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2019 Groundwater Monitoring Report Project Shoal Area: Subsurface Corrective Action Unit 447

February 2021

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Abbreviations

amsl	above mean sea level
^{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
HC	hydrologic characterization
^{129}I	iodine-129
LM	Office of Legacy Management
MCL	maximum contaminant level
m/d	meters per day
MDC	minimum detectable concentration
mg/L	milligrams per liter
µg/L	micrograms per liter
MV	monitoring/validation
NDEP	Nevada Division of Environmental Protection
pCi/L	picocuries per liter
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 is a site in Nevada where an underground nuclear test was conducted in 1963. It later came to be known as the Shoal, Nevada, Site. Surface contamination at the site has been remediated, but investigation of groundwater contamination resulting from the test is still in the corrective action process. Annual sampling and water-level monitoring are conducted as part of the subsurface corrective action strategy, which has focused on revising the site conceptual model and evaluating the adequacy of the monitoring well network. It has also included enhancements to the monitoring well network to address uncertainties in the groundwater flow direction and the cause of rising water levels in site wells west of the shear zone since the first hydrologic characterization (HC) wells were installed in 1996. Revisions to the site conceptual model and enhancements to the monitoring strategy were provided to Nevada Division of Environmental Protection (NDEP) in the *Addendum to: Corrective Action Decision Document/Corrective Action Plan (CADD/CAP) for the Subsurface Corrective Action Unit 447 Shoal, Nevada, Site*. NDEP approved the addendum to the CADD/CAP, which included an expanded contaminant boundary and compliance boundary for the site.

Laboratory results from the 2019 sampling event are consistent with those of previous years. Well HC-4 continues to be the only well with tritium concentrations above the laboratory's minimum detectable concentration. The tritium concentrations of 516 picocuries per liter (pCi/L), with a duplicate result of 667 pCi/L, are consistent with past results and are below the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 20,000 pCi/L and below the well's highest concentration of 1130 pCi/L reported in 1998. Samples from well HC-4 also had gross alpha particle activity and uranium mass concentrations above the EPA MCLs of 15 pCi/L and 30 µg/L, respectively. This is consistent with previous results dating back to 2012, when it was determined that the minimum volume of groundwater was not being removed before sampling because of a misunderstanding in the well configuration.

The sample from the monitoring/validation (MV) well MV-2 had a gross alpha activity above the MCL, but uranium mass concentrations were below the respective MCL. Samples from wells HC-6 and MV-4 also had gross alpha particle activity and uranium mass concentrations above EPA MCLs, but those were consistent with past results. The elevated gross alpha particle activity and uranium mass concentrations in these three wells are interpreted as being from natural sources, because if the gross alpha particle values are adjusted by subtracting activities of uranium-234 (^{234}U) and uranium-238 (^{238}U), the values are less than zero, indicating that uranium accounts for all or nearly all gross alpha particle activity in these samples. This interpretation is further supported by ^{234}U:^{238}U activity ratios that are consistent with activity ratios that are in equilibrium and from a natural uranium source rather than a nuclear test–related source.

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1.0 Introduction

This report presents the 2019 groundwater monitoring results collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Project Shoal Area Subsurface Corrective Action Unit (CAU) 447 in Churchill County, Nevada. Responsibility for environmental site restoration of the Project Shoal Area, now known as the Shoal, Nevada, Site, 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)* (FFACO 1996, as amended) and all applicable Nevada Division of Environmental Protection (NDEP) policies and regulations. The corrective action strategy for the site includes monitoring to verify that all the interpreted potential transport pathways are adequately monitored. This report summarizes results from the annual groundwater monitoring program conducted through September 2019.

2.0 Site Location and Background

The Shoal site is south of U.S. Highway 50, approximately 30 miles southeast of Fallon, Nevada (Figure 1). The U.S. Department of Defense and the U.S. Atomic Energy Commission 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 1211 feet (ft) (DOE 2015a). A cavity created by the test collapsed shortly after the detonation and formed a rubble chimney (Hazleton 1965).

Site deactivation and postshot drilling activities began on October 28, 1963. 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 the Shoal site. 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 (CAU 416) included three corrective action sites that consisted of a mud pit with drilling mud impacted by petroleum hydrocarbons, a muck pile of granite remaining from the excavation of the emplacement shaft, and housekeeping areas containing 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 Corrective Action Unit 416, Project Shoal Area* (DOE 1998), also called the Closure Report. NDEP approved the Closure Report on February 13, 1998, stating that no postclosure monitoring is required, and no land use restrictions apply at CAU 416 (NDEP 1998).

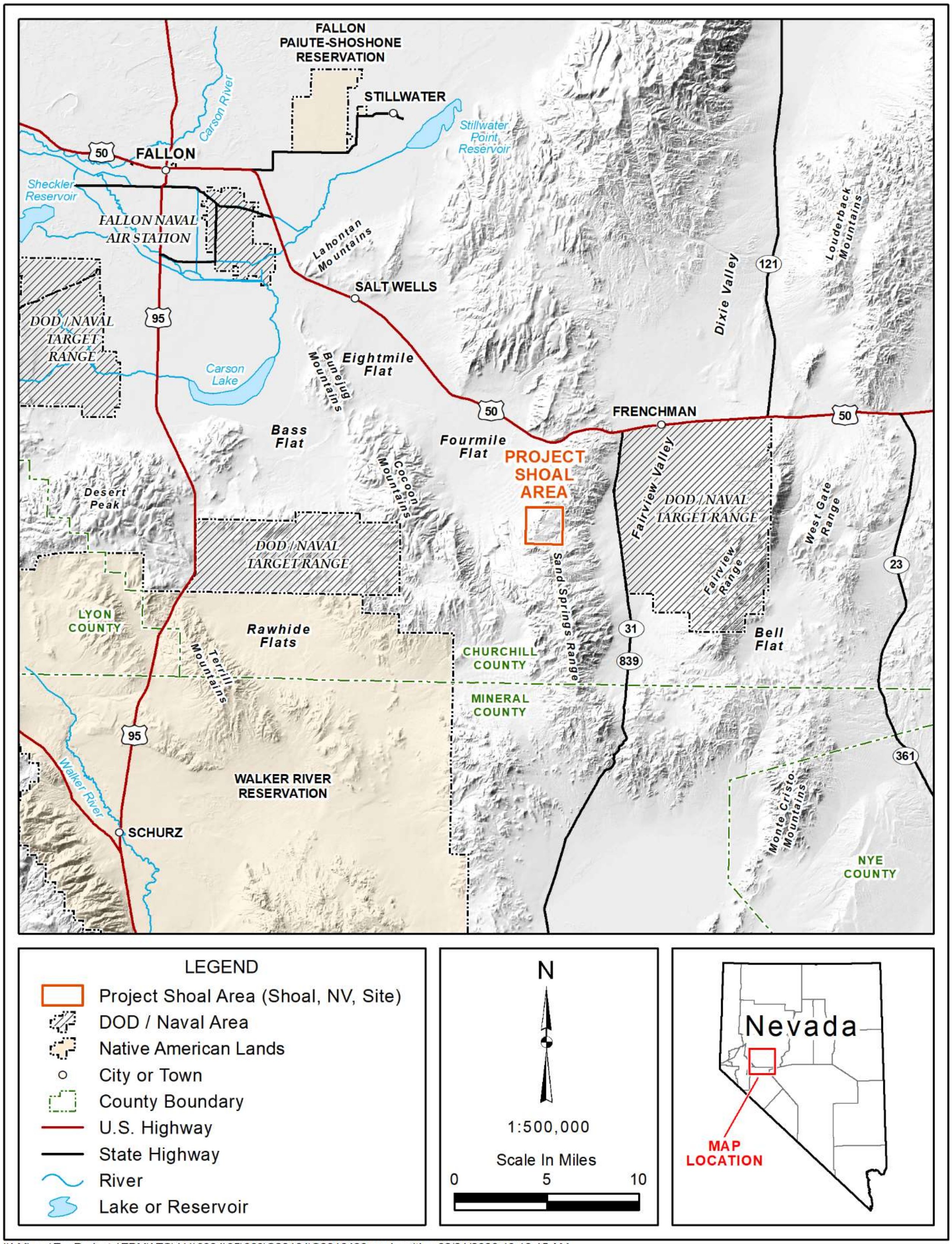

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Figure 1. Location of the Project Shoal Area

The corrective action process for the subsurface, CAU 447, has not been completed, and there is 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 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 is a probabilistic forecast of the maximum extent over 1000 years of radionuclide transport where test-related radionuclides in groundwater outside the boundary have a likelihood of 5% or less of exceeding the radiological standards of the Safe Drinking Water Act. NDEP approved the contaminant boundary as the compliance boundary in a January 19, 2005, letter (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 for Corrective Action Unit 447: Project Shoal Area, Subsurface*, *Nevada* (DOE 2006), also called the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP).

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 groundwater flow and transport model results (Figure 2). The site conceptual model (SCM) is being reevaluated to address inconsistencies with the numerical model forecasts 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 a few feet per year during the time they have been monitored, beginning with the installation of the first hydrologic characterization (HC) wells in the late 1990s at the site. Water levels were not monitored at the site (except in the adjacent valleys) before these wells were installed. Pursuant to the FFACO (FFACO 1996, as amended), LM began implementing a new corrective action strategy for the site in 2009. Figure 2 shows the site and well locations.

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 (DOE 2009). The completed geophysical program included seismic and electromagnetic surveys. As part of the evaluation of data obtained from the surveys, there was a technical exchange meeting in March 2011 among the geophysicists who performed the surveys (Lee Liberty from Boise State University and Jim Hasbrouck from Hasbrouck Geophysics Inc.), 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 the surface geophysics report provided the basis for developing the new data acquisition plan that was submitted to NDEP in October 2011 (DOE 2011a).

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. Laboratory, hydrologic, and geologic data obtained from historical reports were reviewed and compared with more recent data; additional geophysical data were collected to help identify geologic structures that might influence groundwater flow at the site. These data were assembled for three-dimensional visualization (DOE 2011a).

The 2014 data acquisition plan included enhancements to the monitoring well network by installing two monitoring wells (MV-4 and MV-5) and deepening the existing well HC-2, now identified as HC-2d (DOE 2014). Monitoring wells MV-4 and MV-5 were dually completed with a well and piezometer so vertical and horizontal gradients could be determined. The well casing in the existing well HC-2 was removed, and the borehole was deepened to allow the installation of the new well, HC-2d (Figure 2). The new wells and the deepened well were completed with dedicated electric submersible pumps to facilitate the collection of groundwater samples and for aquifer testing. Aquifer testing began in late 2015 but the testing program was not completed until mid-2017, after a malfunctioning pump in well MV-5 had been replaced. Analysis of aquifer test data from these wells (MV-4, MV-5, and HC-2d) obtained hydraulic conductivities that ranged from about 0.09 meters per day (m/d) in MV-5 to about 0.0003 m/d in HC-2d (DOE 2019a). The new wells and existing wells/piezometers were surveyed to obtain new top-of-casing (TOC) measuring point elevations after the drilling program. The TOC 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. 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. Results from the 2014 drilling program are provided in the well completion report (DOE 2015b). The well survey data are provided in the 2014 groundwater monitoring report (DOE 2015c). A hydrologic evaluation report summarizes the aquifer test results (DOE 2019a).

In July 2019, an addendum to the CADD/CAP was finalized. It summarizes the corrective action activities that were completed after the original CADD/CAP was approved in 2006 (DOE 2019b). This includes updates made to the SCM that provides for three potential groundwater flow scenarios and changes to the contaminant and compliance boundaries for the site. The three flow scenarios provide a generalized conceptualization of the groundwater flow system as it relates to the potential fate and transport of radionuclides from the detonation zone. Enhancements made to the monitoring well network in 2006 and 2014 are designed to monitor the interpreted potential transport pathways of the three conceptual groundwater flow scenarios. To account for any potential uncertainty in these groundwater flow scenarios, the compliance boundary and contaminant boundary were expanded. The decision to expand these boundaries was supported by aquifer test data from the wells (MV-4, MV-5, and HC-2d) installed in 2014 that fall within the hydraulic conductivity distribution used in the numerical model. These data reviewed with historical aquifer test data from other onsite wells support the extent, though not the direction, of the numerical model-predicted contaminant boundary. Given that water levels in site wells on the detonation side of the shear zone continue to rise, and at differing rates, a prevailing horizontal flow direction cannot be identified at this time. The expanded compliance boundary and contaminant boundary are designed to account for the transient nature of the groundwater flow system and for any varying lateral groundwater flow directions (DOE 2019b). The contaminant boundary is truncated to the east at depth by the low-permeability shear zone, which is a barrier to groundwater flow (Figure 2). The NDEP approved the CADD/CAP Addendum and changes made to the SCM, compliance boundary, and contaminant boundary in the letter dated August 2019 (NDEP 2019).

3.0 Geologic and Hydrologic Setting

The Shoal site 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 6751 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 5250 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 50º W and N 30º E and are vertical to steeply dipping. Several dikes of varying composition are predominantly along 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).

Groundwater is encountered beneath the site (near surface ground zero and west of the shear zone) at depths ranging from about 950–1100 ft, and it 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 about 1500 ft east of surface ground zero (Figure 2 and Figure 3) is interpreted as a barrier to groundwater flow on the basis of disparate water 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 3 is a cross section showing the well screen zones, potentiometric surface, and shear zone that crosses the site.

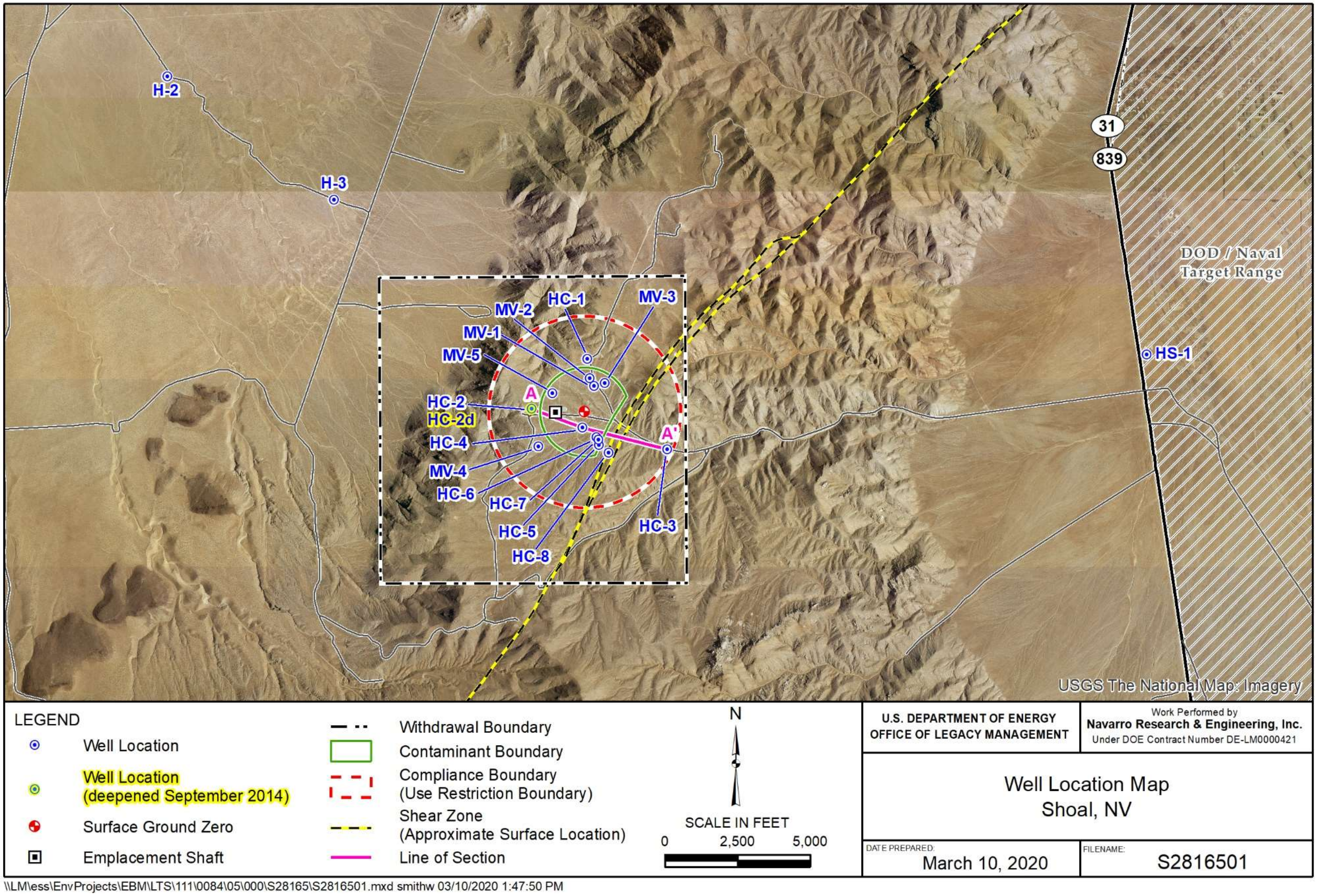


Figure 2. Well Locations at the Shoal, Nevada, Site

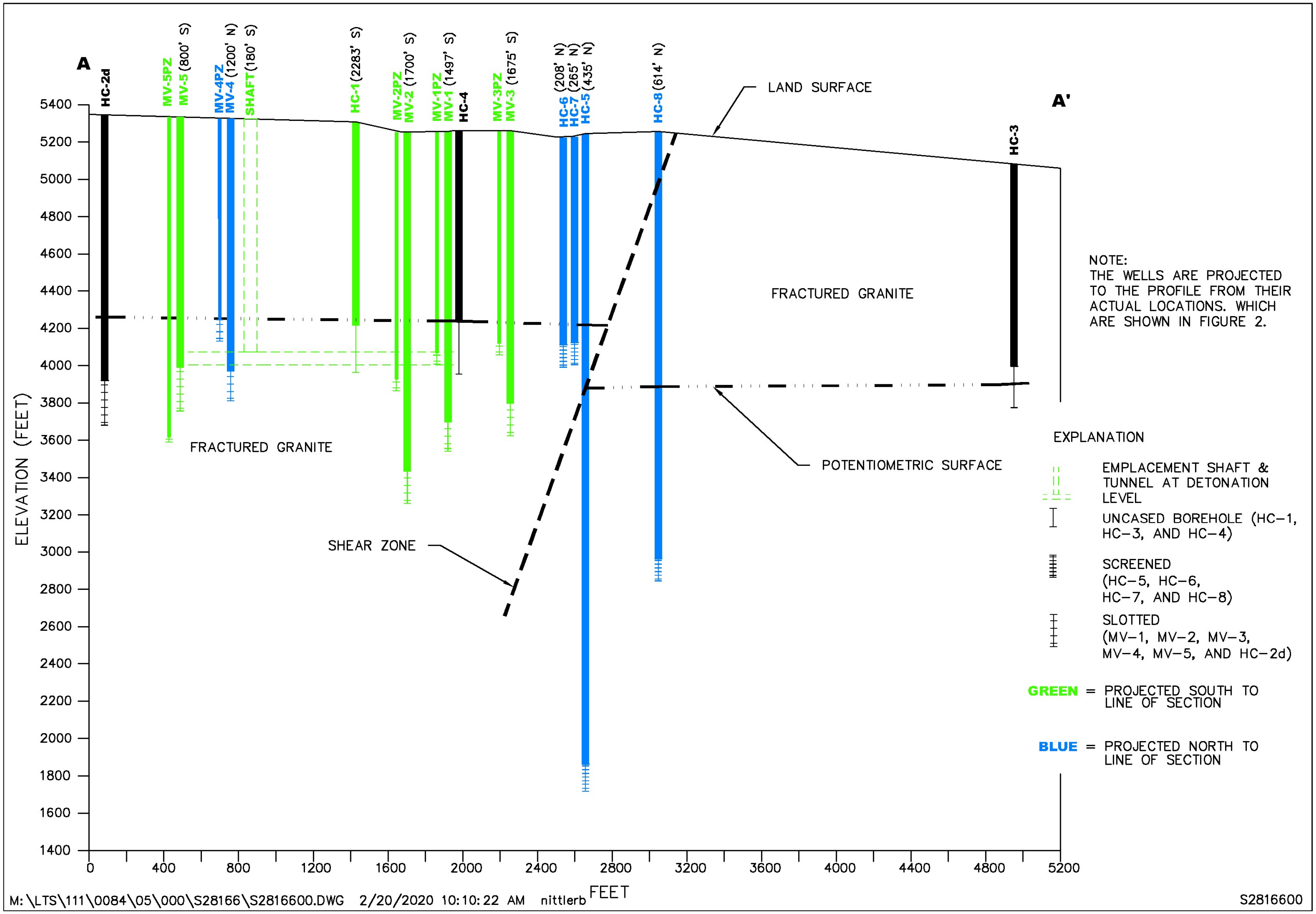


Figure 3. Cross Section A–A' Depicting Monitoring Well and Shear Zone Location, Shoal, Nevada, Site

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 groundwater elevation data for monitoring the overall stability (quasisteady 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 wells MV-1, MV-2, and MV-3. The enhancements are documented in short-term data acquisition plans completed in 2009, 2011, and 2014 to support the CADD/CAP and provide interim guidance until the addendum to the CADD/CAP could be completed. The CADD/CAP Addendum was completed July 2019 and approved by NDEP in August 2019.

The monitoring program includes collecting groundwater samples for laboratory analysis, measuring depth to groundwater, and downloading data from transducers in site monitoring wells. The 2019 monitoring program was enhanced to include the analysis of carbon-14 (^{14}C) and iodine-129 (^{129}I) at all sampled locations in the monitoring network. These analyses were originally planned for 2020 but were included in the 2019 monitoring program so the laboratory results would be available for the subsurface closure report. The 2019 sampling plan was provided to NDEP by letter (DOE 2019c) and approved by NDEP (NDEP 2019). 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 results are summarized in the following sections.

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 June 2019 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 before 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 (Table A-1 in Appendix A). 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. 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 ^{14}C, ^{129}I, tritium, uranium isotopes, gross alpha particle activity (also called gross alpha activity), and mass concentrations of uranium as specified in the short-term data acquisition plans (DOE 2009; DOE 2011a; DOE 2014). These data acquisition plans initiated activities that enhanced the monitoring network defined in the CADD/CAP (DOE 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. Based on this sampling frequency, the collection of samples for ^{14}C and ^{129}I analysis was scheduled for 2020 but was conducted in 2019 to have the results available for the subsurface closure report (DOE 2019b). Tritium is the radionuclide selected as an indicator of contaminant migration from the former detonation cavity due to its mobility and abundance in the first 100 years of the posttest monitoring period.

However, because of tritium's relatively short half-life (12.3 years), ^{14}C and ^{129}I are also monitored to establish baseline conditions in support of long-term postclosure monitoring. Gross alpha activity is included in the laboratory analytical suite because in the past elevated gross alpha activity has been detected at the Shoal site. The U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for gross alpha activity 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 gross alpha activity is from natural sources. The EPA MCLs for tritium, gross alpha particle activity, and uranium are 20,000 picocuries per liter (pCi/L), 15 pCi/L, and 30 micrograms per liter (µg/L), respectively.

The regulatory levels for the site groundwater were established in the CADD/CAP and maintained in the CADD/CAP Addendum. The regulatory levels are 20,000 pCi/L tritium, 2000 pCi/L ^{14}C, and 1 pCi/L ^{129}I (DOE 2019b). These levels are not to be exceeded outside the compliance boundary (Figure 2). The CADD/CAP Addendum 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 its minimum detectable concentrations (MDCs); 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 laboratory results are provided and compared to the RDLs established in the CADD/CAP Addendum. 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 Monitoring Results

Table 1 presents a summary of laboratory results for ^{14}C, ^{129}I, tritium, uranium, and gross alpha particle activity from the samples collected from 2017 through 2019. Tables B-1 and B-2 in Appendix B present laboratory results from when the CADD/CAP monitoring program began in 2007 through the present. The ^{129}I results from the 2019 sampling event continue to be several orders of magnitude below the RDL of 0.1 pCi/L but are not consistent with monitoring results from previous years. Historically the ^{129}I results have been in the 10^{-9} to 10^{-12} pCi/L range, but the 2019 results are in the 10^{-6} to 10^{-8} pCi/L range. The laboratory provided the calculations used to convert the 2019 results to activity concentrations but were unable to provide the calculations to convert the 2008, 2010, and 2015 results (Table B-1 in Appendix B). The laboratory documented this finding in their lab report as a "Non-Conformance." LM reviewed and accepted the methodology for converting the 2019 results. LM will continue using this method to convert all future results. The calculation methodology is provided in Appendix B.

The ^{14}C results from the 2019 sampling event are below the RDL of 5 pCi/L and are consistent with monitoring results from previous years. A time-concentration plot for well HC-4 (Figure 4) presents tritium results from the CADD/CAP monitoring program (2007 to present) with results from sampling events performed by EPA and the Desert Research Institute before the monitoring program began in 2007. Well HC-4 was installed in 1996 and is the only well in which tritium above the laboratory's MDC has been detected using conventional laboratory methods. The presence of tritium in well HC-4 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 Table B-1 in Appendix B). The elevated concentration of ^{14}C in this well is likely the result of its migration in the gas phase, as part of the carbon dioxide molecule, where it moved in the unsaturated zone before being dissolved into groundwater near the detonation. The concentrations of ^{14}C in well HC-4 have historically been below the RDL of 5 pCi/L until the 2015 and 2016 sampling events, when the samples had concentrations of 14.6 and 7.02 pCi/L, respectively (Table B-1 in Appendix B). Well HC-4 was the only well sampled for ^{14}C during the 2016 monitoring event to verify the 2015 result.

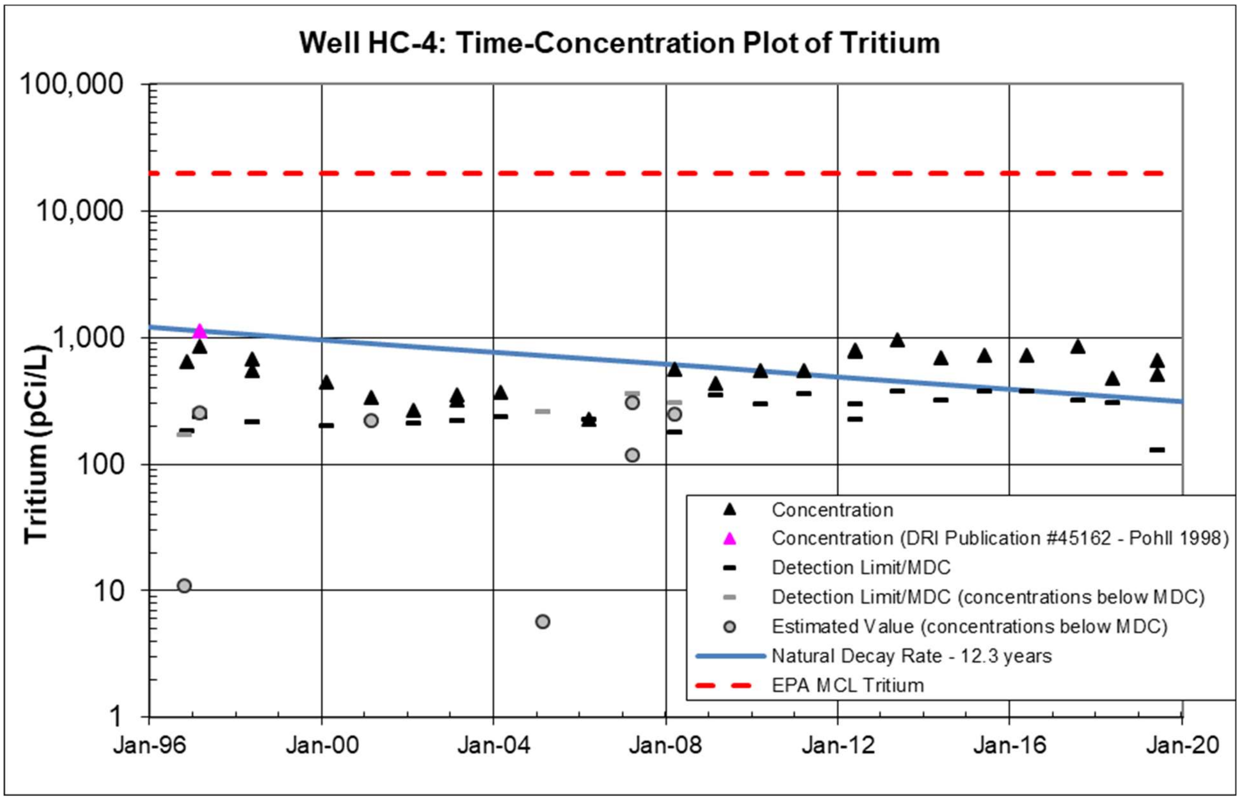


Figure 4. Time-Concentration Plot of Tritium at Well HC-4

Table 1. Shoal Site Radioisotope and Chemical Sampling Results, 2017 Through 2019

Monitoring Location	Date	Carbon-14 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross Alpha (pCi/L)
MV-1	8/3/2017	NA	NA	<314	18	8.91
	5/23/2018	NA	NA	<301	18	9.37
	6/4/2019	<RDL (2.08×10^{-2})	<RDL (8.2×10^{-7})	<400	19	13.8
MV-2	8/3/2017	NA	NA	<305	19	12.2
	5/23/2018	NA	NA	<308	18.3	11
	6/4/2019	<RDL (3.13×10^{-2})	<RDL (2.1×10^{-6})	<400	22	18.6
MV-3	8/3/2017	NA	NA	<316	16	10
	8/3/2017[a]	NA	NA	<319	17	9.62
	5/24/2018	NA	NA	<302	17.4	5.39
	6/4/2019	<RDL (1.80×10^{-2})	<RDL (7.4×10^{-7})	<400	19	13.9
MV-4	8/3/2017	NA	NA	<311	42	21.1
	5/23/2018	NA	NA	<305	34.1	19.5
	6/6/2019	<RDL (4.73×10^{-2})	<RDL (1.2×10^{-7})	<400	29	23.2
MV-5	8/3/2017	NA	NA	<317	3.1	2.26
	5/23/2018	NA	NA	<292	0.844	<1.72
	6/6/2019	<RDL (2.16×10^{-3})	<RDL (1.5×10^{-7})	<400	1.4	<1.7
HC-1	8/2/2017	NA	NA	<331	0.58	<1.89
	5/23/2018	NA	NA	<301	0.694	<1.42
	6/5/2019	<RDL (2.74×10^{-2})	<RDL (1.3×10^{-7})	<400	0.61	6.88
HC-2d	8/2/2017	NA	NA	<317	5.8	4.67
	5/22/2018	NA	NA	<294	5.01	3.39
	6/6/2019	<RDL (1.51×10^{-2})	<RDL (9.5×10^{-8})	<400	2.7	14.3
HC-3	8/2/2017	NA	NA	<321	0.12	<1.93
	5/23/2018	NA	NA	<307	0.114	<1.44
	6/5/2019	<RDL (1.24×10^{-2})	<RDL (7.0×10^{-7})	<400	0.15	2.4
HC-4	8/1/2017	NA	NA	850	120	57.4
	5/22/2018	NA	NA	474	141	52.4
	6/5/2019	<RDL (3.62×10^{-1})	<RDL (8.2×10^{-7})	516	100	68
	6/5/2019[a]	NA	NA	667	100	79.5
HC-5	8/2/2017	NA	NA	<322	0.33	<2.64
	5/23/2018	NA	NA	<311	0.226	<2.0
	5/23/2018	NA	NA	<289	0.226	<1.59
	6/5/2019	<RDL (6.34×10^{-3})	<RDL (3.1×10^{-7})	<400	0.25	<2.8
HC-6	8/2/2017	NA	NA	<360	37	21.1
	5/23/2018	NA	NA	<291	37.4	22.4
	6/5/2019	<RDL (2.68×10^{-2})	<RDL (1.4×10^{-7})	<400	40	17.8
HC-7	8/2/2017	NA	NA	<323	16	12.3
	5/24/2018	NA	NA	<299	14.9	6.75
	6/5/2019	<RDL (9.07×10^{-3})	<RDL (2.2×10^{-7})	<400	15	9.84
HC-8	8/1/2017	NA	NA	<323	0.16	<2.05
	5/24/2018	NA	NA	<306	0.145	<1.62
	6/6/2019	<RDL (5.08×10^{-3})	<RDL (5.1×10^{-7})	<400	0.15	<1.7

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 particle activity (DOE 2019b).

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

Tritium was detected in well HC-4 at a concentration of 516 pCi/L, with a duplicate result of 667 pCi/L during the 2019 sampling event, but it was not detected above the MDC 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 the LM contracted laboratory 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 1130 pCi/L was from a sample collected in 1997 by the Desert Research Institute after approximately 1100 gallons of groundwater were removed during an aquifer test (Pohll et al. 1998). 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 (one well volume). The well purge volumes are not available for samples collected before 2007, with the exception of the sample collected by Desert Research Institute in 1997.

Laboratory results from the 2019 sampling event (Table 1) indicate that samples from wells HC-4, HC-6, and MV-4 had gross alpha particle activity and uranium mass concentrations above the EPA MCLs of 15 pCi/L and 30 µg/L, respectively. Samples from these wells have historically had concentrations above the MCLs. Sample results from well HC-4 show an increase in gross alpha activity and uranium mass concentrations above the MCLs starting in 2012, with the highest concentration of uranium (141 µg/L) detected during the 2018 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. Values of gross alpha activity and uranium concentration detected in well HC-6 are consistent with past results. Well MV-4 has had values of gross alpha activity and uranium concentration above or near the MCLs since the well was installed in 2014. The sample from well MV-2 collected during the 2019 sampling event had a gross alpha activity of 18.6 pCi/L, but uranium mass concentrations were below the respective MCLs. Samples from this well and wells MV-1 and HC-7 have had values above the MCLs in the past (Table B-1 in Appendix B). Historically, samples from well HC-2 have had gross alpha activities and uranium mass concentrations above the MCLs, but this well was deepened in 2014; the new well HC-2d is completed across a deeper interval, and sample results are below the respective MCLs. The remaining laboratory results for gross alpha activity and uranium from the 2019 sampling event are below the MCLs and consistent with previous results. The laboratory results obtained from the annual sampling were validated in accordance with the "Standard Practice for Validation of Environmental Data" section in the *Environmental Procedures Catalog* (LMS/POL/S04325).

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 activity values for samples from wells HC-4, HC-6, 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 zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples

Table 2. Shoal Site Uranium Isotope Sampling Results, 2017 Through 2019

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238 Activity Ratio
MV-1	8/3/2017	7.39	6.21	1.19
	5/23/2018	6.51	5.67	1.15
	6/4/2019	7.41	5.81	1.28
MV-2	8/3/2017	7.72	6.4	1.21
	5/23/2018	6.87	5.81	1.18
	6/4/2019	8.89	6.81	1.31
MV-3	8/3/2017	6.33	6.09	1.04
	8/3/2017[a]	7.12	5.9	1.21
	5/24/2018	6.79	5.94	1.14
	6/4/2019	7.12	6.08	1.17
MV-4	8/3/2017	16.4	15.2	1.08
	5/23/2018	13.8	12.3	1.12
	6/6/2019	9.69	9.19	1.05
MV-5	8/3/2017	1.4	1.06	1.32
	5/23/2018	0.373	0.276	1.35
	6/6/2019	0.633	0.479	1.32
HC-1	8/2/2017	0.267	0.201	1.33
	5/23/2018	0.297	0.236	1.26
	6/5/2019	0.251	0.218	1.15
HC-2d	8/2/2017	2.46	2.45	1.00
	5/22/2018	1.79	1.48	1.21
	6/6/2019	0.943	1.06	0.89
HC-3	8/2/2017	0.092	0.027	3.41
	5/23/2018	0.0548	0.0725	0.76
	6/5/2019	0.0589	0.0632	0.93
HC-4	8/1/2017	42.3	43.4	0.97
	5/22/2018	44.7	45.4	0.98
	6/5/2019	35.2	33.6	1.05
	6/5/2019[a]	34.4	33.5	1.03
HC-5	8/2/2017	0.222	0.139	1.60
	5/23/2018	0.115	0.106	1.08
	5/23/2018[a]	0.114	0.0895	1.28
	6/5/2019	0.165	0.124	1.33
HC-6	8/2/2017	15.4	12.7	1.21
	5/23/2018	15.6	13.1	1.19
	6/5/2019	15.7	13.6	1.15
HC-7	8/2/2017	6.84	5.29	1.29
	5/24/2018	5.97	5.24	1.14
	6/5/2019	6.06	5	1.21
HC-8	8/1/2017	0.125	0.053	2.36
	5/24/2018	0.0886	0.0626	1.42
	6/6/2019	0.129	0.065	1.98

Notes:
[a] Indicates a duplicate sample.
The RDL for uranium isotopes is 0.1 pCi/L (DOE 2019b).

(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 B-2 in Appendix B provides the ^{234}U:^{238}U activity ratios since 2007, which range from 0.76 to 3.41—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 particle activity – ^{234}U – ^{238}U = adjusted result
HC-4: 79.5 – 34.4 – 33.5 = 11.6
HC-6: 17.8 – 15.7 – 13.6 = −11.5
MV-4: 23.2 – 9.69 – 9.19 = 4.3

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

4.3 Water-Level Monitoring

The groundwater flow system was monitored by measuring the depth to groundwater in the onsite wells/piezometers and offsite wells (H-2 and H-3) (Figure 2). Piezometers are distinguished from wells by the notation "PZ." Water-level changes were recorded every hour by transducers installed in the wells and piezometers. The monitoring location HC-7 is no longer monitored using a transducer because of its proximity to well HC-6 and similar groundwater elevation. Wells H-2 and H-3 are also no longer monitored using transducers because water levels have been stable at these locations over the years (DOE 2015c). Water levels were measured manually in all wells/piezometers included in the monitoring network (Table 3), and the data from transducers were downloaded in September as part of water-level monitoring. Manual water levels were used with the TOC elevations to convert the transducer data to groundwater elevations. Table 3 presents the well construction information, TOC elevations, and manual water-level measurements collected in September 2019.

Table 3. Construction Details for Monitoring Wells and 2019 Water-Level Measurements

Well/ Piezometer	TOC Elevation (ft amsl) [a]	Depth to Water (ft)[b]	Date	Elevation Water (ft amsl)[c]	Elevation TSZ (ft amsl)	Elevation BSZ (ft amsl)	Screen Length (ft)
MV-1	5254.64	985.72	9/17/2019	4268.92	3680.24	3526.43	154
MV-1PZ	5254.38	961.25	9/17/2019	4293.13	3915.47	3855.47	60
MV-2	5263.72	995.20	9/17/2019	4268.52	3442.63	3271.86	171
MV-2PZ	5263.60	988.20	9/17/2019	4275.40	4074.80	4015.30	60
MV-3	5258.60	957.90	9/17/2019	4300.70	3793.61	3622.45	171
MV-3PZ	5258.24	959.11	9/17/2019	4299.13	4116.78	4056.75	60
MV-4	5370.78	1078.65	9/17/2019	4292.13	3969.08	3809.08	160
MV-4PZ	5370.41	1077.13	9/17/2019	4293.28	4249.08	4129.08	120
MV-5	5318.16	1048.42	9/17/2019	4269.74	3991.01	3751.01	240
MV-5PZ	5317.50	1047.40	9/17/2019	4270.10	3616.01	3586.01	30
HC-1	5306.32	1056.15	9/18/2019	4270.45	4210.44	3979.64	231
HC-2d	5343.93	1104.75	9/17/2019	4239.62	3925.15	3685.15	240[e]
HC-3	5078.57	1181.32	9/17/2019	3918.98	3893.20	3872.70	21
HC-4	5257.88	995.95	9/18/2019	4265.63	4242.63	3961.63	281
HC-5	5244.33	1370.58	9/18/2019	3873.75	1857.34	1711.74	146
HC-6	5225.73	955.42	9/18/2019	4271.22	4109.00	3992.68	116
HC-7	5226.74	955.61	9/18/2019	4271.35	4119.23	4002.10	117
HC-8	5256.89	1372.75	9/18/2019	3884.70	2960.85	2844.37	116
H-2	4018.22	110.10	9/17/2019	3908.12	3377.06	3237.06	340[e]
H-3	4233.95	325.60	9/17/2019	3908.35	3919.30	3762.30	157

Notes:

[a] The TOC elevations obtained after the drilling program in 2014 are provided in U.S. State Plane, Zone Nevada West 2703 coordinate system, with vertical data based on the North American Vertical Datum 1929 (DOE 2015c).

[b] Manual depth-to-water measurements are not corrected for borehole deviation.

[c] Elevation of water measurements are corrected for borehole deviation.

[d] Indicates the water level/groundwater elevation has not recovered from development with the addition of water.

[e] Indicates the well is screened across multiple intervals and the total effective screen length is provided.

Abbreviations:

BSZ = bottom of open interval; screened, perforated, or open hole
TSZ = top of open interval; screened, perforated, or open hole

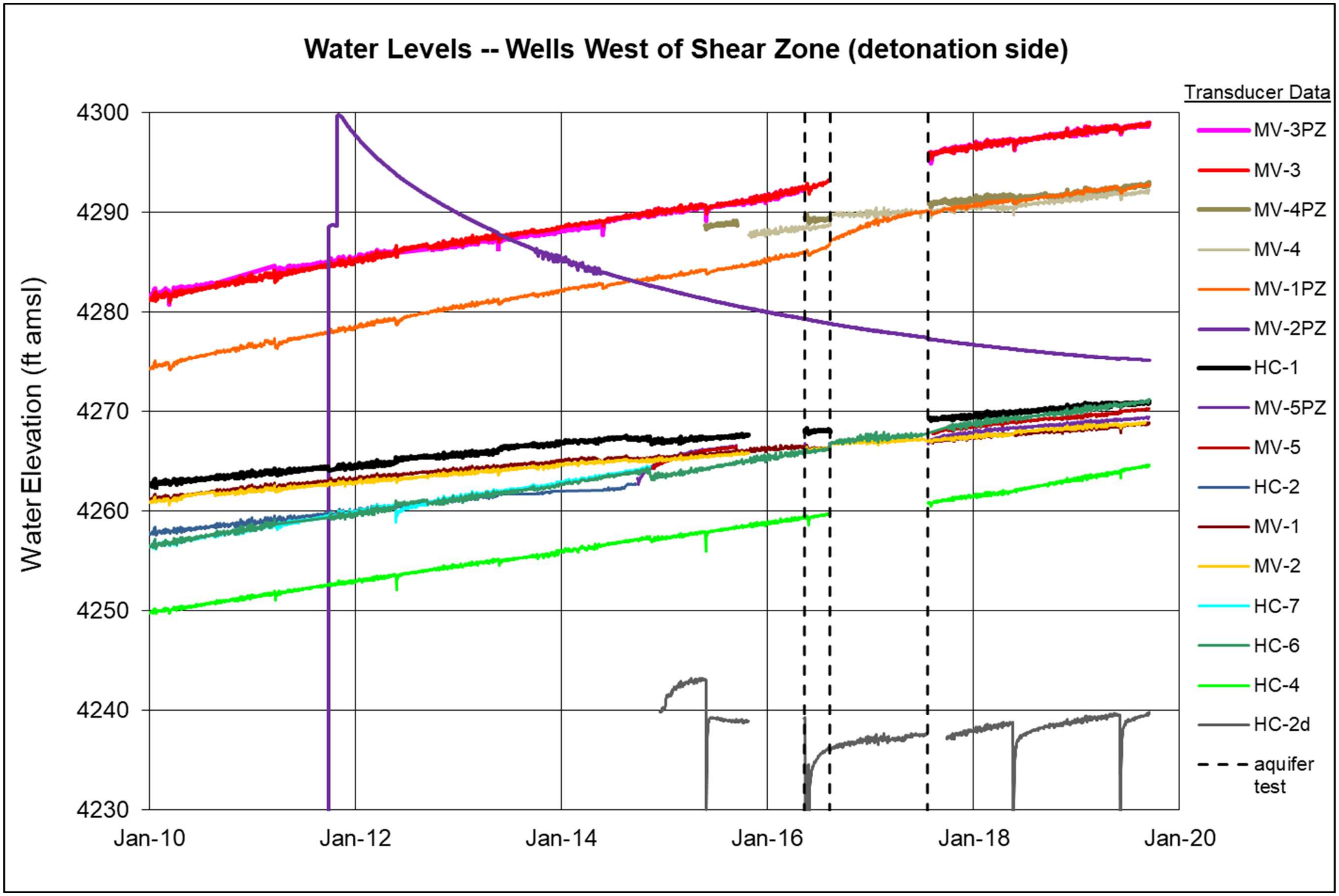
4.4 Water-Level Monitoring Results

Figure 5, Figure 6, and Figure 7 show hydrographs of groundwater elevation data from site wells/piezometers dating back to January 2010, shortly after the CADD/CAP monitoring program was initiated in 2007. Figures C-1, C-2, and C-3 in Appendix C show hydrographs of groundwater elevation data obtained from when the first wells were installed at the site in 1996 to the present. Water-level 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. TOC elevations (Table 3) were used to convert these data to groundwater elevations. 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.

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-2d, HC-4, HC-6, and HC-7 (Figure 3). Water levels in all wells and piezometers west of the shear zone, except in piezometer MV-2PZ, continued to rise through September 2019. The increases ranged from 0.73 ft in MW-2 to 1.96 ft in HC-2d and were similar to observed increases over the previous 10 years. The short-term increase in the rate of water level rise in wells MV-1PZ, MV-3, and MV-3PZ (all completed in the same fault block) that extended from the spring of 2016 through the summer of 2017 (Figure 5) appears to be related to the aquifer tests on wells HC-2d, MV-4, and MV-5, which are in a different fault block. The water level in piezometer MV-2PZ is continuing to decline slowly (Figure 5). This decline is attributed to water being added after a development event in 2012 to remove remnant drilling mud. The water level in piezometer MV-2PZ is not indicative of the static water level in the formation at its screened interval. The water level in HC-2d is beginning to assume a trend similar to that seen in the other wells, though at a lower elevation. Table D-1 in Appendix D shows the annual water-level changes in wells west of the shear zone from July 2007 through July 2019.

Monitoring wells screened east of the shear zone include wells HC-3, HC-5, and HC-8 (Figure 3). Water elevations in these wells are 300–400 ft lower (Figure 6) than those in wells west of the shear zone (Figure 5). Water elevations in wells HC-5 and HC-8 are continuing to decline at a 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 in each sampling event (Table A-1 in Appendix A). Well HC-3 is sampled with a bailer, and only a few gallons of water are removed during sampling.

Wells H-2 and H-3 are offsite monitoring locations in Fourmile Flat (Figure 2). Water elevations in these wells are 300–400 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. These wells are no longer monitored using transducers, but water levels continue to be measured manually as recommended in the 2014 groundwater monitoring report (DOE 2015c). The hydrograph showing groundwater elevation data from wells H-2 and H-3 was updated with the manual water-level measurements (Figure 7).



Note: Vertical dashed lines indicate start dates for aquifer tests on wells HC-2d, MV-4, and MV-5.

Figure 5. Hydrographs for Wells West of the Shear Zone

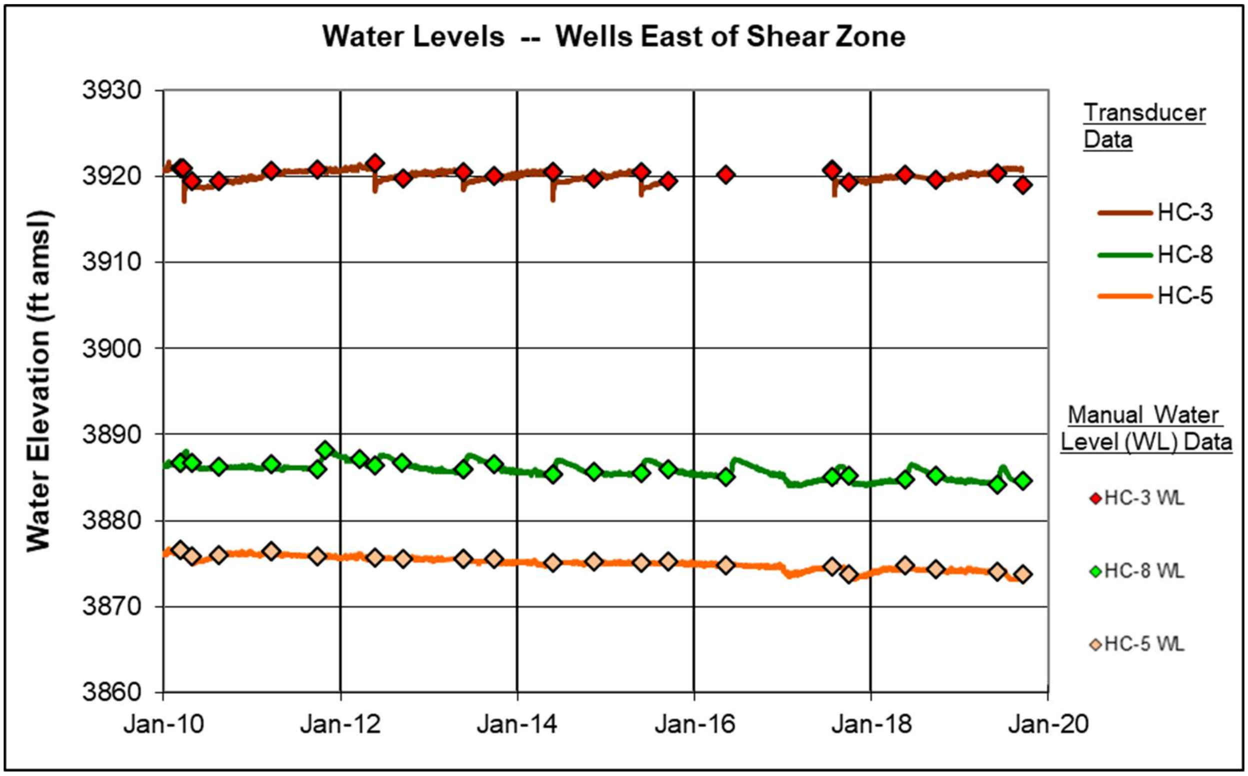


Figure 6. Hydrographs for Wells East of the Shear Zone

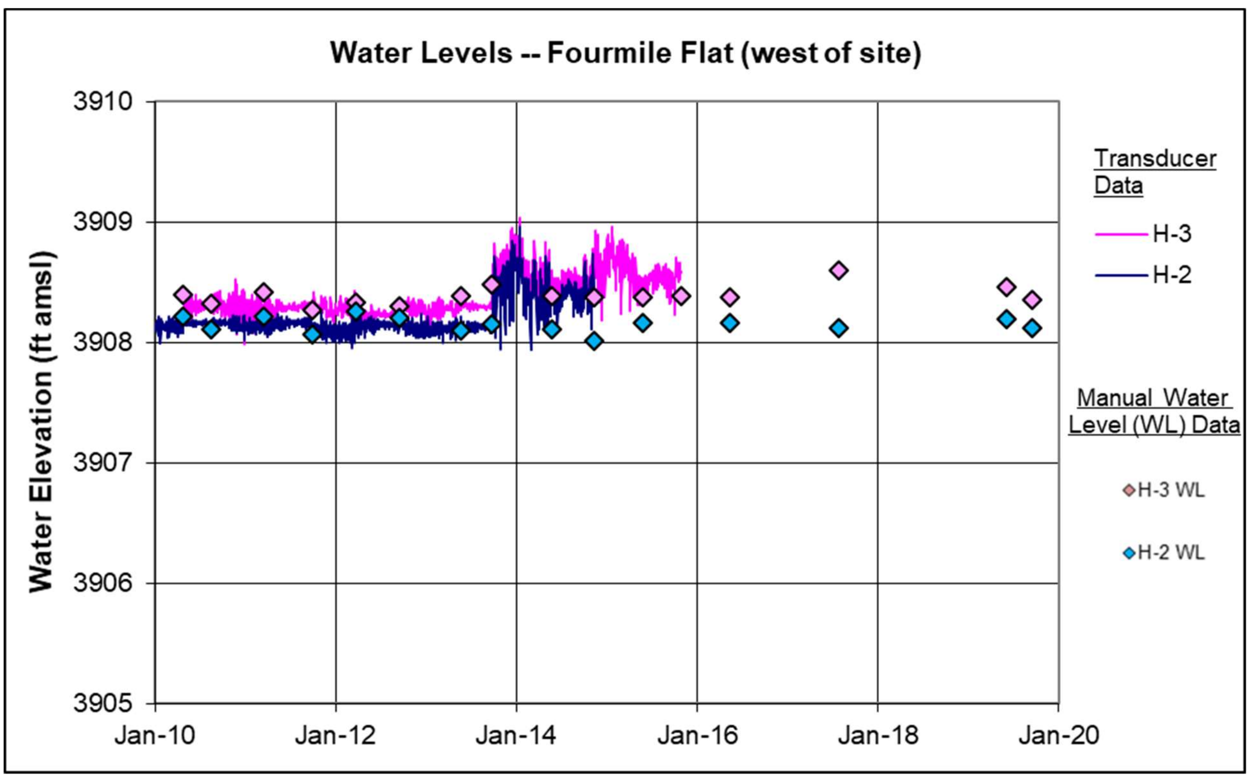


Figure 7. Hydrographs for Wells in Fourmile Flat

5.0 Site Inspection Activities

The site was inspected as part of the field monitoring activities completed during the monitoring period that ended in September 2019. This included inspecting the site roads, wellheads, and monument at surface ground zero for signs of damage or vandalism. The site roads, wellheads, and monument were all in good condition at the time of the 2019 inspections.

6.0 Summary and Recommendations

The site roads, wellheads, rain gage, and monument at surface ground zero were all in good condition during the site inspections. Water-level trends obtained from the 2019 water-level data are consistent with those of previous years. Water levels in all wells and piezometers west of the shear zone (except for the locations described in Section 4.4) continued to rise through September 2019. The increases were similar to those observed over the past 10 years. Water-level data in the onsite wells east of the shear zone continue to show that levels in wells HC-5 and HC-8 are declining at a rate of approximately 1 to 2 ft every 10 years.

Laboratory results from the 2019 sampling event are consistent with those of previous years. Well HC-4 continues to be the only well with tritium concentrations above the laboratory's MDC. The tritium concentrations (516 and 667 pCi/L) are consistent with past results and are below EPA's MCL of 20,000 pCi/L and below the well's highest concentration of 1130 pCi/L reported in 1998 (Pohll et al. 1998). Samples from well HC-4 also had gross alpha particle activity and uranium mass concentrations above the EPA MCLs of 15 pCi/L and 30 µg/L, respectively. This is consistent with previous results dating back to 2012, when it was determined that the minimum volume of groundwater was not being removed before sampling because of a misunderstanding in the well configuration. The sample from well MV-2 had a gross alpha activity above the MCL, but uranium mass concentrations were below the respective MCL. Samples from wells HC-6 and MV-4 also had gross alpha particle activity and uranium mass concentrations above the EPA MCLs, but those were consistent with past results. The elevated gross alpha and uranium mass values in these wells are interpreted as being from natural sources, because if the gross alpha values are adjusted by subtracting activities of ^{234}U and ^{238}U, the values are less than zero, indicating that uranium accounts for all or nearly all gross alpha particle activity in these samples. This interpretation is further supported by ^{234}U:^{238}U activity ratios that are consistent with activity ratios that are in equilibrium and from natural uranium rather than a nuclear test–related source.

LM recommends the following:

- Data collected during this annual monitoring event support LM's recommendation to move the Closure Report phase for subsurface CAU 447. This recommendation is based on groundwater elevation and radioisotope data that continue to support the SCM and a monitoring network that monitors the potential transport pathways.
- The next groundwater sampling event should be conducted in 2021, as prescribed in the Closure Report for CAU 447.

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Appendix A

2019 Monitoring Well Purge Data

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Table A-1. Shoal Site Monitoring Well Purge Data

Monitoring Location	Date Sampled	Purged Volume (gallons)	Temperature (ºC)	pH (s.u.)	Specific Conductance (µmho/cm)	Turbidity (NTU)
MV-1	6/4/2019	1186	23.7	8.11	620	0.82
			23.7	8.08	612	0.57
			23.7	8.06	610	0.69
MV-2	6/4/2019	1375	23.8	8.03	457	1.26
			23.7	8.02	470	4.44
			23.8	7.99	466	2.63
MV-3	6/4/2019	1051	22.8	7.93	751	1.93
			22.8	8.00	728	0.86
			22.8	8.02	691	0.51
MV-4	6/6/2019	698	16.4	8.41	728	3.38
			16.4	8.39	734	9.00
			16.3	8.30	710	7.68
MV-5	6/6/2019	950	22.6	10.26	510	1.85
			22.4	10.27	498	1.52
			22.5	10.21	488	1.48
HC-1	6/5/2019	1.59	19.9	7.67	385	44.6
HC-2d	6/6/2019	800	21.3	8.04	559	5.99
			21.2	8.10	534	9.54
			21.2	8.12	523	9.58
HC-3	6/5/2019	1.59	27.6	7.37	630	46.4
HC-4	6/5/2019	1000	21.5	7.62	684	23.6
			21.4	7.55	661	22.6
			21.4	7.52	630	20.6
HC-5	6/5/2019	2910	27.2	8.21	963	1.79
			27.2	8.24	950	0.96
			27.2	8.35	953	0.66
HC-6	6/5/2019	1.59	22.6	7.65	1146	8.02
HC-7	6/5/2019	390	22.3	7.69	1319	1.69
			22.3	7.67	1285	1.15
			22.3	7.64	1208	1.20
HC-8	6/6/2019	3010	29.0	7.93	833	2.17
			29.0	7.98	783	2.28
			28.9	8.11	763	2.33

Abbreviations:
µmho/cm = micromhos per centimeter
NA = not analyzed
NTU = nephelometric turbidity units
s.u. = standard unit

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Appendix B

Laboratory Data (2007 Through the Present) with Calculations Used to Convert the 2019 Iodine-129 Results to Activity Concentrations

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Table B-1. Shoal Site Radioisotope and Chemical Sampling Results (2007 to Present)

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
	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
	5/24/2016	NA	NA	<364	20	11
	8/3/2017	NA	NA	<314	18	8.91
	5/23/2018	NA	NA	<301	18	9.37
	6/4/2019	<RDL (2.08×10^{-2})	<RDL (8.2×10^{-7})	<400	19	13.8
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
	5/25/2016	NA	NA	<364	21	6.01
	8/3/2017	NA	NA	<305	19	12.2
	5/23/2018	NA	NA	<308	18.3	11
	6/4/2019	<RDL (3.13×10^{-2})	<RDL (2.1×10^{-6})	<400	22	18.6
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
	5/25/2016	NA	NA	<363	11	4.33
	8/3/2017	NA	NA	<316	16	10
	8/3/2017[c]	NA	NA	<319	17	9.62

Table B-1. Shoal Site Radioisotope and Chemical Sampling Results (2007 to Present) (continued)

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross Alpha (pCi/L)
MV-3 (continued)	5/24/2018	NA	NA	<302	17.4	5.39
	6/4/2019	<RDL (1.80×10^{-2})	<RDL (7.4×10^{-7})	<400	19	13.9
MV-4	5/29/2015	<RDL (3.58×10^{-2})	<RDL (5.0×10^{-12})	<370	63	36.7
	5/25/2016	NA	NA	<368	41	22.3
	8/3/2017	NA	NA	<311	42	21.1
	5/23/2018	NA	NA	<305	34.1	19.5
	6/6/2019	<RDL (4.73×10^{-2})	<RDL (1.2×10^{-7})	<400	29	23.2
MV-5	5/28/2015	<RDL (1.35×10^{-2})	<RDL (1.25×10^{-10})	<370	0.23	<1.4
	5/24/2016	NA	NA	<367	0.27	2.96
	5/24/2016[c]	NA	NA	<368	0.23	<1.2
	8/3/2017	NA	NA	<317	3.1	2.26
	5/23/2018	NA	NA	<292	0.84	<1.72
	6/6/2019	<RDL (2.16×10^{-3})	<RDL (1.5×10^{-7})	<400	1.4	<1.7
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	0.94	3.19
	5/27/2014	NA	NA	<320	0.86	<1.2
	5/26/2015	<RDL (1.81×10^{-2})	<RDL (1.31×10^{-10})	<380	0.87	2.04
	5/24/2016	NA	NA	<365	0.6	1.22
	8/2/2017	NA	NA	<331	0.58	<1.89
	5/23/2018	NA	NA	<301	0.69	<1.42
	6/5/2019[b]	<RDL (2.74×10^{-2})	<RDL (1.3×10^{-7})	<400	0.61	6.88
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
	5/25/2016	NA	NA	<367	4.2	6.08
	8/2/2017	NA	NA	<317	5.8	4.67
	5/22/2018	NA	NA	<294	5.0	3.39
	6/6/2019	<RDL (1.51×10^{-2})	<RDL (9.5×10^{-8})	<400	2.7	14.3
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	<1.0
	5/22/2013	NA	NA	<350	2.7	<1.1
	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
	5/24/2016	NA	NA	<351	0.08	<0.98
	8/2/2017	NA	NA	<321	0.12	<1.93

Table B-1. Shoal Site Radioisotope and Chemical Sampling Results (2007 to Present) (continued)

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross Alpha (pCi/L)
HC-3 (continued)	5/23/2018	NA	NA	<307	0.11	<1.44
	6/5/2019[b]	<RDL (1.24×10^{-2})	<RDL (7.0×10^{-7})	<400	0.15	2.4
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
	5/24/2016	7.02	NA	725	120	42.6
	8/1/2017	NA	NA	850	120	57.4
	5/22/2018	NA	NA	474	141	52.4
	6/5/2019[bc]	<RDL (3.62×10^{-1})	<RDL (8.2×10^{-7})	516	100	68
	6/5/2019[bc]	NA	NA	667	100	79.5
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	<2.2
	5/22/2013	NA	NA	<340	0.4	<1.0
	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
	5/25/2016	NA	NA	<368	0.45	<1.6
	8/2/2017	NA	NA	<322	0.33	<2.64
	5/23/2018	NA	NA	<311	0.23	<2.0
	5/23/2018	NA	NA	<289	0.23	<1.59
	6/5/2019	<RDL (6.34×10^{-3})	<RDL (3.1×10^{-7})	<400	0.25	<2.8
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
	5/24/2016	NA	NA	<364	41	19.7
	8/2/2017	NA	NA	<360	37	21.1
	5/23/2018	NA	NA	<291	37.4	22.4
	6/5/2019	<RDL (2.68×10^{-2})	<RDL (1.4×10^{-7})	<400	40	17.8
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

Table B-1. Shoal Site Radioisotope and Chemical Sampling Results (2007 to Present) (continued)

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross Alpha (pCi/L)
HC-7 (continued)	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
	5/26/2016	NA	NA	<364	18	6.94
	8/2/2017	NA	NA	<323	16	12.3
	5/24/2018	NA	NA	<299	14.9	6.75
	6/5/2019	<RDL (9.07×10^{-3})	<RDL (2.2×10^{-7})	<400	15	9.84
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	<0.91
	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
	5/26/2016	NA	NA	<353	0.14	<1.33
	8/1/2017	NA	NA	<323	0.16	<2.05
	5/24/2018	NA	NA	<306	0.14	<1.62
	6/6/2019	<RDL (5.08×10^{-3})	<RDL (5.1×10^{-7})	<400	0.15	<1.7

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 particle activity (DOE 2019b).

Abbreviations:

NA = not applicable (samples not collected or samples not analyzed)
NR = not run (because sample bottle was broken during shipment to the laboratory)

Calculation Methods used to Convert the 2019 Iodine-129 (^{129}I) Results to Activity Concentrations.

^{129}I Specific Activity = 1.75 E-4 Ci/g from Shipley

Rational

We measured the atomic ratio $^{129}I/^{127}I$ in each sample by accelerator mass spectrometry. The Iodine concentration of each water sample was measured by ICPMS and expressed in SI Molar (moles/liter).

The calculations involve determining the number of atoms of ^{129}I per liter of water from the iodine concentration measurements and $^{129}I/^{127}I$ atomic ratio, converting the amount of ^{129}I from atoms to grams, and then to a decay rate using the known ^{129}I Specific activity of 1.75 E-4 Ci/g. From this the activity is converted to the required unit pCi/L.

For example, for SHL01-02.1906001-001, from HC-1

Iodine Conc = 0.0949 E-6 +/- 0.0028E-6 M

$^{129}I/^{127}I$ ratio = 58 E-12 +/- 9 E-12

Step 1, calculate atoms of iodine per liter from concentration
= 0.0949 E-6 +/- 0.0028E-6 moles/L * 6.02E23 atoms/mole
= 5.71 E16 +/- 0.169 E16 atoms iodine/liter

Step 2: calculate atoms of 129 from $^{129}I/^{127}I$ ratio measurements and number of iodine atoms
=5.71 E16 +/- 0.169 E16 * 58 E-12 +/- 9E-12 129/127
= 3.31E6 +/- 0.52E6 ^{129}I atoms/liter

Step 3: calculate grams of ^{129}I
= 3.31E6 +/- 0.52E6 atoms/liter*129g ^{129}I/6.02E23atoms/g129I
= 7.09 E-16 +/- 1.12E-16 g ^{129}I/liter

Step 4: calculate decay rate given ^{129}I specific activity
= 7.09E-16 +/- 1.12E-16 g ^{129}I/liter * 1.75 E-4 Ci/g
= 1.28 E-19 +/- 1.96E-19 Ci/liter
= 128 +/- 20 pCi/liter

Reference

Shipley, G. B. Table of Specific Activities of Selected Isotopes, Engineering and Technical Services Division, Lawrence Berkeley Laboratory, University of California. Publication 3005, 1979.

Table B-2. Shoal Site Uranium Isotope Sampling Results (2007 to Present)

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238 Activity Ratio
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
	5/24/2016	8.45	6.93	1.22
	8/3/2017	7.39	6.21	1.19
	5/23/2018	6.51	5.67	1.15
	6/4/2019	7.41	5.81	1.28
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
	5/25/2016	7.51	6.53	1.15
	8/3/2017	7.72	6.4	1.21
	5/23/2018	6.87	5.81	1.18
	6/4/2019	8.89	6.81	1.31
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
	5/25/2016	4.33	3.66	1.18
	8/3/2017	6.33	6.09	1.04
	8/3/2017	7.12	5.9	1.21

Table B-2. Shoal Site Uranium Isotope Sampling Results (2007 to Present) (continued)

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238 Activity Ratio
MV-3 (continued)	5/24/2018	6.79	5.94	1.14
	6/4/2019	7.12	6.08	1.17
MV-4	5/29/2015	20.4	18.8	1.09
	5/25/2016	14.7	13.6	1.08
	8/3/2017	16.4	15.2	1.08
	5/23/2018	13.8	12.3	1.12
	6/6/2019	9.69	9.19	1.05
MV-5	5/28/2015	0.119	0.064	1.86
	5/24/2016	0.202	0.118	1.71
	5/24/2016[a]	0.092	0.119	0.77
	8/3/2017	1.4	1.06	1.32
	5/23/2018	0.373	0.276	1.35
	6/6/2019	0.633	0.479	1.32
HC-1	3/21/2007[a]	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
	5/24/2016	0.301	0.261	1.15
	8/2/2017	0.267	0.201	1.33
	5/23/2018	0.297	0.236	1.26
	6/5/2019[a]	0.251	0.218	1.15
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
	5/25/2016	1.62	1.51	1.07
	8/2/2017	2.46	2.45	1.00
	5/22/2018	1.79	1.48	1.21
	6/6/2019	0.943	1.06	0.89
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
	5/24/2016	0.066	0.079	0.84

Table B-2. Shoal Site Uranium Isotope Sampling Results (2007 to Present) (continued)

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238 Activity Ratio
HC-3 (continued)	8/2/2017	0.092	0.027	3.41
	5/23/2018	0.055	0.073	0.76
	6/5/2019[a]	0.0589	0.0632	0.93
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
	5/24/2016	39.1	39.4	0.99
	8/1/2017	42.3	43.4	0.97
	5/22/2018	44.7	45.4	0.98
	6/5/2019[ab]	35.2	33.6	1.05
	6/5/2019[ab]	34.4	33.5	1.03
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
	5/25/2016	0.207	0.159	1.30
	8/2/2017	0.222	0.139	1.60
	5/23/2018	0.115	0.106	1.08
	5/23/2018	0.114	0.090	1.27
	6/5/2019	0.165	0.124	1.33
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
	5/24/2016	16.3	13.7	1.19
	8/2/2017	15.4	12.7	1.21
	5/23/2018	15.6	13.1	1.19
	6/5/2019	15.7	13.6	1.15
HC-7	3/11/2010	3.43	3.08	1.11
	3/23/2011	5.9	4.78	1.23

Table B-2. Shoal Site Uranium Isotope Sampling Results (2007 to Present) (continued)

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234:Uranium-238 Activity Ratio
HC-7 (continued)	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
	5/26/2016	6.82	5.84	1.17
	8/2/2017	6.84	5.29	1.29
	5/24/2018	5.97	5.24	1.14
	6/5/2019	6.06	5	1.21
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
	5/26/2016	0.14	0.05	2.08
	8/1/2017	0.125	0.053	2.36
	5/24/2018	0.089	0.063	1.42
	6/6/2019	0.129	0.065	1.98

Notes:
[a] Indicates the sample was filtered.
[b] Indicates a duplicate sample.

Abbreviation:
NA = not applicable (samples not collected or samples not analyzed)

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Appendix C

Groundwater Elevation Data (1996 Through the Present)

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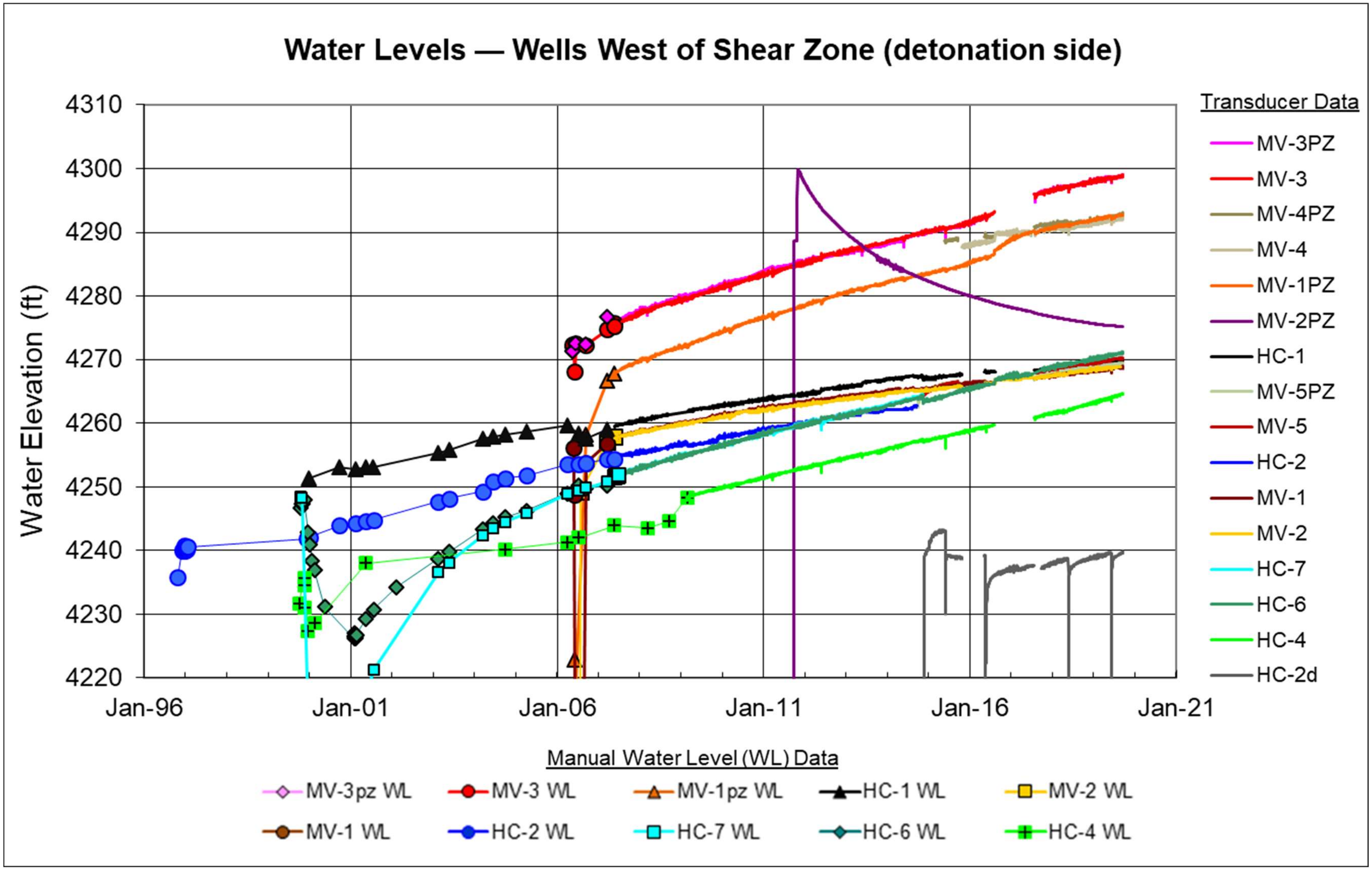

Figure C-1. Hydrographs for Wells West of the Shear Zone

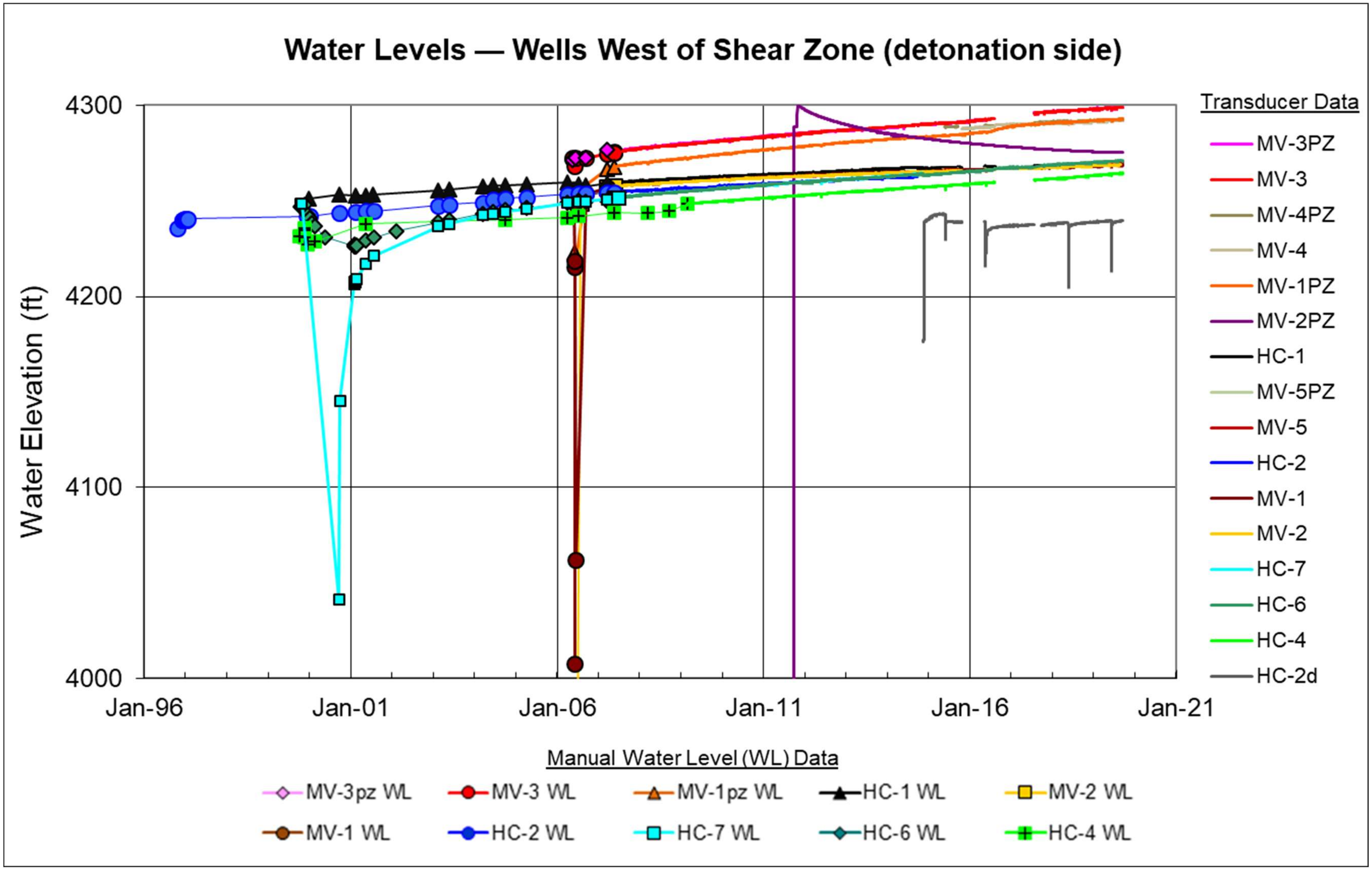

Figure C-2. Hydrographs for Wells West of the Shear Zone (expanded y axis)

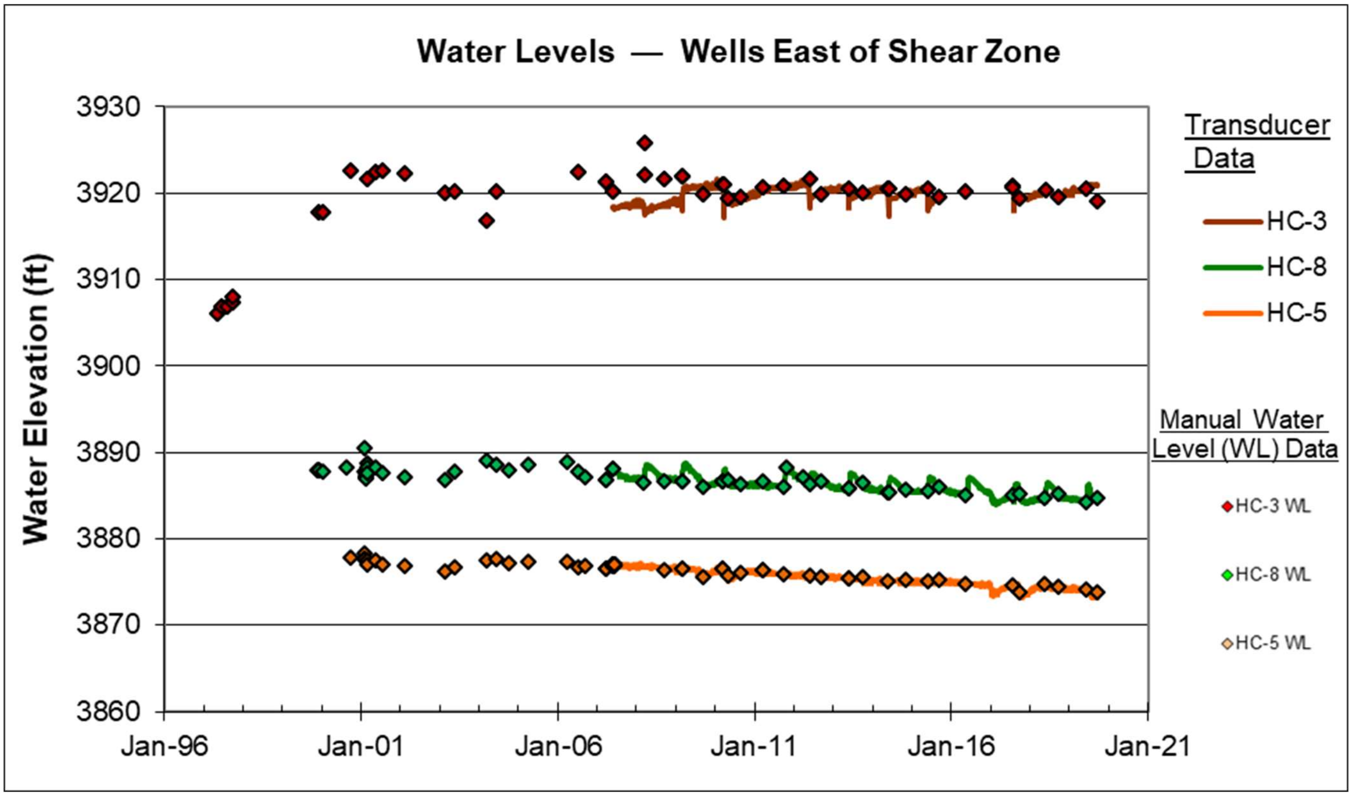

Figure C-3. Hydrographs for Wells East of the Shear Zone

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Appendix D

Annual Water-Level Changes in Wells West of the Shear Zone (July 2007 Through July 2019)

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Table D-1. Shoal Site 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 ft/year)											
	MV-1	MV-1PZ	MV-2	MV-3	MV-3PZ	HC-1	HC-2	HC-2d	HC-4	HC-6	MV-4	MV-5
7/2007–7/2008	1.52	2.67	1.37	2.71	2.57	1.40	1.09		NM	2.00		
7/2008–7/2009	1.40	2.48	0.95	2.16	2.20	1.32	1.40		NM	1.96		
7/2009–7/2010	1.38	2.48	1.36	2.54	2.23	1.49	1.49		2.12	1.79		
7/2010–7/2011	0.79	1.80	0.76	1.82	1.67	1.21	1.02		1.46	NM		
7/2011–7/2012	1.23	2.10	0.94	1.78	1.91	1.08	1.24		1.72	NM		
7/2012–7/2013	0.67	1.71	0.85	1.65	1.84	0.72	1.34		1.35	1.44		
7/2013–7/2014	1.03	1.63	0.82	1.43	1.41	0.94		NM	1.52	1.64		
7/2014–7/2015	0.16	1.21	0.26	1.28	1.13	0.15		NM	1.36	1.29		
7/2015–7/2016	1.00	2.93[b]	0.75	2.20	1.67[d]	0.78		NM	1.57	1.60[d]		
7/2016–7/2017	0.54[a]	3.15	0.80	3.20[c]	4.01	0.77[e]		NS	2.11[f]	0.95	NS	0.98
7/2017–7/2018	0.94	1.20	0.91	1.10	1.24	0.76		0.35	1.60	1.96	0.76	1.12
7/2018–7/2019	0.91	1.16	0.73	1.37	1.35	0.84		1.38	1.96	1.41	1.13	1.07

Notes:

Piezometer MV-2PZ is not included in this table, because the water level is still declining from water being added after a development event in 2012, and it is not indicative of the static water level in the formation at its screened interval.

Well HC-2 was recompleted in 2014 and now is identified as HC-2d. The cells that are blacked out show the change from well HC-2 to HC-2d.

Calculated from yearly water elevations; first reading in July unless noted.

[a] 2017 reading on 7/22/2017.
[b] 2016 reading on 8/12/2016.
[c] 2017 reading on 7/26/2017.
[d] 2016 reading on 5/12/2016.
[e] 2017 reading on 7/25/2017.
[f] 2017 reading on 7/23/2017.

Abbreviations:

NM = not measured because transducer data were not available
NS = not stable from aquifer testing

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Appendix E

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
Steve Sisolak, Governor
Bradley Crowell, Director
Greg Lovato, Administrator

December 15, 2020

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

RE: SUBMITTAL OF DRAFT 2019 GROUNDWATER MONITORING REPORT, PROJECT SHOAL AREA: SUBSURFACE, CORRECTIVE ACTION UNIT 447, JULY 2020

Dear Mr. Kautsky:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities (NDEP) has reviewed the Draft 2019 Groundwater Monitoring Report, Project Shoal Area: Subsurface, Corrective Action Unit 447, July 2020 (Document) received on September 2, 2020 with cover letter dated September 1, 2020. The NDEP has the following comments on the Draft Document, which should be addressed in the Final Document:

1. Page 4, Section 2.1, Summary of Corrective Action Activities, First Partial Paragraph, Second Full Sentence: It is not clear why the verb "will be" is used in this sentence when the addendum to the CADD/CAP was approved in 2019. It is understood that the subject of this paragraph is the 2011 data acquisition plan but as all the activities outlined in the 2011 plan have been completed, the wording of the sentence should reflect that fact.

2. Page 4, Section 2.1, Summary of Corrective Action Activities, First Full Paragraph, Fifth and Last Sentences: What was the reason for the five-year lag between the aquifer tests performed in 2014 and the publication of the hydrologic evaluation report summarizing the aquifer test results in 2019?

3. Page 9, Section 4.1 Radioisotope Monitoring, Second Paragraph, First Sentence: This sentence states, "The CADD/CAP Addendum established regulatory levels ..." Actually, the regulatory levels were first established in Section 5.2.2.1 of the CADD/CAP (2006) and there is a statement in the CADD/CAP Addendum (2019) that the regulatory levels were maintained. As such, please correct the statement in this sentence.

4. Page 9, Section 4.2 Radioisotope Monitoring Results, Second Paragraph, Fourth Sentence: This sentence ends with "... until the 2015 and 2016 sampling events, when samples had

concentrations of 14.6 and 7.02 pCI/L, respectively (Table 1 and Table B-1 in Appendix B)." Please remove the reference to Table 1 as this Table presents data from 2017 to 2019.

5. Page 15, Section 4.4 Water-Level Monitoring Results, First Paragraph, First Sentence: This sentence indicates Figure 5, Figure 6, and Figure 7 show hydrographs from when monitoring was initiated in 2007. However, the data presented in the Figures start at "Jan-2010." Please correct this sentence.

6. Page C-1, Figure C-1, Hydrographs for Wells West of the Sheer Zone: It is noted that the "Date Scale" changed on the x-axis. However, it is not clear why some data points prior to January 2007 have not been included when compared to Figure C-1 in the 2018 Groundwater Monitoring Report Project Shoal Area: Subsurface, Corrective Action Unit 447, August 2019. Also, it is not clear why there is not a Hydrograph similar to Figure C-2 in the 2018 Groundwater Monitoring Report included in the 2019 Groundwater Monitoring Report. Please explain.

7. Information received via a September 17, 20202 email from Mark Kautsky to Christine Andres titled "Iodine-129 results - Shoal Subsurface CAU." The text of the email stated, in part, that the 2020 results were converted to activity concentrations using a different formula than the one used previously for results reported in 2008, 2010, and 2015 by the University of Arizona (UA) laboratory. While the UA laboratory was unable to locate or verify the previous formula, they did provide the current calculation method used to convert the 2020 results to activity concentrations. Following review, the Office of Legacy Management agreed with the methodology used to calculate the 2020 results. While the Iodine-129 results and the calculations were email attachments, it was also stated in the email that, with NDEP agreement, the "nonconformance in the calculation worksheet" will be reported in the 2019 Groundwater Monitoring Report. The NDEP does request that the information presented in the September 17, 2020 email, along with the updated data tables and calculations, be included in the Final document.

8. Information received via a September 17, 20202 email from Mark Kautsky to Christine Andres titled "Iodine-129 results - Shoal Subsurface CAU." In the attachment titled, "SHL-2019GWReport-UpdatedDataTables," the page number on Table 1 is incorrect and it is not clear why the repeated "Error" messages are shown throughout the Tables. Please correct these discrepancies in the Final Document.

If you have questions regarding this matter, please contact either Britt Jacobson or me via email.

Sincerely,

Chris Andres

Christine D. Andres
Chief
Bureau of Federal Facilities

CDA/EJ

ec: FFACO Group, NFO
EM Records, AMEM
Navarro Central Files
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NAVARRO

Contractor to the U.S. Department of Energy Office of Legacy Management

Record of Review

Review requirements are described in the *Quality Assurance Manual* (LMS/POL/S04320) and the *Document Management Manual* (LMS/POL/S09818). Reviewers may document any review with this form. This form should not be converted to a PDF until all reviews are complete.

Document Information

Due date: 02/05/2021 Review number: 1 Project: NVOS – Shoal, Nevada, Site Charge code: LMCP.LMCP.2. Enter text

Document title, number, and revision: Draft "2019 Groundwater Monitoring Report, Project Shoal Area: Subsurface Corrective Action Unit 447"

Author: Mark Kautsky Author's phone: (970) 248-6018 Author's organization: DOE-LM

Reviewer: Christine D. Andres Reviewer's phone: (702) 486-2850 Reviewer's organization: NDEP

Reviewer's recommendation: ☐ Release without comment ☐ Consider comments ☒ Resolve comments and reroute for review Date: 12/15/2020

Author's response: ☒ Comments have been addressed Date: 01/06/2021

Reviewer's response to comment resolution: ☒ Satisfactory ☐ Unsatisfactory[1] Date: Date 1/28/21

Author signifies all comments resolved successfully: emailed to NDEP on 1/19/21 @ 3:53 pm and 1/25/21 @ 2:36 pm. with comment responses Date: Date

[1] If the author or reviewer is dissatisfied with the resolution, the matter may be elevated to the next level of management. If an impasse develops, management must resolve the issue.

Item Number	Reviewer's Comments and Recommendations	Required	Author's Response (if required)
1	Page 4, Section 2.1, Summary of Corrective Action Activities. First Partial Paragraph, Second Full Sentence: It is not clear why the verb "will be" is used in this sentence when the addendum to the CADD/CAP was approved in 2019. It is understood that the subject of this paragraph is the 2011 data acquisition plan but as all the activities outlined in the 2011 plan have been completed, the wording of the sentence should reflect that fact.	Yes	We deleted the last sentence of this paragraph because the main subjects of the sentence (updates made to the SCM, enhancements to the monitoring network, and changes to the contaminant and compliance boundaries) are presented in more detail in the last paragraph on this page, where we discuss the final CADD/CAP Addendum.
2	Page 4, Section 2.1, Summary of Corrective Action Activities, First Full Paragraph, Fifth and Last Sentences: What was the reason for the five-year lag between the aquifer tests performed in 2014 and the publication of the hydrologic evaluation report summarizing the aquifer test results in 2019?	Yes	The wells were installed in late 2014 and the first aquifer test was conducted in September 2015. The Hydrologic Evaluation Report was finalized in January 2019. The delay was attributed to problems with the pump in well MV-5, which was replaced in June 2017. The following sentence was added after the fourth sentence to provide the additional detail: "Aquifer testing began in late 2015 but the testing program was not completed until mid-2017, after a malfunctioning pump in well MV-5 had been replaced."

Record of Review

Item Number	Reviewer's Comments and Recommendations	Required	Author's Response (if required)
3	Page 9, Section 4.1 Radioisotope Monitoring, Second Paragraph, First Sentence: This sentence states, "The CADD/CAP Addendum established regulatory levels ..." Actually, the regulatory levels were first established in Section 5.2.2.1 of the CADD/CAP (2006) and there is a statement in the CADD/CAP Addendum (2019) that the regulatory levels were maintained. As such, please correct the statement in this sentence.	Yes	The first and second sentences of this paragraph were revised, so they now read as follows: "The regulatory levels for the site groundwater were established in the CADD/CAP and maintained in the CADD/CAP Addendum. The regulatory levels are 20,000 pCi/L tritium, 2000 pCi/L 14C, and 1 pCi/L 129I (DOE 2019b). These levels are not to be exceeded outside the compliance boundary (Figure 2)."
4	Page 9, Section 4.2 Radioisotope Monitoring Results, Second Paragraph, Fourth Sentence: This sentence ends with "... until the 2015 and 2016 sampling events, when samples had concentrations of 14.6 and 7.02 pCi/L, respectively (Table 1 and Table B-1 in Appendix B)." Please remove the reference to Table 1 as this Table presents data from 2017 to 2019.	Yes	We removed the reference to Table 1 as requested.
5	Page 15, Section 4.4 Water-Level Monitoring Results, First Paragraph, First Sentence: This sentence indicates Figure 5, Figure 6, and Figure 7 show hydrographs from when monitoring was initiated in 2007. However, the data presented in the Figures start at "Jan-2010." Please correct this sentence.	Yes	The sentence was revised as follows: "Figures 5, 6, and 7 show hydrographs of groundwater elevation data from site wells/piezometers dating back to January 2010, shortly after the CADD/CAP monitoring program was initiated in 2007."
6	Page C-1, Figure C-1, Hydrographs for Wells West of the Sheer Zone: It is noted that the "Date Scale" changed on the x-axis. However, it is not clear why some data points prior to January 2007 have not been included when compared to Figure C-1 in the 2018 Groundwater Monitoring Report Project Shoal Area: Subsurface, Corrective Action Unit 447, August 2019. Also, it is not clear why there is not a Hydrograph similar to Figure C-2 in the 2018 Groundwater Monitoring Report included in the 2019 Groundwater Monitoring Report. Please explain.	Yes	Figure C-1 was revised to include all the water levels as requested. Figure C-2 (as provided in the 2018 report) was also updated and reinserted in this report. This figure is the same as Figure C-1 but with an expanded scale on the y-axis to show the extreme drawdown from aquifer tests completed before 2007. This figure was originally removed from the report because, in our opinion, the expanded scale obscured the well-specific detail, rendering it less useful as a visual reference.
7	Information received via a September 17, 2020 email from Mark Kautsky to Christine Andres titled "Iodine-129 results - Shoal Subsurface CAU." The text of the email stated, in part, that the 2020 results were converted to activity concentrations using a different formula than the one used previously for results reported in 2008, 2010, and 2015 by the University of Arizona (UA) laboratory. While the UA laboratory was unable to locate or verify the previous formula, they did provide the current calculation method used to convert the 2020 results to activity concentrations. Following review,	Yes	The information presented in the September 17, 2020 email, along with the updated data tables and calculations, are included in the final report as requested. The first paragraph of Section 4.2 was revised by including the following sentences after the second sentence of this paragraph. This paragraph includes the following: "The ^{129}I results from the 2019 sampling event continue to be several orders of magnitude below the RDL of 0.1 pCi/L but are not consistent with monitoring results from previous years. Historically the ^{129}I results

Record of Review

Item Number	Reviewer's Comments and Recommendations	Required	Author's Response (if required)
	the Office of Legacy Management agreed with the methodology used to calculate the 2020 results. While the Iodine-129 results and the calculations were email attachments, it was also stated in the email that, with NDEP agreement, the "nonconformance in the calculation worksheet" will be reported in the 2019 Groundwater Monitoring Report. The NDEP does request that the information presented in the September 17, 2020 email, along with the updated data tables and calculations, be included in the Final document.		have been in the 10^{-9} to 10^{-12} pCi/L range, but the 2019 results are in the 10^{-6} to 10^{-8} pCi/L range. The laboratory provided the calculations used to convert the 2019 results to activity concentrations but were unable to provide the calculations to convert the 2008, 2010, and 2015 results (Table B-1 in Appendix B). The laboratory documented this finding in their lab report as a "Non-Conformance." LM reviewed and accepted the methodology for converting the 2019 results. LM will continue using this method to convert all future results. The calculation methodology is provided in Appendix B. The ^{14}C results from the 2019 sampling event are below the RDL of 5 pCi/L and are consistent with monitoring results from previous years."
8	Information received via a September 17, 2020 email from Mark Kautsky to Christine Andres titled "Iodine-129 results - Shoal Subsurface CAU." In the attachment titled, "SHL-2019GWReport-UpdatedDataTables," the page number on Table 1 is incorrect and it is not clear why the repeated "Error" messages are shown throughout the Tables. Please correct these discrepancies in the Final Document.	Yes	The incorrect page numbers and error messages will be removed after we update the tables in the final report.
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