LMS/SHL/S07895

2011 Groundwater Monitoring Report, Project Shoal Area Subsurface, Corrective Action Unit 447

April 2012

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Acronyms

AEC	U.S. Atomic Energy Commission
amsl	above mean sea level
bgs	below ground surface
BSZ	bottom of open interval/screen zone
CADD	Corrective Action Decision Document
CAP	Corrective Action Plan
CAU	Corrective Action Unit
DOE	U.S. Department of Energy
ECH	exploratory core holes
FFACO	Federal Facility Agreement and Consent Order
ft	feet
LM	Office of Legacy Management
MCL	maximum contaminant level
MDC	minimum detectable concentration
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
MV	monitoring/validation
NA	not applicable
NDEP	Nevada Division of Environmental Protection
NR	not run
pCi/L	picocuries per liter
PM	particle motion
PSA	Project Shoal Area
RDL	required detection limit
s.u.	standard unit
SCM	site conceptual model
TOC	top of casing
TSZ	top of open interval/screen zone
TVD	true vertical depth
USBM	U.S. Bureau of Mines

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Executive Summary

The Project Shoal Area (PSA) in Nevada was the site of a 12 kiloton 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. Analytical results from the current 2011 monitoring are consistent with those of the previous year, with tritium detected only in well HC-4. The tritium concentration in groundwater from well HC-4 remains far below the maximum contaminant level of 20,000 picocuries per liter. Concentrations of total uranium and unadjusted gross alpha were also detected during the current period, with uranium accounting for nearly all the gross alpha activity. The total uranium concentrations during the current monitoring were consistent with the 2010 results and reflect a slightly elevated natural uranium concentration, consistent with the mineralized geologic terrain. Isotopic ratios of uranium also indicate a natural source of uranium in groundwater, as opposed to a nuclear-test-related source. Water level trends obtained from the 2011 water level data were consistent with those of previous years.

The corrective action strategy for the PSA is currently focused on revising the site conceptual model (SCM) and evaluating the adequacy of the current 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. Water levels have been rising at the site since the first hydrologic characterization wells were installed in 1996. While 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.

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1.0 Introduction

This report presents the 2011 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 the environmental site restoration of the PSA was transferred from the DOE Office of Environmental Management 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 in support of future site closure. This report summarizes the results from the groundwater monitoring program during fiscal year 2011.

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 Project Shoal underground nuclear test was performed on October 26, 1963, as part of the Vela-Uniform program sponsored jointly by the U.S. Department of Defense and the U.S. Atomic Energy Commission (AEC). The test consisted of detonating a 12-kiloton nuclear device in granitic rock at a depth of approximately 1,211 feet (ft) below ground surface (bgs) (AEC 1964). A cavity created by the test collapsed shortly after the detonation and formed a rubble chimney (Pohll et al. 1998). 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). A radioactive materials survey conducted at the site in 1970 indicated that there were no radiological levels that exceeded background for the area (AEC 1970). The decontamination and restoration activities were minimal, because no large areas of surface radiological contamination were found during or following the test. During this effort the emplacement shaft was covered with a concrete slab, and the particle motion (PM), exploratory Core Holes (ECH), and U.S. Bureau of Mines (USBM) boreholes on the site were plugged and abandoned (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 surface 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).

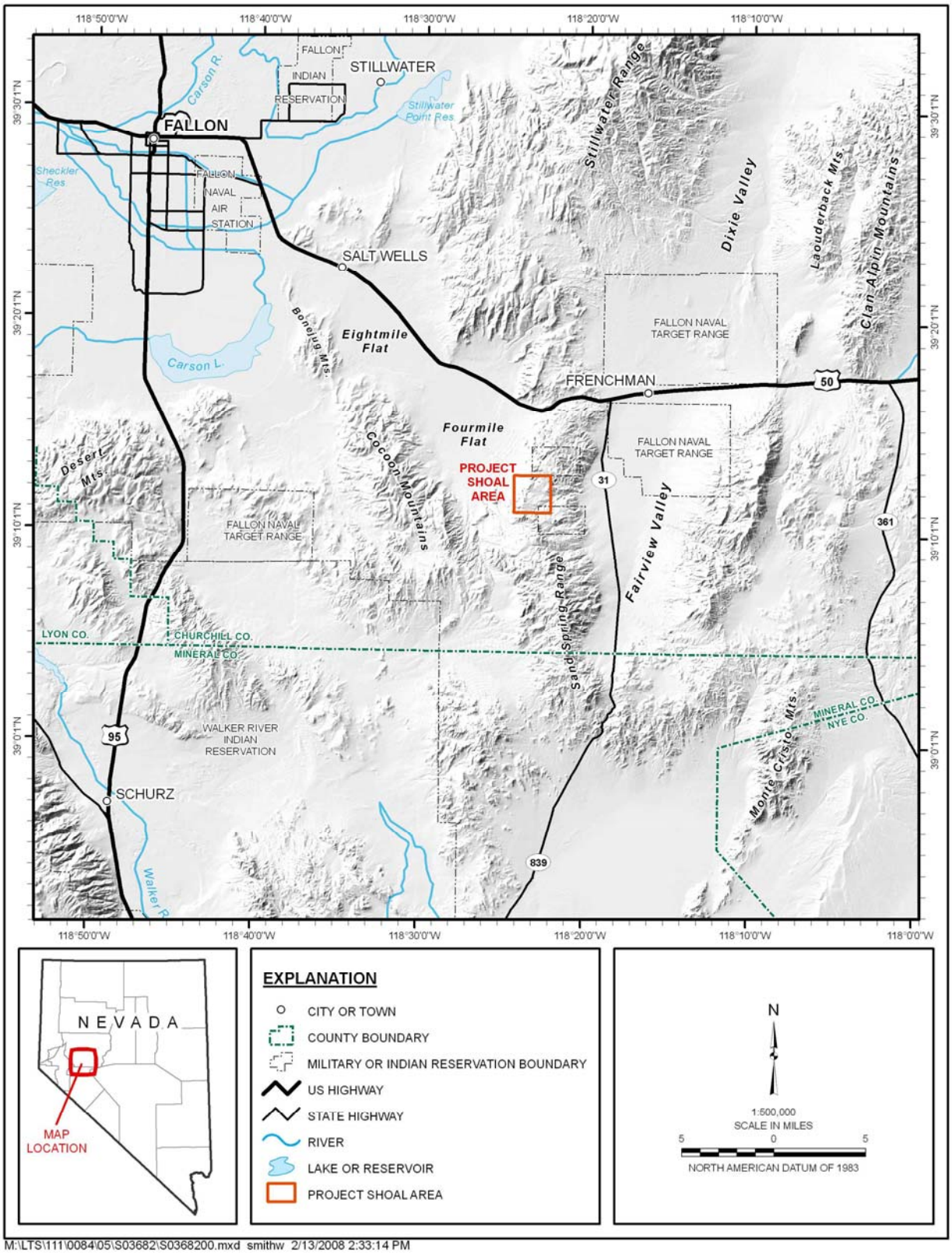

Figure 1. Location Map of the Project Shoal Area

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 groundwater outside the boundary has 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 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 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 increased at rates that ranged from approximately 1 to 2 feet per year during the model validation time period. Pursuant to the Federal Facility Agreement and Consent Order (FFACO 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 the 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 that 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 potential site conceptual models. 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.

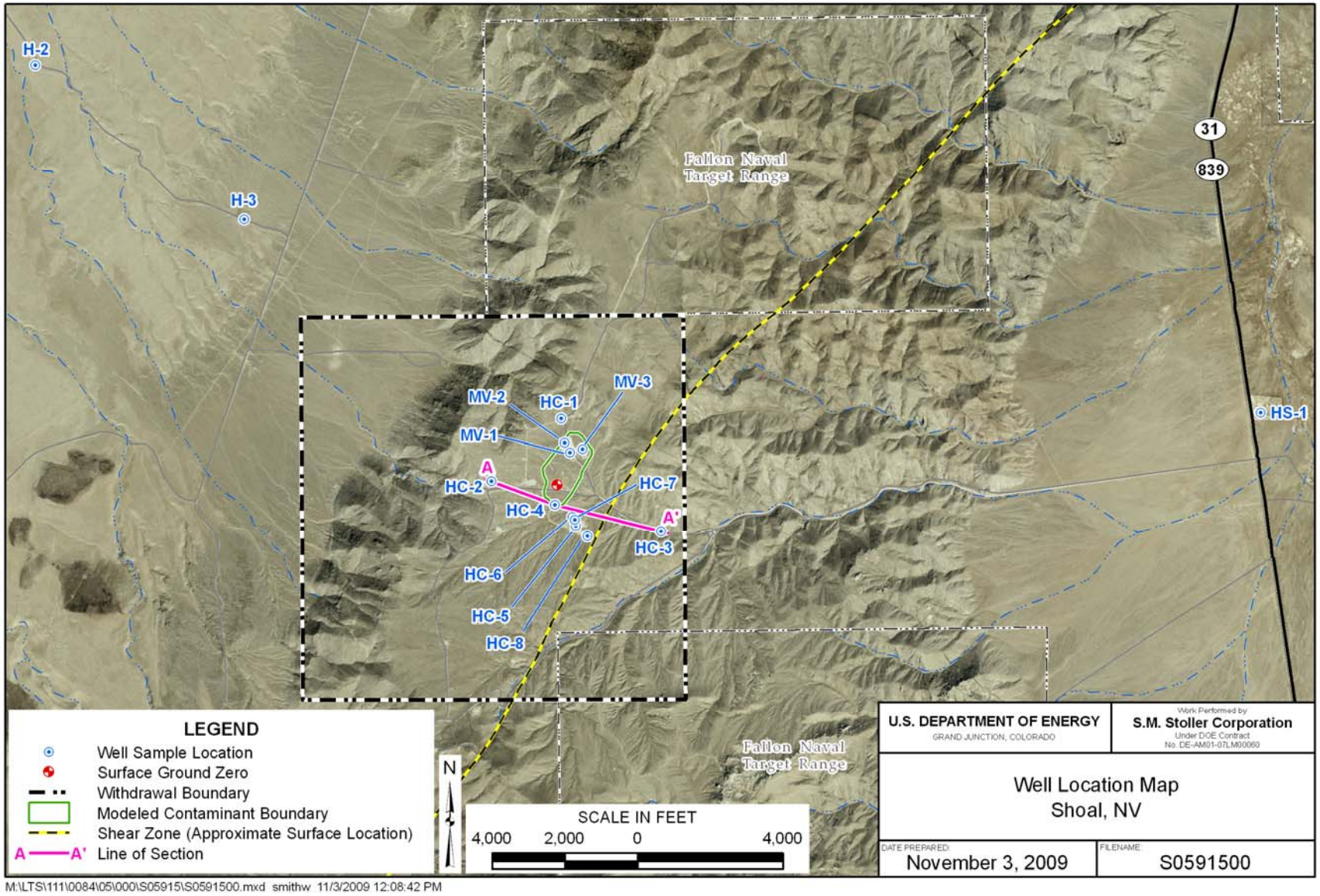

Figure 2. Well Location Map Shoal, Nevada

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 (Figure1). 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 965 to 1,090 ft bgs, 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 due to 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.

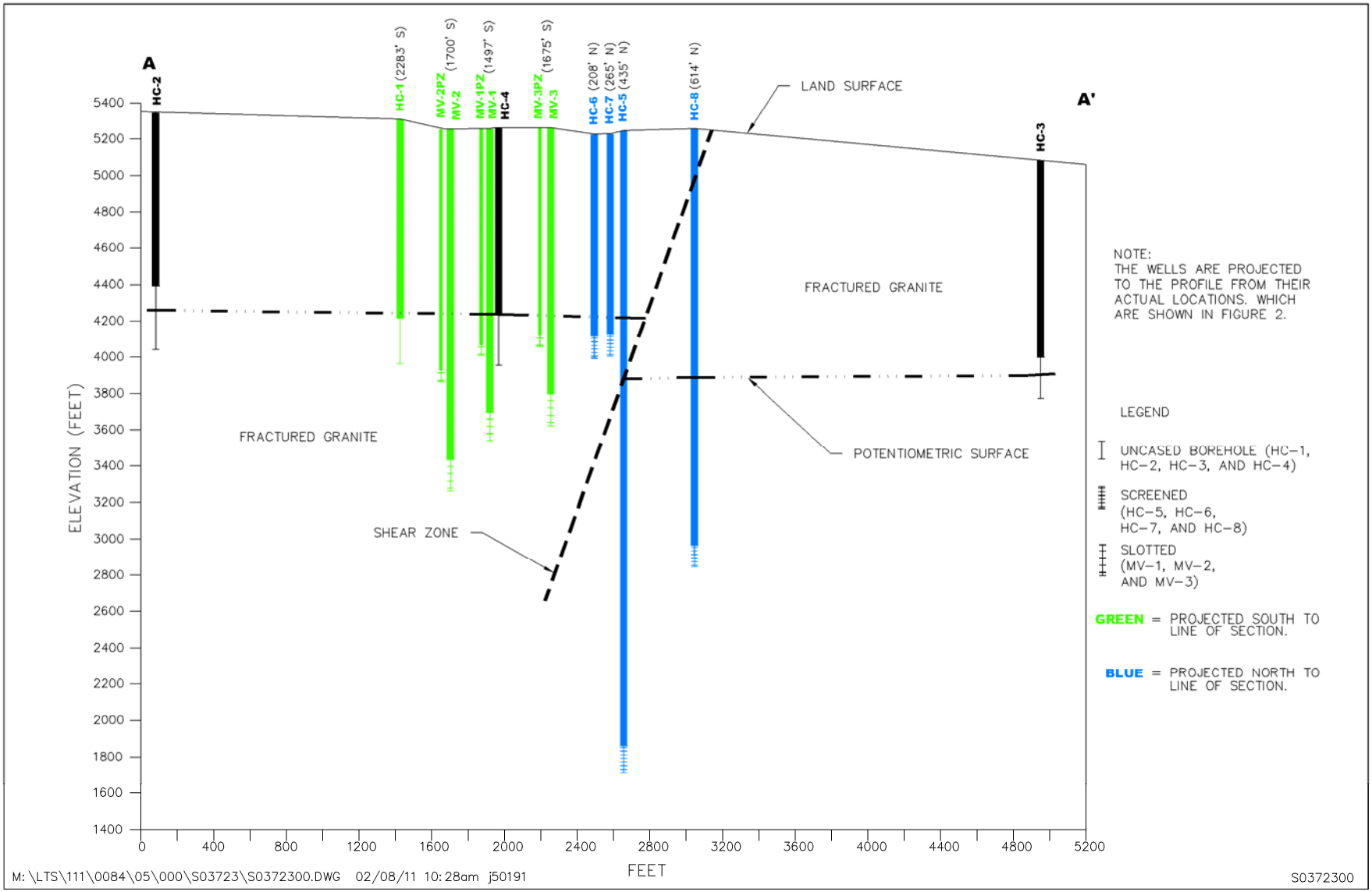

Figure 3. Cross Section A–A' Depicting Monitoring Well and Shear Zone Location, Project Shoal Area, Nevada

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 *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PLN/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. Water levels have been rising at the site 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 at the site. To advance the SCM during this period of monitoring, LM developed a new short-term data acquisition plan that was approved by NDEP (DOE 2011a). The new data acquisition plan includes further review of all available reports and assembling a detailed informational resource tool that includes a summary of pertinent technical data. Analytical, hydrologic, and geologic data obtained from the evaluation of historical reports will be reviewed along with existing data and collected geophysical data to help identify geologic structures that might be influencing groundwater flow at the site. The data obtained from the evaluation will be assembled for three-dimensional visualization. Interpretations obtained from this evaluation will enhance the monitoring program by identifying data gaps, assessing potential groundwater flow directions, and evaluating the site's current monitoring well network.

4.1 Radioisotopic Monitoring

Groundwater samples were collected for radioisotopic analyses from wells MV-1, MV-2, MV-3, HC-1, HC-2, HC-4, HC-5, HC-6, and HC-7 during the March 2011 sampling event. Samples were not collected from wells HC-3 and HC-8 to allow water levels at these locations to be evaluated without disturbance from the sampling activities. This temporary change in the sampling network was approved by NDEP during the technical exchange meeting in March 2011. Monitoring wells MV-1, MV-2, MV-3, HC-4, HC-5, and HC-7 were purged prior to sampling using dedicated submersible pumps. At least one well volume was removed, and field parameters (temperature, pH, and specific conductance) were allowed to stabilize before samples were collected. Samples were collected from wells HC-1, HC-2, and HC-6 using a depth-specific bailer because these wells are not completed with dedicated submersible pumps. The final set of field parameters and well purge volumes are presented in Appendix A.

Groundwater samples collected as part of the annual monitoring in March were analyzed for tritium, uranium isotopes, gross alpha, and mass concentrations of uranium as specified in the CADD/CAP (DOE/NNSA 2006). The analytical results obtained from the annual sampling were validated in accordance with the *Environmental Procedures Catalog* (LMS/PRO/S04325), "Standard Practice for Validation of Laboratory Data." A copy of the Data Validation Package is maintained in the LM records and is available on request.

The frequency for analyzing samples for carbon-14 (^{14}C) and iodine-129 (^{129}I) was reduced to every 5 years beginning after the 2010 sampling event as specified in the short-term data acquisition plan approved by NDEP (DOE 2009). 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, monitoring of ^{14}C and ^{129}I is also conducted 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 maximum contaminant level (MCL) for gross alpha is exclusive of uranium and radon. Including uranium and uranium-isotopic analyses as part of the analytical suite provides data to demonstrate 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 CADD/CAP established regulatory levels for site groundwater of 20,000 picocuries per liter (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 MCLs for adjusted gross alpha and uranium are 15 pCi/L and 30 micrograms per liter (µg/L), respectively. These constituents are believed to be naturally elevated in groundwater in the region. The LM contract-required detection limit (RDL) for tritium is 400 pCi/L, this is slightly higher than the limit of 300 pCi/L established in the CADD/CAP. A record of technical change has been submitted to NDEP to change the RDL to 400 pCi/L in the CADD/CAP. The laboratory radiochemical minimum detectable concentration (MDC) reported with these data is an *a priori* estimate of the detection capability of a given analytical procedure, not an absolute concentration that can or cannot be detected.

4.2 Radioisotopic Results

Table 1 presents a summary of analytical results for ^{14}C, ^{129}I, tritium, uranium, and gross alpha from the sampling event in March 2011 along with the results through 2008 for comparison. Historical analytical results from 2007 through the present are provided in Appendix B. A sample collected from well HC-4 was the only sample with tritium detected above the laboratory's MDC. 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 have 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 the U.S. Environmental Protection Agency 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 to 555 pCi/L from 2008 through 2011. These increases may be related to the volume of water purged from HC-4 during sampling events, and a recommendation to increase the purge time to test this hypothesis during the next sampling event is described in Section 6. The presence of tritium in HC-4 is due to its proximity to the nuclear detonation. It is the well nearest to the detonation point (Figure 2). This interpretation of the tritium source is supported by the elevated levels of ^{14}C in HC-4 compared to levels in the other monitoring wells. The elevated concentration of ^{14}C in well HC-4 is likely the result of its migration in the gas phase near the water table, as part of the CO_2 molecule, where it dissolved into groundwater in the upper saturated zone near the detonation.

Table 1. Radioisotopic and Chemical Sampling Results 2008 through 2011

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross alpha (pCi/L, total unadjusted)
MV-1	3/11/2008	<RDL (2.49E-02)	<RDL (19.0E-11)	<180	21	14.0
	2/26/2009	<RDL (1.95E-02)	<RDL (10.5E-11)	<350	21	12.6
	3/11/2010	<RDL (1.93E-02)	<RDL (7.8E-11)	<300	21	11.3
	3/22/2011	NA	NA	<350	25	16.6
	3/22/2011[c]	NA	NA	<360	25	14.3
MV-2	3/11/2008	<RDL (2.44E-02)	<RDL (29.5E-11)	<180	23	11.1
	2/26/2009	<RDL (2.13E-02)	NR	<360	24	12
	3/11/2010	<RDL (3.31E-02)	<RDL16.5 (E-11)	<300	21	13.8
	3/22/2011	NA	NA	<350	23	9.92
MV-3	3/11/2008	<RDL (1.37E-02)	<RDL (18.0E-11)	<320	3.8	2.11
	2/26/2009	<RDL (8.37E-03)	<RDL (10.7E-11)	<360	3.8	<1.5
	3/12/2010	<RDL (1.29E-02)	<RDL (6.5E-11)	<300	4.2	2.63
	3/22/2011	NA	NA	<350	5.8	4.98
HC-1	3/11/2008	<RDL (2.35E-02)	<RDL (4.9E-11)	<320	4.8	12.5
	2/26/2009	<RDL (2.01E-02)	NR	<360	1.4	<1.4
	3/24/2010	<RDL (3.18E-02)	<RDL (11.9E-11)	<310	3.3	4.93
	3/22/2011	NA	NA	<360	1.6	2.19
HC-2	3/24/2010	<RDL(1.90E-02)	<RDL (2.5E-11)	<300	140	63.8
	3/22/2011	NA	NA	<360	120	197
HC-3	3/24/2010	<RDL (2.37E-02)	<RDL (541E-11)	<300	4.3	2.57
	3/22/2011	NA	NA	NA	NA	NA
HC-4	3/11/2008	<RDL (2.06)	<RDL (21.5E-11)	555	4.5	2.88
	2/26/2009	<RDL (3.20)	<RDL (0.6E-11)	434	2.0	<1.4
	3/11/2010	<RDL (2.93)	<RDL (38.7E-11)	544	6.4	1.79[b]
	3/23/2011	NA	NA	554	8.9	3.82
HC-5	3/11/2010	<RDL (5.11E-03)	<RDL (1.1E-11)	<300	0.48	<1.5
	3/23/2011	NA	NA	<360	0.45	<2.1
HC-6	3/24/2010	<RDL (1.14E-02)	<RDL (5.6E-11)	<300	35	25.7
	3/23/2011	NA	NA	<360	37	20.4
HC-7	3/11/2010	<RDL (5.31E-03)	<RDL (3.0E-11)	<300	7.4	5.77
	3/23/2011	NA	NA	<360	13	10.6
HC-8	3/10/2010	<RDL (9.63E-03)	<RDL (1.3E-11)	<300	0.25	<1.3
	3/23/2011	NA	NA	NA	NA	NA

[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; RDL is 5 pCi/L for ^{14}C, 0.1 pCi/L for ^{129}I, 300 pCi/L for tritium, 50 µg/L for uranium, and 4 pCi/L for gross alpha (DOE/NNSA 2006)
NR = not run, because sample bottle was broken during shipment to the laboratory
NA = not applicable (samples not collected or samples not analyzed)

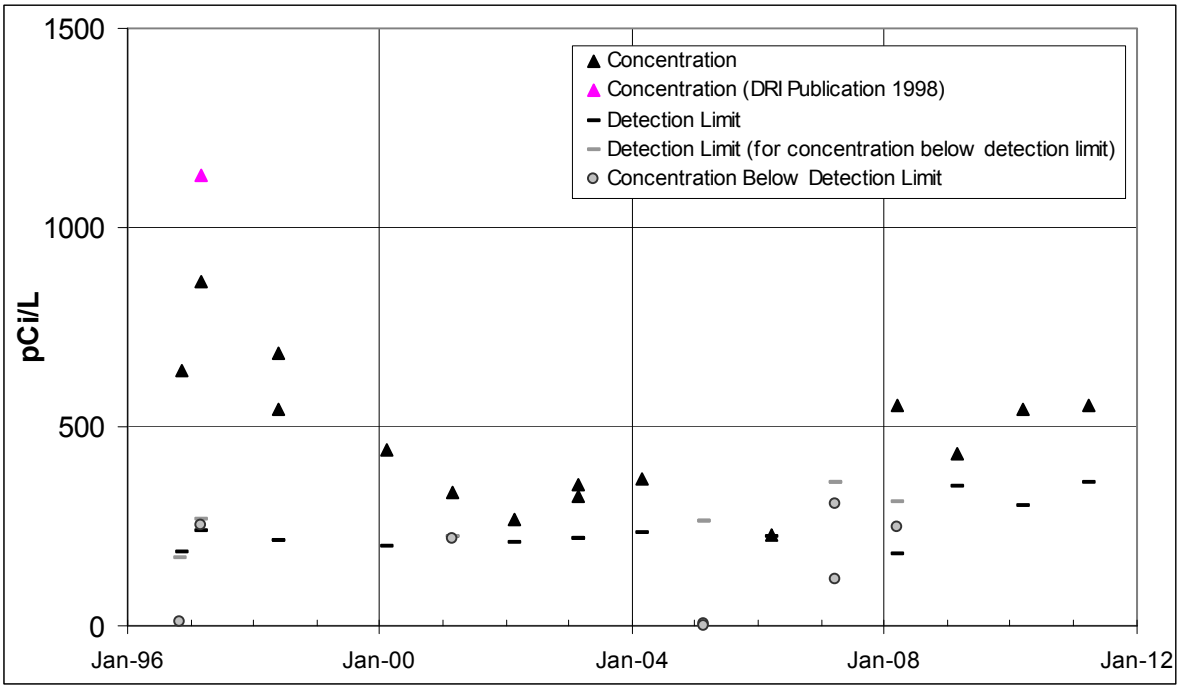

Figure 4. Time-Concentration Plot of Tritium at Well HC-4

Uranium mass concentrations detected in samples collected from wells MV-1 and MV-2 exceeded the MCL of 30 µg/L in 2007 (Appendix B, Table B–1) but declined below that level in 2008 and have remained relatively constant since then. Uranium mass concentrations have also been detected above the MCL in samples collected from wells HC-2 and HC-6 in 2010 and 2011. Total uranium in the sample collected from well HC-6 in 2011 exceeded the MCL at a concentration of 37 µg/L. The sample collected from well HC-2 in 2011 was four times the MCL at a concentration of 120 µg/L. These total uranium concentrations are consistent with the 2010 results and reflect a naturally elevated uranium concentration consistent with mineralized geologic terrain, as described below.

Unadjusted gross alpha activities shown in Table 1 are below the MCL of 15 pCi/L for all samples collected during the 2011 sampling event with the exception of samples collected from wells HC-2 and HC-6. If gross alpha values for HC-2 and HC-6 (Table 1) are adjusted by subtracting activities of ^{234}U and ^{238}U shown in Table 2, values are near or less than zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples. The exception is the sample collected from well HC-2 that increased from the previous sampling event. It is uncertain, due to the small data set, if the increase in gross alpha activity in well HC-2 is an anomaly or a trend. If the gross alpha activity remains relatively high at well HC-2 for the next sampling event, additional analyses to determine the cause of the alpha activity in excess of uranium may be warranted. The increase in gross alpha at HC-2 could be attributable to using a different bailer than was used during previous sampling events. Several attempts were required to get the bailer to fill, increasing turbidity of the sample. The elevated concentrations of uranium observed in the past are believed to be naturally occurring. It has been demonstrated that ambient groundwater in the region surrounding the site is elevated in concentrations of gross alpha and uranium (Bevans et al. 1998). Elevated uranium concentrations are attributed to leaching from granitic bedrock and associated sediments.

Isotopic ratios of uranium further support the interpretation of a natural source of uranium in groundwater as opposed to 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 indicates that most ratios observed in the PSA samples range from 0.91 to 2.26—consistent with a natural uranium source. Very few samples have ratios exceeding 1.2. 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).

Table 2. Uranium Isotopic Sampling Results, 2008 Through 2011

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	$^{234}U/^{238}U$
MV-1	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
MV-2	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
MV-3	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
HC-1	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
HC-2	3/24/2010	45.1	45.3	0.996
	3/22/2011	45.2	45.3	0.998
HC-3	3/24/2010	1.16	1.21	0.96
	3/22/2011	NA	NA	NA
HC-4	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
HC-5	3/11/2010	0.295	0.173	1.71
	3/23/2011	0.264	0.117	2.26
HC-6	3/24/2010	14.4	12.2	1.18
	3/23/2011	15.4	13.5	1.14
HC-7	3/11/2010	3.43	3.08	1.11
	3/23/2011	5.9	4.78	1.23
HC-8	3/10/2010	0.187	0.101	1.85
	3/23/2011	NA	NA	NA

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

4.3 Hydraulic Head Monitoring

Monitoring of the groundwater flow system was performed by measuring hydraulic head in the onsite wells/piezometers (MV-1 through MV-3 and HC-1 through HC-8) and offsite wells (H-2 and H-3) (Figure 2). Heads were recorded every 3 hours by transducers installed in these wells/piezometers. Water levels were measured manually, and transducers were downloaded in March as part of the annual sampling and in September as part of a scheduled monitoring event and site inspection. The manual water level measurements were collected prior to conducting activities that would disturb ambient water level conditions. The manual water level measurements were used to convert the transducer data to groundwater elevations. The transducer in the MV-3 piezometer failed and was replaced during the March sampling event, so no data are available at this location from August 2010 through March 2011. Transducer data were not obtained from well HC-6 from March 2011 through September 2011 because the transducer was lodged in the well. A transducer was installed in the MV-2 piezometer during the March 2011 sampling event after it was determined that the redevelopment conducted in March 2010 to remove remnant drilling mud was somewhat successful. The redevelopment made access to water levels possible using a water level indicator and transducer, whereas previously, a weighted wireline was required to obtain a water level at this location. The screen interval still contains drilling mud/sediment, which has contributed to the very slow recovery from redevelopment bailing. Data were not plotted for the MV-2 piezometer because water level data are not yet considered to be representative of the formation screen interval (see Section 5.2).

4.4 Hydraulic Head Results

Table 3 presents well construction information and the most recent hydraulic head data, obtained in September 2011. Hydrographs of hydraulic head data from site wells and piezometers are shown in Figures 5, 6, and 7. 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 few hours. 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 include the MV-1, MV-2, and MV-3 wells and piezometers and wells HC-1, HC-2, HC-4, HC-6, and HC-7 (Figure 5). Head levels east of the shear zone are monitored by wells HC-3, HC-5, and HC-8 (figure 6). Monitoring locations in Fourmile Flat (west of the site) include the H-2 and H-3 wells (Figure 7). Water levels in onsite wells west of the shear zone (detonation side) continued to rise during the previous year at rates ranging from 0.76 ft in MV-2 to 1.82 ft in MV-3 (July 2010 to July 2011). The rates are declining relative to previous years but still too high to conclude that water levels are beginning to stabilize. Water levels in wells west of the shear zone at the site are 300 to 400 ft higher than those in wells east of the shear zone and in wells west of the site in Fourmile Flat. Refer to Appendix C for hydraulic head data from 1996 to the present. Refer to Appendix D for a table showing annual water level changes in wells west of the shear zone from July 2007 through July 2011.

Table 3. Well Construction Details and September 2011 Head Data for Wells at the PSA

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	5,257.54	991.69	9/28/2011	4,265.85	3,684.81	3,531.00	153.81
MV-1 PZ	5,257.30	976.38	9/28/2011	4,280.92	3,919.80	3,859.80	60.00
MV-2	5,266.62	1,001.15	9/28/2011	4,265.47	3,446.75	3,275.98	170.77
MV-2 PZ[c]	5,266.51	1,080.15[d]	9/28/2011	4,186.36[d]	4,078.82	4,019.32	59.50
MV-3	5,261.50	973.73	9/28/2011	4,287.77	3,797.91	3,626.75	171.16
MV-3 PZ	5,261.17	973.23	9/28/2011	4,287.94	4,120.75	4,060.72	60.03
HC-1	5,309.21	1,062.63	9/29/2011	4,267.79	4,236.01	3,997.12	238.89
HC-2	5,347.12	1,084.52	9/28/2011	4,263.04	4,392.12	4,124.12	268.00
HC-3	5,081.52	1,179.45	9/28/2011	3,922.07	3,918.52	3,898.02	20.50
HC-4	5,260.90	1,009.39	9/28/2011	4,255.31	4,247.90	3,957.90	281.00
HC-5	5,247.37	1,368.47	9/27/2011	3,878.90	1,862.37	1,716.77	145.60
HC-6	5,228.68	967.41	9/28/2011	4,262.16	4,112.70	3,996.38	116.32
HC-7	5,229.72	967.65	9/28/2011	4,262.30	4,123.25	4,006.12	117.13
HC-8	5,259.91	1,371.50	9/27/2011	3,888.97	2,965.51	2,848.99	116.52
H-2	4,017.06[e]	110.15	9/28/2011	3,906.91	3,377.06	3,237.06	140.00
H-3	4,232.30[e]	325.68	9/29/2011	3,906.62	3,919.30	3,762.30	157.00

[a] Depth-to-water measurements not corrected for borehole deviation. Depth-to-water measurements were collected prior to performing activities that disturb ambient water level conditions.
[b] Corrected for borehole deviation.
[c] Indicates that a transducer was not installed in the piezometer.
[d] Indicates the water level and/or groundwater elevation have not recovered from bailing.
[e] Indicates land surface elevation because TOC elevations are not available.
BSZ = (bottom of open interval; screened, perforated, or open hole)
NM = Not measured
TOC = top of casing (well/piezometer)
TSZ = (top of open interval; screened, perforated, or open hole)
Elevation Water (true vertical depth [TVD] corrected), Water Depth (not TVD corrected)

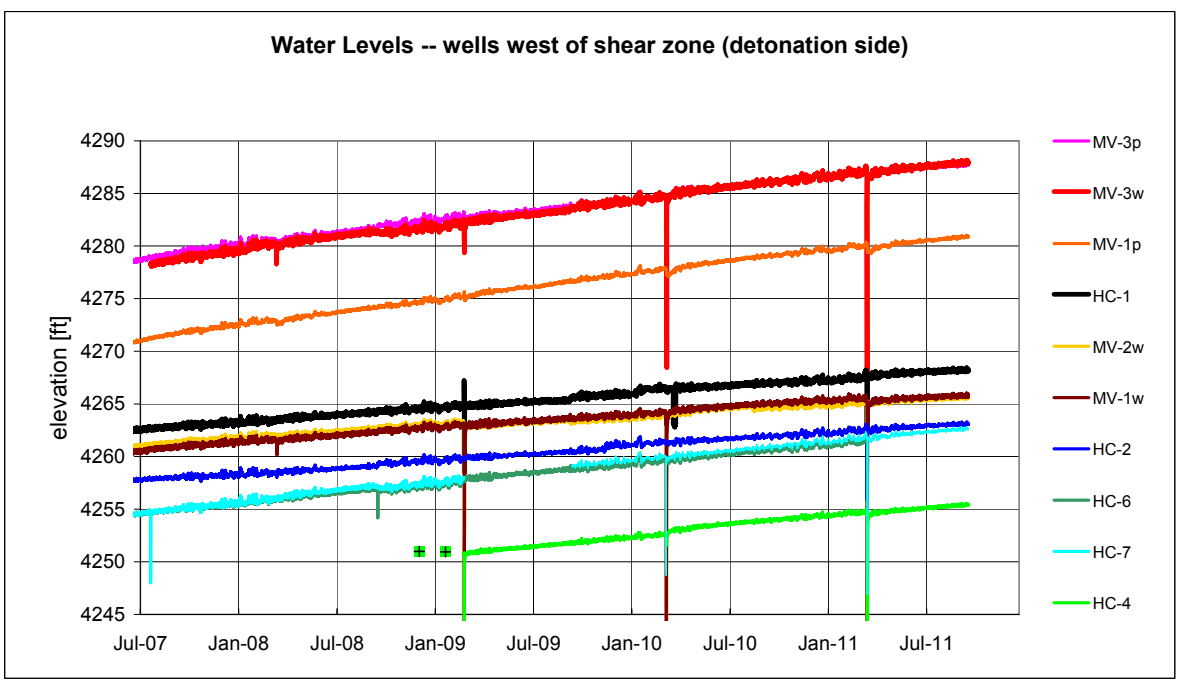

Figure 5. Hydrographs for Wells West of the Shear Zone

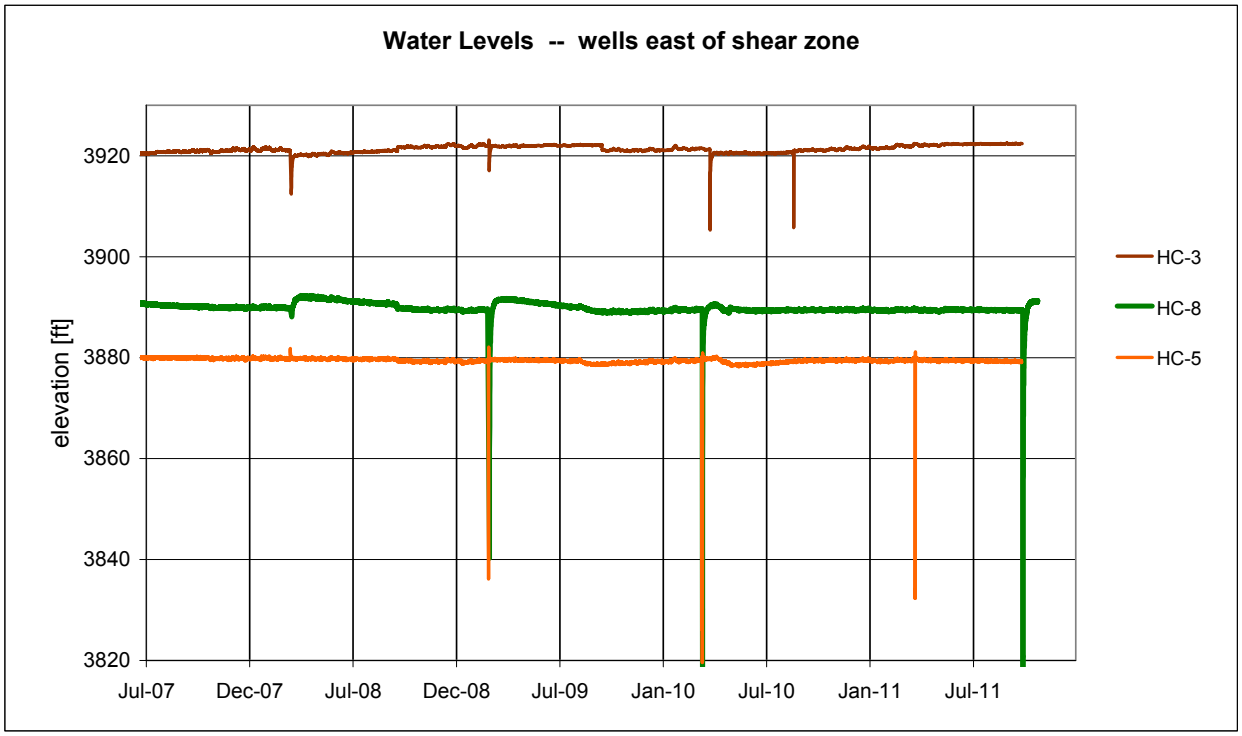

Figure 6. Hydrographs for Wells East of the Shear Zone

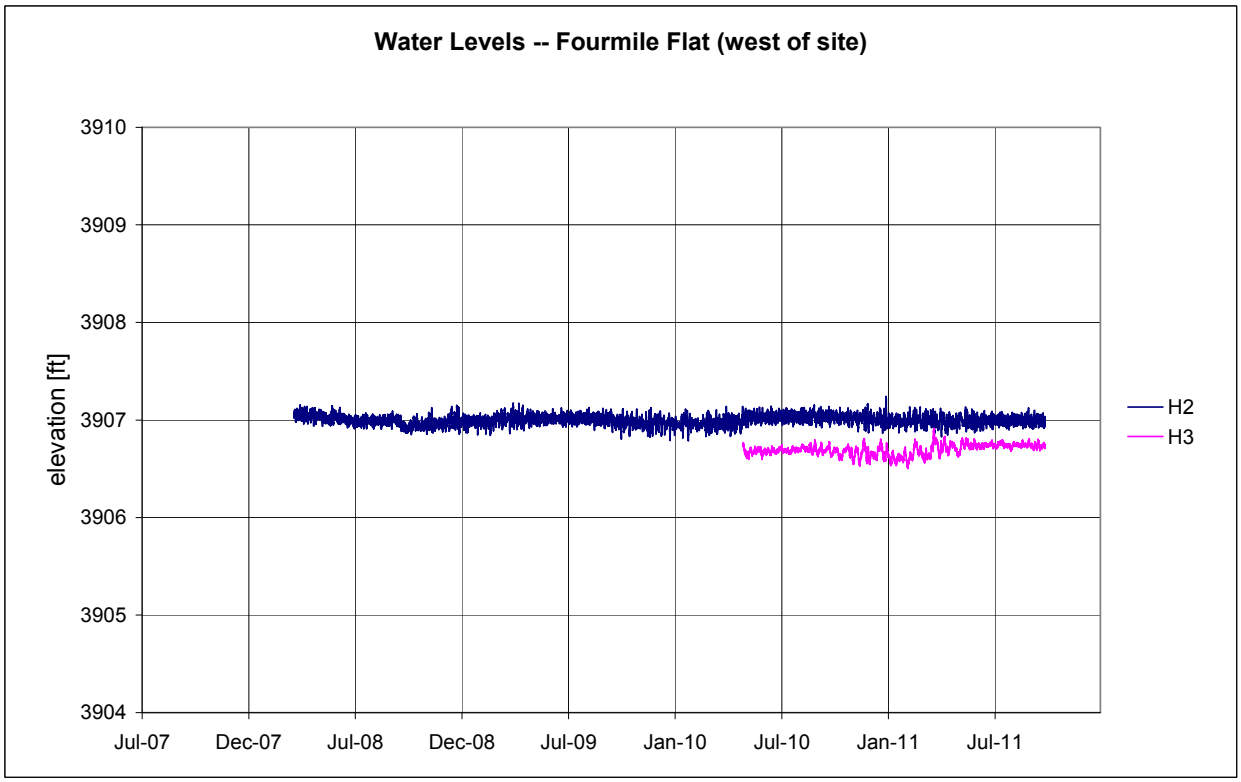

Figure 7. Hydrographs for Wells in Fourmile Flat

5.0 Site Inspection and Supplemental Site Activities

A site inspection is conducted as part of the fall monitoring event, which is typically a 1 day monitoring event to measure water levels, download transducers, and inspect roads, wellheads, and the monument at surface ground zero for signs of damage. Additional activities were conducted as part of the fall monitoring event that included an infiltration test at well HC-8 and adding water to the MV-2 and MV-3 piezometers to test confidence in their observed water level relative to the current ambient conditions at their screened interval. On October 27, 2011, the transducers in well HC-8 and the MV-2 and MV-3 piezometers were downloaded to assess the effects the tests. The roads, wellheads, and monument were all in good condition at the time of the inspection.

5.1 HC-8 Infiltration Testing

The objective of the infiltration test at well HC-8 was to test whether purge water (4,000−5,000 gallons) from sampling events was infiltrating and causing the anomalous 1 to 2 ft over-recovery of water levels observed at HC-8 3 to 4 weeks after annual sampling events (Figure 6). Considering that the depth to water at HC-8 is over 1,300 ft bls and that the depth to the top of the screen is over 2,200 ft, it is unlikely that infiltrating purge water is the cause of the over-recovery. However, the possibility of near-surface fractures that extend to depth cannot be ruled out and can be tested during subsequent sampling events.

The infiltration test was originally designed to discharge water from well HC-5 (about 450 ft northwest of well HC-8) to the usual HC-8 discharge location (approximately 20 ft northeast of the HC-8 wellhead). This would eliminate the possibility that factors directly related to the sampling of HC-8 (such as a leaky check valve) were the cause of the over-recovery. Well HC-8 was not sampled during the March 2011 sampling event to confirm that the discharge of purge water from HC-5 to its usual discharge area was not a factor (Figure 6). During the infiltration test, the additional elevation from the HC-5 wellhead to the HC-8 discharge location, along with friction loss from flow through over 400 ft of hose, caused the motor-saver connected to the HC-5 pump to trip after discharging only 820 gallons of water. The test was completed using water pumped from well HC-8 (4,060 gallons). The necessity of using water directly from HC-8 does not allow factors such as poroelastic effects to be eliminated, but given that the magnitude of the over-recovery after the previous sampling event (March 2010) was noticeably less than that observed after earlier sampling events, it was necessary to confirm that the over-recovery could be reproduced. The possibility of a leaky check valve was ruled out prior to using HC-8 as a water source after determining that water in the HC-8 riser pipe was within about 15 ft of the surface, indicating that the check valve had not leaked since HC-8 was last sampled in March 2010. It is assumed that if poroelastic effects are the cause of the over-recovery, a similar response would be seen at other site wells.

The infiltration test was the first step in trying to determine the cause of the over-recovery of water level in HC-8. During future sampling events, purge water from HC-8 will be discharged at different locations to determine the impact this might have on the over-recovery. During the spring 2012 sampling event, discharge water from HC-8 will be directed to the usual discharge area for well HC-5. If the over-recovery in HC-8 does not occur, purge water will be discharged to nearer locations during future sampling events. If it does occur, the over-recovery is not

infiltration related and is possibly caused by poroelastic effects due to the proximity of HC-8 to the shear zone at the site.

5.2 MV-2 Piezometer Water Level Testing

The observed water level in the MV-2 piezometer has been suspect since the piezometer was installed in 2006. The water level has recovered slowly since the piezometer was redeveloped in March 2010. Ten gallons of water were added in March 2011 to assist the recovery, raising the water level 64 ft from 4,120 to 4,184 ft amsl (Figure 8). The water level continued to rise slowly (at a rate faster than in nearby wells) until September 2011, when an additional 17.5 gallons of water were added, raising the water level approximately 105 ft to an elevation of 4,291 ft amsl. This is several feet higher than the water level elevation of any other site well or piezometer. It was expected that the piezometer would take water, and the level would decline to ambient conditions; however, its water level continued to increase slowly (now at the same rate as that of the MV-3 well and piezometer). An additional 2.5 gallons of water were added to the MV-2 piezometer on October 28, 2011, raising the water level to 4,303 ft amsl. The effect of the latest water level addition to the MV-2 piezometer will be assessed when the data are downloaded during the spring 2012 sampling event. The MV-2 piezometer cannot currently be considered a valid data point for the hydraulic head at its screened interval. For comparison, 1 gallon of water was added to the MV-3 piezometer to determine how quickly a well-developed piezometer screened in a permeable interval would recover from an approximately 5 ft increase in water level. The water level in the MV-3 piezometer quickly recovered to its level prior to the addition of water and was not detected in the transducer data (recorded every 3 hours).

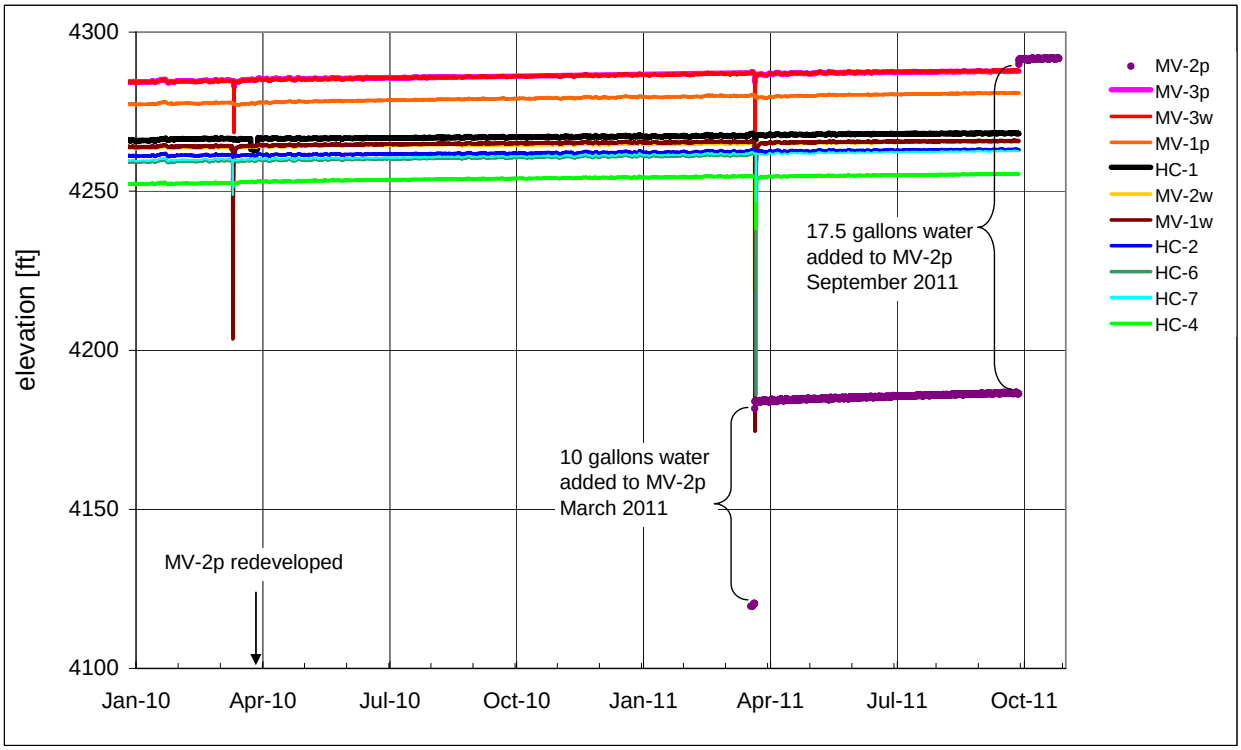

Figure 8. Hydrograph of site wells/piezometers west of the shear zone including the MV-2 piezometer

6.0 Summary and Recommendations

Analytical results from the 2011 monitoring event are consistent with those of the previous year. The concentration of tritium in the sample collected from well HC-4 was above the laboratory MDC but below the high of 1,130 pCi/L that was reported in 1998 (Pohll et al. 1998) and below the tritium MCL of 20,000 pCi/L. Uranium and unadjusted gross alpha in all wells were below the MCL in 2011, with the exception of samples collected from wells HC-2 and HC-6. If the gross alpha values obtained from these samples 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. The exception is the sample collected from well HC-2 that increased from the previous sampling event. It is uncertain, due to the small data set, if the increase in gross alpha activity in well HC-2 is an anomaly or a trend. If the gross alpha activity remains relatively high at well HC-2 for the next sampling event, additional analyses to determine the cause of the alpha activity in excess of uranium may be warranted. Isotopic ratios of uranium obtained from these samples further support the interpretation of a natural source of uranium in groundwater as opposed to a nuclear-test-related source.

To advance the SCM during this period of monitoring, LM recommends continued development of the detailed information resource tool and evaluation of analytical, hydrologic, and geologic data, along with recently acquired geophysical data, to help identify geologic structures that might be influencing groundwater flow at the site. LM expects interpretations obtained from this evaluation to be helpful in identifying data gaps, assessing potential groundwater flow directions, and evaluating the site's monitoring well network. Water levels will need to stabilize before the SCM can be revised and a more effective evaluation of the monitoring well network can be conducted. In addition to the further evaluation of existing information, LM recommends the following activities be performed during the next annual monitoring period:

- Extend the purge time for well HC-4 to evaluate impacts on analytical results.
- Increase the analytical suite for all wells to include major ions.
- Install gauges to measure site precipitation.
- Continue to refine the site conceptual models while waiting for water levels to stabilize.

7.0 References

AEC (U.S. Atomic Energy Commission/Nevada Operations Office), 1964. *Project Manager's Report, Project Shoal*, NVO-11, Las Vegas, Nevada, May.

AEC (U.S. Atomic Energy Commission/Nevada Operations Office), 1970. *Site Disposal Report Fallon Nuclear Test Site (Shoal) Churchill County, Nevada*, NVO-73, Las Vegas, Nevada.

Beal, L.H., S.E. Jerome, I. Lutsey, R.H. Olson, and J.H Schilling, 1964. "Geology of the Sand Springs Range," *Nevada Bureau of Mines and Geology, Final Report, Geological, Geophysical, Chemical and Hydrological Investigations of the Sand Springs Range, Fairview Valley, and Fourmile Flat, Churchill County, Nevada, for Shoal Event, Project Shade, Vela Uniform Program*, U.S. Atomic Energy Commission.

Bevans, H.E., M.S. Lico, and S.J. Lawrence, 1998. *Water Quality in the Las Vegas Valley Area and the Carson and Truckee River Basins, Nevada and California, 1992–96*, Circular 1170, U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada.

Cowart, J.B. and J.K. Osmond, 1977. "Uranium Isotopes in Groundwater: Their Use in Prospecting for Sandstone-type Uranium Deposits," *Journal of Geochemical Exploration*, 8: 365−379.

DOE (U.S. Department of Energy), 2009. *Final Path Forward: Short-Term Data Acquisition Plan for New Closure Strategy Subsurface Corrective Action Unit 447, Project Shoal Area, Nevada*, Office of Legacy Management, Grand Junction, Colorado, November.

DOE (U.S. Department of Energy), 2011a. *Path Forward: 2011 Short-Term Data Acquisition Plan, Project Shoal Area, Subsurface Corrective Action Unit 447, Nevada*, Office of Legacy Management, Grand Junction, Colorado, October.

DOE (U.S. Department of Energy), 2011b. *Surface Geophysics Survey Report Subsurface Corrective Action Unit 447, Project Shoal Area, Nevada*, Office of Legacy Management, Grand Junction, Colorado, April.

DOE/NNSA (U.S. Department of Energy, National Nuclear Security Administration), 2006. *Corrective Action Decision Document/Corrective Action Plan for Corrective Action Unit 447: Project Shoal Area, Subsurface*, *Nevada*, DOE/NV-1025, Rev. 3, Las Vegas, Nevada.

DOE/NV (U.S. Department of Energy/Nevada Operations Office), 1998. *Closure Report for Corrective Action Unit 416: Project Shoal Area*, DOE/NV-11718-179, Rev. 0, Las Vegas, Nevada, January.

Hazleton-Nuclear Science Corporation, 1965. *Vela Uniform Project Shoal Fallon, Nevada*, VUF-1014, Post-Shot Hydrologic Safety, October.

NDEP (Nevada Division of Environmental Protection), 1996. *Federal Facility Agreement and Consent Order (FFACO)* (as amended), Nevada Division of Environmental Protection, Las Vegas, Nevada, May 10.

NDEP (Nevada Division of Environmental Protection), 1998. Letter of Acceptance of Closure Report for CAU 416, Project Shoal Area Surface, Nevada Division of Environmental Protection, Las Vegas, Nevada, February.

NDEP (Nevada Division of Environmental Protection), 2005. Identification of the Contaminant Boundary for Corrective Action Unit (CAU) 447, Project Shoal Area (PSA)—Subsurface, *Federal Facility Agreement and Consent Order*, Letter dated January 19, 2005.

Pohll, G., J. Chapman, A. Hassan, C. Papelis, R. Andricevic, and C. Shirley, 1998. *Evaluation of Groundwater Flow and Transport at the Shoal Underground Nuclear Test: An Interim Report*, Publication No. 45162, DOE/NV/11508-35, UC-703, July.

Carroll, Rosemary W., H., K. Pohlmann, G. Pohll, and T. Mihevc, 2001. *Investigation of Hydraulic Properties and Groundwater Levels Related to the Shear Zone at the Project Shoal Site*, Publication No. 45183, DOE/NV/13609-12, September.

Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites, LMS/PLN/S04351, continually updated, prepared by S.M. Stoller Corporation for the U.S. Department of Energy Office of Legacy Management, Grand Junction, Colorado.

Smith, D.K., 2001. *Unclassified Radiological Source Term for the Nevada Test Site Areas 19 and 20*, URCL-ID-141706, Lawrence Livermore National Laboratory, Livermore, California.

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Appendix A

Well Purge Data

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Table A−1. Monitor Well Purge Data

Well	Date Sampled	Purged Volume (gallons)	Temperature (°C)	pH (s.u.)	Specific Conductance (µmhos/cm)
MV-1	3/22/2011	1480	21.4	7.45	736
			21.7	7.70	727
			21.7	7.84	728
MV-2	3/22/2011	1500	22.6	8.07	480
			23.0	8.09	480
			22.8	8.07	485
MV-3	3/22/2011	910	21.1	7.90	755
			21.0	8.03	751
			21.0	8.06	763
HC-1	3/22/2011	NA	17.9	8.3	310
HC-2	3/22/2011	NA	17.1	6.60	673
HC-4	3/23/2011	420	20.7	7.45	765
			20.8	7.45	765
			20.7	7.45	765
HC-5	3/22/2011	3770	27.3	8.26	985
			27.1	8.28	985
			27.1	8.28	980
HC-6	3/23/2011	NA	19.0	8.04	1,024
HC-7	3/23/2011	400	21.0	8.25	1,195
			21.0	8.20	1,210
			21.3	8.20	1,225

µmhos/cm = micromhos per centimeter
NA = not applicable; sample collected with depth-specific bailer because well is not equipped with submersible pump.
s.u. = Standard Unit

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Appendix B

Analytical Data: 2007 Through the Present

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Table B–1. Radioisotopic 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, total unadjusted)
MV-1	3/21/2007	<RDL (5.83E-03)[a]	<RDL (7.3E-11)	<359	42	25.6
	3/21/2007	NA	NA	NA	41[b]	21.5[b]
	3/11/2008	<RDL (2.49E-02)	<RDL (19.0E-11)	<180	21	14.0
	2/26/2009	<RDL (1.95E-02)	<RDL (10.5E-11)	<350	21	12.6
	3/11/2010	<RDL (1.93E-02)	<RDL (7.8E-11)	<300	21	11.3
	3/22/2011	NA	NA	<350	25	16.6
	3/22/2011[c]	NA	NA	<360	25	14.3
MV-2	3/21/2007	<RDL (1.77E-02)[a]	<RDL (8.3E-11)	<361	34	16.3
	3/21/2007	NA	NA	NA	34[b]	17.3[b]
	3/11/2008	<RDL (2.44E-02)	<RDL (29.5E-11)	<180	23	11.1
	2/26/2009	<RDL (2.13E-02)	NR	<360	24	12
	3/11/2010	<RDL (3.31E-02)	<RDL16.5 (E-11)	<300	21	13.8
	3/22/2011	NA	NA	<350	23	9.92
MV-3	3/21/2007	<RDL (5.90E-03)[a]	<RDL (13.5E-11)	<357	14	10.2
	3/21/2007	NA	NA	NA	14[b]	9.57[b]
	3/11/2008	<RDL (1.37E-02)	<RDL (18.0E-11)	<320	3.8	2.11
	2/26/2009	<RDL (8.37E-03)	<RDL (10.7E-11)	<360	3.8	<1.5
	3/12/2010	<RDL (1.29E-02)	<RDL (6.5E-11)	<300	4.2	2.63
	3/22/2011	NA	NA	<350	5.8	4.98
HC-1	3/21/2007	<RDL (1.52E-02)[a]	<RDL (9.6E-11)	<355	3.3	3.9
	3/21/2007	NA	NA	NA	3.4[b]	4.46[b]
	3/11/2008	<RDL (2.35E-02)	<RDL (4.9E-11)	<320	4.8	12.5
	2/26/2009	<RDL (2.01E-02)	NR	<360	1.4	<1.4
	3/24/2010	<RDL (3.18E-02)	<RDL (11.9E-11)	<310	3.3	4.93
	3/22/2011	NA	NA	<360	1.6	2.19
HC-2	3/24/2010	<RDL(1.90E-02)	<RDL (2.5E-11)	<300	140	63.8
	3/22/2011	NA	NA	<360	120	197
HC-3	3/24/2010	<RDL (2.37E-02)	<RDL (541E-11)	<300	4.3	2.57
	3/22/2011	NA	NA	NA	NA	NA
HC-4	3/21/2007	<RDL (0.565)[a]	<RDL (32.4E-11)	<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 (34.2E-11)	<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 (21.5E-11)	555	4.5	2.88
	2/26/2009	<RDL (3.20)	<RDL (0.6E-11)	434	2.0	<1.4
	3/11/2010	<RDL (2.93)	<RDL (38.7E-11)	544	6.4	1.79[b]
	3/23/2011	NA	NA	554	8.9	3.82
HC-5	3/11/2010	<RDL (5.11E-03)	<RDL (1.1E-11)	<300	0.48	<1.5
	3/23/2011	NA	NA	<360	0.45	<2.1
HC-6	3/24/2010	<RDL (1.14E-02)	<RDL (5.6E-11)	<300	35	25.7
	3/23/2011	NA	NA	<360	37	20.4

Table B–1 (continued). Radioisotopic 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, total unadjusted)
HC-7	3/11/2010	<RDL (5.31E-03)	<RDL (3.0E-11)	<300	7.4	5.77
	3/23/2011	NA	NA	<360	13	10.6
HC-8	3/10/2010	<RDL (9.63E-03)	<RDL (1.3E-11)	<300	0.25	<1.3
	3/23/2011	NA	NA	NA	NA	NA

[a] Estimated based on sample volume of 200 milliliters for 2007 samples.
[b] Indicates the sample was filtered.
[c] Indicates a duplicate sample.
NA = not applicable (samples not collected or samples not analyzed).
NR = not run, because sample bottle was broken during shipment to the laboratory.
<RDL = below required detection limit with laboratory result in parentheses; RDL is 5 pCi/L for C^{14}, 0.1 pCi/L for I^{129}, 300 pCi/L for tritium, 50 µg/L for uranium, and 4 pCi/L for gross alpha (DOE/NNSA 2006).

Table B–2. Uranium Isotopic Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	U^{234}/U^{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
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
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
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
HC-2	3/24/2010	45.1	45.3	0.996
	3/22/2011	45.2	45.3	0.998
HC-3	3/24/2010	1.16	1.21	0.96
	3/22/2011	NA	NA	NA
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
HC-5	3/11/2010	0.295	0.173	1.71
	3/23/2011	0.264	0.117	2.26
HC-6	3/24/2010	14.4	12.2	1.18
	3/23/2011	15.4	13.5	1.14

Table B–2 (continued). Uranium Isotopic Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	U^{234}/U^{238}
HC-7	3/11/2010	3.43	3.08	1.11
	3/23/2011	5.9	4.78	1.23
HC-8	3/10/2010	0.187	0.101	1.85
	3/23/2011	NA	NA	NA

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

Appendix C

Hydraulic Head Data: 1996 Through the Present

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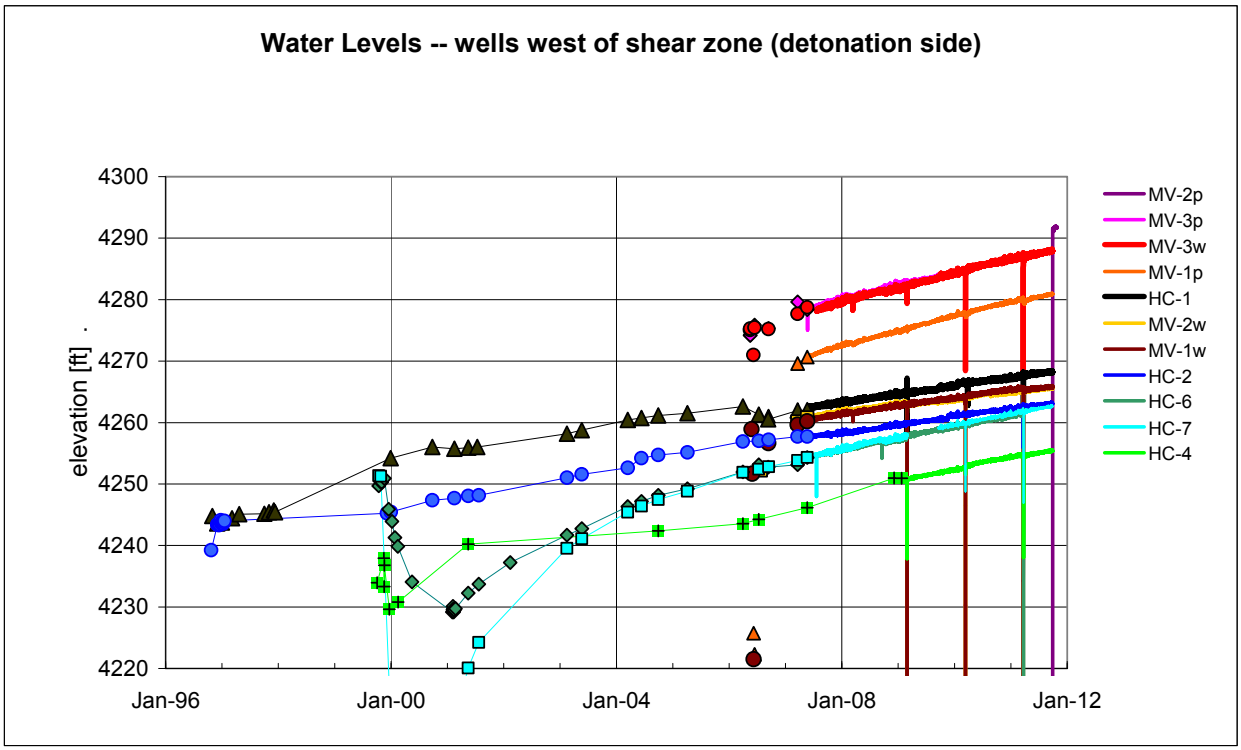
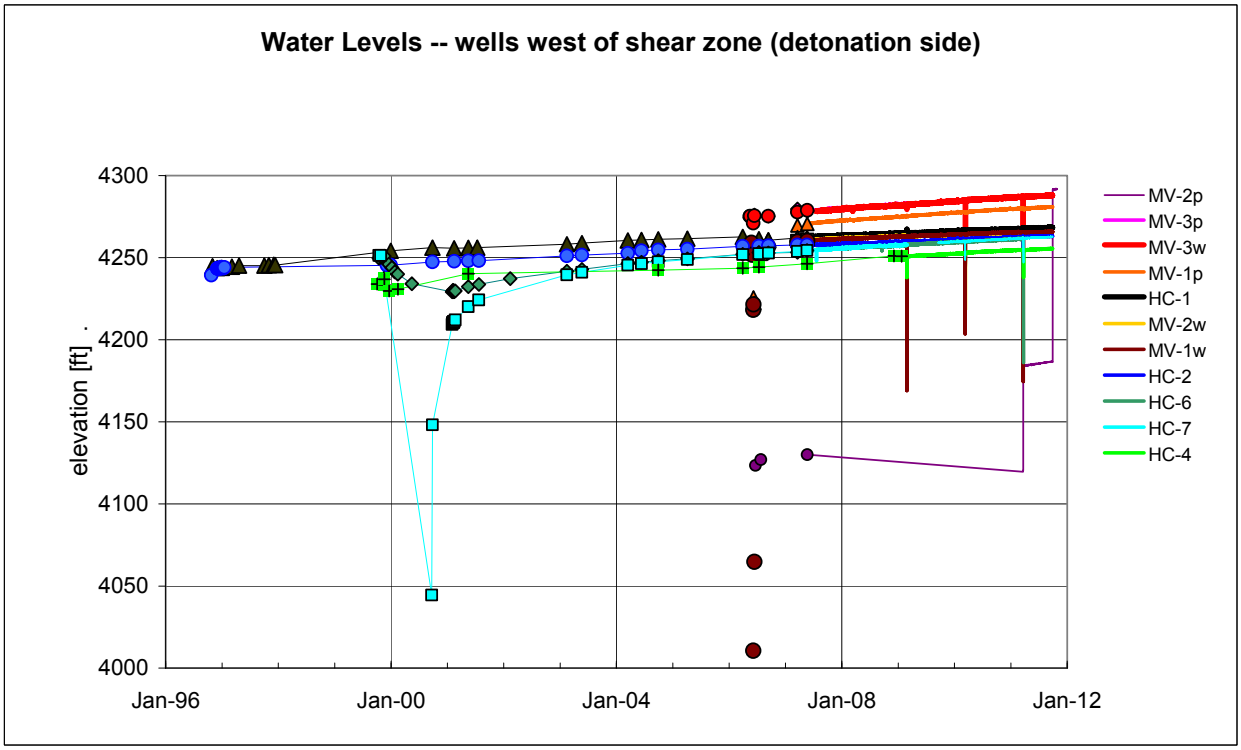
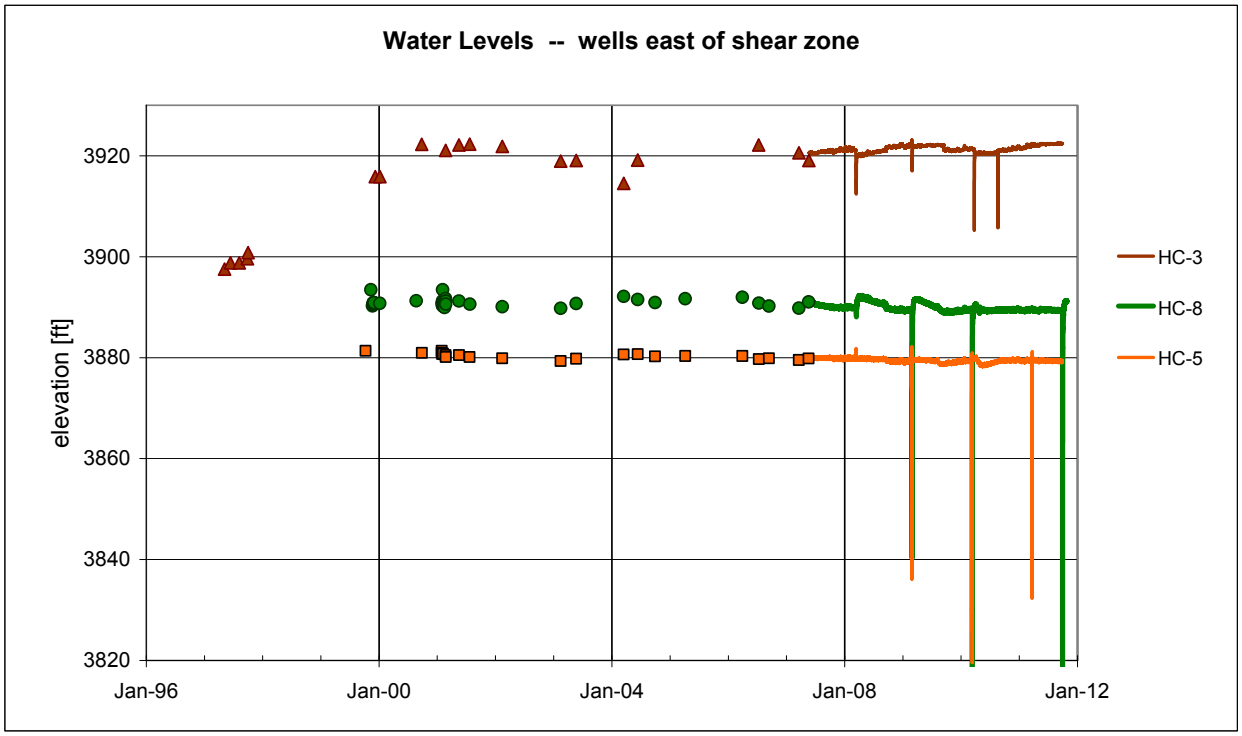

Water Levels -- wells west of shear zone (detonation side)
elevation [ft]
4300
4290
4280
4270
4260
4250
4240
4230
4220
Jan-96
Jan-00
Jan-04
Jan-08
Jan-12
MV-2p
MV-3p
MV-3w
MV-1p
HC-1
MV-2w
MV-1w
HC-2
HC-6
HC-7
HC-4


Water Levels -- wells west of shear zone (detonation side)
elevation [ft]
4300
4250
4200
4150
4100
4050
4000
Jan-96
Jan-00
Jan-04
Jan-08
Jan-12
MV-2p
MV-3p
MV-3w
MV-1p
HC-1
MV-2w
MV-1w
HC-2
HC-6
HC-7
HC-4


Water Levels -- wells east of shear zone
elevation [ft]
3920
3900
3880
3860
3840
3820
Jan-96
Jan-00
Jan-04
Jan-08
Jan-12
HC-3
HC-8
HC-5

Appendix D

Annual Water Level Changes in Wells West of the Shear Zone: July 2007 through July 2011

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

Date Range	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-4**	**HC-6**	**HC-7**
7/1/2007 – 7/1/2008	1.52	2.67	1.37	NM	2.71	2.57	1.40	1.09	NM	2.00	2.28
7/1/2008 – 7/1/2009	1.40	2.48	0.95	NM	2.16	2.20	1.32	1.40	NM	1.96	NM
7/1/2009 – 7/1/2010	1.38	2.48	1.36	NM	2.54	2.23	1.49	1.49	2.12	1.79	NM
7/1/2010 – 7/1/2011	0.79	1.80	0.76	NM	1.82	1.67	1.21	1.02	1.46	NM	1.64

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

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Appendix E

NDEP Correspondence with Record of Review and Response to Comments

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ndep
NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations

STATE OF NEVADA
Department of Conservation & Natural Resources
DIVISION OF ENVIRONMENTAL PROTECTION

Brian Sandoval, Governor
Leo M. Drozdoff, P.E., Director
Colleen Cripps, Ph.D., Administrator

RECEIVED DOE
JAN 30 2012
GRAND JUNCTION OFFICE

January 25, 2012

Mr. Mark Kautsky
Site Manager
U. S. Department of Energy
Office of Legacy Management
2597 B ¾ Road
Grand Junction, CO 81503

RE: Draft 2011 Groundwater Monitoring Report, Subsurface Correction Action Unit 447, Shoal, Nevada
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 2011 Groundwater Monitoring Report, Subsurface Correction Action Unit 447, Shoal, Nevada* (Report) received on January 13, 2012. The NDEP has the following comments or questions on the Report which should be addressed in the Final version of the Report:

1. Page iii, Second Paragraph, First Sentence: For clarity, it is suggested that "current" be added between "…evaluating the adequacy of the" and "monitoring well network." at the end of the sentence.

2. Page 1, Section 1.0, Second Last Sentence: It is suggested that "future" be added between "…site includes monitoring in support of" and "site closure." at the end of the sentence.

3. Page 3, Last Paragraph, Second Sentence: It is suggested that "recently" be removed from this sentence as the work referred to was completed in 2009 and more work has been done since the surveys.

4. Page 5, Section 4.0, First Sentence: For clarity, it is suggested that "current" be added between "…evaluating the adequacy of the" and "monitoring well network." at the end of the sentence.

5. Page 5, Section 4.0, Fifth and Sixth Sentences: For consistency, it is suggested that "new" be added between "…LM developed a" and "short-term data acquisition plan…" in the fifth sentence. In the sixth sentence, "new" should be added between "The" and "data acquisition plan" at the beginning of the sentence.

6. Page 5, Section 4.0, Seventh Sentence: For consistency, it is suggested that "recently" be removed between "...with existing data and" and "collected geophysical data..."

7. Page 5, Section 4.0, Last Sentence: It is suggested that "current" be added between "...evaluating the site's" and "monitoring well network." at the end of the sentence.

8. Page 7, First Paragraph, Last Sentence and Table 1: It should be stated in the last sentence that the 2011 data presented in Table 1 is from the September monitoring event and site inspection so as not to be confused with the March annual sampling event. It is not clear however, why data from the March annual sampling event is not included in the Table.

9. Page 7, Table 1 Footnotes: The "definition" for BSZ and TSZ are listed as the same (i.e., top and bottom of open interval). It should be one or the other.

10. Page 8, First Paragraph, First Sentence: For clarity, it is requested that "in March" be inserted between "...of the annual monitoring" and "were analyzed for..."

11. Page 8, Section 4.2, Second Paragraph, Second Sentence: The use of the word "near" should be defined in terms of direction and distance from Wells HC-5 and/or HC-8.

12. Page 9, Section 4.2, First Partial Paragraph, After the Second Full Sentence: There is no conclusion or findings presented in regards to the infiltration test. It is the NDEP's observation that with the pumping of well HC-8 there will be two signals in the hydraulic head data obtained from HC-8, which makes the analysis of the infiltration test very uncertain and invalidates the infiltration test as originally designed. How will the analysis of the data be conducted and will the uncertainty in the results be investigated?

13. Page 9, Section 4.2, First Full Paragraph: The hydraulic head data obtained during September and October 2011 will be influenced by the activities from the infiltration test, various wells being developed and the addition of water to various wells. Thus, the hydraulic head data obtained during this period are not representative of ambient conditions and this information should be indicated in some way in any reports or databases that used this hydraulic head data.

14. Page 10, Section 5.1, Seventh Sentence and Figure 4: It cannot be inferred from the sentence, "Results for 2011 are back to 2008 levels." that tritium levels began trending upward after 2008. This upward trend should be stated as it is shown on Figure 4.

15. Page 12, First Paragraph: It should be referenced that the uranium mass concentrations from 2007 through 2011 summarized in this paragraph can be found in Table B-1.

16. Page 12, Second Paragraph, Second Sentence: It is not clear how subtracting activities of U^{234} and U^{238} shown in Table 3 from the gross alpha values for HC-2 and HC-6 shown in

Table 2 results in values near or less than zero. The method of calculation should be provided.

If you need any clarification on the comments or questions above, please contact Chris Andres at 702-486-2850, ext. 232.

Sincerely,

T. H. Murphy
Chief
Bureau of Federal Facilities

THM/CDA

cc: FFACO Group, NNES, Las Vegas, NV
Janet Appenzeller-Wing, DAMEN, NNSA/NSO, Las Vegas, NV
R. F. Boehlecke, NNSA, Las Vegas, NV
Jeffrey Fraher, DTRA/CXTS, Kirtland AFB, NM
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R. Hutton, Stoller, Grand Junction, CO

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Record of Review

Due Date	Review No.	Project	Type of Review
02/24/2012	1	Offsites Project	Technical

Document Title and\or Number and Revision
2011 Groundwater Monitoring Report, Project Shoal Area, Subsurface Corrective Action Unit 447

Author
Mark Kautsky

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Legacy Management

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T. H. Murphy

Reviewer's Organization
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(702) 486-2863

Reviewers' Recommendation

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

Signature of Reviewer and Date

- ☒ Comments Have Been Addressed

Mark Kautsky
2012.04.18 14:21:56 -06'00'

Signature of Author and Date

- ☒ Comment Resolution Satisfactory
- ☐ Comment Resolution Unsatisfactory

Christ Andres 4/18/12

Signature of Reviewer and Date

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
--	--	--	--	Note - The report format was changed from the original draft submittal to provide additional clarification to the comments received from NDEP. The use of the words "generally" and "slightly" was also reduced to be more concise.
1.	Page iii, Second Paragraph, First Sentence: For clarity, it is suggested that "current" be added between "...evaluating the adequacy of the" and "monitoring well network." at the end of the sentence.	Y	1	The change was made as requested.
2.	Page 1, Section 1.0, Second Last Sentence: It is suggested that "future" be added between "...site includes monitoring in support of" and "site closure." at the end of the sentence.	Y	2	The change was made as requested.
3.	Page 3, Last Paragraph, Second Sentence: It is suggested that "recently" be removed from this sentence as the work referred to was completed in 2009 and more work has been done since the surveys.	Y	3	The change was made as requested.
4.	Page 5, Section 4.0, First Sentence: For clarity, it is suggested that "current" be added between "...evaluating the adequacy of the" and "monitoring well network." at the end of the sentence.	Y	4	Page 7, Section 4.0, first sentence of the second paragraph. The change was made as requested.

Record of Review (continuation)

Review No. 1	Project Offsites Project

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
5.	Page 5, Section 4.0, Fifth and Sixth Sentences: For consistency, it is suggested, that "new" be added between "...LM developed a" and "short-term data acquisition plan..." in the fifth sentence, In the sixth sentence, "new" should be added between "The" and "data acquisition plan" at the beginning of the sentence.	Y	5	Page 7, Section 4.0, fifth and sixth sentence of the second paragraph. The changes were made as requested.
6.	Page 5, Section 4.0, Seventh Sentence: For consistency, it is suggested that "recently" be removed between "...with existing data and" and "collected geophysical data..."	Y	6	Page 7, Section 4.0, seventh sentence of the second paragraph. The change was made as requested.
7.	Page 5, Section 4.0, Last Sentence: It is suggested that "current" be added between "...evaluating the site's" and "monitoring well network." at the end of the sentence.	Y	7	Page 7, Section 4.0, last sentence of the second paragraph. The change was made as requested.
8.	Page 7, First Paragraph, Last Sentence and Table 1: It should be stated in the last sentence that the 2011 data presented in Table 1 is from the September monitoring event and site inspection so as not to be confused with the March annual sampling event. It is not clear however, why data from the March annual sampling event is not included in the Table.	Y	8	Page 12, Section 4.4, first sentence and Table 3. The sentence and Table 3 title were revised as follows: "Table 3 presents well construction information and the most recent hydraulic head data, obtained in September 2011" and "Table 3. Well Construction Details and September 2011 Head Data for Wells at the PSA" September data are provided in Table 3 because it is the most recent data and typically the September monitoring event includes the collection of all the water levels on the same day. Further explanation is provided in the revised Section 4.3.
9.	Page 7, Table 1 Footnotes: The "definition" for BSZ and TSZ are listed as the same (i.e., top and bottom of open interval). It should be one or the other.	Y	9	Table 3. The change was made as requested.
10.	Page 8, First Paragraph, First Sentence: For clarity, it is requested that "in March" be inserted between "...of the annual monitoring" and "were analyzed for..."	Y	10	Page 7, first sentence of the last paragraph. The change was made as requested.
11.	Page 8, Section 4.2, Second Paragraph, Second Sentence: The use of the word "near" should be defined in terms of direction and distance from Wells HC-5 and/or HC-8.	Y	11	Page 15, Section 5.1, first sentence of the second paragraph. Section 4.2 was rewritten and changed to Section 5.0. The comment is resolved in the second paragraph of Section 5.1 as requested.
12.	Page 9, Section 4.2, First Partial Paragraph, After the Second Full Sentence: There is no conclusion or findings presented in regards to the infiltration test. It is the NDEP's observation that with the pumping of well HC-8 there will be two signals in the hydraulic head data obtained from HC-8, which makes the analysis of the infiltration test very uncertain and	Y	12	Page 15, Section 5.1, second and third paragraphs. Section 4.2 was rewritten and changed to Section 5.0. The comment is resolved in the second and third paragraphs of Section 5.1 as requested.

Record of Review (continuation)

Review No. 1	Project Offsites Project

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
	invalidates the infiltration test as originally designed. How will the analysis of the data be conducted and will the uncertainty in the results be investigated?			
13.	Page 9, Section 4.2, First Full Paragraph: The hydraulic head data obtained during September and October 2011 will be influenced by the activities from the infiltration test, various wells being developed and the addition of water to various wells. Thus, the hydraulic head data obtained during this period are not representative of ambient conditions and this information should be indicated in some way in any reports or databases that used this hydraulic head data.	Y	13	Page 12, Section 4.3, first paragraph. A footnote was added to Table 3 and the following sentences were added to Section 4.3 to provide additional clarification. "The manual water level measurements were collected prior to conducting activities that would disturb ambient water level conditions. The manual water level measurements were used to convert the transducer data to groundwater elevations." The site transducers provide continuous data (every 3-hours) to record water level changes (adding or removing water from a well) and document changes to ambient water level conditions.
14.	Page 10, Section 5.1, Seventh Sentence and Figure 4: It cannot be inferred from the sentence, "Results for 2011 are back to 2008 levels." that tritium levels began trending upward after 2008. This upward trend should be stated as It is shown on Figure 4.	Y	14	Page 8, Section 4.2, first paragraph. The sentence has been revised as follows: "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 to 555 pCi/L from 2008 through 2011. These increases may be related to the volume of water purged from HC-4 during sampling events, and a recommendation to increase the purge time to test this hypothesis during the next sampling event is described in Section 6."
15.	Page 12, First Paragraph: It should be referenced that the uranium mass concentrations from 2007 through 2011 summarized in this paragraph can be found in Table B-1.	Y	15	Page 10, first paragraph. The sentence was modified to include the reference to Table B-1 in Appendix B as requested.
16.	Page 12, Second Paragraph, Second Sentence: It is not clear how subtracting activities of U234 and U238 shown in Table 3 from the gross alpha values for HC-2 and HC-6 shown in Table 2 results in values near or less than zero. The method of calculation should be provided.	Y	16	Page 10, last paragraph has been revised as follows: "If gross alpha values for HC-2 and HC-6 (Table 1) are adjusted by subtracting activities of ^{234}U and ^{238}U shown in Table 2, values are near or less than zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples. The exception is the sample collected from well HC-2 that increased from the previous sampling event. It is uncertain, due to the small data set, if the increase in gross alpha activity in well HC-2 is an anomaly or a trend. If the gross alpha activity remains relatively high at well HC-2 for the next sampling event,

Record of Review (continuation)

Review No. 1	Project Offsites Project

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
				additional analyses to determine the cause of the alpha activity in excess of uranium may be warranted."

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