-5C are not listed. Advise whether there is value in monitoring.	WW-4, WW-4a, and WW-5c are in shallow alluvial/volcanic aquifers in CP basin and Frenchman Flat, and have no value as far as Yucca Flat/Climax Mine is concerned.
2. WW C-1 has been down since late 2012, and there are no plans to bring it back on-line. It should still be identified, but costs to monitor would need to be considered.	Being located at the southern end of Yucca Flat at the terminus of several major faults makes it an ideal early detection well. Because it is no longer used as a water-supply well, it will be characterized as an early detection well rather than a point-of-use well.
B.2.3 Distal Wells	
1. Remove ER-8-1 from sample network. Even if radionuclides are detected in this well from Climax Mine tests, all contamination has to funnel through Yucca Flat before it becomes a problem. Also, this well is in granite and has a very low hydraulic conductivity, which makes it a poor monitoring well for detecting transport.	Yes, it’s a long-shot that contamination from Climax Mine will be detected in Yucca Flat. However, ER-8-1 is downgradient from the Climax Mine detonations in the same HSU (MGCU). Let’s think about this one.
2. ER-2-1 piezometer should either be removed or called a source term well. This well is open to extremely tight tuffs. Monitoring the shallower well, ER-2-1 main, should be sufficient for early detection of radionuclides migrating upward from the tuff confining unit.	Agreed.
3. ER-6-1 main, ER-6-1-1, and ER-6-1-2 main all monitor essentially the same spatial location, aquifer, and depth interval. Although they are in an important downgradient location, monitoring all three wells seems like overkill. Suggest picking only one for sampling.	Agreed. Because ER-6-1-2 was the MWAT pumping well and upgradient wells near major detonations responded, let’s go with this as the monitoring well and drop ER-6-1-1 and ER-6-1 main.

Table B-2
Yucca Flat Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 2 of 2)

Comment	Response
B.2.3 Distal Wells *(continued)*	
4. Remove ER-6-2 from sample network. As stated by Ed, it's far from ideal and with a hydraulic head of 2447 ft, it is hard to imagine a flow path that would allow radionuclides to move past this well. ER-6-2 is an upgradient well, not an early detection well.	Agreed.
5. SM-23-1 is currently monitored annually for tritium (standard).	?
6. Army #1 is monitored quarterly for tritium (low level). Although this is not part of the NNSS permitted water system, it is discussed when others express interest in withdrawing NNSS ground water (Nye County, solar projects).	Excellent. That will more than satisfy our desire for samples from this well.
B.2.4 Early Detection Wells	
1. RREMP well, UE-1q, is not listed - advise whether there is value in monitoring.	UE-1q is an interesting well in that it is open to the LCA, yet has geochemical characteristics that suggest it receives drainage from the overlying tuff and alluvial aquifers. We will add UE-1q to the list of early detection wells.
2. TW-D – comments indicate there is no value to monitoring this well – is that correct?	No. TW-D was discussed as an early detection well but inadvertently was not included in the final recommendation (Table A-1). It will be added.
3. WW-A monitoring indicates 300+ pCi/L tritium (DOE/NV/25946—1604, Chapter 5, 5.1.7), which, as currently defined, would place this well in the Contaminant Migration group.	Yes it is now classified as a source/plume well.
B.2.5 Contaminant Migration Wells	
1. UE-7nS monitoring indicates < 100 pCi/L tritium (DOE/NV/25946—1604, Chapter 5, 5.1.7), which, as currently defined, would place this well in the Early Detection group.	Now it is a source/plume well because it is within the plume.
2. I don't think that pumping UE-7nS is feasible except at very slow flow rates.	Point taken, but still worth sampling.
3. TW-F is 156 degrees, how does this affect flow paths?	Agreed. Flow will probably not be toward or through the vicinity of TW-F.

Table B-3
Frenchman Flat Comments from the Sampling Plan Committee and Responses from the CAU Lead

Comment	Response
B.3.1 Point-of-Use Wells	
1. The RREMP Well, WW-5C, is not listed. Advise whether there is value in continued monitoring. This is a non-potable water source, so there are no requirements to monitor for worker or public health concerns.	There are no conceptual circumstances that have contamination at WW-5C, and as it is non-potable supply, discontinue monitoring.
B.3.2 Distal Wells	
1. There ought to be criteria for frequency. I don't necessarily believe all early detection wells have to be the same frequency, but there should be a rationale for differences in sampling frequency. Confining units, if they are sampled at all, should have low frequencies. I see that Greg got around this by categorizing ER-11-2 (open to a confining unit) as a distal well, even though many might perceive this as an early detection well. ER-11-2 is really close to PIN STRIPE. It just seems strange to categorize this proximal well as "Distal."	Because ER-11-2 is directly downgradient of PIN STRIPE it should be classified as an early detection well and monitored for low-level ^{3}H every 2 years (based on the general criteria). I believe there are only a few cases where the general criteria don't make sense and so we can address these on a case-by-case basis.
2. UE5 PW-1 and UE5 PW-3 are not listed – currently, water levels, tritium (low level), and non-radiological analytes are monitored under the RCRA permit, so data are available.	Add as distal wells.
3. SM-23-1 and Army #1 are identified in the Distal group for Yucca Flat, so should they be here as well?	SM-23-1 is open to only 36 ft of LCA. We believe the paths go southwest through Rock Valley, and we shouldn't ever see anything in Army-1. If it is still being used a potable supply, then it is already taken care of. I reject both of these.
B.3.3 Early Detection Wells	
1. No comments.	No response.
B.3.4 Contaminant Migration Wells	
1. Given the very slow flow velocity and unlikely migration, I would expect sampling to be focused on the three contaminated wells (RNM-1, RNM-2s, UE-5n) at a 5 year sampling frequency. RREMP will continue point of use sampling.	These wells are classified as source/plume wells and the current plan is to sample these wells every 5 years for mobile radioisotopes and Pu.
2. The two wells downstream of milkshake and pinstripe should be monitored for low level tritium (i.e., Distal wells) at 5 year sampling frequency (after well characterization phase is completed).	I am OK with this, but with the provision that pumping is minimized, for the obvious reasons.
3. I don't think that radionuclide outside the "non-sorbing" group need to be analyzed on a defined schedule unless NDEP or other parties require it. Maybe radionuclides such as ^{90}Sr, ^{137}Cs, Pu, U such be analyzed during "well characterization" phase and not otherwise?	This should include ^{237}Np as well.

Table B-4
Rainier Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 1 of 6)

Comment	Response
B.4.1 Distal Wells	
1. What do you do with a well that is physically fairly close to UGTs, like UE12t#6, but is probably up-gradient (not to mention in a TCU)?	One concern of mine is that a combination of unlikely events could violate our premise of institutional control for RM/SM CAU. One such combination consists of contaminant transport breakthrough beneath either T-Tunnel or T-Tunnel pond, and flow to the north either within the LCA3 or (as Steve Carle of LLNL has advocated) in the tertiary welded tuffs. The distance to the boundary of the NNSS in that direction is only a little more than 2 miles, and we don't have any monitoring points to verify transport is or is not moving in that direction. I would like to establish one and will argue the case for it in the closure report. Until such time, UE12t #6 is our only monitoring point that I'm aware that is north of T-Tunnel, although its distance and bearing is actually about 0.6 miles west northwest. It is a poor substitute for a well north of T-Tunnel completed in both the LCA3 and the welded tuffs, but you work with what you've got. I'm not wedded to the concept of using UE-12t#6, any well north of and in the vicinity of T-Tunnel will do. If you know of any wells that are more suitably located, then we should use them instead.

Table B-4
Rainier Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 2 of 6)

Comment	Response
***B.4.1 Distal Wells** (continued)*	
2. The target monitoring zone in ER-12-1 accesses a sliver (97 ft thick) of LCA3 encapsulated within UCCU. Probably not connected to any viable flow paths. ER-12-1 is currently monitored biennially for ^3H (standard), gross alpha and gross beta under permit NEV 96021 (E-Tunnel discharge).	Arguments advocating for the continued monitoring of ER-12-1 can be lumped into two categories. The first is the most compelling but not the most interesting. E-Tunnel ponds have been simulated as releasing large amounts of ^3H to the saturated zone. Boundary conditions within the saturated zone model include no-flow boundaries on its eastern edge. This precludes contaminant transport toward the east. The rationale for establishing this boundary as a no-flow boundary is the presence of the Elena Formation/Chainman Shale and corresponding steep hydraulic gradients to the east indicative of limited flow. This argument is a sound one and should be sufficient to defend the conceptualization of that boundary as a no-flow boundary. The purpose of the monitoring program is partially geared toward “verifying results are consistency with CAU model” ER-12-1 offers a perfect location to verify that transport is, in fact, not moving in the direction of Yucca Flat in a substantial manner. This is a low-cost monitoring point (given that it exists) to actively verify that our conceptual model of transport is a correct one. The second argument is much more interesting. I recently reviewed the ER-12-1 completion report and found documentation of **tritium** detects in the upper interval of ER-12-1 by both LLNL and DRI at the end of the long-term aquifer test back in 1992 (~350 pCi/L). Subsequent samples have not detected tritium in the well; however, these later samples have not purged the well for as long and have sometimes been analyzed using unenriched methods. So, to make a long story short, detection of tritium at ER-12-1is equivocal. If it is present it’s only present in low levels and required extensive pumping in order to observe. Continued monitoring of this well is advisable using the pump installed therein coupled with enriched methods. Monitoring conducted under the E-Tunnel discharge permit uses unenriched methods.

Table B-4
Rainier Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 3 of 6)

Comment	Response
B.4.1 Distal Wells *(continued)*	
3. HTH #1 is currently monitored annually for tritium at 4 depths; 1935', 2040', 2130', 2300'. Advise on which depth(s) warrant continued monitoring. *(repeated on next page)*	I sent an email to Irene Farnham (N-I) on 05/06/2013 in which the following guidance on this matter was provided: *"I went back and evaluated the existing data for HTH-1. It appears Sig's recommendations to for identifying sampling depths within this well were primarily based on getting samples that were close to the tops or bottoms of several perforation intervals. It's pretty much the same approach DRI used when it sampled the well back in 1990. Both sampling efforts (DRI's and RREMPs) appear to be guided by the temperature, chem-tool data and TFM logs contained in the well validation report I sent you. Looking back at the validation report it appears the elevated tritium sample obtained from 472 m (1549 ft) was in a zone containing elevated Ca and SO_4. This can be interpreted as indicating water that has interacted to some extent with cement, which should be present as this is where the casing transitions from one diameter to a smaller one and cement appears to have been used to tack the lower portion of the upper casing. One would expect a zone containing this chemical signature to be a low-flow or stagnant interval. We need to confirm the presence or absence of tritium so I recommend one enriched tritium sample, gross cations and anions, and alkalinity (as you suggested) from 472 m (1549 ft).* *The RREMP is currently collecting samples from the following depths in HTH-1: 590, 622, 649, and 701 m (1935, 2040, 2130, and 2300 ft). If we assume the well validation study conducted by DRI back in 1990 is representative of conditions today then there are temperature deflections (refer to well validation report) at approximate depths of 582, 680, and 741 m (1909, 2230, and 2431 ft) which one can use to identify intervals in which groundwater is flowing into or out of the well. Zones in between the temperature perturbations are considered to be zones where intraborehole flow is fairly consistent. Given these assumptions, one sample above, in-between, and below each temperature perturbation should be sufficient. Samples above 582, between 582* *(continued on next page)*

Table B-4
Rainier Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
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Comment	Response
***B.4.1 Distal Wells** (continued)*	
(repeated from previous page) 3. HTH #1 is currently monitored annually for tritium at 4 depths; 1935', 2040', 2130', 2300'. Advise on which depth(s) warrant continued monitoring.	*(continued from previous page)* *and 680 m, 680 m and 741 m, and below 741 m would be warranted. The sample recommendation of 472 m (1549 ft) satisfies the need to sample above 582 m (1909 ft). Any of RREMPs sample depths of 590, 622, or 649 m (1935, 2040, or 2130 ft) satisfies the need to sample between 582 and 680 m (1909 and 2230 ft). I would recommend sampling only one of these depths as they are probably redundant with the others. I'd pick the deepest one, 649m (2130 ft) as it's a composite of everything above it. The sample depth of 701 m (2300 ft) satisfies the need to sample between 680 and 741 m (2230 and 2431 ft). I'd also like to add a sample below 741 m (2431 ft). The water in this zone may or may not be stagnant. It may be representative of the groundwater flowing from the volcanics into the Paleozoic section below. A potential sample depth of 800 m should work fine.* To summarize my recommendations: • 472 m (1549 ft) – enriched tritium, gross cations, gross anions, alkalinity • 649 m (2130 ft) – unenriched tritium • 701 m (2300 ft) – unenriched tritium • 800 m (2625 ft) – unenriched tritium - Finally, this well is a good place to monitor the LCA3 south of RM. Current access to the LCA3I within the well is prevented by an obstruction at 1128 m (3,700 ft). In addition, if ambient flow is moving down from the Tertiary interval to the LCA3 then this zone will yield water that is representative of the tertiary section for quite a while, even after the well has been recompleted. It's more likely than not that a recommendation will be made to recomplete the well so that one sample of the tertiary section and one sample from the LCA3 can be obtained. Decisions related to this will be delayed for quite a while until/if the RM F&T model passes an external peer review and DOE and NDEP complete negotiations wrt the compliance and use restriction boundaries for RM.

Table B-4
Rainier Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
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Comment	Response
B.4.2 Early Detection Wells	
1. The RREMP Well, ER-19-1 is currently monitored at 2 depths; 2710' (middle) and 3280' (deep). Advise whether there is value in continued monitoring of the deep string.	I don't think a sample from ER-19-1 deep is warranted given that it accesses a fairly thick wedge of the LCCU1. The LCCU1 at ER-19-1 is allochthonous; it's been thrust faulted in place, so theoretically, one could drill through it and potentially encounter either the UCCU or less likely the LCA3. Neither the UCCU or the LCA3 is considered to be a viable path from the upgradient sources (WINESKIN and CLEARWATER). These are thought to release to welded tuffs in the Tertiary section, to include the RVA intersected by the intermediate piezometer at ER-19-1. I'd recommend not sampling the lower piezometer given that it is completed in the LCCU1, which is a low permeability unit; it is not the probable transport path away from sources in the western portion of Rainier Mesa, and we have more suitably located monitoring points to access the HSUs of interest.
2. All early detection or contaminated wells should be sampled on a 5 year cycle. I agree with the 10 pCi/L detection limit and list of radionuclides.	I concur with everything you said with the exception of one issue. I think 3 to 5 years should be the sample frequency, the selection of which is dependent upon the likelihood of the monitoring well detecting contaminant transport. Higher probability of transport translates to more frequent sampling. A good example is ER-19-1 shallow and intermediate piezometers. The shallow piezometer at ER-19-1 access Tunnel Bed 2. This is a testing horizon but its permeability is so low that transport in this unit should be marginal and a sample frequency of every 5 years is entirely appropriate. The intermediate piezometer accesses the RVA. This is the primary transport pathway out from both WINESKIN and CLEARWATER. A sample frequency of 5 years is too long to wait before compliance is demonstrated in a zone with the highest probability of transport.
3. Not sure that you actually need to measure $^{3}He/^{4}He$.	$^{3}He/^{4}He$ is difficult to analyze but it provides a mobile constituent that can be used to detect contaminant transport even after tritium has decayed away. The plot below is a scatter plot of ^{3}H versus ^{3}He from groundwater samples collected from wells on the NNSS (I also provided ^{3}H and ^{85}Kr). Data were obtained from the UGTA Geochemistry Database. (Figure B-2). Tritium will decay away but its former presence will be discernible from the presence of elevated levels of ^{3}He. Given that monitoring will occur for 100 years, we need to develop viable surrogates for assessing the extent of contaminant transport—not for the purpose of determining whether the MCL has been exceeded, but rather for determining whether our conceptualization of transport is consistent with observations, even after ^{3}H has decayed away.

Table B-4
Rainier Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
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Comment	Response
B.4.3 Point-of-Use Wells	
1. Why do we need quarterly water-level measurements?	Water-level monitoring at points of use is important to ensure that observed heads remain consistent with simulated heads. Large deviations may require additional transport simulations if deviations have the potential to impact simulated transport. Quarterly monitoring of the points of use ensure that drawdowns are consistent with model assumptions.
2. UE16d accesses the UCA (Tippipah Limestone at Syncline Ridge). It is an isolated island within/surrounded by UCCU and not likely connected to any viable flow paths from RM.	UE-16d is a point-of-use well adjacent to the RM/SM CAU-scale model. Transport to this well is extremely unlikely. Monitoring verifies that conceptualization, and it provides a level of certainty with regards to our arguments that risk is a nonissue for this CAU. Monitoring of this well, given that it is a water-supply well, is already mandated via DOE orders. We are asking for a minor change to the samples collected.
3. I would recommend point of use wells be tested for low level tritium but nothing else.	I agree with you in terms of demonstrating protection of human health and the environment, but UGTA is not limited to compliance modeling. It also has a requirement for "verifying results are consistency with CAU model." If we say the mobile radionuclides are not going to arrive at a point-of-use well then we should be willing to demonstrate that periodically. Perhaps a compromise position is to sample for enriched ^{3}H annually and for the other radionuclides every 3 to 5 years.
B.4.4 Contaminant Migration Wells	
1. I would strongly recommend adding U-12n.10 and vent #2 to the list of wells to sample. These are important for two reasons. First, it would be wise if perched water levels could be monitored in the tunnels; this is essential to monitoring for sudden changes in perched water hydraulics (breaches, etc.). Second, these well establish the longterm evolution of the perched water source term. Consider adding U12n Vent Hole #2. It accesses the flooded N-tunnel complex.	Good idea. I had forgotten about the vent holes. These would be considered source-term holes. The standard suite of source-term radionuclides should be collected and water levels monitored. Frequency for both water levels and radionuclides would be once every 3 years. ***Explosive gases have been detected in these vents.*** Procedures for dealing with explosive gases should be followed every time access to the vents is undertaken.
2. I did not see any mention of monitoring E tunnel effluent. Is this assumed to happen through some other mechanism? What radionuclides are being monitored there? Since this is creating a new source term, the standard list of "mobile" radionuclides should be monitored (this has not been done to date). E-tunnel ponds are not listed here, but would be important for UGTA. Though sampled for regulatory purposes, they should at least be mentioned in the Sampling Plan.	Good idea! I had assumed E-Tunnel discharge would be monitored as part of the E-Tunnel discharge permit and did not mention it here. I am unaware of the current requirements for sampling E-Tunnel but they should be identical to any other source monitored by UGTA. Frequency would be once every 3 years. We should be sampling discharge rates on a quarterly basis.

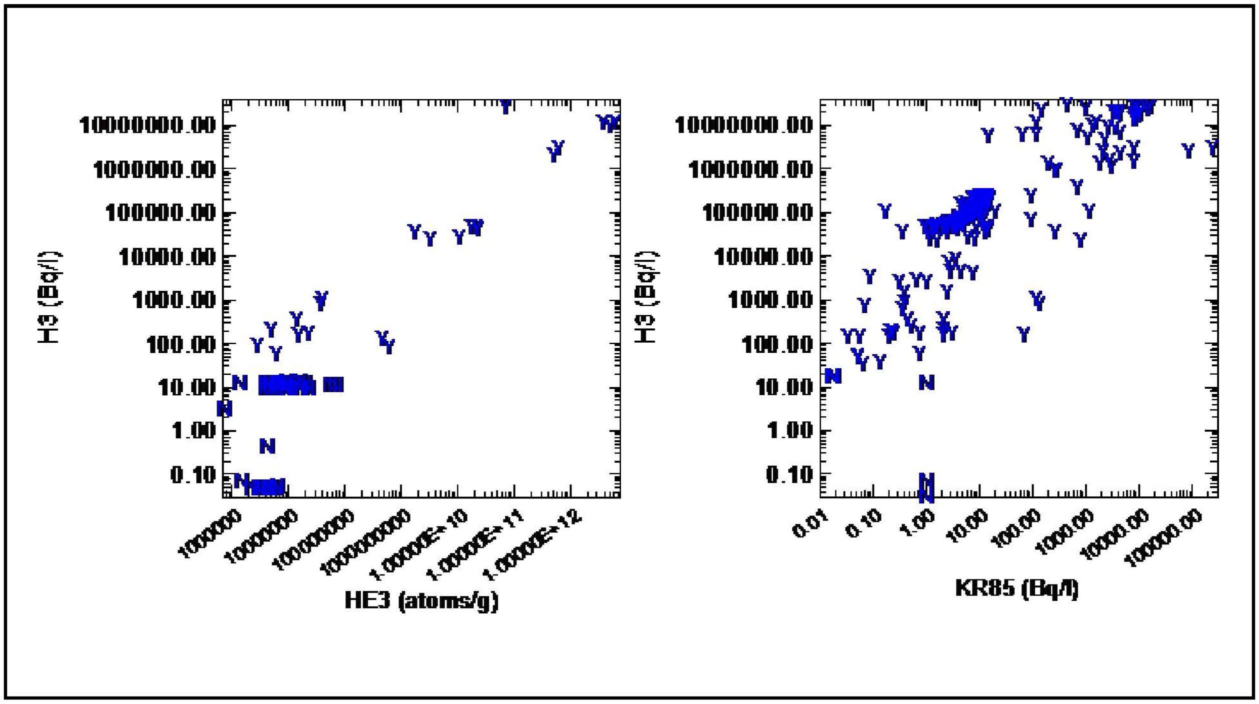

Figure B-2
^{3}H versus ^{3}He and ^{3}H versus ^{85}Kr for Groundwater Samples
Collected from NNSS Wells

Table B-5
Pahute Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 1 of 3)

Comment	Response
B.5.1 Distal Wells	
1. The following RREMP Wells are not listed. Is there value in continued monitoring at wells which have historically been non-detect (Critical Value ~25 pci/L) for ^{3}H. If so, we'll continue with a ^{3}H analysis (move to standard, MDC at 300 pCi/L). • ER-20-1 • ER-20-2#1 • U-19BH	Add ER-20-1 as an early detection well for tests upgradient (TENABO, SALUT, DELAMAR, KNICKERBOCKER). ER-20-2#1 is not considered because its open interval is in zeolitic tuff of Calico Hills and can't be expected to monitor migration. Based upon the narrative from USGS Data Series 533 (Elliott and Fenelon, 2010; see below). I don't think U-19bh is monitoring any groundwater system we care about. *Well U-19bh is open below the water table to about 63 ft of devitrified, partially zeolitized, nonwelded ash-flow tuff. Initial water levels, through 1992, show recovery from dewatering of the 96-inch diameter well on 06/18/1991. Water levels beginning in 1993, although rising, are assumed to represent steady-state conditions in a perched or semi-perched volcanic aquifer. These rising levels are attributed to wetter-than-average climatic conditions, and are consistent with rising water-level trends in Area 18, south of well U-19bh. However, this interpretation is highly uncertain. One alternative interpretation is that the well is open to low permeability rocks that allow groundwater to seep into the large-diameter well at only very low rates (slightly less than 1 gal/d). In this interpretation, water levels are still equilibrating from disturbances from well drilling and dewatering. In this case, the last water level measurement represents a minimum estimate of the steady-state water-level altitude in this well. A second alternative is that water levels are equilibrating to effects from past nearby nuclear tests. Seven nuclear tests, six near or below the water table, were detonated within 1 mi of well U-19bh. Two tests were within 1,100 ft of well U-19bh and the Inlet test, with an estimated yield of 200 to 1,000 kilotons, was detonated about 2,300 ft southeast of the well. Water levels in well U-19bh are considered elevated relative to water levels in deeper volcanic rocks. In the vicinity of well U-19bh, O'Hagan and Laczniak (1996) suggest that wells open to stratigraphically shallow volcanic units (wells U-19aq, U-19az, and U-19bh) had high water-level altitudes, a well open to a stratigraphically intermediate unit (well U-19x) had an intermediate water-level altitude, and wells open to stratigraphically deep units (wells U-19ae and UE-19fS) had low water-level altitudes. The shallow wells had water-level altitudes of greater than 4,650 ft, the intermediate well had an altitude of 4,567 ft, and the deep wells had altitudes of less than 4,500 ft. O'Hagan and Laczniak (1996) further suggest that the large downward hydraulic gradient is caused by a bedded tuff confining unit that separates a shallow volcanic aquifer from a deep volcanic aquifer.*

Table B-5
Pahute Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 2 of 3)

Comment	Response
***B.5.1 Distal Wells** (continued)*	
2. Based on ^3H concentrations (~60 pCi/L), shouldn't PM-3 be included in the Early Detection group?	It is identified as an early detection well that is presently under investigation. It may be categorized as a source/plume well if the presence of ^3H is verified and it is determined that the source of the ^3H is likely an underground nuclear test.
3. If numerous up-gradient wells are non-detects, why continue to sample so many of the very distal wells now (the ER-OV- wells)?	We have reduced the sampling frequency and the analytes to only ^3H. Wells may be made inactive in the future.
4. Wells ER-18-2 may not be on the expected flow path but we may still want to monitor to be sure. PM-3 wasn't on an expected pathway either.	I disagree that PM-3 wasn't on an expected pathway—this is not an argument for sampling ER-18-2. Basic hydrologic considerations and Phase I calculations showed paths from the few tests conducted west of the Purse fault passed by PM-3. I still don't think we should monitor ER-18-2.
5. Add ER-EC-4 to the sample network. Although ER-EC-4 might not be along a flowpath, as currently conceptualized, it's not inconceivable that it could be (there is very limited water-level data on the west side of Pahute Mesa to accurately assess flow directions). Also, ER-EC-4 is open to highly transmissive rocks, and therefore, is could likely transmit radionuclides through this corridor.	It is true that our understanding isn't perfect here, but it is still so far west and downgradient I see little value now. Because it has sufficient transmissivity to be sampled is a poor reason to monitor it. I don't think we should monitor ER-EC-4.
6. Add ER-20-1 to the sample network. ER-20-1 monitors the top of the regional water table and despite its limitations because it is very shallow, it should be monitored for potential radionuclides from northern tests. Greg decided not to deepen ER-20-1 because, among other reasons, it was representative of the formation based on water chemistry data which is a change since his well list recommendation.	Agreed. Added as an early detection well.
7. If ER-EC-12 has 7.9 pCi/L of ^3H now, why is it labeled a distal well? (Categorized prior to these data)	ER-EC-12 has been reclassified as a characterization well.
8. U-20WW is close to UGTs, why not call it an Early Detection well?	The test nearest U-20 WW is U-20ah (GIBNE), followed by U-20bd (BULLION). Tests to the west are in a different fault block and can't be expected to influence U-20 WW. Both these tests' exchange volumes substantially intersect the CHZCM. Agreed.
9. I would prefer a 5 year frequency. I would also recommend a lower detection limit for ^3H (10 pCi/L) which would require enrichment. In general, I would favor sampling more wells over greater frequency. Any radionuclide migration will be quite slow (as we've seen historically) so frequent sampling should be avoided if possible.	The current plan is for a 5-year sampling frequency and a higher detection limit for ^3H in the distal wells relative to the early detection wells. The objective of the distal wells is to verify that the contaminant levels are not nearing exceedance. Once ^3H is detected, presence verified, and thought to be attributed to underground nuclear testing, in an upgradient early detection well, the early detection well is upgraded to a source/plume well and the distal well is upgraded to an early detection well. Early detection wells are analyzed for low-level ^3H.

Table B-5
Pahute Mesa Comments from the Sampling Plan Committee and Responses from the CAU Lead
(Page 3 of 3)

Comment	Response
B.5.2 Early Detection Wells	
1. The RREMP Well, PM-1 is not listed. Advise whether there is value in continued monitoring. Historic concentrations are ~120 pCi/L.	There is no conceptual model that explains ^{3}H at PM-1, and I don't see any value in continuing if we aren't even sure what we are monitoring. U-20z (KASSERI) and U-20aw (CONTACT) are the closest upgradient tests. CONTACT's exchange volume barely intersects the water table in the CHZCM, and KASSERI's is in the Bullfrog confining unit. If there is contamination at PM-1, it seems more likely to be from equipment than an underground nuclear test.
B.5.3 Contaminant Migration Wells	
1. May want to consider U19q PS1d (camembert). Well is quite muddy, but, if it can be cleaned up, provides a good example of hydrologically isolated well.	Agreed.
2. The BA at ER-EC-11 has 12,000 pCi/l of ^{3}H (though it was cased off at this location so the well could continue on to the deeper target aquifers). So, this well, for the BA should be recognized as a Contaminant Migration well (>300 pCi/l).	That is correct, but for now it will be classified as a characterization well.
3. I would rather sample more wells less frequently than the reverse. I would analyze for ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, and ^{129}I at low levels to establish that they are all below MCL (or not). If sampling occurs only every five years, I think that analyzing for all these mobile radionuclides would be wise. Might need to look at other radionuclides to identify sources on an as-needed basis. Measuring the non-^{3}H radionuclides will be critical to establishing the likelihood that contaminant plumes beyond 200 years from present will be above MCLs. If we can establish this early on, we will reduce requirements for long term monitoring, etc.	Characterization wells will be sampled multiple times for an extensive suite of geochemical analytes and radioisotopes. Once the baseline is established, the well is recategorized and sampled at a frequency and for a suite of analytes depending on (1) the observed level of ^{3}H (and other radioisotopes) and (2) its position relative to nuclear testing.
4. I would analyze for ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, and ^{129}I at low levels to establish that they are all below MCL (or not).	Characterization wells will be sampled multiple times for an extensive suite of geochemical analytes and radioisotopes. Once the baseline is established, the well is recategorized and sampled at a frequency and for a suite of analytes depending on (1) the observed level of ^{3}H (and other radioisotopes) and (2) its position relative to nuclear testing.
5. If sampling occurs only every five years, I think that analyzing for all these mobile radionuclides would be wise. Might need to look at other radionuclides to identify sources on an as-needed basis. Measuring the non-^{3}H radionuclides will be critical to establishing the likelihood that contaminant plumes beyond 200 years from present will be above MCLs. If we can establish this early on, we will reduce requirements for long term monitoring, etc.	See the responses to Contaminant Migration Wells comments #4 and #5. Also, source/plume wells are analyzed for radionuclides of concern determined by (1) characterization well results and (2) upgradient source/plume well results. The results determine the suite of parameters to focus on for the downgradient wells.

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Appendix C

Well Sampling Technologies

C.1.0 RECOMMENDATIONS FROM UGTA ACTIVITY TOPICAL COMMITTEE ON WELL DEVELOPMENT AND SAMPLING

C.1.1 Introduction

The UGTA Activity Topical Committee on Well Development and Sampling evaluated several methods for collecting samples, including currently used methods and some new technologies that may be used once testing and evaluations are performed. The purpose of this evaluation was to identify more cost-effective methods for collecting samples. This is especially important in wells with multiple completions because of the expense of setting and removing bridge plugs and pumps. Current methods use bailers or submersible pumps. Criteria for evaluating new technologies included sampling from small-diameter access tubing and ability to lift water from depths of 600 m or more. New technologies evaluated included pumping with a jack pump, coil tubing, Besst Blatypus, and MagLift systems. The jack pump was tested at Well PM-3 in fiscal year (FY) 2013 and further tested in Pahute Mesa (ER-EC-11, ER-20-8, and ER-20-8-2) in FY 2014 and FY 2015. A report summarizing the results is planned for FY 2015. Other technologies need further testing before they can be deployed.

The committee evaluated seven mobile (moved from well to well) technologies and eight permanently deployed technologies in terms of their suitability for deployment for a variety of well types (single piezometer, annular piezometer, single completion - no piezometer, multiple completion - no piezometer, slant drilled, and wide-diameter boreholes). Each technology was evaluated against 18 criteria with suitability of a given technology to a particular criterion assessed on a scale of 1 to 10. Three criteria were answerable in a binary fashion using a yes or no statement. Not all members of the committee assessed all technologies, and not all criteria were evaluated by all participating committee members.

A flowchart was developed that encapsulates the committee’s recommendations and provides a way to guide the selection of the appropriate sampling technology for each well type (see Plate 1).

C.1.2 Piezometer Sampling

The following subsections present recommendations regarding technology capable of sampling a stand-alone (single) piezometer with an inside diameter of less than 2 in. or a piezometer installed within the casing of a preexisting well are presented in the following subsections. Both mobile and permanently deployed technologies are considered.

C.1.2.1 Mobile Technologies

The committee's consensus opinion regarding the three remaining mobile technologies is that bailers are very well suited for obtaining samples from piezometers, but they are resource intensive in terms of production rates. They should be employed as the mobile technology of choice in wells where limited sample volumes are to be collected and micropurging is an option (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).

Jack pumps are a hybrid solution in terms of mobile technologies. Their deployment requires setting rods in the piezometers and, as such, they are expensive in terms of initial costs. The deployment costs may be minimized over the course of multiple sampling events. The biggest impact of jack pumps is that they preclude obtaining water-level measurements in single or internal piezometers. Jack pumps should not be deployed in single or internal piezometers from which water levels need to be collected. If this statement is acknowledged as true, then jack pumps should be located only in single or internal piezometers that do not require water levels to be obtained. In those cases, a jack pump is best used as a permanently deployed unit. For this reason, the jack pump should no longer be considered as a mobile technology with single or internal piezometers.

The Besst Blatypus pump has many attributes that make it an attractive option for sampling single or internal piezometers. 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 water quality of the sample. There are some unknowns that need to be addressed; the reliability of the unit has to be established; and the efficacy of the modifications, in terms of long-term economical pumping from piezometers, needs to be determined. The committee recommends that a unit be purchased, the aforementioned modifications be made, and the method undergo field testing to determine whether it is the optimal choice for mobile technologies that can effectively purge single and internal piezometers. Successful tests will support routine deployment on the NNSS. Unsuccessful tests will require evaluations of the coil tubing pump or the MagLift pumps for modification and use on the NNSS in single or internal piezometers.

C.1.2.2 Permanently Deployed Technologies

The committee's consensus opinion is that the advantages of the jack pump outweigh the advantages of the Besst Blatypus pump in terms of permanent deployment in single or internal piezometers. The jack pumps, although more expensive to purchase and deploy, have a significantly greater history of successful deployment and have no issue with obtaining samples from wells containing grit suspended in the water column. The technology can be left fallow for long periods of time and can purge a well much faster than the Blatypus pump can. The jack pump is the technology of choice for single or internal piezometers having diameters of 2 7/8 in. or less, as long as water-level measurements are not desired from the well in which the jack pump will be deployed.

C.1.3 Annular Piezometers

The following subsections present recommendations regarding technology capable of sampling an annular piezometer with an inside diameter of less than 2 in. Both mobile and permanently deployed technologies are considered.

C.1.3.1 Mobile Technologies

The committee's consensus opinions regarding the mobile technologies for annular piezometers are identical to the opinions expressed for single or internal piezometers. See Section C.1.2.1 for details.

C.1.3.2 Permanently Deployed Technologies

The committee's consensus opinions regarding the permanently deployed technologies for annular piezometers are identical to the opinions expressed for single or internal piezometers.
See Section C.1.2.2 for details.

C.1.4 Single Completion - No Piezometer

The following subsections present recommendations regarding technology capable of sampling single-completion wells that have no piezometer. Both mobile and permanently deployed technologies are considered.

C.1.4.1 Mobile Technologies

The committee's consensus opinion regarding the three remaining mobile technologies is that bailers are very well suited for obtaining samples from single-completion wells, but they are resource intensive in terms of production rates. They should be employed as the mobile technology of choice in wells where limited sample volumes are to be collected and micropurging is an option (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). Deployment of bailers in the absence of these conditions would be labor intensive and not cost effective.

The Besst Blatypus pump has many attributes that make it an attractive option for sampling single completion with no piezometers. 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 water quality of the sample. There are some unknowns that need to be addressed; 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. In addition, the purge rate is very low, limiting the volume that can be effectively purged in a few days. The committee recommends that a unit be purchased, the aforementioned modifications be made, and the method undergo field testing to determine whether it is the optimal choice for mobile technologies that can effectively purge single completions with no piezometers. Wells with larger volumes should be purged using a coil tubing unit. At least one coil tubing unit will need to be designed, built, and dedicated to sampling clean single completions with no piezometers.

Alternatively, wells of larger diameter may allow for the deployment of submersible pumps without check valves or the running of two access tubes that would allow for a jack pump to be installed along with an access tube that could facilitate water-level measurement. If the alternative is pursued, then some type of cost-benefit analysis of the jack pump versus the submersible pump should be conducted to determine which technology is more cost effective from cradle to grave.

C.1.4.2 Permanently Deployed Technologies

The committee's consensus opinion is that single-completion wells with no piezometers are well suited to the permanent deployment of sampling technologies if the acquisition of water levels are not required. The advantages of the submersible pump and the jack pump outweigh the advantages of the Besst Blatypus pump, the EZlift pump, and the coil tubing pump in terms of permanent deployment in a single completion with no piezometers. The submersible pumps allow for high discharge rates, and water levels can be obtained if check valves are not emplaced (eliminating the need to remove the pump). Jack pumps are a good choice for wells too small in diameter to allow for the placement of submersible pumps, but would preclude obtaining water levels if installed in a small-diameter well. The coil tubing unit and the Blatypus pump have much lower discharge rates and may be susceptible to fouling of the intake screens. These technologies should be considered as a secondary option if the emplacement of submersible pumps and jack pumps are not possible.

C.1.5 Multiple Completion - No Piezometer

The following subsections present recommendations regarding technology capable of sampling wells with multiple completions that have no piezometer are presented in the following subsections. Both mobile and permanently deployed technologies are considered.

C.1.5.1 Mobile Technologies

The committee's consensus opinion is that most mobile technologies are applicable to the uppermost zone in multiple-completion wells but not to deeper intervals unless access tubes are installed in the primary casing and seals are established between the intervals. Submersible pumps and jack pumps can be moved from interval to interval, but the cost of doing so is prohibitive. Prioritization of the intervals in terms of sampling is highly desirable. If only a single interval needs to be sampled, then issues associated with sampling multiple-completion wells with no piezometers becomes relatively simple. Alternatively, prioritization of intervals in terms of frequency of sampling can greatly reduce overall costs as well.

Committee consensus of the remaining mobile technologies is that bailers are very well suited for obtaining samples from the uppermost interval of multiple-completion wells, but they are resource intensive in terms of production rates. They should be employed as the mobile technology of choice in wells where limited sample volumes are to be collected and micropurging is an option (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 submersible pump and the jack pump were also relatively highly rated relative to all of the criteria, but cost of their deployment should limit their use as a mobile technology. The Besst Blatypus pump has many attributes that make it an attractive option for sampling the uppermost completion of a multiple-completion well with no piezometers. 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 water quality of the sample. There are some unknowns that need to be addressed; 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. In addition, the purge rate is very low, limiting the volume that can be effectively purged in a few days. The committee recommends that a unit be purchased, the aforementioned modifications be made, and the method undergo field testing to determine whether it is the optimal choice for mobile technologies that can effectively purge single completions with no piezometers. Wells with larger volumes should be purged using a coil tubing unit. At least one coil tubing unit will need to be designed, built, and dedicated to sampling clean multiple completions with no piezometers.

C.1.5.2 Permanently Deployed Technologies

The committee's consensus opinion is that prioritization of the intervals in terms of sampling is highly desirable. If only a single interval needs to be sampled, then issues associated with sampling multiple-completion wells with no piezometers becomes relatively simple. Alternatively, prioritization of intervals in terms of frequency of sampling can greatly reduce overall costs as well.

The submersible pump is the only sampling technology that can be deployed in the deeper intervals if access tubes are not run in the primary casing with some sort of seals installed to isolate the intervals. In the absence of doing that, then submersible pumps are the only permanently deployed technology that should be considered. Installation of access tubes allows for use of the other technologies, although existing well diameters will limit the number of intervals that can be isolated, so some prioritization of which interval to isolate may be required.

Installation of small-diameter access tubes would preclude the use of the submersible pump. The advantages of the submersible pump and the jack pump outweigh the advantages of the Besst Blatypus pump, the EZlift pump, and the coil tubing pump in terms of permanent deployment in multiple completion with no piezometers. The submersible pumps allow for high discharge rates, and water levels can be obtained if check valves are not emplaced. Jack pumps are a good choice for wells too small in diameter to allow for the placement of submersible pumps. Jack pumps would preclude obtaining water levels unless the jack pump is emplaced in one access tube and a second access tube is emplaced from which water levels may be obtained. The coil tubing unit and the Blatypus pump have much lower discharge rates and may be susceptible to fouling of the intake screens. The EZlift pump would require access tubing.

C.1.6 Slant Drilled

The following subsections present recommendations regarding technology capable of sampling slant wells are presented in the following subsections. Both mobile and permanently deployed technologies are considered.

C.1.6.1 Mobile Technologies

The committee's consensus opinion is that mobile technologies for sampling slant wells have some definite drawbacks. The first is that some of the technologies cannot be deployed in slant wells where the slant extends to the surface (jack pump and Besst Blatypus pump). Other mobile technologies have the possibility of greater exposure to workers pulling the technology from the borehole after each sampling event. The preferred method is to use a permanently deployed technology. If that fails, then there are two mobile technologies left to use in these wells: coil tube units and bailing. Coil tubing units on the NNSS have a proven history of use in slant drilled holes to obtain samples. They may be susceptible to fouling of the intake screens, but the pumps can be pulled if needed to service them. The technology is robust and can purge relatively larger volumes than the alternative. Bailers are very well suited for obtaining samples from slant drilled holes when all other technologies fail. They have little opportunity for adequately purging the well, but given the high concentrations of suspended solids, it may be the only choice in some situations. If coil tubing units are selected as the technology of choice, an additional unit may need to be built that can be used when the existing unit is down for repairs or if some slant drilled holes have diameters less than 2 7/8 in.

C.1.6.2 Permanently Deployed Technologies

The committee's consensus opinion is that slant drill holes are well suited to the permanent deployment of sampling technologies if that technology allows for the acquisition of water levels or if water-level measurements are not required. The advantages of the submersible pump outweigh the advantages of the EZlift pump and the coil tubing pump in terms of permanent deployment in a slant drill hole. The submersible pumps are associated with demonstrable long-term reliability and allow for high discharge rates, and water levels can be obtained if check valves are not emplaced (eliminating the need to remove the pump). Submersible pumps are less susceptible to fouling due to suspended solids. Coil tubing units can be used, but given their need for servicing, they should not be run as a permanently deployed unit. MagLift pumps may be susceptible to fouling due to suspended solids. MagLift pumps may be an option if existing casing can be retrofitted with suitable anchor points or if diameters are large enough to accept a smaller casing containing the anchor point.

C.1.7 Wide-Diameter Boreholes

The following subsections present recommendations regarding technology capable of sampling wide-diameter boreholes are presented in the following subsections. Both mobile and permanently deployed technologies are considered.

C.1.7.1 Mobile Technologies

The committee’s consensus opinion is that mobile technologies for sampling wide-diameter boreholes have some definite drawbacks. The principal difficulty is the large volume of water that must be purged in order to get a representative sample. Smaller portable technology is usually associated with lower purge rates, resulting in unacceptably long durations of time to acquire representative samples. Of the remaining three technologies with acceptable purge rates, all three will require installation of casing, pump rods, or pumping columns in order to operate. This will require the use of a workover rig and will be very expensive if conducted for every sampling event. Given the large diameter of the wells, the installed technology does not preclude the collection of water levels if access tubes are installed to facilitate those measurements.

Mobile technologies are a poor choice for wide-diameter boreholes, and permanently deployed technologies should be considered first. If mobile technologies are desired, then the consensus opinion is that submersible pumps and jack pumps are preferred relative to MagLift pumps. Submersible pumps have the highest discharge rates, followed by EZlifts, then jack pumps. The submersible pump and jack pumps are proven products, and neither preclude the collection of water levels in wide-diameter boreholes. EZlift pumps are the most mobile of these technologies. If that criterion is highly valued, then it may outweigh the disadvantages of this technology with respect to a lack of demonstrable reliability.

C.1.7.2 Permanently Deployed Technologies

The committee's consensus opinion is that wide-diameter boreholes are poorly suited for sampling with mobile technologies or with technology characterized by having a low-volume purge rate. Ample room exists inside the casing such that permanently deployed technology can be installed without sacrificing the ability to collect water levels. Of the high-volume durable technologies, the committee felt that advantages associated with the submersible pump slightly outweighed the advantages of the jack pump. One committee member noted that there was no real basis for determining the relative costs for operating a jack pump versus a submersible pump. A study should be conducted.

C.2.0 DATA SUPPORTING SAMPLE COLLECTION TECHNOLOGY SELECTION

Information needed to select a sample collection technology is provided in Table C-1. This table includes the following:

- **Dedicated Sampling Pump Installed?:** Identifies wells with dedicated sampling pumps.
- **Cased Completion?:** Identifies wells with casing.
- **Cased Completion Immediately Accessible for Sampling?:** Identifies cased wells (i.e., not piezometers).
- **Casing Diameter (in.):** Minimum diameter in inches of casing down to the sampling zone.
- **Piezometer to Access Completion Interval?:** Identifies wells with piezometers that can access the completion interval.
- **Piezometer Tubing Inside Diameter (in.):** Minimum inside diameter in inches of access tubing down to the sampling zone.
- **Open Top (ft):** Top of the open interval for the well. If there is a gravel pack, this is the top of the gravel pack.
- **Open Bottom (ft):** Bottom of the open interval for the well. If there is a gravel pack, this is the bottom of the gravel pack.
- **Annulus Filled?:** Is access to the annulus of the well at the target zone blocked by gravel, cement, or known borehole collapse fill.
- **Open Hole Diameter (in.):** If the well annulus is not filled or if the well is simply an open borehole, this is minimum drilled diameter of the borehole to the zone of interest. Otherwise, it is left blank.

Table C-1
Information Supporting Selection of Sampling Technology
(Page 1 of 5)

ID	Sampling Location	USGS Site ID	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 (in.)	Water Level		HSU	Comments
													Depth (ft)	Date		
Frenchman Flat																
9714	ER-11-2	365314115561901	No	No	No	N/A	Yes	2.375	Water level	1,304	Yes	N/A	1,161	09/25/2012	LTCU	Piezometer only.
5149	ER-5-3 shallow	365223115561703	No	No	No	N/A	Yes	2.875	927	1,012	Yes	N/A	927	03/20/2013	BLFA/OAA1	Piezometer only.
5197	ER-5-3-3	365223115561704	No	No	No	N/A	Yes	2.875	1,456	1,795	Yes	N/A	927	03/20/2013	OAA1	Well is a piezometer.
1920	RNM-1	364928115580101	No	Yes	Yes	5.5	No	N/A	Water level	1,002	No	9.875	730	03/20/2013	AA3	21 degree (average) slant hole. Several perforation zones with packers below the accessible completion.
1922	RNM-2S	364922115580101	Yes	Yes	Yes	9.6	Yes	1.9	Water level	1,120	Yes	N/A	724	03/20/2013	AA3	Diagram shows two sections of tubing run down to gravel screen, but no slots.
1937	UE-5 PW-2	365152115565701	Yes	No	No	N/A	Yes	2.88	820	919	Yes	N/A	840	08/02/2012	AA3	Piezometer only. Pump is installed in the piezometer and should be ready for sampling.
1919	UE-5n	364915115574101	--	Yes	--	9.9	No	N/A	Water level	1,687	No	15	706	03/20/2013	AA3	Bottom of the hole is cemented. Annulus is not open all the way to total depth (1,687 ft bgs). Inside of casing is bridged at 1,185 ft bgs. Casing is perforated between 720 and 730 ft bgs Accessed on 07/23/1991 (DRI temperature/conductivity log). NWIS reports two open intervals in 82–1,460 ft bgs.
1898	WW-5B	364805115580801	--	Yes	Yes	10.0	No	N/A	Water level	900	Yes	N/A	688	03/04/2013	AA2	Casing perforated from 700–900 ft bgs.
Pahute Mesa																
6768	Amargosa Valley RV Park	363832116234801	--	Yes	Yes	8.6	No	N/A	300	1,280	Yes	N/A	--	--	--	Well Log number 50458 in the state engineer's database (sequence number 27119).
4917	Ash-B Deep Well	364329116402901	--	Yes	--	5.6	No	N/A	1,062	1,185	Yes	N/A	315	03/11/2013	Volcanic rocks	Well Log number 46918 in the state engineer's database (sequence number 22667). Open Interval from NWIS.
4917	Ash-B Shallow Well	364329116402902	--	Yes	--	5.6	No	N/A	362	428	Yes	N/A	315	03/11/2013	Valley fill	Well Log number 46918 in the state engineer's database (sequence number 22667). Open Interval from NWIS.
4908	Cind-R-Lite Mine	364105116302601	Yes	Yes	Yes	8.9	No	N/A	320	460	Yes	N/A	331	12/19/2011	Unconsolidated deposits	Well Log number 38906 in the state engineer's database (sequence number 14643).
3468	ER-20-1	371043116142103	No	Open hole	Yes	N/A	No	N/A	Water level	2,065	No	20.50	1,989	03/04/2013	TM-LVTA/PBPCU/BA/UPCU/TCA	--
9712	ER-20-11	371146116290301	Planned	Yes	Yes	6.6	Yes	2.38	2,591	3,004	Yes	N/A	1,656	02/27/2013	FCCU/BA/UPCU	--
16	ER-20-5#1	371312116283801	Yes	Yes	Yes	5.5	Yes	2.88	2,278	2,655	Yes	N/A	2,054	11/17/1995	TSA/CHZCM	--
21	ER-20-5#3	371311116283801	Yes	Yes	Yes	5.5	No	N/A	3,393	3,954	Yes	N/A	2,051	05/12/2011	CHZCM	--
20	ER-20-6#3	371533116251801	Yes	Yes	Yes	5.5	Yes	2.88	2,480	2,807	Yes	N/A	2,014	06/25/2012	CHZCM	--
6769	ER-20-7	371247116284502	Yes	Yes	Yes	7.6	No	N/A	2,332	2,924	Yes	N/A	2,023	02/16/2011	LPCU/TSA/CHZCM	--
6771	ER-20-8 deep	371135116282602	No	Yes	No	5.5	Yes	2.38	3,095	3,440	Yes	N/A	1,667	09/29/2011	LPCU/TSA/CHZCM	--
6771	ER-20-8 intermediate	371135116282603	Yes	Yes	Yes	5.5	Yes	2.38	2,471	2,940	Yes	N/A	1,667	02/27/2013	MPCU/TCA/LPCU	--
6771	ER-20-8 shallow	371135116282604	No	No	No	N/A	Yes	1.60	Water level	2,150	No	14.75	1,667	03/28/2012	UPCU/SPA	Piezometer only.
6963	ER-20-8-2	371135116282701	Yes	Yes	Yes	7.6	Yes	2.38	1,623	2,339	Yes	N/A	1,668	02/27/2013	BA/UPCU/SPA/MPCU	--

Table C-1
Information Supporting Selection of Sampling Technology
(Page 2 of 5)

ID	Sampling Location	USGS Site ID	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 (in.)	Water Level		HSU	Comments
													Depth (ft)	Date		
Pahute Mesa (continued)																
4178	ER-EC-1 deep	371223116314701	Yes	Yes	Yes	5.5	No	N/A	4,433	4,840	Yes	N/A	1,855	05/19/2009	CFCM	All three completion zones open to well. No packers or bridge plugs currently installed.
4178	ER-EC-1 intermediate	371223116314701	Yes	Yes	Yes	5.5	No	N/A	3,318	3,776	Yes	N/A	1,855	05/19/2009	LPCU/TSA/CHCU	
4178	ER-EC-1 shallow	371223116314701	Yes	Yes	Yes	5.5	No	N/A	2,284	2,867	Yes	N/A	1,855	05/19/2009	CPA/UPCU/TCA	
6770	ER-EC-11 deep	371151116294102	No	Yes	No	7.6	Yes	2.88	3,620	4,148	Yes	N/A	1,477	08/23/2011	TSA/CHCU	--
6770	ER-EC-11 intermediate	371151116294103	Yes	Yes	Yes	7.6	Yes	2.38	3,134	3,385	Yes	N/A	1,477	02/27/2013	UPCU/TCA	--
6770	ER-EC-11 shallow	371151116294104	No	No	No	N/A	Yes	2.38	1,662	3,024	No	18.50	1,478	08/22/2011	FCCU/BA	Piezometer only.
6770	ER-EC-11 water table	371151116294105	No	No	No	N/A	Yes	2.38	Water level	1,557	No	26.00	1,477	10/06/2009	TM-WTA	Piezometer only.
6772	ER-EC-12 deep	371024116293102	No	No	No	N/A	Yes	2.38	3,853	3,902	Yes	N/A	1,358	09/29/2011	CHCU/CFCU	Piezometer only.
6772	ER-EC-12 intermediate	371024116293103	No	Yes	No	6.6	Yes	2.38	3,231	3,770	Yes	N/A	1,360	09/29/2011	TSA/CHCU	--
6772	ER-EC-12 shallow	371024116293104	Yes	Yes	Yes	6.6	Yes	2.38	1,893	2,744	Yes	N/A	1,362	02/27/2013	THCM/TCA/LPCU	--
6773	ER-EC-13 deep	371010116325402	No	Yes	No	5.5	Yes	2.38	2,263	2,680	Yes	N/A	1,010	10/17/2012	FCCM	--
6773	ER-EC-13 intermediate	371010116325403	Yes	Yes	Yes	6.6	Yes	2.38	1,916	2,136	Yes	N/A	1,010	03/13/2012	FCCM	--
6773	ER-EC-13 shallow	371010116325404	No	No	No	N/A	Yes	2.38	Water level	1,530	No	14.75	1,011	11/05/2010	FCCM	Piezometer only.
6774	ER-EC-14 deep	370825116302402	No	Yes	No	6.6	Yes	2.38	1,920	2,372	Yes	N/A	1,023	11/05/2012	RM-WTA	--
6774	ER-EC-14 shallow	370825116302403	No	Yes	Yes	6.6	Yes	2.38	1,328	1,704	Yes	N/A	1,023	11/05/2012	RM-WTA	--
6775	ER-EC-15 deep	371110116310502	No	Yes	No	5.5	Yes	2.38	2,784	3,189	Yes	N/A	1,187	04/29/2011	TSA/CHCU	--
6775	ER-EC-15 intermediate	371110116310503	No	Yes	No	5.5	Yes	2.38	2,139	2,427	Yes	N/A	1,189	04/28/2011	TCA/LPCU	--
6775	ER-EC-15 shallow	371110116310504	No	Yes	Yes	7.6	Yes	2.38	1,191	1,769	Yes	N/A	1,191	03/12/2013	FCCU/CPA/PBPCU	--
5151	ER-EC-2A deep	370852116340501	No	Yes	No	5.5	No	N/A	4,454	4,969	Yes	N/A	748	06/28/2000	TMCM	--
5151	ER-EC-2A intermediate	370852116340501	No	Yes	No	5.5	No	N/A	3,057	3,450	Yes	N/A	748	06/28/2000	FCCM/TMCM	--
5151	ER-EC-2A shallow	370852116340502	Yes	Yes	Yes	5.5	No	N/A	2,587	2,730	Yes	N/A	754	09/28/2010	FCCM	--
4103	ER-EC-5 deep	370504116335201	Yes	Yes	Yes	5.5	No	N/A	2,223	2,480	Yes	N/A	1,016	03/13/2013	TMCM	All three completion zones open to well.
4103	ER-EC-5 intermediate	370504116335201	Yes	Yes	Yes	5.5	No	N/A	1,885	2,146	Yes	N/A	1,016	03/13/2013	TMCM	
4103	ER-EC-5 shallow	370504116335201	Yes	Yes	Yes	5.5	No	N/A	1,187	1,443	Yes	N/A	1,016	03/13/2013	TMCM	
4180	ER-EC-6 deep	--	No	Yes	No	5.5	No	N/A	4,413	5,000	Yes	N/A	--	--	CFCM	Completion is currently inaccessible under several packers and a bridge plug. Part of a 5.5-in. string has multiple screens and gravel packed intervals.
4180	ER-EC-6 deep intermediate	371120116294803	No	Yes	No	5.5/2.4	No	N/A	3,423	3,820	Yes	N/A	1,426	08/17/2011	TSA/CHCU	5.5-in. slotted casing isolated from intervals above using a straddle packer. Accessible via 2.375-in. tubing.
4180	ER-EC-6 shallow	371120116294805	No	Yes	No	5.5/2.4	No	N/A	1,608	1,948	Yes	N/A	1,425	04/07/2011	FCCU/BA	2.375-in. access tubing runs below water level, but not to screened interval. No packers to block access to the completion from the surface via 7.625/5.5-in. casing, but existing access tubing might cause constrictions.
4180	ER-EC-6 shallow intermediate	371120116294804	No	Yes	No	5.5/1.9	No	N/A	2,170	2,510	Yes	N/A	1,426	04/05/2011	UPCU/TCA	5.5-in. slotted casing isolated from intervals above using a straddle packer. Accessible via 1.9-in. tubing.
4104	ER-EC-8 deep	370610116375301	Yes	Yes	Yes	5.5	No	N/A	1,660	1,990	Yes	N/A	322	03/23/2011	TMCM	All three completion zones open to well.

Table C-1
Information Supporting Selection of Sampling Technology
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ID	Sampling Location	USGS Site ID	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 (in.)	Water Level Depth (ft)	Water Level Date	HSU	Comments
Pahute Mesa (continued)																
4104	ER-EC-8 intermediate	370610116375301	Yes	Yes	Yes	5.5	No	N/A	1,428	1,558	Yes	N/A	322	03/23/2011	TMCM	All three completion zones open to well.
4104	ER-EC-8 shallow	370610116375301	Yes	Yes	Yes	5.5	No	N/A	662	1,050	Yes	N/A	322	03/23/2011	FCCM	All three completion zones open to well.
9715	EW-4	--	Yes	--	Yes	--	--	--	--	--	--	--	--	--	--	No Redbook or NWIS data available. Either sequence_no 12053 or 23521 in the state engineer's database.
3645	PM-3-1	371421116333703	No	No	No	N/A	Yes	2.88	1,901	2,192	Yes	N/A	1,457	03/14/2012	TCA/LPCU	Piezometer only.
3645	PM-3-2	371421116333704	No	No	No	N/A	Yes	2.88	1,428	1,687	Yes	N/A	1,454	05/22/2013	UPCU	Piezometer only.
5454	U-19ad PS1A	371613116211701	Yes	Yes	Yes	5.5	No	N/A	Water level	2,579	No	--	2,085	09/01/2004	PLFA	Slant hole (about 22 degrees). Main casing is not stemmed. Pump placed in hole in 2004.
3390	U-19q PS 1D	371649116215401	--	--	--	9.6	--	--	3,665	4,304	--	--	--	--	--	Not much detail available for this hole. 2004 Sampling report says the hole is obstructed at 3,690 ft bgs. 9.635-in. liner to 3,665 ft bgs.
3399	U-19v PS 1D	371453116205751	--	Yes	--	6.6	No	N/A	3,960	4,113	--	--	2,194	09/15/2009	BFCU	Well installed to the base of the ALMENDRO test cavity. Redbook lists total depth to 4,113 ft bgs and mentions "6.63" drill pipe & bit. Casing" to 3,960 ft bgs. A piece of drill string may be stuck in the hole now used for casing. More detail about this hole is needed. Sampled by wireline bailer in 2003 and 2009. NWIS open interval is 3,875–3,885 ft bgs.
3647	U-20 WW	371505116254501	No	Yes	Yes	13.4	No	N/A	Water level	3,268	No	18	2,052	05/22/2013	CHZCM	Description of HSUs based upon average depth to water of ~2,000 ft bgs. Per Jeff Wurtz, the pump installed in the well is not functional (June 2013). USGS reports pumping in 2008.
3533	U-20n PS1 DDh	371425116252403	--	Yes	--	5.5	No	N/A	2,417	4,285	Yes	N/A	2,051	07/09/1998	CHZCM	Bridge plug in casing at 4,309 ft.
4936	U.S. Ecology	364600116413001	--	Yes	--	8.0	No	N/A	453	573	--	--	315	06/27/1961	--	Well Log number 6000 in the state engineer's database (sequence number 95790).
3309	UE-18r	370806116264001	No	Open hole	Yes	10.8	No	N/A	1,636	4,930	No	9.88	1,363	02/26/2013	TMCM	Open hole 1,629–4,930 ft bgs.
3534	UE-20n1	371425116251901	Yes	Open hole	Yes	N/A	Yes	2.38	2,323	2,824	No	8.50	2,041	09/08/2004	CHZCM	Open hole 2,323–2,824 ft bgs. Casing (9.625 in.) to 2,280 ft. Monyo pump stator in place.
Rainier Mesa																
2876	ER-12-1 (1,641–1,846 ft)	371106116110401	Yes	Yes	Yes	5.5	No	N/A	1,641	1,846	Yes	N/A	1,519	03/25/2013	UCCU	Sliding sleeve over screened section is open.
5452	ER-12-3 Deep	371142116125102	Yes	Yes	Yes	5.5	No	N/A	Water level	4,903	No	12.25	3,107	03/25/2013	LCA3 (limestone)	--
5452	ER-12-3 Shallow	371142116125101	No	No	No	N/A	Yes	2.38	Water level	2,210	No	18.50	1,244	03/25/2013	LTCU/OBSCU/ATCU	Piezometer only.
5453	ER-12-4 Main	371311116105902	No	Yes	Yes	5.5	No	N/A	Water level	3,715	No	12.25	2,564	03/25/2013	LCA3	--
5453	ER-12-4 Shallow	371311116105901	No	No	No	--	Yes	2.38	Water level	1,988	No	18.50	943	03/25/2013	LVTA1/BRCU/LTCU/OSBCU	--
5276	ER-16-1	370031116121103	No	Yes	Yes	5.5	No	N/A	Water level	3,832	No	12.25	4,089	03/26/2013	LCA	3,832–4,005 ft at bottom of borehole is filled at last available measurement.

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ID	Sampling Location	USGS Site ID	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 (in.)	Water Level		HSU	Comments
													Depth (ft)	Date		
Rainier Mesa (continued)																
3317	ER-19-1-2	371043116142101	Yes	Yes	No	2.9	Yes	1.90	2,577	2,738	Yes	N/A	1,148	03/04/2013	RVA/ATCU	Permanently Moyno pump stator installed in 2.875-in. casing. Requires pump rotor and rods to be installed before pumping.
3317	ER-19-1-3	371043116142102	Yes	Yes	No	2.9	Yes	1.90	1,331	1,422	Yes	N/A	1,004	03/04/2013	OSBCU	Permanently Moyno pump stator installed in 2.875-in. casing. Requires pump rotor and rods to be installed before pumping.
3809	ER-30-1 Deep	370301116185801	Yes	No	No	N/A	Yes	2.875	712	790	Yes	N/A	450	06/24/1994	FCCM	Pump installed, but it must be verified that it is still serviceable. Breach in deep piezometer where the shallow piezometer is screened.
3237	TW-1	370929116132311	--	Open hole	--	8.0	No	N/A	1,840	4,206	No	7.625	1,460	02/25/2013	OSBCU/RVA/LTCU1/ATCU/LCA3	Per Fenix and Scisson hole history, this well has gun perforated sections to borehole annulus above the open hole.
3069	U-12n Vent Hole 2	371213116130501	--	Open hole	--	--	No	N/A	20	--	No	13.75	--	--	--	Hole is probably open to the full extent of N-Tunnel. Diameter of the hole into the tunnel is probably 13.75 in., although the Redbook borehole segment data are unclear.
3043	U-12n.10 Vent Hole	371228116122001	--	Yes	--	4.5	No	N/A	1,238	--	Yes	N/A	--	--	--	Vent hole into N-Tunnel. Looks like two strings of 4.5-in. casing inside a single string of 30-in. casing down into the tunnel adit. Unknown whether 4.5-in. casing is cemented into 30-in. casing. Bottom is probably open to the rest of the tunnel complex.
3117	UE-12t-6 (1,461 ft)	371332116112802	No	Yes	See comment s	4.5	No	N/A	Water level	1,461	--	3.94	829	03/25/2013	LTCU/OSBCU/LCCU1	Obstruction encountered at 149.96 m bgs (492 ft bgs) on 08/09/2006, with 3.75-in. diameter tool. However, water levels in the well have been acquired at 800–830 ft bgs since that time.
3235	UE-16d (2,117–2,293 ft)	370412116095101	Yes	Open hole	Yes	7.0	No	N/A	Water level	1,944	No	10.00	753	03/04/1981	UCCU	Assumes pump is functional. There is a lower section of this well that is closed by a bridge plug.
3311	UE-18t	370741116194501	No	Yes	No	3.5	Yes	2.38	--	2,600	Yes	2.98	913	11/14/2011	TMCM	Open hole 1,896–2,600 ft bgs. 2.38-in. casing to 1,896 ft bgs. No good hole history or completion diagram found.
3316	WW-8	370956116172101	Yes	Open hole	Yes	7.6	No	N/A	2,031	5,490	Yes	N/A	1,081	09/13/2000	OSBCU/RVA/LTCU1/ATCU	Open hole 2,946–5,499 ft bgs. Assumes top of open zone begins at the base of the liner.
Yucca Flat																
3648	Army 1 WW	363517116021501	--	Yes	--	12.3	No	N/A	611	1,931	Yes	6.75	785	07/11/2013	LCA	The well has 12.25-in. casing that is perforated from 792–1,042 ft bgs. Below 1,360 ft, the well is open hole.
5204	ER-2-1 (1,642–2,076 ft)	370725116033901	No	Yes	Yes	7.0	No	N/A	1,700	2,177	No	12.25	1,725	03/19/2013	TM-WTA/TM-LVTA/LTCU	--
5204	ER-2-1 (2,495–2,557 ft)	370725116033902	No	No	No	N/A	Yes	2.88	2,313	2,557	Yes	N/A	766	03/19/2013	LTCU	Piezometer only.
5150	ER-5-3-2	365223115561801	Yes	Yes	Yes	5.5	No	N/A	4,674	5,683	Yes	N/A	941	03/20/2013	LCA	Open interval is fill, not a gravel pack. Slotted casing only extends to 4,908 ft bgs.
5203	ER-6-1-2 main (1,834–3,200 ft)	365901115593501	No	Open hole	Yes	N/A	No	N/A	1,834	3,200	No	12.25	1,544	03/20/2013	LCA	Open hole 1,629–4,930 ft bgs.
5199	ER-7-1 deep	370424115594301	Yes	Yes	Yes	7.0	No	N/A	Water level	2,500	No	12.25	1,852	03/19/2013	LCA	--

Table C-1
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ID	Sampling Location	USGS Site ID	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 (in.)	Water Level Depth (ft)	Water Level Date	HSU	Comments
Yucca Flat (continued)																
1892	TW-D	370418116044501	--	Open hole	--	10	No	N/A	1,700	1,950	--	12	1,723	03/18/2013	ATCU/LCA	NWIS states five open intervals between 1,700–1,950 ft bgs.
1747	TW-7	370353116020201	No	Open hole	Yes	N/A	No	N/A	Water level	2,272	No	10.63	1,645	03/19/2013	LTCU	Open hole 2,014–2,272 ft bgs.
1015	U-3cn 5	370320116012001	Yes	Open hole	Yes	6.6	Yes	2.38	2,832	3,030	No	5.75	1,619	03/19/2013	LCA	Open hole 2,835–3,030 ft bgs. 2.375-in. access tube and Centrilift tandem pump assembly in hole as of 01/23/1997. 55-gal drum samples acquired on 03/29/2011.
1018	U-3cn PS 2	370338116011901	--	Yes	Yes	4.5	No	N/A	Water level	2,603	No	9.00	1,550	09/16/1977	LTCU	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 1,680–1,729 ft bgs.
1838	U-4u PS 2A	370513116025101	--	Yes	No	2.4	No	N/A	1,602	2,280	Yes	N/A	1,492	07/22/1998	LTCU	Piezometer only. Pump in hole at least since 1998. Can't measure water level.
2719	UE-10j-3 (2,232–2,297 ft)	371108116045303	Yes	Yes	Yes	5.5	No	N/A	2,232	2,297	Yes	N/A	2,156	03/19/2013	LCA	Sampling will require sliding sleeved to be opened. Assumption made that Moyno pump installed is still functional.
69	UE-1h	370005116040301	No	Open hole	Yes	N/A	No	N/A	2,134	3,358	No	8.75	1,552	03/18/2013	LCA	Open hole 2,134–3,358 ft bgs.
22	UE-1q (2,600 ft)	370337116033002	No	Open hole	Yes	N/A	No	N/A	2,470	2,600	No	6.75	1,655	03/18/2013	LCA	Open hole 2,470–2,600 ft bgs.
319	UE-2ce	370831116080700	--	Yes	--	8.6	No	N/A	Water level	1,650	Yes	N/A	1,453	02/25/2013	LCA3	USGS diagram shows two access tubes into the perforated casing.
2059	UE-7nS	370556116000901	--	Yes	--	7.6	No	N/A	1,707	2,205	Yes	N/A	1,969	03/19/2013	LCA	Redbook notes 7.63-in. casing to 2,199 ft bgs. NWIS states 3-in. casing at depth.
549	WW-2	370958116051501	Yes	Yes	Yes	6.6	No	N/A	2,940	3,422	Yes	N/A	2,052	03/19/2013	LCA	Borehole Index 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 samples separately if so desired. Further divisions of the upper zone might be possible.
1971	WW-3 (1,800 ft)	365942116032901	No	Yes	Yes	6.0	No	N/A	Water level	1,800	No	8.00	1,527	03/18/2013	AA3	Open hole 1,765–1,800 ft bgs.
1745	WW-A	370142116021101	--	Yes	--	10.8	No	N/A	Water level	1,870	Yes	N/A	1,599	03/19/2013	AA3	Requires verification that pump is still installed and is serviceable.
1970	WW-C-1	365500116003901	Yes	Yes	Yes	16.6	No	N/A	Water level	1,650	No	18.63	1.540	05/11/1998	LCA	--

-- = Not applicable

AA2 = Alluvial aquifer 2
ATCU = Argillic tuff confining unit
BFCU = Bullfrog confining unit
BRCU = Belted Range confining unit
CFCM = Crater Flat composite unit
CFCU = Crater Flat confining unit
CHCU = Calico Hills confining unit
FCCM = Fortymile Canyon composite unit
FCCU = Fortymile Canyon confining unit
LCCU = Lower clastic confining unit
LCCU1 = Lower clastic confining unit 1
LPCU = Lower Paintbrush confining unit
LTCU1 = Lower tuff confining unit 1
LVTA1 = Lower vitric-tuff aquifer 1
MPCU = Middle Paintbrush confining unit
OAA1 = Older altered aquifer 1
PBPCU = Post-Benham Paintbrush confining unit
PLFA = Paintbrush lava-flow aquifer
RM-WTA = Rainier Mesa welded-tuff aquifer
SPA = Scrugham Peak aquifer
THCM = Tannenbaum Hill composite unit
TMCM = Timber Mountain composite unit
UPCU = Upper Paintbrush confining unit

Plate 1

Sample Technology Flow Chart


Mobile Technologies
Permanently Deployed Technologies
START
Will water-level or any other measurements be required through the same access-point used by the sampling equipment?
Is ambient flow entering the zone of interest? If so, then zone is self-purging.
Is the sample suite for the zone of interest limited to ≤ 5 L?
Collect sample using a bailer!
End
Is the well of interest drilled at an angle?
What is the outer diameter of the access point of interest?
<= 2 7/8"
=> 24"
> 2 7/8" and < 24"
Has the Blatypus pump been successfully tested as a reliable pumping technology for the NNSS?
Collect sample using a Blatypus system!
Can access tubing be installed that would facilitate permanent deployment of jack pump and access tube for water level monitoring or can a submersible pump w/o check valve be installed?
Collect sample using either a permanently deployed submersible pump or a permanently deployed jack pump emplaced in an access tube coupled with a second access tube for measuring water levels! The method deployed should be based upon a cradle-to-grave cost analysis.
Has a coil tubing unit been built that allows for sampling of the zone of interest?
Collect sample using a coil tubing unit!
Is the well a multicompletion well with no piezometers in the zone of interest?
Has a prioritization process been conducted and a single interval been selected for sampling and the well configured to isolate and provide access to that interval?
Are contamination levels such that field workers risk some exposure while pulling sampling equipment?
Are suspended solids an issue where routine clogging of intake screens are anticipated?
Collect sample using a coil tubing unit!
Is the hole of sufficient diameter such that a submersible pump w/o a check valve or 2 access tubes - 1 for a jack pump and one for water-level measurements can be installed ?
Is the zone of interest the uppermost interval of the well and is that zone isolated from the lower zones?
Temporarily install bridge plugs and/or straddle packers in conjunction with access tube for jack pump or production tubing for submersible pump to sample hole! A cradle-to-grave cost analysis is needed to determine which method to use.
Is the Maglift system available, has it been successfully tested for use on the NNSS, and can the zone of interest be retrofitted for its use?
Collect sample using a MagLift system!
Can the access point of interest be effectively purged using micropurging techniques implemented through the use of the Blatypus pump (<= 0.7 Lpm)?
Collect sample using a Blatypus system!
Will this configuration be maintained long enough to warrant a permanent installation?
Collect sample using a bailer
Collect sample using a coil tubing system!
Are Ezlift systems available, have they been demonstrated as feasible for use on the NNSS and has access tubing and anchor point for Ezlift system been installed?
Collect sample using EZlift System!
Collect sample using submersible pump as a mobile system!
What is the outer diameter of the well of interest?
Collect sample using a permanently deployed jack pump or submersible pump! Which technology is chosen depends upon a cradle-to-grave cost analysis.
Collect sample using a permanently deployed jack pump!
Is the well diameter large enough such that a submersible pump can be installed?
Collect sample using a permanently deployed submersible pump!
Collect sample using a bailer!
Is well diameter sufficiently large such that a submersible pump Can be installed?
Collect sample using a coil tubing units!
Collect sample using a permanently deployed Submersible pump!
Y
N