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2015 Groundwater Monitoring Report Project Shoal Area: Subsurface Corrective Action Unit 447

April 2016

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

AEC	U.S. Atomic Energy Commission
amsl	above mean sea level
BSZ	bottom of open interval/screen zone
^{14}C	carbon-14
CADD	Corrective Action Decision Document
CAP	Corrective Action Plan
CAU	Corrective Action Unit
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FFACO	Federal Facility Agreement and Consent Order
ft	feet
^{129}I	iodine-129
LM	Office of Legacy Management
MCL	maximum contaminant level
MDC	minimum detectable concentration
µg/L	micrograms per liter
mg/L	milligrams per liter
MV	monitoring/validation
NDEP	Nevada Division of Environmental Protection
pCi/L	picocuries per liter
PSA	Project Shoal Area
RDL	required detection limit
SCM	site conceptual model
TOC	top of casing
^{234}U	uranium-234
^{238}U	uranium-238

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Executive Summary

The Project Shoal Area in Nevada was the site of a 12-kiloton-yield underground nuclear test in 1963. Although the surface of the site has been remediated, investigation of groundwater contamination resulting from the test is still in the corrective action process. Annual sampling and hydraulic head monitoring are conducted at the site as part of the subsurface corrective action strategy. The corrective action strategy is currently focused on revising the site conceptual model (SCM) and evaluating the adequacy of the monitoring well network. Some aspects of the SCM are known; however, two major concerns are the uncertainty in the groundwater flow direction and the cause of rising water levels in site wells west of the shear zone. Water levels have been rising in the site wells west of the shear zone since the first hydrologic characterization wells were installed in 1996. Although water levels in wells west of the shear zone continue to rise, the rate of increase is less than in previous years. The SCM will be revised, and an evaluation of the groundwater monitoring network will be conducted when water levels at the site have stabilized to the agreement of both the U.S. Department of Energy Office of Legacy Management and the Nevada Division of Environmental Protection.

Analytical results from the 2015 sampling event are consistent with those of previous years with the exception of sample results from well HC-4. This well continues to be the only well with tritium concentrations above the laboratory's detection limit. The tritium concentration (731 picocuries per liter [pCi/L]) is consistent with past results and is below the U.S. Environmental Protection Agency's (EPA's) maximum contaminant level (MCL) of 20,000 pCi/L and below the well's highest concentration of 1,130 pCi/L reported in 1998 (Pohll et al. 1998). However, concentrations of gross alpha, uranium, and carbon-14 (^{14}C) all increased in the samples from well HC-4 during this sampling event. The concentrations of ^{14}C have historically been below the required detection limit of 5 pCi/L but increased during the 2015 sampling event to a concentration of 14.6 pCi/L. Concentrations of gross alpha and uranium have been above the EPA MCLs in this well since 2012, and the highest concentrations of gross alpha (60.6 pCi/L) and uranium (110 micrograms per liter) were detected during this sampling event. Samples from wells HC-6 and MV-4 also had gross alpha activity and uranium mass concentrations above the EPA MCLs but were consistent with past results. A sample from well MV-2 had a gross alpha activity that was at the MCL of 15 pCi/L, but the uranium mass concentration and results from the duplicate sample were below the respective MCLs. If the gross alpha values in samples collected from wells HC-4, HC-6, MV-2, and MV-4 are adjusted by subtracting activities of uranium isotopes (^{234}U and ^{238}U), the values are near or less than zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples. Isotope ratios of uranium obtained during this monitoring event continue to support the interpretation of a natural source of uranium in groundwater rather than a nuclear-test-related source.

Water level trends obtained from the 2015 water level data are consistent with those of previous years. However, the rate of the increasing water levels in wells west of the shear zone (detonation side) was lower during the monitoring period from July 2014 to July 2015 because of impacts from the drilling and well development completed in late 2014.

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1.0 Introduction

This report presents the 2015 groundwater monitoring results collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Project Shoal Area (PSA) Subsurface Corrective Action Unit (CAU) 447 in Churchill County, Nevada. Responsibility for environmental site restoration of the PSA was transferred from the DOE, National Nuclear Security Administration, Nevada Field Office to LM on October 1, 2006. The environmental restoration process and corrective action strategy for CAU 447 are conducted in accordance with the *Federal Facility Agreement and Consent Order (FFACO)* (NDEP 1996, as amended) and all applicable Nevada Division of Environmental Protection (NDEP) policies and regulations. The corrective action strategy for the site includes monitoring in support of future site closure. This report summarizes results from the annual groundwater monitoring program conducted through October 2015.

2.0 Site Location and Background

The PSA is south of U.S. Highway 50, approximately 30 miles southeast of Fallon, in Churchill County, Nevada (Figure 1). The U.S. Department of Defense and the U.S. Atomic Energy Commission (AEC) jointly conducted the Project Shoal underground nuclear test on October 26, 1963, as part of the Vela-Uniform program. The test consisted of detonating a 12-kiloton-yield nuclear device in granitic rock at a depth of approximately 1,211 feet (ft) below ground surface (AEC 1964). A cavity created by the test collapsed shortly after the detonation and formed a rubble chimney (Hazleton-Nuclear Science Corporation 1965). The radius of the cavity is reported to be 85 ft (26 meters) (Hazleton-Nuclear Science Corporation 1965).

Site deactivation and post-shot drilling activities began on October 28, 1963. Re-entry drilling indicated that the Shoal rubble chimney extended approximately 356 ft above the shot point (Hazleton-Nuclear Science Corporation 1965). The decontamination and restoration activities were minimal, because no large areas of surface radiological contamination were found during or following the test. During the cleanup effort, the emplacement shaft was covered with a concrete slab, and the particle motion boreholes, exploratory core holes, and U.S. Bureau of Mines boreholes on the site were plugged and abandoned. A radioactive materials survey conducted at the surface of the site in 1970 indicated that no radioactivity exceeded background for the area (AEC 1970).

2.1 Summary of Corrective Action Activities

Surface and subsurface contamination resulted from the underground nuclear test at PSA. To address these areas of contamination, surface and subsurface CAUs were identified, and the areas of contamination were addressed through separate corrective action processes. The surface CAU included three Corrective Action Sites that consisted of a mud pit with drilling mud impacted by petroleum hydrocarbons, a muckpile of granite that remained from excavation of the emplacement shaft, and housekeeping areas that consisted of approximately 20 rusted and empty oil cans. Remediation of the surface of CAU 416 was completed in 1998 and is summarized in the *Closure Report for CAU No. 416, Project Shoal Area* (DOE/NV 1998). NDEP approved the Closure Report on February 13, 1998, stating that no post-closure monitoring is required, and no land use restrictions apply at CAU 416 (NDEP 1998).

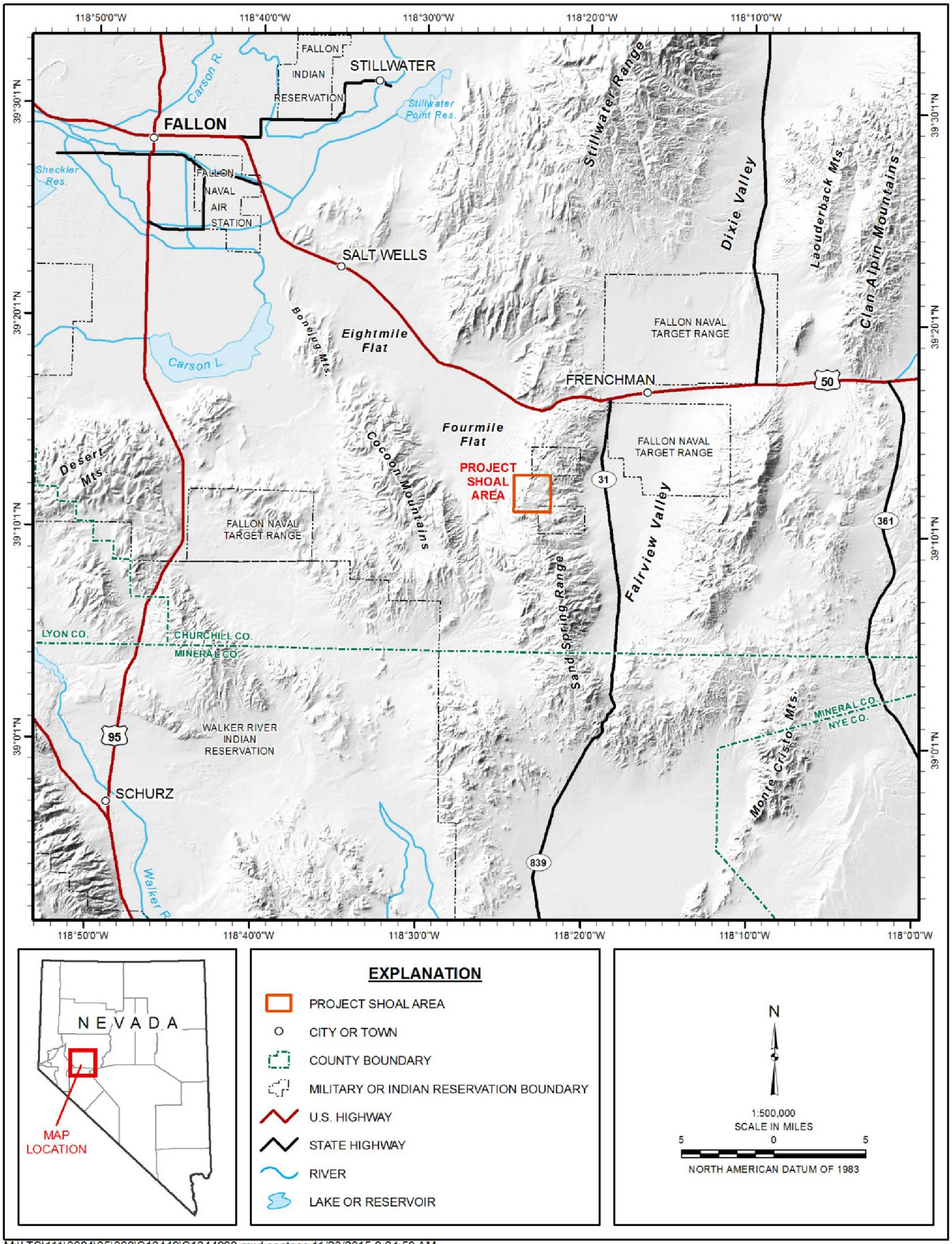

Figure 1. Location of the Project Shoal Area

The corrective action process for the subsurface has not been completed, and there is currently no known technology to remediate the remaining subsurface radioactive contamination at the site. The original corrective action strategy for the subsurface used a groundwater flow and transport model developed by Desert Research Institute to help evaluate data and select a corrective action alternative. The model results were used to determine a contaminant boundary and establish a restricted region surrounding the site. The contaminant boundary (Figure 2) is a probabilistic forecast of the maximum extent over 1,000 years of radionuclide transport where test-related radionuclides in groundwater outside the boundary have a 5 percent or less likelihood of exceeding the radiological standards of the Safe Drinking Water Act. NDEP approved the contaminant boundary as the compliance boundary in their letter dated January 19, 2005 (NDEP 2005). The corrective action alternative selected for the site includes monitoring with institutional controls and is presented in the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP; DOE/NNSA 2006).

As part of the original corrective action strategy, three monitoring/validation (MV) wells (MV-1, MV-2, and MV-3) were installed in 2006 for the dual purpose of monitoring for contaminant migration and evaluating the flow and transport model results. The site conceptual model (SCM) is being reevaluated to address inconsistencies with the numerical model predictions and monitoring well data. Concerns with the model stem from two observations. First, the horizontal component of groundwater flow predicted by the model was primarily toward the north-northeast, whereas horizontal gradients inferred from water levels measured in site wells do not support the modeled flow direction. Second, the model incorrectly assumed that the groundwater flow system is in a steady state; in fact, water levels west of the shear zone have been rising approximately 1 to 2 ft per year during the time they have been monitored, beginning with the installation of the HC wells in the late 1990s. Water levels were not monitored at the site, except for the adjacent valleys, prior to the installation of the HC wells and later MV wells. Pursuant to the FFACO (NDEP 1996, as amended), LM began implementing a new corrective action strategy for the site in 2009.

On November 24, 2009, LM submitted an initial Short-Term Data Acquisition Plan to NDEP, detailing data collection activities that included a surface geophysical program and enhanced groundwater monitoring. The completed geophysical program included seismic and electromagnetic surveys. As part of the evaluation of data obtained from the surveys, a technical exchange meeting was conducted in March 2011 with the geophysicists who performed the surveys (Lee Liberty from Boise State University and Jim Hasbrouck from Hasbrouck Geophysics), Desert Research Institute, and NDEP to discuss the results and the potential SCMs. During the meeting it was agreed that further understanding of the groundwater flow system was needed for the enhancement of potential SCMs and that a new Short-Term Data Acquisition Plan was necessary to outline future activities at the site. The Surface Geophysics Report recommended that geophysical data be evaluated further and compared to existing data to assess and enhance any potential SCMs (DOE 2011b). The technical exchange and Surface Geophysics Report provided the basis for developing the new Data Acquisition Plan that was submitted to NDEP in October 2011.

The 2011 Data Acquisition Plan included further review of available reports and preparation of a detailed information resource tool that includes a summary of pertinent technical data. Analytical, hydrologic, and geologic data obtained from historical reports have been reviewed with more recent data and collected geophysical data to help identify geologic structures that might be influencing groundwater flow at the site. These data have been assembled for three-dimensional visualization. Revisions to the SCM and enhancements to the monitoring well network will be provided to NDEP in a future addendum to the CADD/CAP (DOE/NNSA 2006).

The 2014 Data Acquisition Plan included a drilling program to enhance the monitoring well network at the site. Drilling consisted of installing two monitoring wells (MV-4 and MV-5) and deepening the existing well HC-2 that is now identified as HC-2d (DOE 2014). Monitoring wells MV-4 and MV-5 were dually completed with a well and piezometer to allow determination of vertical and horizontal gradients at the installed location. The well casing was removed from the existing well HC-2, and the borehole was deepened to allow installation of a new well HC-2d. The new wells and deepened well were completed with dedicated electric submersible pumps for collecting groundwater samples and conducting aquifer tests. The new wells and existing wells/piezometers were surveyed to obtain new top-of-casing measuring point elevations as part of the drilling program. Results from the 2014 drilling program are provided in a Well Completion Report for CAU 447 (DOE 2015a).

3.0 Geologic and Hydrologic Setting

The PSA is in the northern portion of the Sand Springs Range in west-central Nevada's Churchill County. The Sand Springs Range is the southern extension of the Stillwater Range, a north-northeast-trending fault block range that traverses Churchill County. The Sand Springs Range rises to an elevation of approximately 6,751 ft above mean sea level (amsl) and is flanked by Fourmile Flat to the west and Fairview Valley to the east (Figure 1). The Shoal site is in Gote Flat at an elevation of approximately 5,250 ft amsl and is within an area that is part of the Cretaceous-age Sand Springs granitic batholith.

The Sand Springs batholith is composed of granodiorite and granite, aplite, and pegmatite dikes; andesite dikes; rhyolite dikes; and rhyolitic intrusive breccia. Internal deformation of the Sand Springs granite is largely by high-angle normal faults and fractures distributed between two dominant structural trends that strike approximately N 50° W and N 30° E and are vertical to steeply dipping. Several dikes of varying composition predominantly follow the same two orientations and intrude along these lines of preexisting weakness. These orthogonal-type sets of faults and fractures appeared early in the history of the Sand Springs granite and affected much of the subsequent structural and chemical evolution of this large intrusion (Beal et al. 1964).

The water table beneath the site (near surface ground zero and west of the shear zone) occurs at depths ranging from approximately 960 to 1,100 ft below ground surface, and groundwater moves primarily through fractures in the granite. Recharge occurs by infiltration of precipitation on the mountain range, and regional discharge occurs in the adjacent valleys. A shear zone, located about 1,500 ft east of surface ground zero (Figure 2 and Figure 3), is interpreted as a barrier to groundwater flow on the basis of disparate head levels in wells separated by the shear zone (Carroll et al. 2001). Groundwater within Fairview Valley to the east has been used for ranching, seasonal residential purposes, and military purposes within the last 5 years.

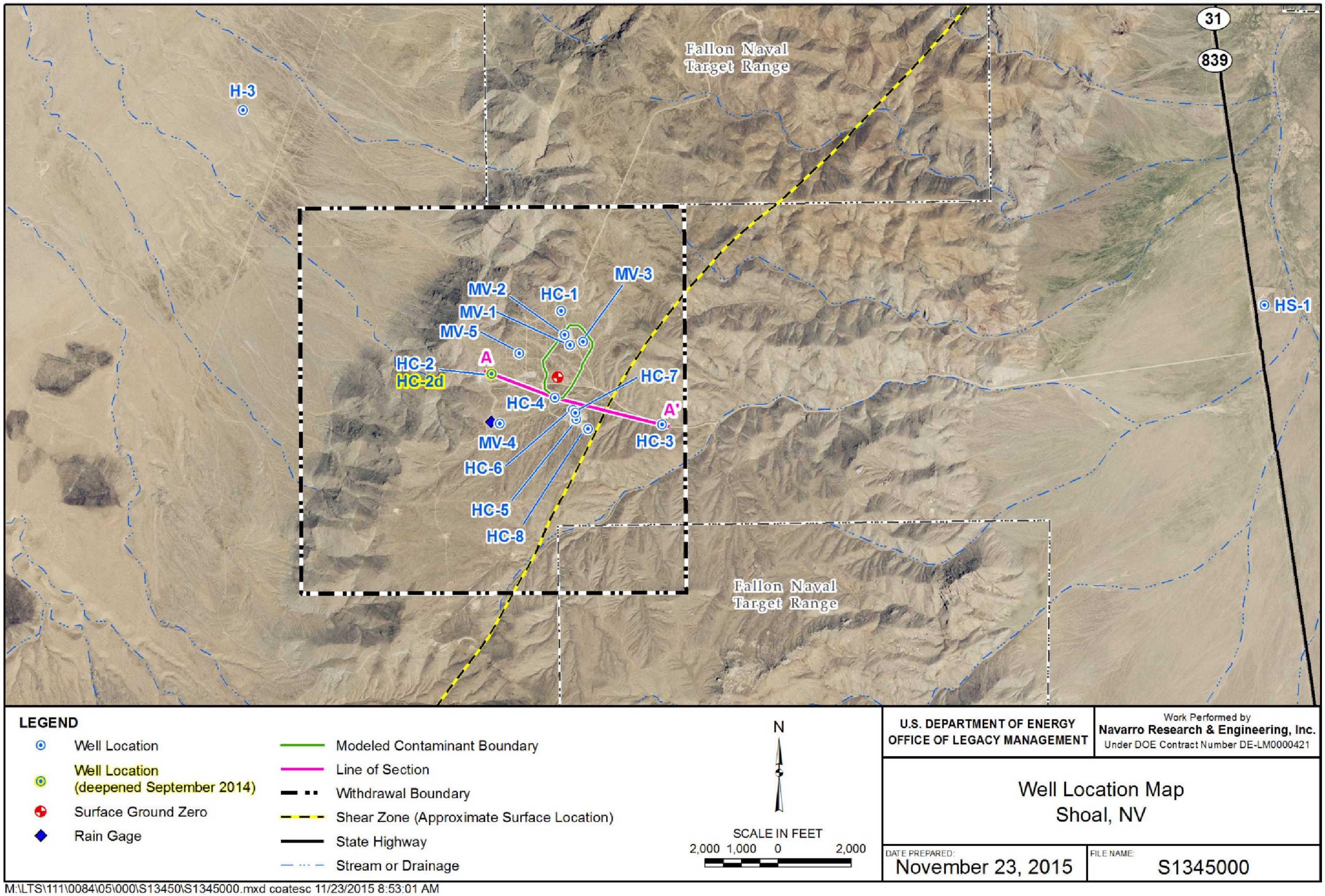

Figure 2. Well Locations, Shoal, Nevada

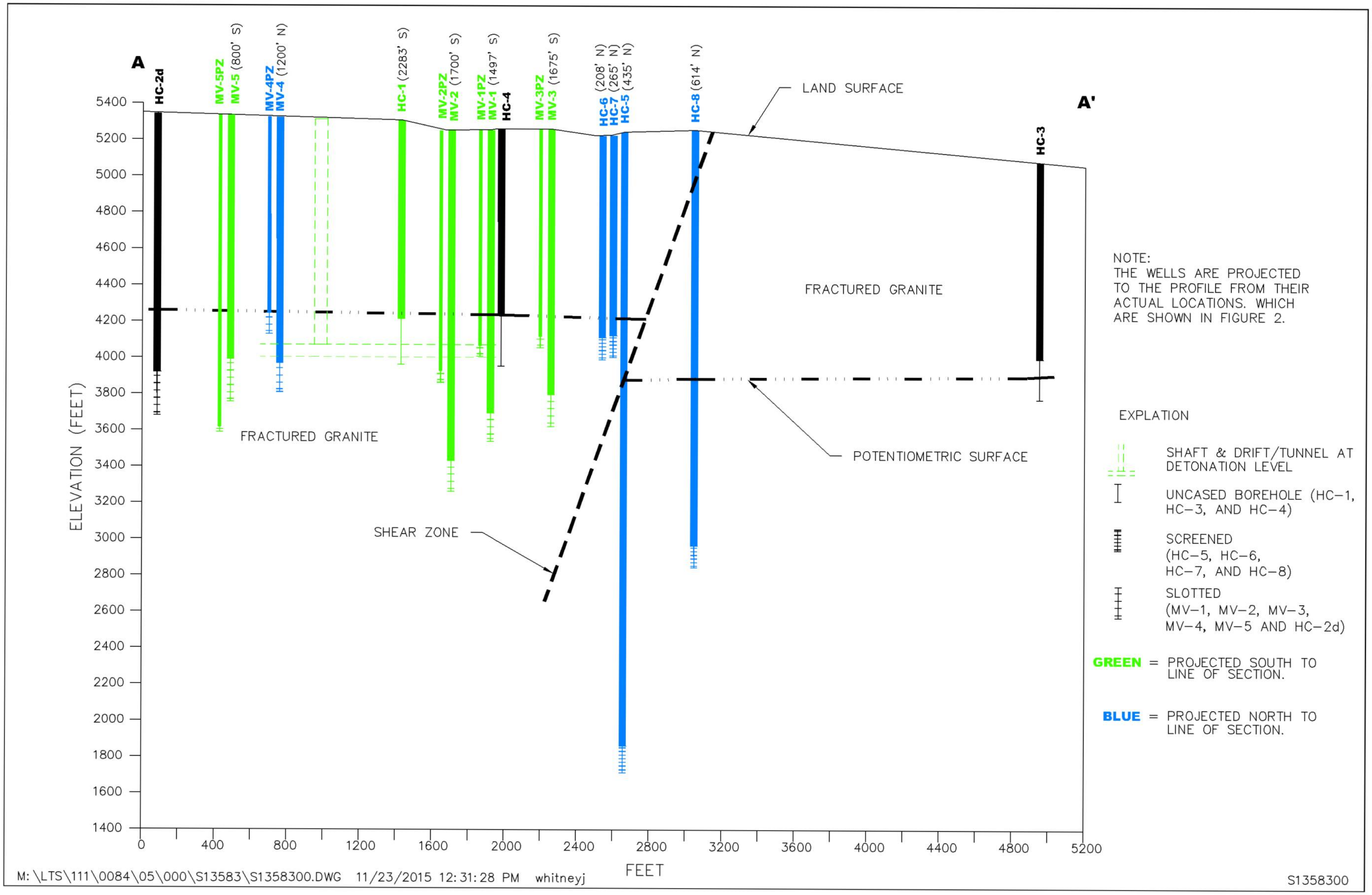

Figure 3. Cross Section A–A' Depicting Monitoring Well and Shear Zone Location, Project Shoal Area, Nevada

4.0 Monitoring Program and Objectives

The primary objectives of the monitoring program are (1) "detection monitoring" to identify any migration of radiologic contamination from the test cavity and (2) "system monitoring" to obtain hydraulic head data for monitoring the overall stability (quasi-steady state) of the hydrogeologic system. The monitoring program and objectives were established in the CADD/CAP, and the program was initiated after NDEP approved the CADD/CAP and wells MV-1, MV-2, and MV-3 were installed in 2006. Enhancements were made to the monitoring program after the numerical model could not be verified against data obtained from the MV wells (MV-1, MV-2, and MV-3). The enhancements are documented in short-term Data Acquisition Plans that were completed in 2009, 2011, and 2014 to support the CADD/CAP and provide interim guidance documents until an addendum to the CADD/CAP can be completed. The 2014 Data Acquisition Plan included the installation of two new monitoring wells (MV-4 and MV-5) and deepening of the existing well HC-2 that is now identified as HC-2d (DOE 2014). The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351) is used to guide the quality assurance/quality control of the annual sampling and monitoring program.

The corrective action strategy is focused on revising the SCM and evaluating the adequacy of the current monitoring well network. Aspects of the SCM are currently known; however, two major concerns are the uncertainty in the groundwater flow direction and the cause of the rising water levels in site wells that are west of the shear zone. Water levels have been rising in the site wells west of the shear zone since the first wells were installed in 1996. LM continues to evaluate site data to enhance the SCM and monitor water levels as part of the ongoing groundwater monitoring program, which includes collecting samples for laboratory analysis, measuring depth to groundwater, downloading transducers in site monitoring wells, and downloading the rain gage data (the rain gage was installed in August 2012). The 2015 monitoring program was enhanced to include supplemental activities that included sampling of two wells (H-3 and HS-1) that are not on the Shoal site (Figure 2). The plans for the 2015 monitoring program were specified in the 2015 Sampling Plan that was provided to NDEP (DOE 2015b). Results from the monitoring program are provided below, and results from the supplemental activities are provided in Section 5.0.

4.1 Radioisotope Monitoring

Groundwater samples were collected from wells MV-1, MV-2, MV-3, MV-4, MV-5, HC-1, HC-2d, HC-3, HC-4, HC-5, HC-6, HC-7, and HC-8 during the May 2015 sampling event. Monitoring wells MV-1, MV-2, MV-3, MV-4, MV-5, HC-2d, HC-4, HC-5, HC-7, and HC-8 were purged prior to sampling using dedicated submersible pumps. At least one well casing volume was removed, and field parameters (temperature, pH, and specific conductance) were allowed to stabilize before samples were collected (Appendix A, Table A-1). Samples were collected from wells HC-1, HC-3, and HC-6 using a depth-specific bailer because these wells are not completed with dedicated submersible pumps. The analytical results obtained from the annual sampling were validated in accordance with the *Environmental Procedures Catalog* (LMS/POL/S04325), "Standard Practice for Validation of Environmental Data." A copy of the Data Validation Package is maintained in the LM records and is available on request. Table A-1 in Appendix A presents the final measurements of field parameters and well purge volumes.

Groundwater samples collected as part of the annual monitoring event were analyzed for carbon-14 (^{14}C), iodine-129 (^{129}I), tritium, uranium isotopes, gross alpha, and mass concentrations of uranium as specified in the Short-Term Data Acquisition Plans (DOE 2009, 2011a, 2014), which enhanced the monitoring network defined in the CADD/CAP (DOE/NNSA 2006). The Short-Term Data Acquisition Plan completed in 2009 (DOE 2009) reduced the frequency for analyzing samples for ^{14}C and ^{129}I to every 5 years beginning after the 2010 sampling event. Tritium is the analyte selected as an indicator of contaminant migration from the cavity due to its mobility and abundance in the first 100 years of the post-shot monitoring period. However, because of tritium's short half-life, ^{14}C and ^{129}I are also monitored in support of long-term post-closure monitoring. Gross alpha is included in the analytical suite because elevated concentrations of gross alpha have been detected in the past at the PSA. The U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for gross alpha is exclusive of uranium and radon. Including uranium mass and uranium isotope analyses as part of the analytical suite provides data to demonstrate that the elevated concentrations of gross alpha are from natural sources. Radon is not included in the analytical suite because it volatilizes during analysis and is an insignificant contributor to gross alpha. The EPA MCLs for gross alpha and uranium are 15 picocuries per liter (pCi/L) and 30 micrograms per liter (µg/L), respectively.

The CADD/CAP established regulatory levels for site groundwater of 20,000 pCi/L tritium, 2,000 pCi/L ^{14}C, and 1 pCi/L ^{129}I (DOE/NNSA 2006). These levels are not to be exceeded outside the compliance boundary, which is the modeled contaminant boundary (Figure 2). The CADD/CAP also established laboratory required detection limits (RDLs) to provide a minimum standard for the analytical laboratories to report the radiochemical results. The RDL originally established for tritium (300 pCi/L) was changed to 400 pCi/L to be consistent with the LM laboratory contract requirements. This change was documented in a record of technical change submitted to NDEP and approved in March 2012. The RDLs are higher than what the analytical laboratory provides as their minimum detectable concentrations (MDCs), and when applicable, the results are referenced to the laboratory MDCs. The exceptions are the results for ^{14}C and ^{129}I, which, because of the analytical method, do not report MDCs, and the analytical results are provided and compared to the RDLs established in the CADD/CAP. The RDLs are provided as footnotes to Table 1 and Table 2. The laboratory radiochemical MDCs reported with these data are a priori estimates of the detection capability of a given analytical procedure, not absolute concentrations that can or cannot be detected.

4.2 Radioisotope Results

Table 1 presents a summary of analytical results for ^{14}C, ^{129}I, tritium, uranium, and gross alpha from the samples collected in 2013 through 2015. Tables B-1 and B-2 in Appendix B present analytical results from when the CADD/CAP monitoring program began in 2007 through the present. A time-concentration plot for well HC-4 (Figure 4) presents tritium results from the CADD/CAP monitoring program and sampling events performed by EPA and Desert Research Institute before the CADD/CAP monitoring program began in 2007. Well HC-4 was installed in 1996 and is the only well that has had detections of tritium above the laboratory's MDC using conventional laboratory methods. The presence of tritium in this well is attributed to its proximity to the nuclear detonation (Figure 2). This interpretation of the tritium source is supported by the elevated levels of ^{14}C detected in samples collected from well HC-4 compared to levels in samples from the other monitoring wells (Table 1 and Appendix B, Table B-1). The elevated concentration of ^{14}C in this well is likely the result of its migration in the gas phase near

Table 1. Radioisotope and Chemical Sampling Results, 2013 through 2015

Monitoring Location	Date	Carbon-14 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross Alpha (pCi/L)
MV-1	5/22/2013	NA	NA	<370	21	13.6
	5/27/2014	NA	NA	<320	21	10.7
	5/29/2015	<RDL (1.13×10^{-2})	<RDL (1.6×10^{-11})	<380	21	12.8
MV-2	5/22/2013	NA	NA	<320	22	9.79
	5/27/2014	NA	NA	<320	22	11.6
	5/27/2014[a]	NA	NA	<320	21	10.8
	5/29/2015	<RDL (1.77×10^{-2})	<RDL (1.6×10^{-11})	<380	22	15
	5/29/2015[a]	NA	NA	<370	23	14
MV-3	5/21/2013	NA	NA	<340	8	5.08
	5/21/2013[a]	NA	NA	<380	8	5.84
	5/27/2014	NA	NA	<320	8.3	4.98
	5/28/2015	<RDL (9.75×10^{-3})	<RDL (2.0×10^{-11})	<370	10	4.61
MV-4	5/29/2015	<RDL (3.58×10^{-2})	<RDL (5.0×10^{-12})	<370	63	36.7
MV-5	5/28/2015	<RDL (1.35×10^{-2})	<RDL (1.25×10^{-10})	<370	0.23	<1.4
HC-1	5/22/2013	NA	NA	<340	0.9	3.19
	5/27/2014	NA	NA	<320	0.8	<1.2
	5/26/2015	<RDL (1.81×10^{-2})	<RDL (1.31×10^{-10})	<380	0.87	2.04
HC-2	5/22/2013	NA	NA	<330	100	61.1
	5/27/2014	NA	NA	<320	100	46.8
HC-2d	5/29/2015	<RDL (1.10×10^{-2})	<RDL (<1.4×10^{-11})	<380	3.2	8.54
HC-3	5/22/2013	NA	NA	<350	2.7	0.724
	5/28/2014	NA	NA	<320	0.32	<1.9
	5/26/2015	<RDL (6.24×10^{-3})	<RDL (<2.3×10^{-10})	<380	0.26	<1.2
HC-4	5/21/2013	NA	NA	964	60	35.1
	5/28/2014	NA	NA	700	62	27.8
	5/27/2015	14.6	<RDL (3.35 x 10^{-10})	731	110	60.6
HC-5	5/22/2013	NA	NA	<340	0.40	0.957
	5/28/2014	NA	NA	<320	0.33	<2.2
	5/28/2015	<RDL (2.52×10^{-3})	<RDL (3.2 x 10^{-11})	<380	0.53	<1.7
HC-6	5/22/2013	NA	NA	<360	36	19.1
	5/27/2014	NA	NA	<320	39	16.9
	5/26/2015	<RDL (1.30×10^{-2})	<RDL (5.5×10^{-11})	<370	41	28.7
HC-7	5/21/2013	NA	NA	<370	15	13.8
	5/28/2014	NA	NA	<320	11	6.76
	5/27/2015	<RDL (6.20×10^{-3})	<RDL (<1.3×10^{-11})	<370	16	13.3
HC-8	5/23/2013	NA	NA	<380	0.14	1.24
	5/28/2014	NA	NA	<320	0.23	<1.9
	5/28/2015	<RDL (1.23×10^{-2})	<RDL (1.5×10^{-11})	<380	0.23	2.13

Notes:
[a] Indicates a duplicate sample.
<RDL = below required detection limit with laboratory result in parentheses; the RDLs are 5 pCi/L for ^{14}C, 0.1 pCi/L for ^{129}I, 400 pCi/L for tritium, 50 µg/L for uranium, and 4 pCi/L for gross alpha (DOE/NNSA 2006).

Abbreviations:
NA = not applicable (samples not collected or samples not analyzed).

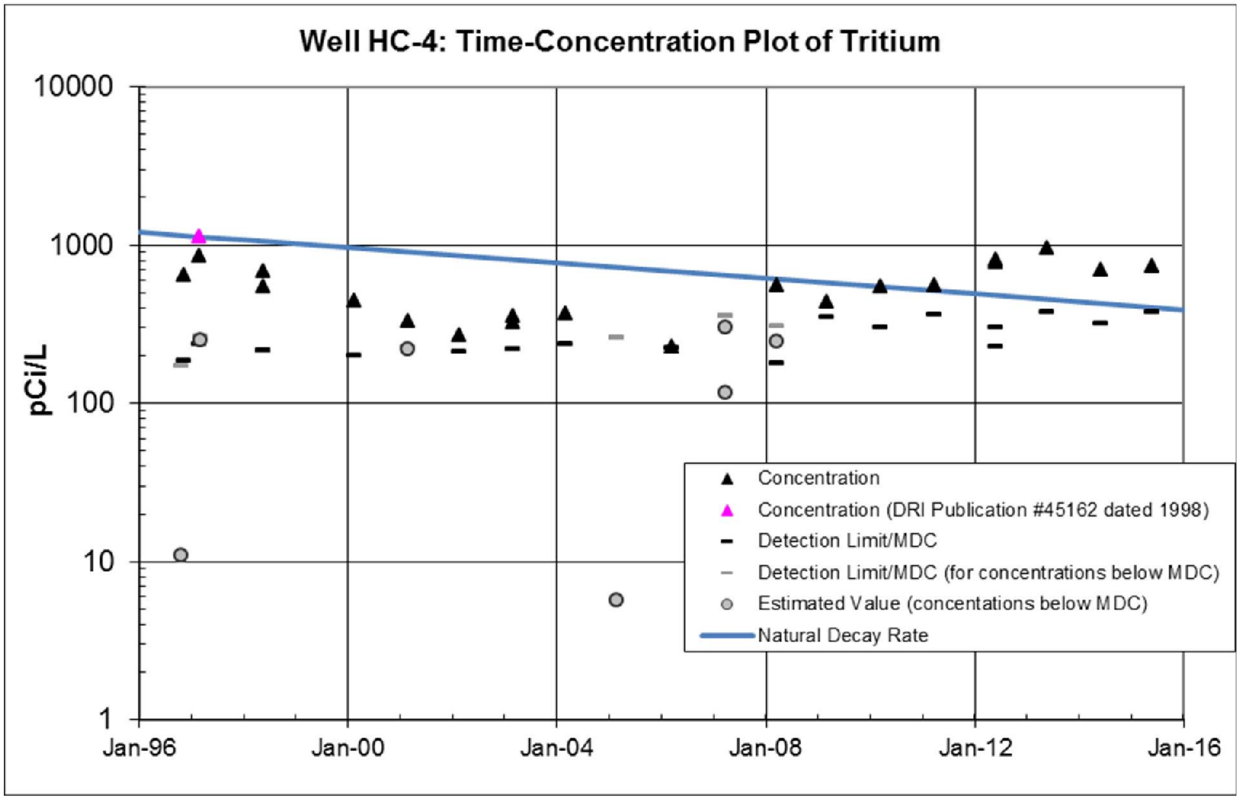

Figure 4. Time-Concentration Plot of Tritium at Well HC-4

the water table, as part of the carbon dioxide molecule, where it dissolved into groundwater in the upper saturated zone near the detonation. The concentrations of ^{14}C in well HC-4 have historically been below the RDL of 5 pCi/L (Tables B-1 in Appendix B) until this sampling event, when the sample had a concentration of 14.6 pCi/L (Table 1). Concentrations of ^{14}C continue to remain below the RDL in samples collected from all the other wells at the site. Concentrations of ^{129}I were below the RDL in the samples collected during this sampling event, which is consistent with historical results. Table B-3 in Appendix B provides the calculations with supporting laboratory data used to convert the ^{14}C data to pCi/L concentrations.

Tritium was detected in well HC-4 at a concentration of 731 pCi/L during the 2015 sampling event but was not detected in any of the remaining wells at the site (Table 1). Tritium levels in well HC-4 (Figure 4) were typically above laboratory MDCs from the mid-1990s until 2006, though some duplicate analyses were below MDCs. Tritium levels had been trending lower and were below the laboratory MDC for the 2005 and 2007 sampling events (Figure 4). Of the two samples analyzed in 2008 (one by EPA and one by Paragon), results were above the MDC for one sample and below the MDC for the other. Since 2008, tritium results have increased from a concentration that was below the laboratory MDC in 2007 to concentrations above the MDC, ranging from 434 pCi/L in 2009 to 964 pCi/L in 2013. The variation in tritium concentrations is related to the different volumes of groundwater removed during the sampling events. The highest tritium concentration of 1,130 pCi/L was from a sample collected in 1997 by Desert Research Institute after approximately 1,100 gallons of groundwater were removed during an aquifer test. From 2007 through 2011 the well purge volumes for this well ranged from 200 to 420 gallons. These volumes were less than one well volume because of a misunderstanding in the well configuration (DOE 2013). The volume of groundwater removed from well HC-4 was increased after the 2011 sampling event to a minimum volume of 700 gallons (1 well volume). The well purge volumes are not available for samples collected prior to 2007, with the exception of the sample collected by Desert Research Institute in 1997.

Analytical results from the 2015 sampling event (Table 1) indicate that samples from wells HC-4, HC-6, and MV-4 had gross alpha activity and uranium mass concentrations above the EPA MCLs of 15 pCi/L and 30 µg/L, respectively. Samples from wells HC-4 and HC-6 have historically had concentrations above the MCLs. The sample results from well HC-4 show an increase in gross alpha and uranium concentrations above the MCLs starting in 2012, with the highest concentrations of gross alpha (60.6 pCi/L) and uranium mass concentrations (110 µg/L) detected during this sampling event. The increase that started in 2012 may be attributed to an increase in the volume of groundwater removed from the well during sampling. Concentrations detected in well HC-6 are consistent with the past results. Well MV-4 was installed in late 2014 and was sampled for the first time during this sampling event, so more data are needed to determine if concentrations above the MCLs will be a continuing trend. Historically, samples from well HC-2 have also had concentrations of gross alpha and uranium mass concentrations above the MCLs, but this well was deepened in 2014, and the new well HC-2d is completed across a deeper interval having sample results below the respective MCLs. The recent sample from well MV-2 had a gross alpha activity of 15 pCi/L, which is at the MCL, but uranium mass concentrations and results from the duplicate sample were below the respective MCLs. Historically, samples from wells MV-1, MV-2, and HC-7 have had gross alpha activity and uranium mass concentrations above the MCLs (Appendix B, Table B-1), but these results have not consistently been above the MCLs. The remaining analytical results for gross alpha and uranium from the 2015 sampling event are below the MCLs and are consistent with previous results.

Bevans et al. (1998) demonstrated that concentrations of uranium are elevated in ambient groundwater in the region surrounding the site. The elevated uranium concentrations are attributed to leaching from granitic bedrock and associated sediments. If the gross alpha values for samples from wells HC-4, HC-6, MV-2, and MV-4 (Table 1) are adjusted by subtracting activities of uranium-234 (^{234}U) and uranium-238 (^{238}U) shown in Table 2, values are less than or near zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples (see example calculation below for adjusted results). Isotope ratios of uranium further support the interpretation of a natural source of uranium in groundwater rather than a nuclear-test-related source. Natural uranium-bearing systems typically have ^{234}U:^{238}U activity ratios near 1 (Cowart and Osmond 1977), which is indicative of secular equilibrium between the two isotopes. Table 2 in Appendix B provides the ^{234}U:^{238}U activity ratios since 2007, which range from 0.91 to 2.77—consistent with activity ratios that are in equilibrium and from a natural uranium source. In contrast, average estimates of radionuclides resulting from nuclear tests at the Nevada National Security Site suggest a residual source term with a ^{234}U:^{238}U activity ratio of 56.25 (Smith 2001).

Example calculation (pCi/L): Gross alpha – ^{234}U – ^{238}U = Adjusted result

HC-4 : 60.6 – 31.2 – 32.9 = −3.5

HC-6 : 28.7 – 15.3 – 13.0 = 0.4

MV-2: 15.0 – 8.37 – 7.15 = −0.52

MV-4: 36.7 – 20.4 – 18.8 = −2.5

Note: Adjusted gross alpha results can be less than 0 due to laboratory measurement uncertainty.

Table 2. Uranium Isotope Sampling Results, 2013 Through 2015

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238
MV-1	5/22/2013	8.72	7.35	1.19
	5/27/2014	7.69	6.42	1.20
	5/29/2015	8.52	7.2	1.18
MV-2	5/22/2013	8.83	7.85	1.12
	5/27/2014	8.38	7.0	1.20
	5/27/2014[a]	8.15	7.16	1.14
	5/29/2015	8.37	7.15	1.17
	5/29/2015[a]	7.73	6.44	1.20
MV-3	5/21/2013	3.6	2.73	1.32
	5/21/2013[a]	3.58	2.84	1.26
	5/27/2014	2.95	2.52	1.17
	5/28/2015	3.54	2.93	1.21
MV-4	5/29/2015	20.4	18.8	1.09
MV-5	5/28/2015	0.119	0.064	1.86
HC-1	5/22/2013	0.425	0.291	1.46
	5/27/2014	0.373	0.25	1.49
	5/26/2015	0.353	0.264	1.34
HC-2	5/22/2013	37.2	37.2	1.00
	5/27/2014	33.4	32.5	1.03
HC-2d	5/29/2015	1.35	1.14	1.18
HC-3	5/22/2013	0.932	0.966	0.96
	5/28/2014	0.102	0.106	0.96
	5/26/2015	0.101	0.078	1.29
HC-4	5/21/2013	22	20.8	1.06
	5/28/2014	21.4	21.5	1.00
	5/27/2015	31.2	32.9	0.95
HC-5	5/22/2013	0.240	0.122	1.97
	5/28/2014	0.255	0.149	1.71
	5/28/2015	0.392	0.307	1.28
HC-6	5/22/2013	15.7	12.6	1.25
	5/27/2014	15.6	13.6	1.15
	5/26/2015	15.3	13	1.18
HC-7	5/21/2013	6.31	5.56	1.13
	5/28/2014	4.1	3.76	1.09
	5/27/2015	5.65	4.72	1.20
HC-8	5/23/2013	0.107	0.041	2.61
	5/28/2014	0.102	0.094	1.09
	5/28/2015	0.155	0.072	2.15

Notes:
[a] Indicates a duplicate sample.
The RDL for uranium isotopes is 0.1 pCi/L (DOE/NNSA 2006).

4.3 Hydraulic Head Monitoring

The groundwater flow system was monitored by measurements of hydraulic head in the onsite wells/piezometers and offsite wells (H-2 and H-3) (Table 3). Piezometers are distinguished from the wells by the notation “PZ”. Heads were recorded every hour by transducers installed in the wells and piezometers. Water levels were measured manually, and the transducers were downloaded in May as part of the sampling and in September and October as part of the water level monitoring. A water level could not be measured in the offsite well H-2 during the October monitoring event because the dirt road used to access the well was eroded from recent rain events. The manual water levels were used with the top-of-casing elevations to convert the transducer data to groundwater elevations. The wells/piezometers were surveyed after the 2014 drilling program to obtain new top-of-casing elevations (Table 3). The new top-of-casing elevations ranged from 2.89 to 3.04 ft lower than what was obtained from the 2006 well survey and included in the previous reports. The offsite wells H-2 and H-3 were not included in the 2006 survey, so previous reports used the ground surface elevations provided in the CADD/CAP. Table 3 presents the well construction information, new top-of-casing elevations, and 2015 manual water level measurements.

The transducers in the wells are non-vented, meaning that they “feel” the weight of overlying water plus the weight of the atmosphere. The battery in the barometric transducer (used to monitor atmospheric pressure at the site) failed, causing a loss of atmospheric pressure data during a period in 2014. The average atmospheric pressure at the site, a single number, was used to correct the transducer data during the period with no atmospheric pressure readings. This results in an apparent increase in variability in water elevations during this time period. The effect is most obvious on the MV-2 piezometer hydrograph (Figure 5) and offsite wells H-2 and H-3 (Figure 7). The MV-2 piezometer has a poor connection to the formation and “feels” the entire weight of the atmosphere. The time periods when atmospheric pressure data are available to correct the MV-2 piezometer data result in a smooth line. For the time period when a single average value is used, the MV-2 piezometer data show the variability in atmospheric pressure superposed on the water level results.

4.4 Hydraulic Head Results

Hydrographs of hydraulic head data from site wells/piezometers from when the CADD/CAP monitoring program was initiated in 2007 are shown in Figure 5, Figure 6, and Figure 7. Hydrographs of hydraulic head data obtained from when the first wells were installed at the site in 1996 to the present are shown in Figures C-1, C-2, and C-3 of Appendix C. Head data collected using a water level tape appear as individual symbols, and data collected with transducers appear as lines due to the recording frequency of every hour or two. The new top-of-casing elevations (Table 3) were used to convert these data to groundwater elevations. The new top-of-casing elevations were projected back to early 2009, which resulted in a downward shift of approximately 3 ft in the groundwater elevations that are shown in the hydrographs provided as Figure 5 and Figure 6. The new well survey data are provided in Appendix D, Table D-2 and Table D-3. The hydrographs are grouped according to the location of the open interval of each well relative to the north-northeast-trending shear zone that transects the site.

Table 3. Monitoring Well Construction Details and 2015 Water Level Measurements

Well/ Piezometer	TOC Elevation (ft amsl)	Water Depth (ft)[a]	Date	Elevation Water (ft amsl)[b]	Elevation TSZ (ft amsl)	Elevation BSZ (ft amsl)	Screen Length (ft)
MV-1	5,254.64	988.75	10/27/15	4,265.89	3,680.24	3,526.43	154
MV-1 PZ	5,254.38	969.65	10/27/15	4,284.73	3,915.47	3,855.47	60
MV-2	5,263.72	998.98	10/27/15	4,264.74	3,442.63	3,271.86	171
MV-2 PZ	5,263.60	983.19[c]	10/27/15	4,280.41[c]	4,074.80	4,015.30	60
MV-3	5,258.60	967.60	10/27/15	4,291.00	3,793.61	3,622.45	171
MV-3 PZ	5,258.24	967.15	10/27/15	4,291.09	4,116.78	4,056.75	60
MV-4	5,370.78	1,082.75	9/14/15	4,288.03	3,969.08	3,809.08	160
MV-4PZ	5,370.41	1,081.55	9/14/15	4,288.86	4,249.08	4,129.08	120
MV-5	5,318.16	1,051.70	9/15/15	4,266.46	3,991.01	3,751.01	240
MV-5PZ	5,317.50	1,050.85	9/15/15	4,266.65	3,616.01	3,586.01	30
HC-1	5,306.32	1,059.35	10/28/15	4,246.97	4,210.44	3,979.64	231
HC-2d	5,343.93	1,105.56	10/27/15	4,238.37	3,925.15	3,685.15	240
HC-3	5,078.57	1,180.77	9/16/15	3,897.80	3,893.20	3,872.70	21
HC-4	5,257.88	1,003.25	10/27/15	4,254.63	4,242.63	3,961.63	281
HC-5	5,244.33	1,369.15	9/16/15	3,875.18	1,857.34	1,711.74	146
HC-6	5,225.73	961.38	9/16/15	4,264.35	4,109.00	3,992.68	116
HC-7	5,226.74	961.55	9/16/15	4,265.19	4,119.23	4,002.10	117
HC-8	5,256.89	1,371.42	9/15/15	3,885.47	2,960.85	2,844.37	116
H-2	4,018.22	110.06	5/26/2015	3,908.16	3,377.06	3,237.06	340[d]
H-3	4,233.95	325.56	10/28/15	3,908.39	3,919.30	3,762.30	157

[a] Manual depth-to-water measurements are not corrected for borehole deviation.
[b] Elevation of water are corrected for borehole deviation.
[c] Indicates the water level/groundwater elevation have not recovered from bailing.
[d] Indicates the well is screened across multiple intervals and the total effective screen length is provided.
BSZ = bottom of open interval; screened, perforated, or open hole.
TOC = top of casing (well/piezometer).
TSZ = top of open interval; screened, perforated, or open hole.
The TOC elevations are provided in U.S. State Plane, Zone Nevada West 2703 coordinate system, with vertical data based on the North American Vertical Datum (NAVD) 1929.

Monitoring locations west of the shear zone (detonation side) include the MV-1, MV-2, MV-3, MV-4, and MV-5 wells and piezometers and wells HC-1, HC-2, HC-2d, HC-4, HC-6, and HC-7 (Figure 5). The monitoring location HC-7 is no longer monitored using a transducer because of its proximity to well HC-6 and similar hydraulic head. Well HC-2 is also no longer monitored because it was deepened during the drilling program completed in late 2014. The new deepened well at this location is identified as well HC-2d (Figure 2) and was added to the network during this monitoring period. The MV-4 and MV-5 wells and piezometers were also added during this monitoring period, but transducer data from well MV-4 were not included in Figure 5 because the transducer was under too much water pressure, which resulted in damage to the transducer and erroneous data. The damaged transducer was replaced during the September monitoring event. The head data from wells MV-5 and HC-2d (Figure 5) show water levels that are recovering from the drilling and development that continued after the drilling program and may not represent static conditions at these locations. Water levels in the onsite wells west of the shear zone continued to rise during the period from July 2014 through July 2015. However, the rate of increase ranging from 0.15 ft in HC-1 to 1.36 ft in HC-4 decreased from previous periods. This decrease is attributed to impacts from the drilling and well development activities and is most evident in wells MV-1, MV-2, and HC-1 which show that water levels in these wells did not increase during the drilling and development program that was completed in late 2014 (Figure 5). Table D-1 in Appendix D shows the annual water level changes in wells west of the shear zone from July 2007 through July 2015.

The hydrograph for the MV-2 piezometer was added to Figure 5 in 2012. The water level in this piezometer was recovering very slowly after its installation, and water was added in several stages until it began to take water, resulting in the current slowly declining water level that is not indicative of the static head level in the formation at its screened interval. The MV-2 piezometer is not well-connected to the formation, either due to the few fractures within the screened interval having a limited extent or consolidation of drilling mud within those fractures. There is some connection because the water level is slowly falling after water was added to the piezometer. The water elevation in the MV-2 piezometer will always be suspect due to the lack of fractures and low permeability of the MV-2 piezometer open interval. It was recommended in the 2014 Groundwater Monitoring Report that this piezometer be transitioned to manual water level readings only when the battery in the installed transducer fails (DOE 2015c).

Monitoring locations east of the shear zone include wells HC-3, HC-5, and HC-8 (Figure 6). Water levels in these wells are 300 to 400 ft lower (Figure 6) than those in wells west of the shear zone (Figure 5). The water levels in wells HC-3, HC-5, and HC-8 have been interpreted as being stable, not increasing or decreasing, except for times when they are sampled. As more data have become available, it is apparent that the water levels in wells HC-5 and HC-8 are declining at the rate of approximately 1 to 2 ft every 10 years (Figure 6). This decline may be the cumulative result of purge water being removed during the sampling events. These wells (HC-5 and HC-8) have submersible electric pumps, and thousands of gallons are removed each sampling event (Table A-1, Appendix A). Well HC-3 is sampled with a bailer, and only a few gallons of water are removed during sampling.

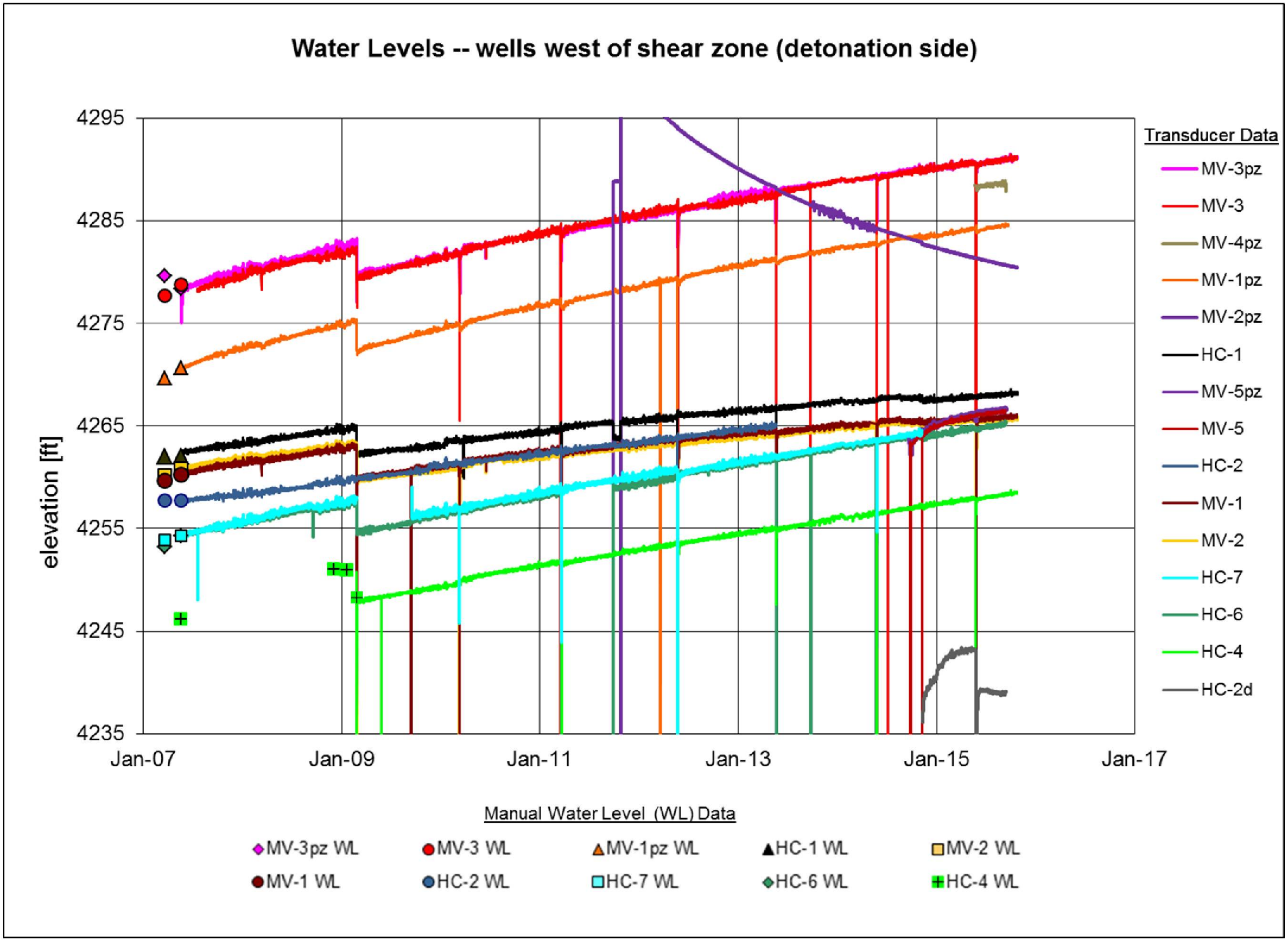

Figure 5. Hydrographs for Wells West of the Shear Zone

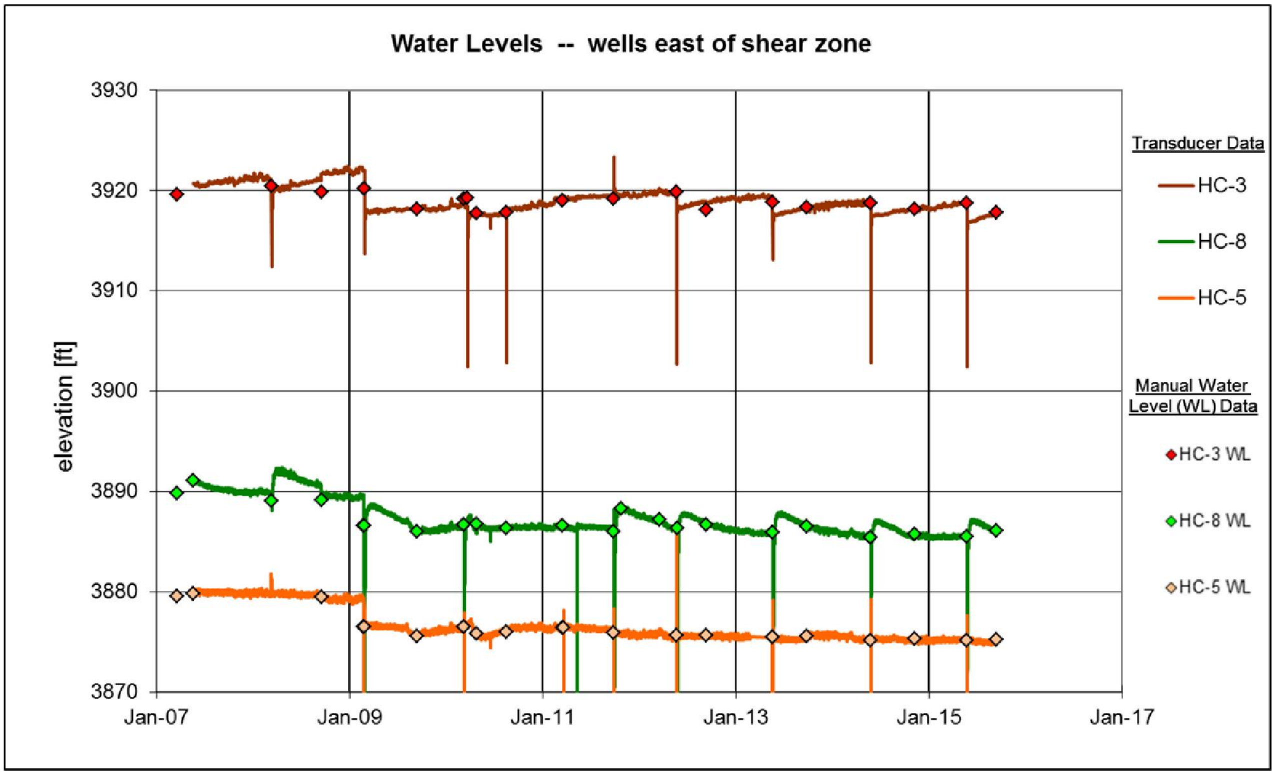

Figure 6. Hydrographs for Wells East of the Shear Zone

Monitoring locations to the west and offsite in Fourmile Flat include wells H-2 and H-3 (Figure 7). Water levels in these wells are 300 to 400 ft lower (Figure 7) than those in wells west of the shear zone at the site (Figure 5) and have been stable since they were installed in 1962. The hydrograph showing head data from wells H-2 and H-3 (Figure 7) was updated using the top-of-casing measure point elevations obtained from the recent well survey. Previously, top-of-casing elevations were not available for these wells, so water levels were converted to elevations using the ground surface elevations provided in the CADD/CAP (DOE/NNSA 2006). The new survey resulted in an upward shift in the head data and a change in the order of the hydrographs with well H-3 now having a higher head than well H-2. Despite the change in elevations, these wells continue to have very similar heads that are within a few inches of each other. The transducer in well H-2 could not be downloaded during this monitoring period because the battery in the transducer failed. The transducer will not be replaced, but water levels will continue to be measured manually in accordance with the 2014 Groundwater Monitoring Report, which recommended transitioning to manual water level measurements in wells H-2 and H-3 when the batteries in the transducers fail (DOE 2015c). A water level could not be measured in well H-2 during the October 2015 monitoring event because the dirt road used to access the well was eroded from recent rain events. As mentioned in Section 4.3, the transducer recording barometric pressure near these wells failed, requiring a static atmospheric pressure correction to the water level data (this is apparent by the increase in variability that started in September 2013).

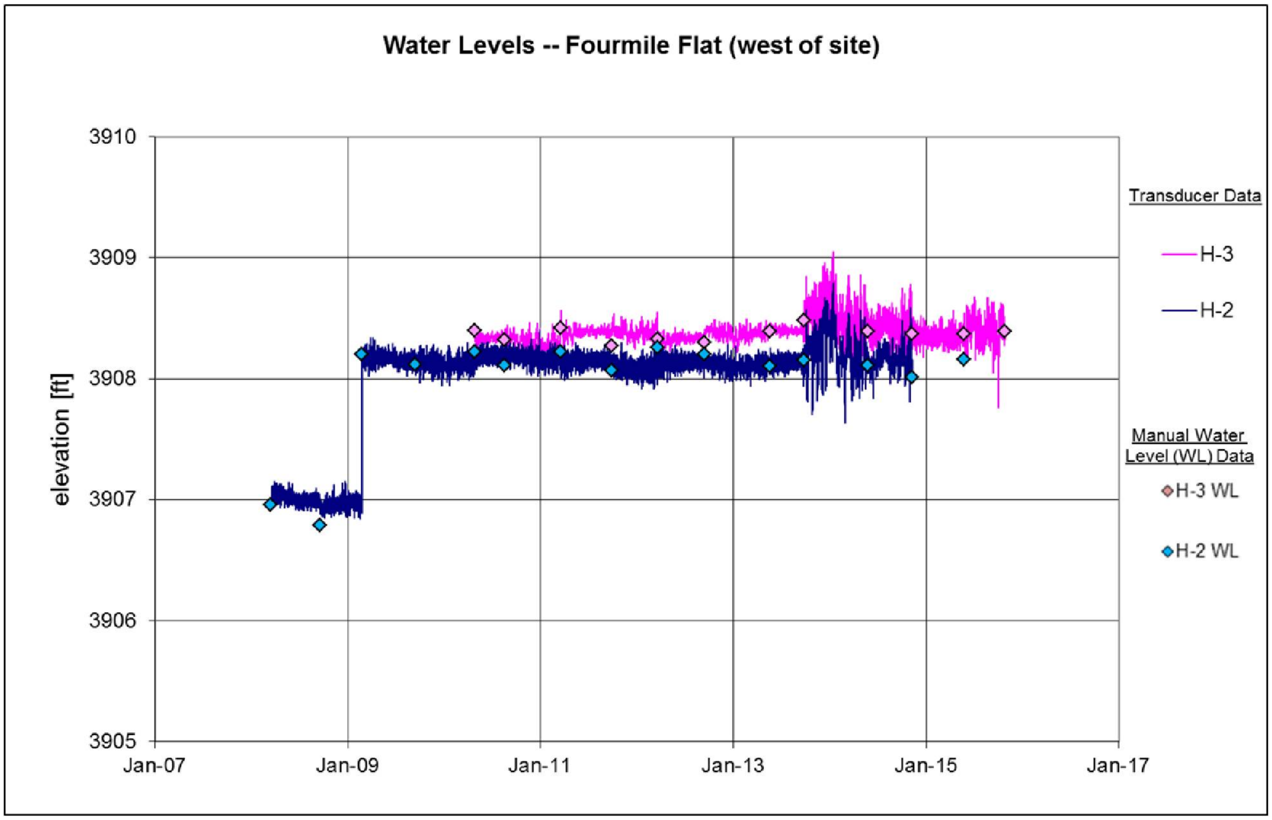

Figure 7. Hydrographs for Wells in Fourmile Flat

4.5 Rain Gage Monitoring Results

A Campbell Scientific tipping bucket rain gage with HOBO data logger was installed on August 8, 2012, to collect precipitation data at the site (Figure 2). The rain gage data logger could not be downloaded during the May 2015 sampling. Several attempts to connect to the data logger were unsuccessful. Communication with the data logger was reestablished by starting a new data collection test, but data from November 2014 through May 2015 could not be recovered. The rain gage was inspected, winterized, and downloaded during the October monitoring event. The data obtained for this monitoring period (May 2015 through October 2015) are presented with the historical data as Figure 8. The total precipitation measured from May 25 through October 28, 2015, was 4.36 inches.

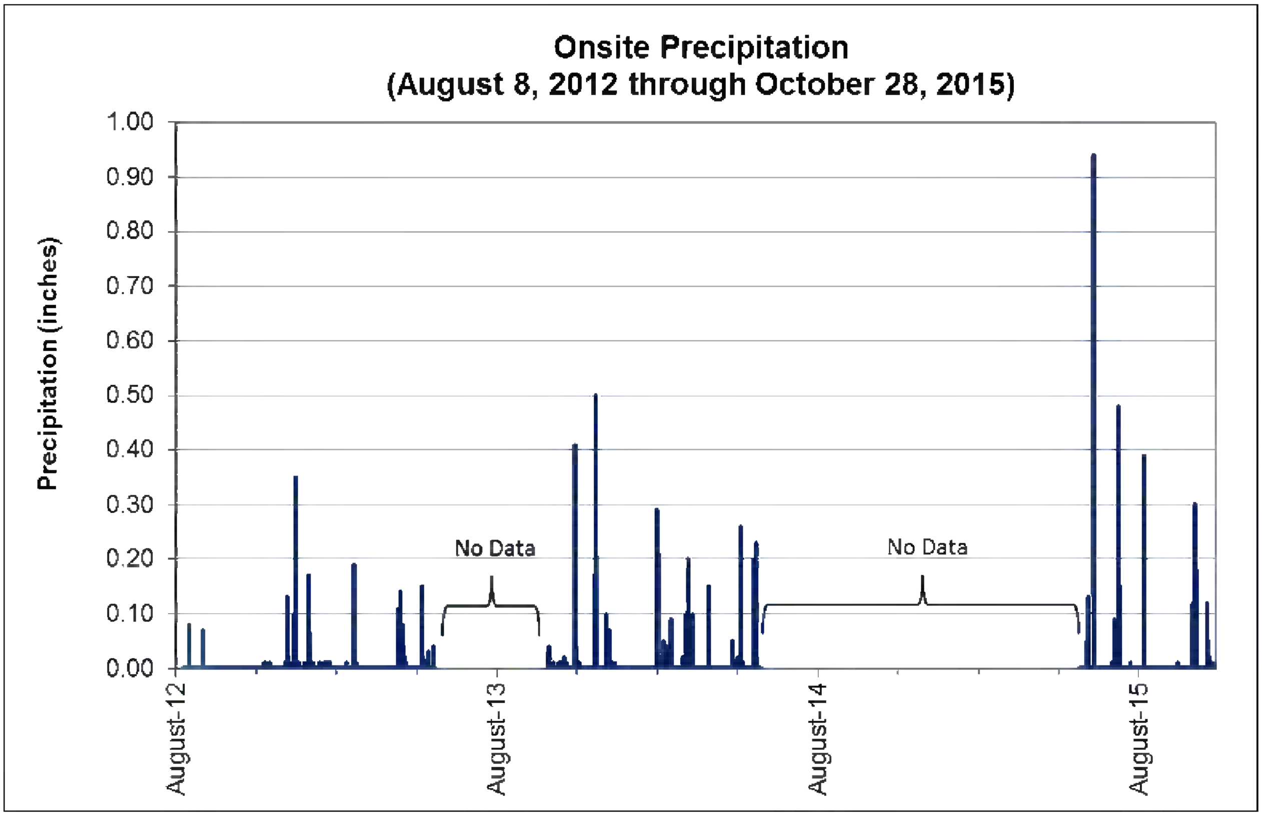

Figure 8. Precipitation Data, August 8, 2012, Through October 28, 2015

5.0 Site Inspection and Supplemental Site Activities

The site was inspected as part of the monitoring events in May, September, and October 2015. The inspection included site roads, wellheads, rain gage, and monument at surface ground zero for signs of damage. It was observed during the May sampling event that the dirt road leading to the site (GZ Canyon Road) was badly eroded from a recent rain event, but the road was repaired before the sampling event was completed on May 29, 2015. The site roads, wellheads, rain gage, and monument were all in good condition at the time of the inspections in September and October 2015. Supplemental activities conducted during the annual sampling event in May included collecting samples from the onsite wells to be analyzed for bromide and collecting samples from the offsite wells H-3 and HS-1 to be analyzed for tritium. Results from the supplemental activities are summarized in the following sections.

5.1 Bromide Analysis

The May 2015 sampling event was enhanced by analyzing samples from the onsite wells for bromide. Bromide was an additive used during recent (2014) and previous drilling programs to evaluate well development. It was also used during a groundwater tracer test between wells HC-6 and HC-7 in 1999. The highest bromide concentration was 6.9 milligrams per liter (mg/L) detected in well HC-6. This well was used as the injection well during the tracer test in 1999. Samples from the new wells MV-4 and MV-5 had bromide concentrations of 3.1 and 4.3 mg/L, respectively. These wells will be further developed, and bromide concentrations will continue to be monitored as part of aquifer tests that are planned at the site. The sample from well HC-3 had a bromide concentration of 2.3 mg/L. This well is constructed with a small-diameter casing (2.4-inch inside diameter) because of difficulties encountered during the installation in 1996 and 1997, which made development difficult. All remaining wells had concentrations that were below 1 mg/L. The results are consistent with the results obtained in 2014. Table E-1 in Appendix E presents a summary of the bromide results from the 2014 and 2015 sampling events.

5.2 Wells H-3 and HS-1

The May 2015 sampling event was enhanced by collecting samples from the offsite wells H-3 and HS-1 to be analyzed for tritium. Well H-3 is in Fourmile Flat approximately 2 miles west of surface ground zero, and well HS-1 is in Fairview Valley approximately 4 miles east of surface ground zero (Figure 2). The sample analytical results indicate that tritium concentrations were below the laboratory MDC. Table E-2 in Appendix E presents a summary of the tritium results from the offsite wells H-3 and HS-1.

6.0 Summary and Recommendations

Analytical results from the 2015 sampling event are consistent with those of previous years with the exception of sample results from well HC-4. This well continues to be the only well with tritium concentrations above the laboratory's MDC. The tritium concentration (731 pCi/L) is consistent with past results and is below the EPA's MCL of 20,000 pCi/L and below the well's highest concentration of 1,130 pCi/L reported in 1998 (Pohll et al. 1998). However, concentrations of gross alpha, uranium, and ^{14}C all increased in the samples from well HC-4 during this sampling event. The concentrations of ^{14}C have historically been below the RDL of 5 pCi/L but increased during this sampling event to a concentration of 14.6 pCi/L. Concentrations of gross alpha and uranium have been above the EPA MCLs in this well since 2012, with the highest concentrations of gross alpha (60.6 pCi/L) and uranium (110 µg/L) detected during the 2015 sampling event. Samples from wells HC-6 and MV-4 also had gross alpha activity and uranium mass concentrations above the EPA MCLs, but were consistent with past results. A sample from well MV-2 had a gross alpha activity that was at the MCL of 15 pCi/L, but the uranium mass concentration and results from the duplicate sample were below the respective MCLs. If the gross alpha values in samples collected from wells HC-4, HC-6, MV-2, and MV-4 are adjusted by subtracting activities of ^{234}U and ^{238}U, the values are near or less than zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples. Isotope ratios of uranium obtained during this monitoring event continue to support the interpretation of a natural source of uranium in groundwater rather than a nuclear-test-related source.

Water level trends obtained from the 2015 water level data are consistent with those of previous years. Water levels in the onsite wells west of the shear zone (detonation side) continued to rise during the period from July 2014 through July 2015. However, the rate of increase ranging from 0.15 ft in HC-1 to 1.36 ft in HC-4 decreased from previous periods. This decrease is attributed to impacts from the drilling and well development activities and is most evident in wells MV-1, MV-2, and HC-1. Water levels in the onsite wells east of the shear zone continue to show that water levels in wells HC-5 and HC-8 are declining at a rate of approximately 1 to 2 ft every 10 years.

The site roads, wellheads, rain gage, and monument at surface ground zero were all in good condition during the site inspections. The total precipitation measured at the site from May 25, through October 28, 2015, was 4.36 inches. No data were available from May 28, 2014, through May 25, 2015, because of problems connecting to the rain gage data logger. Supplemental activities included analyzing samples from the onsite wells for bromide and analyzing samples from the offsite wells H-3 and HS-1 for tritium. Tritium was not detected in the samples from these wells at concentrations above the laboratory MDC. Bromide was detected in wells MV-4, MV-5, HC-3, and HC-6 at concentrations of 3.1, 4.3, 2.3, and 6.9 mg/L, respectively. The concentrations in wells HC-3 and HC-6 were consistent with results from 2014. The new wells MV-4 and MV-5 will be developed further, and bromide concentrations will continue to be monitored as part of aquifer testing planned at these locations.

LM recommends the following:

- Transition to manual water levels only in the piezometer MV-2PZ when the battery in the transducer fails, in accordance with the recommendation provided in the 2014 Groundwater Monitoring Report (DOE 2015c).
- Transition to manual water levels only in well H-3 when the battery in the transducer fails, in accordance with the recommendation provided in the 2014 Groundwater Monitoring Report (DOE 2015c).
- Further develop and monitor bromide concentrations during the aquifer testing at well MV-4.
- Further develop and monitor bromide concentrations during the aquifer testing at well MV-5.

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Appendix A

2015 Monitoring Well Purge Data

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Table A-1. Monitoring Well Purge Data

Monitoring Location	Date Sampled	Purged Volume (gallons)	Temperature (°C)	pH (s.u.)	Specific Conductance (µmhos/cm)	Turbidity (NTU)
MV-1	5/29/2015	940	22.65	8.07	701	1.27
			22.81	8.15	709	2.12
			22.71	8.17	708	1.92
MV-2	5/29/2015	1190	22.85	8.08	470	3.44
			23.66	8.25	472	0.88
			23.85	8.27	474	1.06
MV-3	5/28/2015	892	22.08	8.34	740	0.80
			21.99	8.35	746	2.06
			22.06	8.34	744	2.72
MV-4	5/29/2015	770	19.01	8.22	799	31.7
			20.07	8.20	801	12.9
			20.47	8.17	780	10.8
MV-5	5/28/2015	621	20.22	11.48	1809	0.90
			20.27	11.54	1818	1.09
			20.30	11.61	1786	0.77
HC-1	5/26/2015	1.59	NA	7.56	401	71.9
HC-2d	5/29/2015	970	21.61	8.28	612	13.8
			21.73	8.26	625	18.5
			21.81	8.24	624	21.0
HC-3	5/26/2015	1.59	NA	7.65	640	216
HC-4	5/27/2015	952	22.32	7.68	757	19.5
			22.18	7.70	754	16.5
			23.34	7.69	758	18.2
HC-5	5/28/2015	2710	26.64	8.44	997	2.02
			26.33	8.45	990	3.08
			25.99	8.47	990	1.59
HC-6	5/26/2015	1.59	NA	7.44	1154	9.92
HC-7	5/27/2015	430	21.65	7.99	1401	1.31
			21.64	7.98	1414	1.27
			21.57	7.93	1408	1.65
HC-8	5/28/2015	1380	28.65	8.34	849	5.74
			29.48	8.34	846	3.53
			29.51	8.32	846	2.13
HS-1	5/27/2015	1555	25.49	7.87	453	2.88
H-3	5/28/2015	0.20	20.46	8.73	5677	68

µmhos/cm = micromhos per centimeter
NA = not analyzed
NTU = Nephelometric Turbidity Units
s.u. = Standard Unit

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Appendix B

Analytical Data: 2007 through Present and Carbon-14 Calculations

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Table B-1. Radioisotope and Chemical Sampling Results

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross alpha (pCi/L)
MV-1	3/21/2007	<RDL (5.83×10^{-3})[a]	<RDL (7.3×10^{-11})	<359	42	25.6
	3/21/2007	NA	NA	NA	41[b]	21.5[b]
	3/11/2008	<RDL (2.49×10^{-2})	<RDL (1.90×10^{-10})	<180	21	14.0
	2/26/2009	<RDL (1.95×10^{-2})	<RDL (1.05×10^{-10})	<350	21	12.6
	3/11/2010	<RDL (1.93×10^{-2})	<RDL (7.8×10^{-11})	<300	21	11.3
	3/22/2011	NA	NA	<350	25	16.6
	3/22/2011[c]	NA	NA	<360	25	14.3
	5/25/2012	NA	NA	<300	22	14.3
	5/22/2013	NA	NA	<370	21	13.6
	5/27/2014	NA	NA	<320	21	10.7
	5/29/2015	<RDL (1.13×10^{-2})	<RDL (1.6×10^{-11})	<380	21	12.8
MV-2	3/21/2007	<RDL (1.77×10^{-2})[a]	<RDL (8.3×10^{-11})	<361	34	16.3
	3/21/2007	NA	NA	NA	34[b]	17.3[b]
	3/11/2008	<RDL (2.44×10^{-2})	<RDL (2.95×10^{-10})	<180	23	11.1
	2/26/2009	<RDL (2.13×10^{-2})	NR	<360	24	12
	3/11/2010	<RDL (3.31×10^{-2})	<RDL (1.65×10^{-10})	<300	21	13.8
	3/22/2011	NA	NA	<350	23	9.92
	5/24/2012	NA	NA	<300	22	10.6
	5/22/2013	NA	NA	<320	22	9.79
	5/27/2014	NA	NA	<320	22	11.6
	5/27/2014[c]	NA	NA	<320	21	10.8
	5/29/2015	<RDL (1.77×10^{-2})	<RDL (1.6×10^{-11})	<380	22	15
	5/29/2015[c]	NA	NA	<370	23	14
MV-3	3/21/2007	<RDL (5.90×10^{-3})[a]	<RDL (1.35×10^{-10})	<357	14	10.2
	3/21/2007	NA	NA	NA	14[b]	9.57[b]
	3/11/2008	<RDL (1.37×10^{-2})	<RDL (1.8×10^{-10})	<320	3.8	2.11
	2/26/2009	<RDL (8.37×10^{-3})	<RDL (1.07×10^{-10})	<360	3.8	<1.5
	3/12/2010	<RDL (1.29×10^{-2})	<RDL (6.5×10^{-11})	<300	4.2	2.63
	3/22/2011	NA	NA	<350	5.8	4.98
	5/25/2012	<RDL (1.06×10^{-2})	NA	<300	7	2.72
	5/21/2013	NA	NA	<340	8	5.08
	5/21/2013[c]	NA	NA	<380	8	5.84
	5/27/2014	NA	NA	<320	8.3	4.98
	5/28/2015	<RDL (9.75×10^{-3})	<RDL (2.0×10^{-11})	<370	10	4.61
MV-4	5/29/2015	<RDL (3.58×10^{-2})	<RDL (5.0×10^{-12})	<370	63	36.7
MV-5	5/28/2015	<RDL (1.35×10^{-2})	<RDL (1.25×10^{-10})	<370	0.23	<1.4

Table B-1 (continued). Radioisotope and Chemical Sampling Results

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross alpha (pCi/L)
HC-1	3/21/2007	<RDL (1.52×10^{-2})[a]	<RDL (9.6×10^{-11})	<355	3.3	3.9
	3/21/2007	NA	NA	NA	3.4[b]	4.46[b]
	3/11/2008	<RDL (2.35×10^{-2})	<RDL (4.9×10^{-11})	<320	4.8	12.5
	2/26/2009	<RDL (2.01×10^{-2})	NR	<360	1.4	<1.4
	3/24/2010	<RDL (3.18×10^{-2})	<RDL (1.19×10^{-10})	<310	3.3	4.93
	3/22/2011	NA	NA	<360	1.6	2.19
	5/23/2012	<RDL (1.23×10^{-2})	NA	<300	1.1	<0.75
	5/22/2013	NA	NA	<340	0.9	3.19
	5/27/2014	NA	NA	<320	0.8	<1.2
	5/26/2015	<RDL (1.81×10^{-2})	<RDL (1.31×10^{-10})	<380	0.87	2.04
HC-2	3/24/2010	<RDL(1.90×10^{-2})	<RDL (2.5×10^{-11})	<300	140	63.8
	3/22/2011	NA	NA	<360	120	197
	5/22/2012	NA	NA	<300	110	64.5
	5/22/2013	NA	NA	<330	100	61.1
	5/27/2014	NA	NA	<320	100	46.8
HC-2d	5/29/2015	<RDL (1.10×10^{-2})	<RDL (<1.4×10^{-11})	<380	3.2	8.54
HC-3	3/24/2010	<RDL (2.37×10^{-2})	<RDL (5.41×10^{-9})	<300	4.3	2.57
	3/22/2011	NA	NA	NA	NA	NA
	5/23/2012	<RDL (1.45×10^{-2})	NA	<300	2	0.283
	5/22/2013	NA	NA	<350	2.7	0.724
	5/28/2014	NA	NA	<320	0.32	<1.9
	5/26/2015	<RDL (6.24×10^{-3})	<RDL (<2.3×10^{-10})	<380	0.26	<1.2
HC-4	3/21/2007	<RDL (0.565)[a]	<RDL (3.24×10^{-10})	<359	0.75	1.41
	3/21/2007	NA	NA	NA	0.85[b]	1.93[b]
	3/21/2007[c]	<RDL (0.436)[a]	<RDL (3.42×10^{-10})	<359	0.69	1.75
	3/21/2007[c]	NA	NA	NA	0.81[b]	<0.876[b]
	3/11/2008	<RDL (2.06)	<RDL (2.15×10^{-10})	555	4.5	2.88
	2/26/2009	<RDL (3.20)	<RDL (6.0×10^{-12})	434	2.0	<1.4
	3/11/2010	<RDL (2.93)	<RDL (3.87×10^{-10})	544	6.4	1.79[b]
	3/23/2011	NA	NA	554	8.9	3.82
	5/24/2012[c]	NA	NA	774	46	16.7
	5/24/2012	<RDL (2.50)	NA	803	46	22.9
	5/21/2013	NA	NA	964	60	35.1
	5/28/2014	NA	NA	700	62	27.8
	5/27/2015	14.6	<RDL (3.35×10^{-10})	731	110	60.6
HC-5	3/11/2010	<RDL (5.11×10^{-3})	<RDL (1.1×10^{-11})	<300	0.48	<1.5
	3/23/2011	NA	NA	<360	0.45	<2.1
	5/23/2012	<RDL (3.70×10^{-3})	NA	<300	0.49	0.349
	5/22/2013	NA	NA	<340	0.40	0.957
	5/28/2014	NA	NA	<320	0.33	<2.2
	5/28/2015	<RDL (2.52×10^{-3})	<RDL (3.2×10^{-11})	<380	0.53	<1.7

Table B-1 (continued). Radioisotope and Chemical Sampling Results

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross alpha (pCi/L)
HC-6	3/24/2010	<RDL (1.14×10^{-2})	<RDL (5.6×10^{-11})	<300	35	25.7
	3/23/2011	NA	NA	<360	37	20.4
	5/23/2012	<RDL (1.16×10^{-2})	NA	<300	38	14.1
	5/22/2013	NA	NA	<360	36	19.1
	5/27/2014	NA	NA	<320	39	16.9
	5/26/2015	<RDL (1.30×10^{-2})	<RDL (5.5×10^{-11})	<370	41	28.7
HC-7	3/11/2010	<RDL (5.31×10^{-3})	<RDL (3.0×10^{-11})	<300	7.4	5.77
	3/23/2011	NA	NA	<360	13	10.6
	5/23/2012	NA	NA	<300	41	23.9
	5/21/2013	NA	NA	<370	15	13.8
	5/28/2014	NA	NA	<320	11	6.76
	5/27/2015	<RDL (6.20×10^{-3})	<RDL (<1.3×10^{-11})	<370	16	13.3
HC-8	3/10/2010	<RDL (9.63×10^{-3})	<RDL (1.3×10^{-11})	<300	0.25	<1.3
	3/23/2011	NA	NA	NA	NA	NA
	5/25/2012	NA	NA	<300	0.2	0.454
	5/23/2013	NA	NA	<380	0.14	1.24
	5/28/2014	NA	NA	<320	0.23	<1.9
	5/28/2015	<RDL (1.23×10^{-2})	<RDL (1.5×10^{-11})	<380	0.23	2.13

Notes:

[a] Estimated based on sample volume of 200 milliliters for 2007 samples.

[b] Indicates the sample was filtered.

[c] Indicates a duplicate sample.

<RDL = below required detection limit with laboratory result in parentheses; the RDLs are 5 pCi/L for ^{14}C, 0.1 pCi/L for ^{129}I, 400 pCi/L for tritium, 50 µg/L for uranium, and 4 pCi/L for gross alpha (DOE/NNSA 2006).

Abbreviations:

NA = not applicable (samples not collected or samples not analyzed).

NR = not run, because sample bottle was broken during shipment to the laboratory.

Table B-2. Uranium Isotope Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238
MV-1	3/21/2007	16.8[a]	14.2[a]	1.18[a]
	3/21/2007	15.4	12.6	1.22
	3/11/2008	7.35	6.2	1.19
	2/26/2009	8.75	6.98	1.25
	3/11/2010	9.06	7.64	1.19
	3/22/2011	10.8	8.89	1.21
	3/22/2011[b]	10.4	8.77	1.19
	5/25/2012	8.14	6.81	1.20
	5/22/2013	8.72	7.35	1.19
	5/27/2014	7.69	6.42	1.20
	5/29/2015	8.52	7.2	1.18
MV-2	3/21/2007	13.6[a]	11.4[a]	1.19[a]
	3/21/2007	13.2	11.7	1.13
	3/11/2008	8.95	7.89	1.13
	2/26/2009	8.64	6.7	1.29
	3/11/2010	9.66	8.32	1.16
	3/22/2011	10.1	8.65	1.17
	5/24/2012	7.9	7.01	1.13
	5/22/2013	8.83	7.85	1.12
	5/27/2014	8.38	7.0	1.20
	5/27/2014[b]	8.15	7.16	1.14
	5/29/2015	8.37	7.15	1.17
	5/29/2015[b]	7.73	6.44	1.20
MV-3	3/21/2007	4.64[a]	4.37[a]	1.06[a]
	3/21/2007	5.47	4.68	1.17
	3/11/2008	1.47	1.17	1.25
	2/26/2009	1.33	0.998	1.33
	3/12/2010	1.7	1.42	1.20
	3/22/2011	2.55	2.2	1.16
	5/25/2012	2.49	2.3	1.08
	5/21/2013	3.6	2.73	1.32
	5/21/2013[b]	3.58	2.84	1.26
	5/27/2014	2.95	2.52	1.17
	5/28/2015	3.54	2.93	1.21
MV-4	5/29/2015	20.4	18.8	1.09
MV-5	5/28/2015	0.119	0.064	1.86

Table B-2 (continued). Uranium Isotope Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238
HC-1	3/21/2007	1.28[a]	1.19[a]	1.08[a]
	3/21/2007	1.4	1.19	1.18
	3/11/2008	1.84	1.51	1.21
	2/26/2009	0.572	0.385	1.49
	3/24/2010	1.24	1.05	1.18
	3/22/2011	0.9	0.609	1.48
	5/23/2012	0.401	0.35	1.15
	5/22/2013	0.425	0.291	1.46
	5/27/2014	0.373	0.25	1.49
	5/26/2015	0.353	0.264	1.34
HC-2	3/24/2010	45.1	45.3	0.996
	3/22/2011	45.2	45.3	0.998
	5/22/2012	38.1	36.2	1.05
	5/22/2013	37.2	37.2	1.00
	5/27/2014	33.4	32.5	1.03
HC-2d	5/29/2015	1.35	1.14	1.18
HC-3	3/24/2010	1.16	1.21	0.96
	3/22/2011	NA	NA	NA
	5/23/2012	0.678	0.668	1.01
	5/22/2013	0.932	0.966	0.96
	5/28/2014	0.102	0.106	0.96
	5/26/2015	0.101	0.078	1.29
HC-4	3/21/2007	0.349[a]	0.308[a]	1.12[a]
	3/21/2007[b]	0.313[a]	0.33[a]	0.95[a]
	3/21/2007	0.293	0.305	0.96
	3/21/2007[b]	0.31	0.336	0.92
	3/11/2008	1.53	1.63	0.94
	2/26/2009	0.654	0.722	0.91
	3/11/2010	2.27[a]	1.95[a]	1.16[a]
	3/23/2011	2.69	2.86	0.941
	5/24/2012[b]	14.4	15.1	0.95
	5/24/2012	14.2	14.8	0.96
	5/21/2013	22	20.8	1.06
	5/28/2014	21.4	21.5	1.00
	5/27/2015	31.2	32.9	0.95
HC-5	3/11/2010	0.295	0.173	1.71
	3/23/2011	0.264	0.117	2.26
	5/23/2012	0.227	0.126	1.80
	5/22/2013	0.240	0.122	1.97
	5/28/2014	0.255	0.149	1.71
	5/28/2015	0.392	0.307	1.28

Table B-2 (continued). Uranium Isotope Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238
HC-6	3/24/2010	14.4	12.2	1.18
	3/23/2011	15.4	13.5	1.14
	5/23/2012	14.4	12.2	1.18
	5/22/2013	15.7	12.6	1.25
	5/27/2014	15.6	13.6	1.15
	5/26/2015	15.3	13	1.18
HC-7	3/11/2010	3.43	3.08	1.11
	3/23/2011	5.9	4.78	1.23
	5/23/2012	16.1	13.9	1.16
	5/21/2013	6.31	5.56	1.13
	5/28/2014	4.1	3.76	1.09
	5/27/2015	5.65	4.72	1.20
HC-8	3/10/2010	0.187	0.101	1.85
	3/23/2011	NA	NA	NA
	5/25/2012	0.153	0.0553	2.77
	5/23/2013	0.107	0.041	2.61
	5/28/2014	0.102	0.094	1.09
	5/28/2015	0.155	0.072	2.15

[a] Indicates the sample was filtered.
[b] Indicates a duplicate sample.
NA = not applicable (samples not collected or samples not analyzed).

Table B−3. Carbon-14 Radioisotope Calculation Data

Well ID	Sample Date	Mass Concentration C (mg/L)	Fraction mc	±1 s	Carbon-14 (pMC)	Carbon-14 (pCi/L)[a]
HC-1	5/26/2015	8.1	0.3639	0.0018	36.39	1.81E-02
HC-2d	5/29/2015	8.5	0.2104	0.0012	21.04	1.10E-02
HC-3	5/26/2015	3.9	0.2606	0.0013	26.06	6.24E-03
HC-4	5/27/2015	19.2	124.1100	0.3600	12,411	1.46E+01
HC-5	5/28/2015	4.5	0.0914	0.0010	9.14	2.52E-03
HC-6	5/26/2015	12.95	0.1633	0.0010	16.33	1.30E-02
HC-7	5/27/2015	10.1	0.1000	0.0010	10	6.20E-03
HC-8	5/28/2015	9.85	0.2034	0.0017	20.34	1.23E-02
MV-1	5/29/2015	8.5	0.2174	0.0012	21.74	1.13E-02
MV-2	5/29/2015	8.6	0.3349	0.0015	33.49	1.77E-02
MV-3	5/28/2015	6.65	0.2391	0.0012	23.91	9.75E-03
MV-4	5/29/2015	15.45	0.3778	0.0017	37.78	3.58E-02
MV-5	5/28/2015	4.05	0.5451	0.0021	54.51	1.35E-02

[a] Modern C-14 standard at 1950 AD has a specific activity of 13.6 disintegrations per minute per gram.
C = 2.27×10^{-4} disintegrations per second per milligram C.
1 µCi = 3.7×10^{4} dps; therefore, modern C-14 standard at 1950 AD has a specific activity of 6.135×10^{-9} µCi/mg.
pMC = percent modern carbon; mc = modern carbon; s = standard deviation

Example activity calculation (HC-1)

$$8.1\frac{mg\ C}{1\ L}\left(0.3639\frac{mg\ MC}{mg\ C}\right)\left(6.135*10^{-9}\frac{\mu Ci}{mg\ MC}\right)\left(1*10^{6}\frac{pCi}{\mu Ci}\right)=1.81*10^{-2}\ \frac{pCi}{L}$$

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Appendix C

Hydraulic Head Data: 1996 through Present

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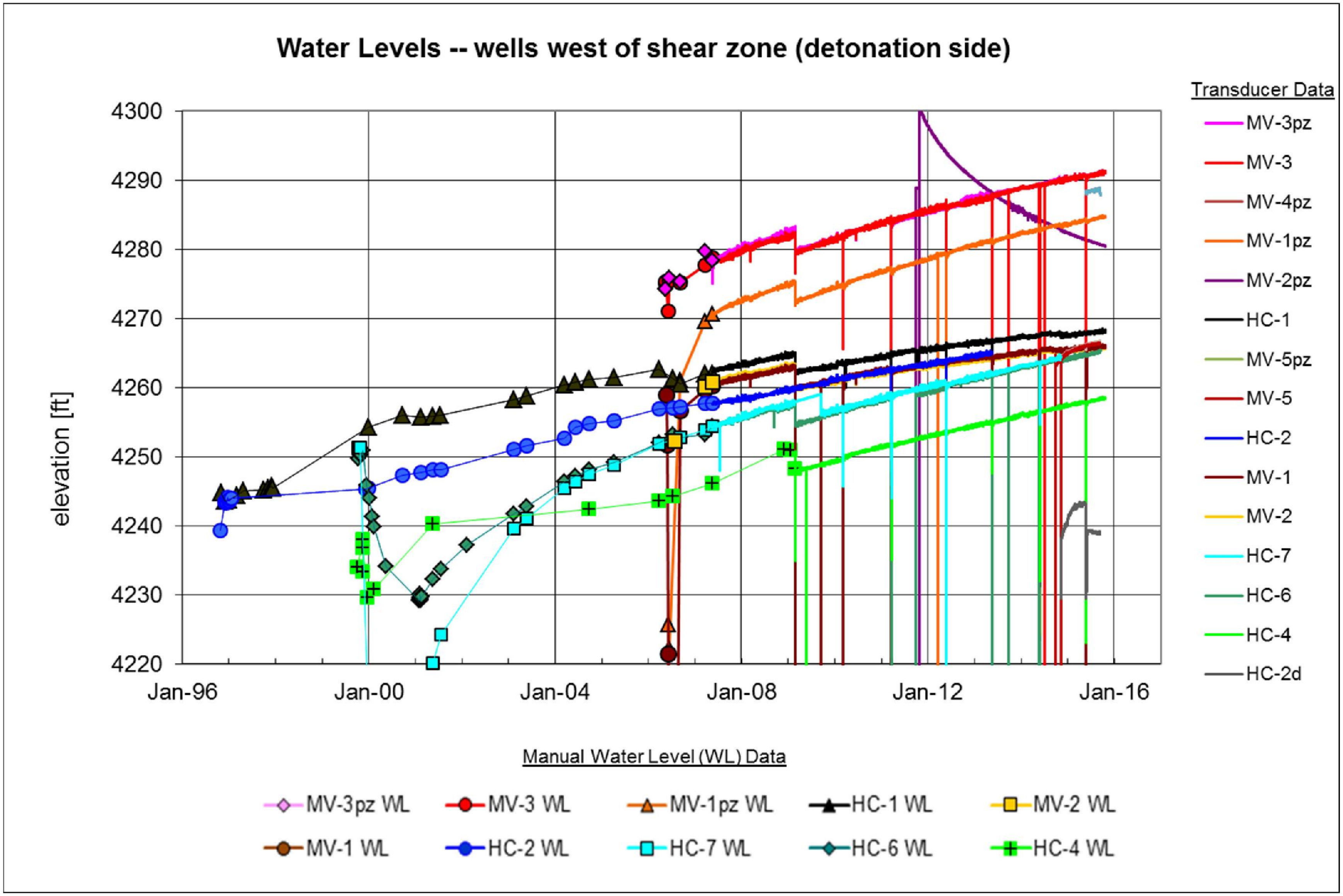

Figure C-1. Hydrographs for Wells West of the Shear Zone (expanded scale on Y axis)

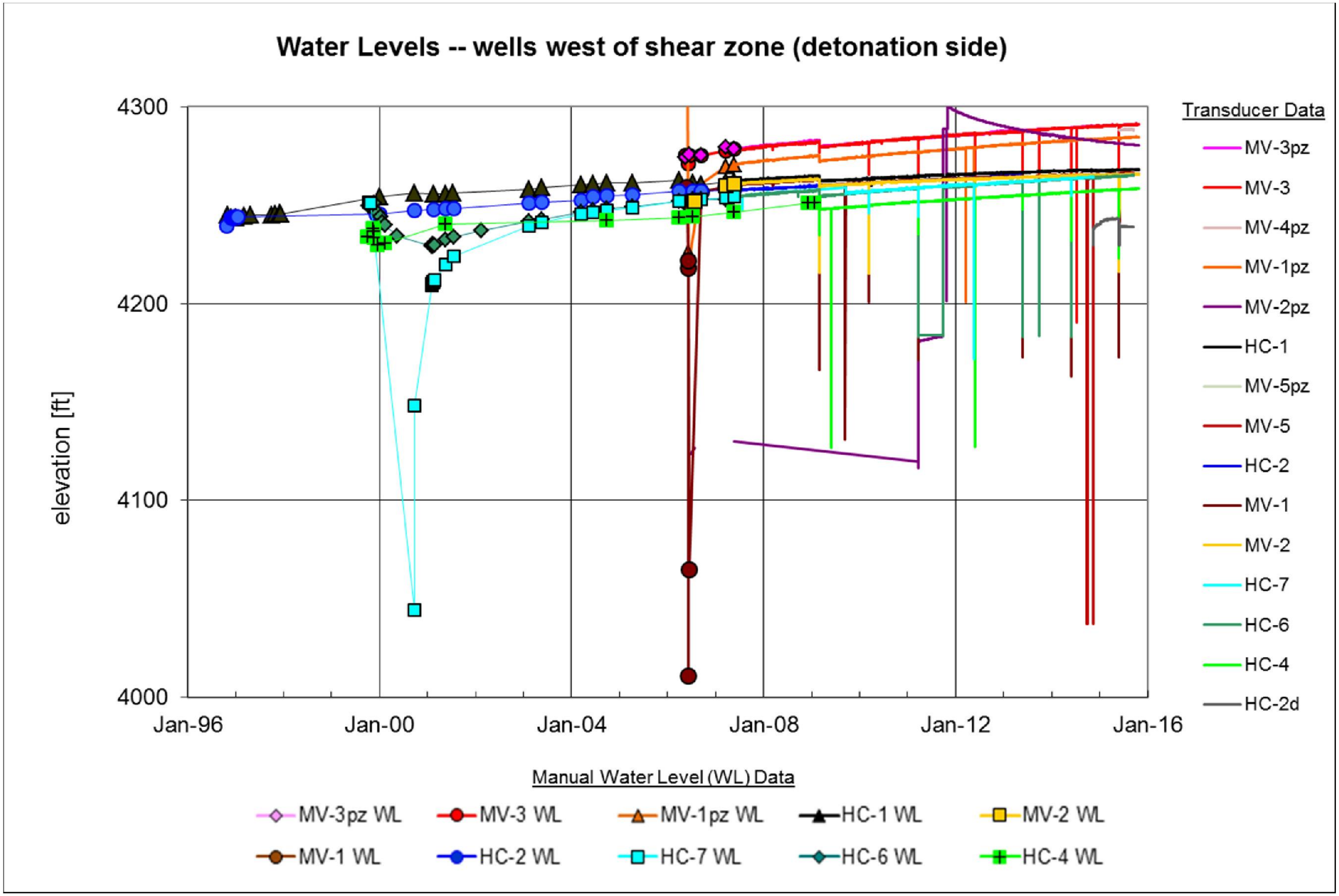

Figure C-2. Hydrographs for Wells West of the Shear Zone

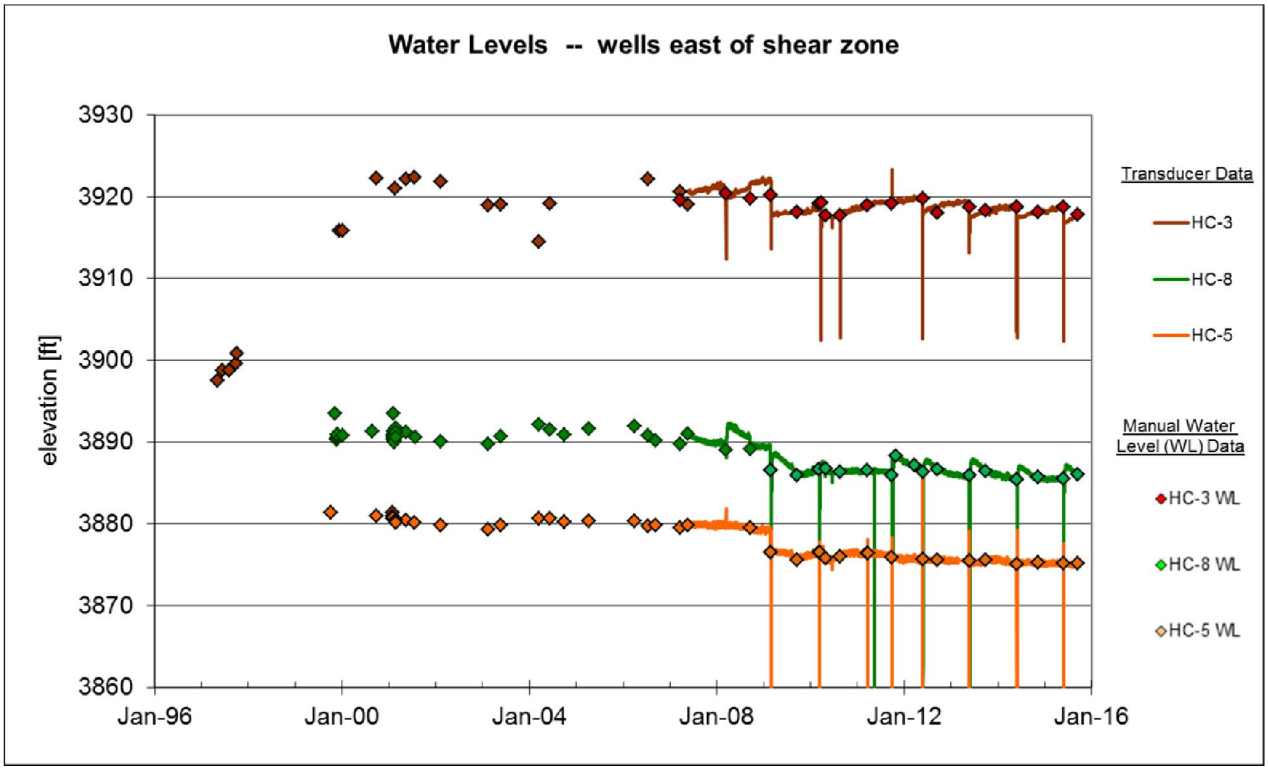

Figure C-3. Hydrographs for Wells East of the Shear Zone

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Appendix D

Annual Water Level Changes in Wells West of Shear Zone: July 2007 through July 2014 and 2014 Well Survey Data: NAD27/NAVD29 and NAD83/NAVD88

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Table D-1. Annual Water Level Changes in Wells West of the Shear Zone

Date Range (month/year)	Wells/Piezometers West of Shear Zone (water level change in feet/year)										
	MV-1	**MV-1PZ**	**MV-2**	**MV-2PZ**	**MV-3**	**MV-3PZ**	**HC-1**	**HC-2**	**HC-2d**	**HC-4**	**HC-6**	**HC-7**
7/2007–7/2008	1.52	2.67	1.37	NM	2.71	2.57	1.40	1.09	NM	NM	2.00	2.28
7/2008–7/2009	1.40	2.48	0.95	NM	2.16	2.20	1.32	1.40	NM	NM	1.96	NM
7/2009–7/2010	1.38	2.48	1.36	NM	2.54	2.23	1.49	1.49	NM	2.12	1.79	NM
7/2010–7/2011	0.79	1.80	0.76	NM	1.82	1.67	1.21	1.02	NM	1.46	NM	1.64
7/2011–7/2012	1.23	2.10	0.94	NM	1.78	1.91	1.08	1.24	NM	1.72	NM	1.35
7/2012–7/2013	0.67	1.71	0.85	NM	1.65	1.84	0.72	1.34	NM	1.35	1.44	1.59
7/2013–7/2014	1.03	1.63	0.82	NM	1.43	1.41	0.94	NM	NM	1.52	1.64	1.57
7/2014–7/2015	0.16	1.21	0.26	NM	1.28	1.13	0.15	NM	NM	1.36	1.29	NM

NM = Not measured, because transducer data were not available.

Table D-2. 2014 Wellhead Survey Data in NAD 27/NAVD29

Location Identification	Northing (ft)	Easting (ft)	Top of Casing Elevation (ft)
HC-1	1621982.53	557638.31	5,306.32
HC-2d	1620263.52	555725.90	5,343.93
HC-3	1627471.94	548930.97	4,233.95
HC-4	1619615.99	557465.96	5,257.88
HC-5	1619022.26	558042.18	5,244.33
HC-6	1619278.73	557949.55	5,225.73
HC-7	1619203.43	558018.70	5,226.74
HC-8	1618755.26	558369.59	5,256.89
MV-1	1621056.50	557878.03	5,254.64
MV-1PZ	1621056.85	557878.41	5,254.38
MV-2	1621327.59	557731.38	5,263.72
MV-2PZ	1621327.87	557730.91	5,263.60
MV-3	1621150.26	558232.20	5,258.60
MV-3PZ	1621149.66	558231.86	5,258.24
MV-4	1618968.08	555950.40	5,370.78
MV-4PZ	1618967.70	555950.26	5,370.41
MV-5	1620801.32	556441.09	5,318.16
MV-5PZ	1620801.38	556440.79	5,317.50
H-3	1627471.94	548930.97	4,233.95
H-2	1631710.87	543189.22	4,018.22

PZ = piezometer
d = indicates the well was deepened from the originally completed depth
Top of casing elevations represent the measuring point location for determining depth to groundwater and are provided in feet above mean sea level.

Coordinate System: U.S. State Plane, Zone Nevada West 2703
Horizontal Datum: North American Datum 1927
Vertical Datum: North American Vertical Datum 1929

Table D-3. 2014 Wellhead Survey Data in NAD 83/NAVD 88

Location Identification	Northing (ft)	Easting (ft)	Top of Casing Elevation (ft)
HC-1	14745325	2682030	5,309.69
HC-2d	14743606	2680117	5,347.32
HC-3	14742221	2684784	5,081.96
HC-4	14742959	2681857	5,261.27
HC-5	14742365	2682433	5,247.73
HC-6	14742621	2682341	5,229.12
HC-7	14742546	2682410	5,230.13
HC-8	14742098	2682761	5,260.29
MV-1	14744399	2682269	5,258.01
MV-1PZ	14744400	2682270	5,257.75
MV-2	14744670	2682123	5,267.09
MV-2PZ	14744671	2682122	5,266.97
MV-3	14744493	2682624	5,261.97
MV-3PZ	14744492	2682623	5,261.61
MV-4	14742311	2680342	5,374.18
MV-4PZ	14742310	2680342	5,373.81
MV-5	14744144	2680832	5,321.54
MV-5PZ	14744144	2680832	5,320.88
H-3	14750815	2673322	4,237.25
H-2	14755054	2667581	4,021.47

PZ = piezometer
d = indicates the well was deepened from the originally completed depth
Top of casing elevations represent the measuring point location for determining depth to groundwater and are provided in feet above mean sea level.

Coordinate System: U.S. State Plane, Zone Nevada West 2703
Horizontal Datum: North American Datum 1983
Vertical Datum: North American Vertical Datum 1988

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Appendix E

Bromide Results from 2014 and 2015 Sampling Events and 2015 Tritium Results from Offsite Wells H-3 and HS-1

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Table E-1. Bromide Sample Results from 2014 and 2015 Sampling Events

Monitoring Location	Sample Date	Bromide (mg/L)
MV-1	5/27/2014	0.60
	5/29/2015	0.55
MV-2	5/27/2014	0.25
	5/27/2014[a]	0.26
	5/29/2015	0.20
	5/29/2014[a]	0.20
MV-3	5/27/2014	0.89
	5/28/2015	0.87
MV-4	5/29/2015	3.10
MV-5	5/28/2015	4.30
HC-1	5/27/2014	0.40
	5/26/2015	0.32
HC-2	5/27/2014	0.42
HC-2d	5/29/2015	0.29
HC-3	5/28/2014	2.50
	5/26/2015	2.30
HC-4	5/28/2014	0.67
	5/27/2015	0.54
HC-5	5/28/2014	0.27
	5/28/2015	0.26
HC-6	5/27/2014	7.00
	5/26/2015	6.90
HC-7	5/28/2014	0.96
	5/27/2015	0.81
HC-8	5/28/2014	0.43
	5/28/2015	0.35

[a] Indicates a duplicate sample
mg/L = milligrams per liter

Table E-2. Tritium Sample Results from Wells H-3 and HS-1

Monitoring Location	Sample Date	Tritium (pCi/L)
H-3	5/28/2015	<370
HS-1	5/27/2015	<370

pCi/L = picocuries per liter

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Appendix F

NDEP Correspondence with Record of Review and Response to Comments

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NEVADA DIVISION OF
ENVIRONMENTAL PROTECTION

STATE OF NEVADA
Department of Conservation & Natural Resources
Brian Sandoval, Governor
Leo M. Drozdoff, P.E., Director
David Emme, Administrator

February 17, 2016

Mr. Mark Kautsky
Site Manager
U. S. Department of Energy
Office of Legacy Management
2597 Legacy Way
Grand Junction, CO 81503

RE: Submittal of Draft 2015 Groundwater Monitoring Report: Project Shoal Area: Subsurface Corrective Action Unit (CAU) 447
Federal Facility Agreement and Consent Order

Dear Mr. Kautsky:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities (NDEP) has reviewed the U. S. Department of Energy, Office of Legacy Management's *Draft 2015 Groundwater Monitoring Report Project Shoal Area: Subsurface CAU 447,* received on January 12, 2016 and Tables 1 and B-1 received by e-mail on February 10, 2016. While this letter serves as a Notice of Completion for the January 15, 2016 Milestone Deadline for the "Draft 2015 Groundwater Monitoring Report," the NDEP has the following comments on the Report which should be addressed in the Final version of the Report:

1) Page 10, Section 4.2, Radioisotope Results, Second paragraph, third sentence: The 2005 data mentioned in the sentence are not included in Figure 4. Please include the data or explain why it is not there.

2) Page 15, Section 4.4, Hydraulic Head Results, first paragraph, fifth sentence: "… transducer data from well MV-4 were not included in Figure 5 because the data were in error." Please explain in the text how the data were in error.

3) Section 4.4, Hydraulic Head Results: Figures 5, 6, and 7 (on pages 15, 16, and 17 respectively), have point measurement indicators of diamonds, squares and circles. There are no labels on these figures that indicate the meaning of the various symbols. Please add this information to the figures.

4) Page 15, Section 4.4, Hydraulic Head Results, Figure 5: It is difficult to distinguish the various hydrographs for the wells. It would make it easier if the figure was a full page in landscape view. Please consider making this change.

5) Section 6.0: It is suggested that the four (4) Recommendations stated throughout the Report also be combined at the end of this Section as bulleted items. The four (4) Recommendations are found at: (1) Page 16, First Partial Paragraph, Last Sentence; (2) Page 17, Eighth Sentence, which is a carry-over recommendation from 2014; and (3) and

(4) Page 19, Section 5.1, Seventh Sentence (which are also restated in the last sentence in Section 6.0 of the Draft Report).

6) General Statement: Insert the recompleted Tables 1 and B-1 in their proper place.

If you would like to discuss these comments, please contact me at 702-486-2850, ext. 232, or Mark McLane at ext. 226.

Sincerely,

Christine D. Andres
Chief
Bureau of Federal Facilities

CDA/MM

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Navarro Central Files
R. Findley, Navarro, Grand Junction, CO

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Record of Review

Due Date	Review No.	Project	Type of Review
3/18/2016	1	Shoal	Draft Report - Technical Review

Document Title and\or Number and Revision
Draft 2015 Groundwater Monitoring Report, Project Shoal Area: Subsurface Corrective Action Unit 447

LMS/SHL/S13448

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Reviewers' Recommendation

- ☐ Release Without Comment
- ☐ Consider Comments
- ☒ Resolve Comments and Reroute for Review

Comments provided in NDEP letter dated February 22, 2016

Signature of Reviewer and Date

- ☒ Comments Have Been Addressed

Mark Kautsky
2016.04.10 18:07:36 -06'00'

Signature of Author and Date

- ☐ Comment Resolution Satisfactory
- ☐ Comment Resolution Unsatisfactory

Mark McLane 04/11/2016

Signature of Reviewer and Date

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
1	Page 10, Section 4.2, Radioisotope Results, Second paragraph, third sentence: The 2005 data mentioned in the sentence are not included in Figure 4. Please include the data or explain why it is not there.	Y	1	Figure 4 was revised by increasing the range on the vertical axis from 10 to 10,000 pCi/L to 1 to 10,000 pCi/L to allow the tritium result 5.7 pCi/L, which was below the laboratory MDC in 2005, to be plotted on the chart.
2	Page 15, Section 4.4, Hydraulic Head Results, first paragraph, fifth sentence: "···transducer data from well MV-4 were not included in Figure 5 because the data were in error." Please explain in the text how the data were in error.	Y	2	The sentence was revised as follows: "…transducer data from well MV-4 were not included in Figure 5 because the transducer was under too much water pressure, which resulted in damage to the transducer and erroneous data." The following sentence was added after the revised sentence to document that the transducer was replaced. "The damaged transducer was replaced during the September monitoring event."
3	Section 4.4, Hydraulic Head Results: Figures 5, 6, and 7 (on pages 15, 16, and 17 respectively), have point measurement indicators of diamonds, squares and circles. There are no labels on these figures that indicate the meaning of the various symbols. Please add this information to the figures.	Y	3	Figures 5, 6, and 7 have been revised to include a separate legend for the manual water level measurement symbols. This change was also applied to Figures C-1, C-2, and C-3 provided in Appendix C.

Record of Review (continuation)

Review No.	Project

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
4	Page 15, Section 4.4, Hydraulic Head Results, Figure 5: It is difficult to distinguish the various hydrographs for the wells. It would make it easier if the figure was a full page in landscape view. Please consider making this change.	Y	4	The page layout for Figure 5 was changed so it could be displayed as a full page in landscape view. This change was also applied to Figures C-1 and C-2 in Appendix C.
5	Section 6.0: It is suggested that the four (4) Recommendations stated throughout the Report also be combined at the end of this Section as bulleted items. The four (4) Recommendations are found at: (1) Page 16, First Partial Paragraph, Last Sentence; (2) Page 17, Eighth Sentence, which is a carry-over recommendation from 2014; and (3) and (4) Page 19, Section 5.1, Seventh Sentence (which are also restated in the last sentence in Section 6.0 of the Draft Report).	Y	5	The sentences with the recommendations (1) and (2) were reworded to be consistent with the original recommendation referenced in the 2014 Groundwater Monitoring Report. The following recommendations have been added to the end of Section 6.0: LM recommends the following: • Transition to manual water levels only in the piezometer MV-2PZ when the battery in the transducer fails, in accordance with the recommendation provided in the 2014 Groundwater Monitoring Report (DOE 2015c). • Transition to manual water levels only in well H-3 when the battery in the transducer fails, in accordance with the recommendation provided in the 2014 Groundwater Monitoring Report (DOE 2015c). • Further develop and monitor bromide concentrations during the aquifer testing at well MV-4. • Further develop and monitor bromide concentrations during the aquifer testing at well MV-5.
6	General Statement: Insert the recompleted Tables 1 and B-1 in their proper place.	Y	6	Tables 1 and B-1 were inserted in the report as requested.

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