LMS/CNT/S22937

2018 Postclosure Groundwater Monitoring and Inspection Report, Central Nevada Test Area, Nevada, Subsurface Corrective Action Unit 443

July 2019

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

amsl	feet above mean sea level
BLM	U.S. Bureau of Land Management
^{14}C	carbon-14
CAS	corrective action site
CAU	Corrective Action Unit
CNTA	Central Nevada Test Area
DOE	U.S. Department of Energy
DRI	Desert Research Institute
FFACO	Federal Facility Agreement and Consent Order
ft	feet
^{129}I	iodine-129
ICs	institutional controls
LM	Office of Legacy Management
LPZ	lower piezometer
MCL	maximum contaminant level
m/d	meters per day
MDC	minimum detectable concentration
MV	monitoring/validation
NDEP	Nevada Division of Environmental Protection
pCi/L	picocuries per liter
PZ	piezometer
RDL	required detection limit
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
SGZ	surface ground zero
UPZ	upper piezometer

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Executive Summary

The Central Nevada Test Area, Nevada, Site, was where a 0.2- to 1-megaton nuclear device was detonated underground in 1968—a test that resulted in residual contamination at and near the detonation depth of 3200 feet. Subsurface corrective action activities were completed in 2015, and *Closure Report, Central Nevada Test Area, Subsurface Corrective Action, Unit 443* (DOE 2018a), hereafter called the Closure Report, was approved in 2016 (Andres 2016). These activities were conducted in accordance with the Federal Facility Agreement and Consent Order (1996, as amended) and all applicable Nevada Division of Environmental Protection policies and regulations. The Closure Report established the long-term postclosure monitoring program and inspection requirements for the site. The postclosure monitoring program is designed to (1) assess the effectiveness of the compliance boundary by monitoring for the radioisotopes of interest and (2) evaluate the effectiveness of monitoring locations within the groundwater flow system by monitoring water elevations to ensure that monitoring wells are located along the potential migration pathways. This includes annual site inspections to maintain the institutional controls and ensure protectiveness of the site.

The 2018 sample analytical results indicate tritium was not detected above the laboratory-required minimum detectable concentrations in all sampled wells in the monitoring network. These sample results combined with past results support the determination that radioisotopes of interest (tritium, carbon-14, and iodine-129) have not migrated outside the compliance boundary. Water elevations continue to support interpreted flow directions and the adequacy of the site monitoring network. Water levels in the reentry well UC-1-P-2SR are still recovering from the dewatering effects of the detonation. The currently depressed water levels in this area direct groundwater flow in the alluvial aquifer near surface ground zero toward the chimney. In the volcanic section, water level data from well UC-1-P-2SR also indicate a downward gradient from the source zone to the densely welded tuff units below the detonation. The downward gradient could increase as water levels continue to recover in the chimney. Water level data from the piezometer (screened inside the graben) and well (screened outside the graben) at the monitoring/validation (MV) locations MV-4 and MV-5 continue to confirm that the southeast-bounding graben fault acts as a barrier to groundwater flow.

This report and the Closure Report are available on the LM public website at https://www.lm.doe.gov/CNTA/Sites.aspx. Data collected during previous monitoring events (including sample analytical results and water level data) are available on the Geospatial Environmental Mapping System (GEMS) website at https://gems.lm.doe.gov/#site=CNT.

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1.0 Introduction

This report presents the groundwater monitoring data collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) from the Central Nevada Test Area (CNTA), Nevada, Site, Subsurface Corrective Action Unit (CAU) 443 in Nye County, Nevada (Figure 1). CNTA is the site of an underground nuclear test in 1968 that resulted in residual contamination near the detonation depth of 3200 feet (ft); the contamination requires long-term monitoring. Responsibility for the environmental restoration and long-term monitoring was transferred from DOE’s National Nuclear Security Administration, Nevada Field Office, to LM on October 1, 2006. The environmental restoration and site closure process were completed in 2015 in accordance with the amended Federal Facility Agreement and Consent Order (FFACO) (FFACO 1996, as amended) and all applicable Nevada Division of Environmental Protection (NDEP) policies and regulations. The *Closure Report, Central Nevada Test Area, Subsurface Corrective Action, Unit 443* (DOE 2018a), also called the Closure Report, originally was completed in January 2016 and revised in October 2018; it describes LM’s plan for long-term postclosure monitoring. This includes monitoring of the radioisotopes of interest and water elevations, inspecting the site and maintaining the institutional controls (ICs), evaluating and reporting data, and documenting the site’s records and data management processes (DOE 2018a).

The purpose of the postclosure monitoring is to monitor the groundwater for the potential migration of contamination, evaluate the effectiveness of the monitoring network with respect to groundwater flow directions, and ensure that the ICs are protective of the site and human health and the environment. This report summarizes the results of the monitoring and site inspection activities conducted during the July 2016 through June 2018 reporting period.

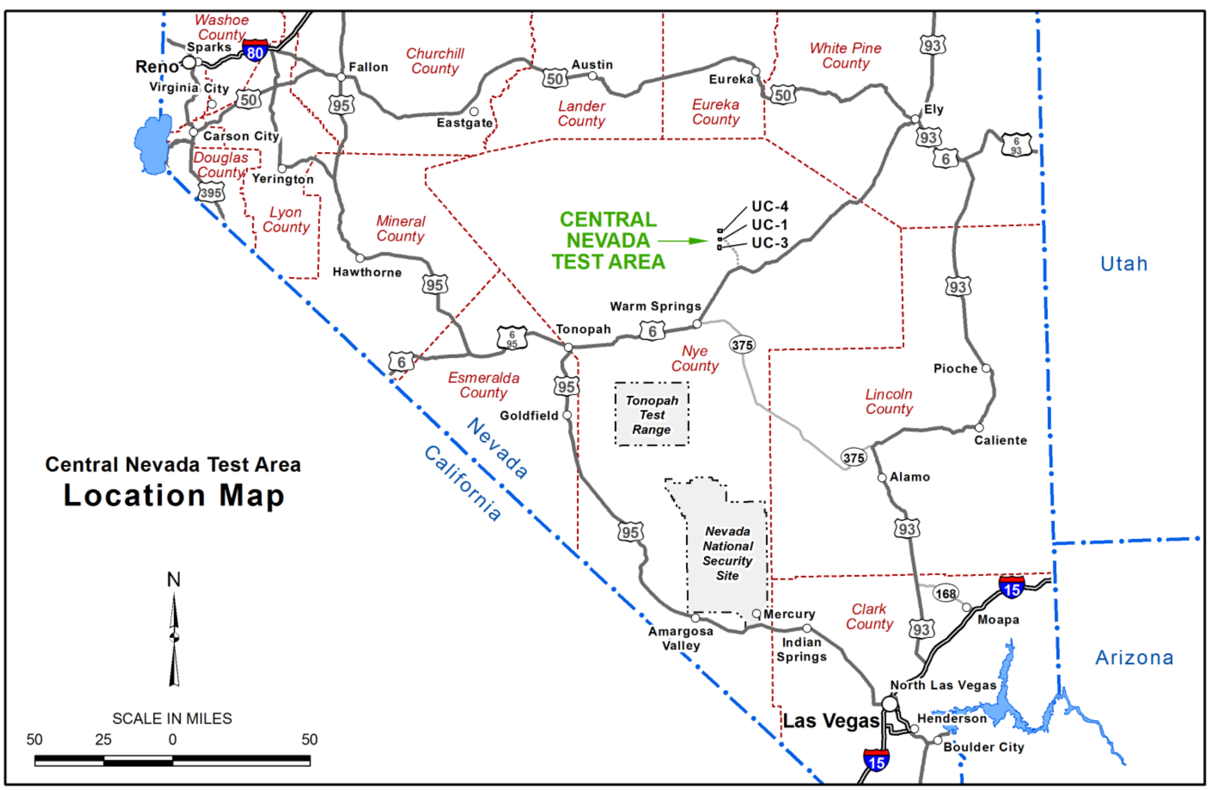

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Figure 1. CNTA Location Map Showing Emplacement Boreholes UC-1, UC-3, and UC-4

2.0 Site Background

The U.S. Atomic Energy Commission (predecessor to DOE) acquired the CNTA site through two separate land withdrawals from the U.S. Bureau of Land Management (BLM) in the late 1960s to develop sites for underground nuclear testing that could serve as alternatives to the Nevada National Security Site (formerly known as the Nevada Test Site). Three emplacement boreholes—UC-1, UC-3, and UC-4—were drilled at CNTA for underground nuclear weapons testing (Figure 1). The land withdrawals for these boreholes were authorized through Public Land Orders 4338 and 4748 in 1967 and 1969, respectively. The initial land withdrawal, Public Land Order 4338, included approximately 640 acres for land surrounding the UC-1 emplacement borehole. The second land withdrawal, Public Land Order 4748, was for two separate parcels of land totaling approximately 1920 acres for land surrounding the UC-3 and UC-4 emplacement boreholes (Figure 2). The underground nuclear test, identified as Faultless, was conducted in borehole UC-1 at a depth of 3200 ft on January 19, 1968. The nuclear device had a reported yield that was estimated to be 0.2 to 1 megaton (DOE 2015a). The test resulted in a down-dropped fault block (also referred to as a subsidence graben) that extends to land surface (Figure 3). Two additional tests were planned (UC-3 and UC-4 boreholes), but neither was completed, and no further nuclear testing was conducted at CNTA. The UC-3 and UC-4 boreholes were abandoned, secured at the surface by a welded steel plate and concrete cap, and the site was decommissioned as a testing facility in 1973.

The underground nuclear test resulted in residual contamination at and near the detonation depth. The intense heat of the detonation vaporized a volume of rock, temporarily creating a cavity or void space. In seconds to hours after the detonation, the overlying material collapsed into the void space, forming a collapse chimney. The former cavity, now the lower part of the collapse chimney, and the surrounding damaged zone are together referred to as the detonation zone. The detonation zone is contaminated by residual radioactive isotopes, with higher concentrations at the bottom of the former cavity, which contains the majority of radioactive fission products: uranium, plutonium, and tritium (DOE 2005). The rest of the detonation zone is contaminated by lower concentrations of mobile radioisotopes, such as tritium. The mobile radioisotopes in the detonation zone are a source of contamination (source zone) that could potentially migrate with groundwater. The remaining subsurface contamination is identified as CAU 443.

2.1 Geologic and Hydrologic Setting

CNTA is in the northern portion of the Hot Creek Valley (Figure 2), a 68-mile-long, north–south trending graben in the Basin and Range physiographic province. Surface and subsurface geologic data indicate that CNTA is within the Hot Creek Valley caldera complex, which contains several overlapping volcanic cauldrons. This caldera complex has been disrupted by basin-and-range style, normal faulting that formed the Hot Creek Valley graben. Hot Creek Valley varies in width from 5 to 19 miles and contains two major stratigraphic units—a thick sequence of Quaternary- and Tertiary-age alluvial deposits (alluvium) underlain by a thick section of Tertiary-age volcanic rocks (volcanic sediments). Borehole lithologic information obtained from groundwater monitoring wells installed at the site (Figure 3) indicates that the thickness of the alluvium near UC-1 (Faultless test location) ranges in depth from 1960 to 2410 ft (DOE 2006). The volcanic section below the alluvium includes tuffaceous sediments (volcanic sediments), densely welded and nonwelded tuffs, and rhyolite lavas.

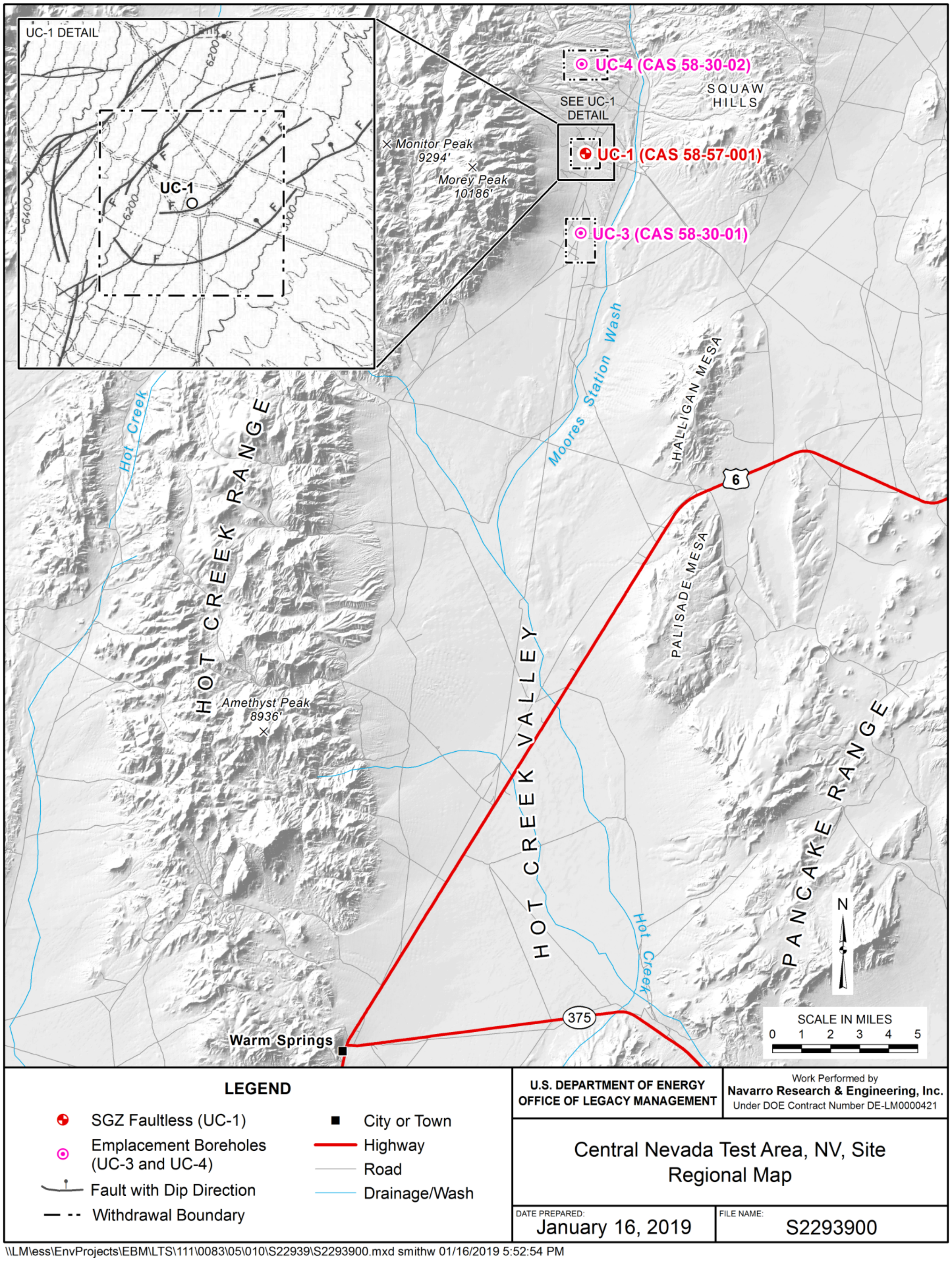

Figure 2. CNTA Regional Location Map

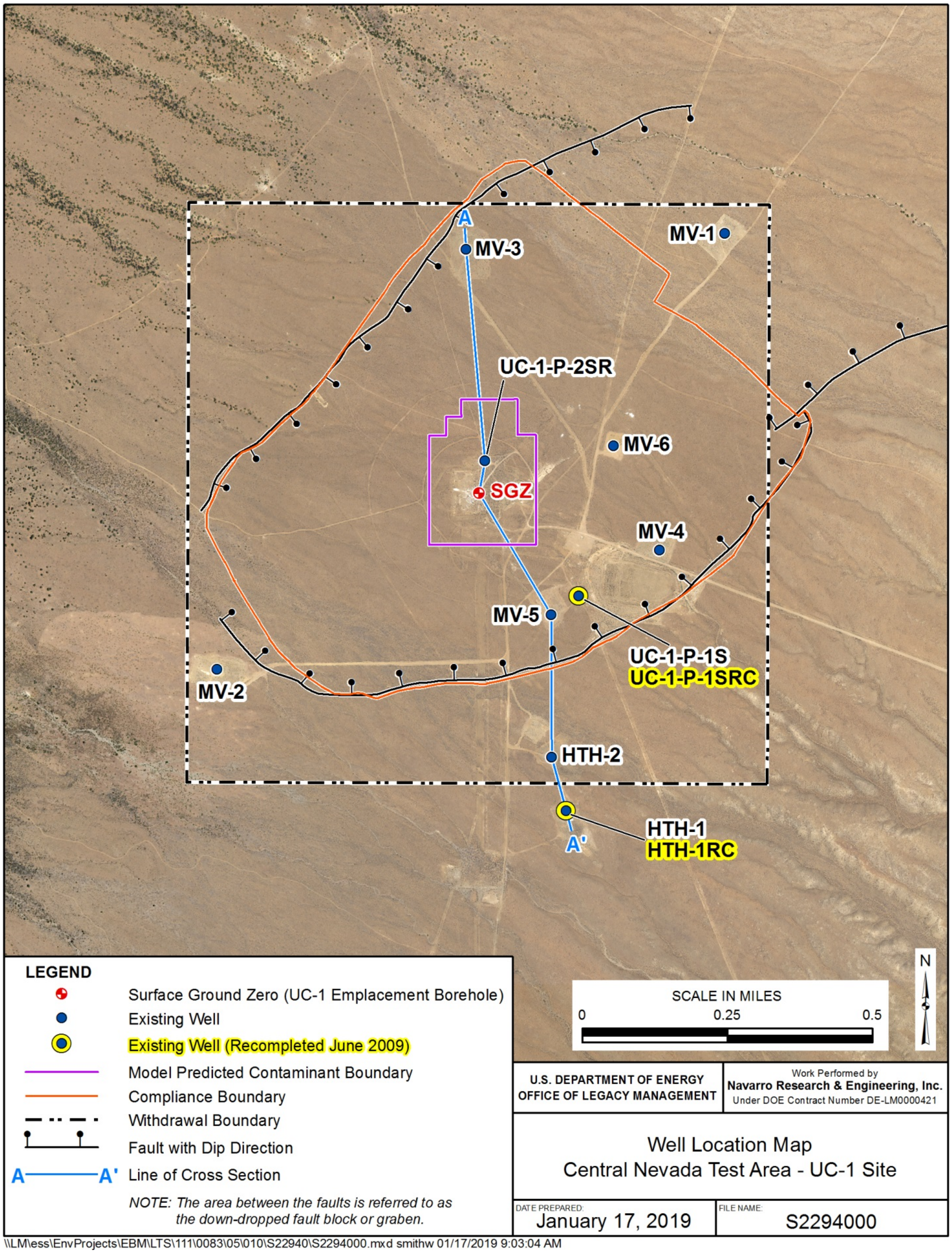

Figure 3. CNTA UC-1 Site Map with Well Locations

The underground nuclear test triggered numerous small earthquakes and aftershocks that resulted in surface subsidence and surface rupture along preexisting faults (see UC-1 site detail in Figure 2), caused strike-slip movement along previously unknown subsurface faults, and induced seismic activity as far away as 24 miles (McKeown and Dickey 1969). The test created a down-dropped fault block (also referred to as a subsidence graben) elongated to the northeast and parallel to preexisting faults in the Quaternary valley-fill deposits (Figure 3). Maximum surface displacement after the test was 14.8 ft. In some places along the south side of the graben, dip on the faults is 77 degrees to the north, based on fault intercepts in postshot boreholes and postshot map data. High-speed photography showed that subsidence occurred along the preexisting graben faults immediately following the test, indicating that subsidence resulted from the immediate release of tectonic stress that was triggered by the underground test and not from the collapse of the former cavity (McKeown et al. 1968; McKeown and Dickey 1969). Figure 4 is a cross section of the UC-1 site depicting the former cavity and chimney with faults and lithologic units.

The Faultless test took place in the low-permeability volcanic sediments (Figure 4). It was estimated that the chimney extends into the overlying alluvium to a depth of approximately 1200 ft. This estimate is based on drilling records that indicate a loss of circulation while drilling the reentry well UC-1-P-2SR at this depth. Well UC-1-P-2SR began to deviate from vertical at a depth below 1500 ft (elevation of 4600 ft above mean sea level [amsl]) to intercept the chimney as planned. The well was drilled to a measured depth of 3554 ft (3513 ft true vertical depth) and perforated from measured depths of 1148 ft to 2792 ft (1148 ft to 2760 ft true vertical depth). The water level in the chimney is still recovering from the dewatering effects of the detonation. The water level in reentry well UC-1-P-2SR (elevation of 5628 ft amsl in mid-2018) has increased more than 1800 ft in the last 44 years (Figure 5) and is expected to rise another 125 ft in the next 40 years or so (estimated based on current trend) to eventually reach the water level in the alluvial aquifer in this area (elevation of approximately 5750 ft amsl). The rate of water level rise in UC-1-P-2SR is decreasing as the recovery proceeds, and it is estimated that it will be a number of decades before the water level stabilizes.

Groundwater depth in the alluvium varies at the UC-1 site. Water levels in the alluvial aquifer within the graben are about 250 ft higher than those in the alluvium south of the southeast-bounding graben fault (Figure 4). Groundwater flow in the alluvial aquifer is controlled on a large scale by topography, which slopes from northwest to southeast near the site. Horizontal flow in the upper alluvium is toward the chimney, where the water level in well UC-1-P-2SR is still recovering from the detonation (Figure 4). Away from the influence of the chimney, horizontal flow is to the east–southeast and is likely diverted to the east–northeast by the southeast-bounding graben fault, which acts as a barrier to flow (DOE 2018a). Aquifer test results suggest that the hydraulic conductivity of the alluvial aquifer decreases with depth, grading from a productive aquifer in the upper alluvium tested in well UC-1-P-1SRC (hydraulic conductivity of 1.0 meters per day [m/d]) to a poor producer in the lower alluvium tested in monitoring/validation (MV) wells MV-4 and MV-5 (hydraulic conductivity of 1.2×10^{-4} to 5.0×10^{-4} m/d). The low hydraulic conductivity of the lower part of the alluvial aquifer is more comparable to that of the densely welded tuff units tested in the MV-1, MV-2, and MV-3 wells (8.5×10^{-6} to 6.7×10^{-5} m/d) and is likely similar to the hydraulic conductivity of the upper part of the underlying volcanic sediments (DOE 2010).

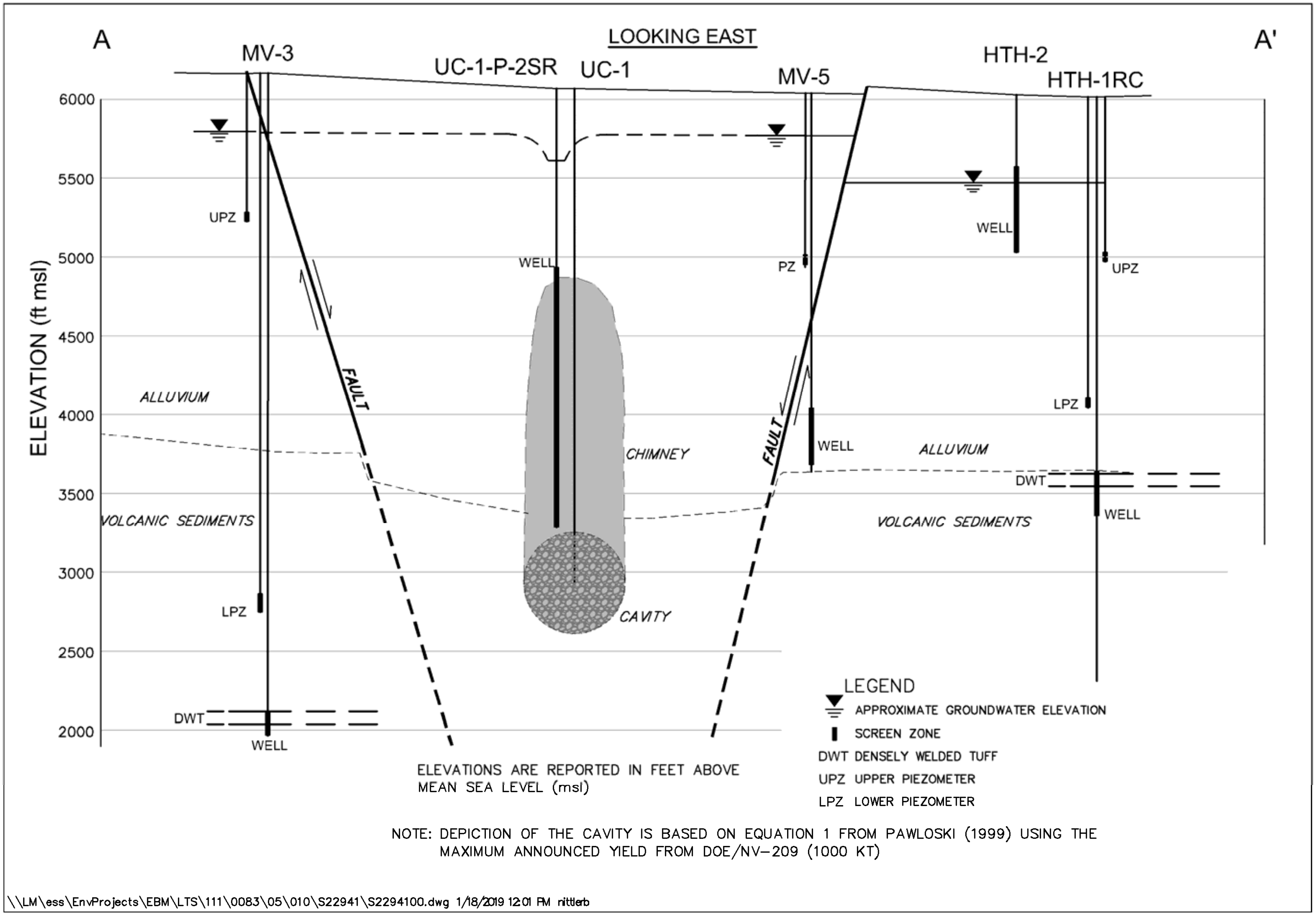

Figure 4. Cross Section View of A-A' Looking East

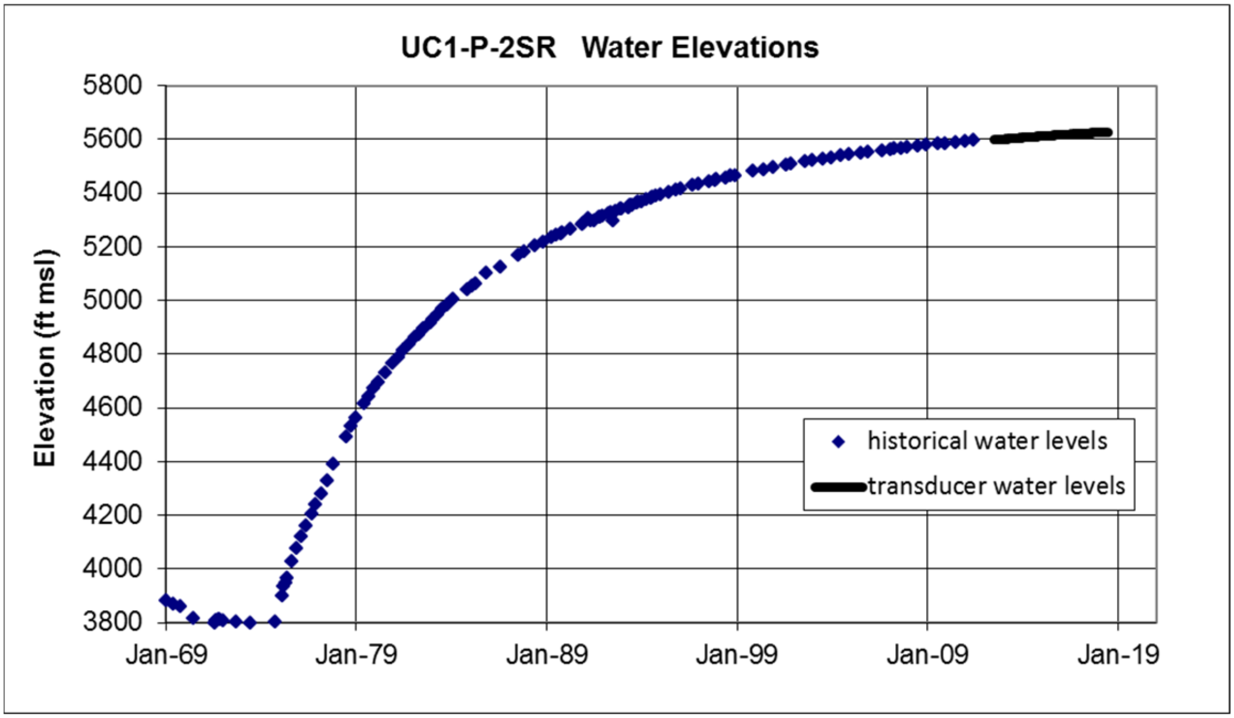

Figure 5. Water Elevations in Reentry Well UC-1-P-2SR
(https://nwis.waterdata.usgs.gov/nv/nwis/gwlevels?site_no=383806116125951&agency_cd=USGS&format=gif)

Water elevations in the volcanic sediments are highest at the detonation depth, likely due to a detonation-related pressure response. This is most evident inside the graben where the water elevation is approximately 5990 ft amsl in the MV-1 lower piezometer (LPZ) that is screened at the detonation depth. The water elevations at the site suggest that the most likely flow direction from the source zone is down, toward the densely welded tuff units (elevations of about 5560 ft amsl). Wells MV-1, MV-2, and MV-3 are screened in densely welded tuff units near and below the source zone. Water elevations from these wells and interpretations of the geometry of the major graben faults at these depths suggest a flow direction that is to the northeast in the densely welded tuff units. Aquifer tests performed on the MV-1, MV-2, and MV-3 wells indicate low hydraulic conductivity values ranging from 8.5×10^{-6} to 6.7×10^{-5} m/d (Lyles et al. 2006). The low hydraulic conductivities and anomalously long water level recovery time in UC-1-P-2SR (chimney) (Figure 5) is consistent with a detonation zone surrounded by low-permeability material.

3.0 Summary of Corrective Action Activities

Subsurface corrective action activities were completed in 2015 and are summarized in the Closure Report (DOE 2018a). The subsurface CAU 443 consists of three corrective action sites: UC-1 Cavity Corrective Action Site (CAS) 58-57-001, Emplacement Well UC-3 CAS 58-30-01, and Emplacement Well UC-4 CAS 58-30-02 (Figure 2). It was concluded during the corrective actions that the CAS associated with the UC-3 and UC-4 emplacement boreholes would require no further action and that corrective actions would focus on the UC-1 former cavity as the source of contamination for CAU 443 (DOE 1999). The corrective action alternative selected for UC-1 is proof of concept and monitoring with ICs, which included establishing a monitoring program, use restrictions, and other ICs to protect human health and the environment (DOE 2004).

The Closure Report provides justification for closure of CAU 443 and a summary of completed closure activities; describes the selected corrective action alternative; provides an implementation plan for long-term monitoring with well network maintenance and approaches and policies for ICs; and presents the contaminant, compliance, and use-restriction boundaries for the site (DOE 2018a). Environmental restoration and site closure was conducted in accordance with the FFACO and all applicable NDEP policies and regulations.

3.1 Institutional Controls and Site Boundaries

The term “institutional controls” (ICs) is used to broadly define the instruments (documents) and mechanisms (physical features) that are maintained to ensure long-term protectiveness of a site (DOE 2015b). ICs are part of the final remedy for CNTA, which was approved by NDEP in March 2016 (Andres 2016). CNTA site lands are under jurisdiction of the federal government, which controls land use. These lands (currently 2560 acres) are administered by BLM and the U.S. Forest Service as part of the Toiyabe National Forest, and current land use includes livestock grazing, ranching, and recreation. The total acreage is currently withdrawn from all forms of appropriation associated with mining laws and leasing through Public Land Orders 4338 and 4748, which prohibit future oil and gas leasing or mineral claims at the site. LM monitors the Nevada websites responsible for leasing, mineral claims, and well permitting to ensure new activities do not impact the site. This includes inspecting the site annually for evidence of land use changes or significant land disturbances. It also includes evaluating the site roads and inspecting the monitoring network, the concrete caps that cover the UC-3 and UC-4 emplacement boreholes (Figure 2), and the UC-1 monument for signs of damage, natural deterioration from weather, or vandalism.

LM is working with BLM to expand the subsurface restrictions at the UC-1 site by expanding the UC-1 land withdrawal boundary to fully encompass the compliance boundary. The compliance boundary is the area within which the radioisotopes with concentrations above the Safe Drinking Water Act (SDWA) standards are to remain (DOE 2004). The compliance boundary is considerably larger than the model-predicted contaminant boundary that delineates the probable (95th percentile) extent to which radioisotope-contaminated groundwater from the underground nuclear test would migrate over 1000 years (Pohll et al. 2003). The lateral extent of contaminated groundwater in the subsurface represents the contaminant boundary perimeter when projected to the surface. Contaminated groundwater is defined as water with radioisotope concentrations that exceed the SDWA standards (State of Nevada et al. 1996). The contaminant and compliance boundaries were approved in the Closure Report (DOE 2018a).

3.2 Migration Pathways and Monitoring Network

The monitoring well network is designed to monitor both the most likely transport path (densely welded tuff) near and below the source zone and the most likely access path, the higher-permeability alluvial aquifer above the source zone (Table 1). The well network that monitors for the presence of radioisotopes in the densely welded tuff units includes wells MV-1, MV-2, MV-3, and HTH-1RC. Well HTH-1RC is screened above the detonation depth, but the original well casing remains open below the HTH-1RC well screen, allowing contribution from the volcanic section below the detonation depth (Figure 4). The MV-1 well is completed in the densely welded tuff below the detonation depth and is in the most likely flow direction from the source zone. The wells completed in densely welded tuff units are monitored for radioisotopes less frequently because of the low permeability and limited potential transport distances. Well UC-1-P-2SR is a near-field monitoring well that is screened in the chimney and upper portion of the alluvium (Figure 4).

Table 1. Monitoring Network with Zones of Completion and Unit Monitored

Monitoring Wells / Piezometers	TOC Elevation[a] (ft)	TSZ Elevation[a] (ft)	BSZ Elevation[a] (ft)	Screen Length (ft)	Lithologic Unit Monitored	
MV-1UPZ	6069.98	5190	5130	60		
MV-2UPZ	6190.66	5230	5180	50		
MV-3UPZ	6167.75	5287	5227	60		
MV-4PZ	6019.45	5101	5041	60		
MV-5PZ	6040.85	5023	4963	60	Upper	
MV-6	6053.84	5215	5052	163		
UC-1-P-1SRC	6031.58	5520	5458	62		Alluvium
HTH-2	6026.05	5522	5026	496		
HTH-1UPZ	6011.27	5033	4973	60		
HTH-1LPZ	6011.31	4113	4053	60		
MV-4	6019.57	4300	3996	304	Lower	
MV-5	6041.85	4203	3879	324		
UC-1-P-2SR[b]	6080.51	4933	3320	1644	Chimney	
MV-1LPZ	6069.91	3067	3007	60	Tuffaceous sediments	
MV-3LPZ	6167.69	2867	2747	120		
MV-1	6070.57	2319	2160	160		
MV-2LPZ	6190.39	2643	2583	60		Volcanic
MV-2	6190.66	3150	2987	163	Densely welded tuff	
MV-3	6168.27	2121	1959	162		
HTH-1RC	6011.70	3654	3354	300		

Notes:
Coordinate system used here is U.S. State Plane System 1927 (Nevada Central Zone), Vertical Datum, NGVD29.
[a] All elevations are corrected for true vertical depth and reported in units of ft amsl.
[b] UC-1-P-2SR well is perforated, not screened.

Abbreviations:
BSZ = bottom of open interval/screen zone
TOC = top of casing
TSZ = top of open interval/screen zone
UPZ = upper piezometer

The alluvial aquifer monitoring network includes wells and piezometers (distinguished from the wells by the abbreviation PZ) that surround the portion of the chimney extending into the alluvium. The alluvial monitoring network includes wells MV-4, MV-5, MV-6, UC-1-P-1SRC, and HTH-2 and piezometers MV-1UPZ (an upper piezometer [UPZ]) and MV-4PZ (Table 1). Wells MV-4, MV-5, MV-6, and UC-1-P-1SRC will be sampled at an increased frequency because of their proximity to the chimney. Well HTH-2 will be sampled less frequently because it is outside the graben and farther from the chimney. Piezometers MV-4PZ and MV-1UPZ are not designed to be efficiently sampled and have a small diameter casing (1.9 inch inside diameter); these will be sampled less frequently. Table 1 provides the zone of completion (top and bottom) with elevations and lithologic unit monitored by wells and PZs in the monitoring network. For locations with two piezometers, UPZ and LPZ are used to denote the upper piezometer and lower piezometer, respectively.

3.3 Action Levels

The Closure Report (DOE 2018a) established the compliance levels and laboratory-required minimum detectable concentrations (MDCs) for the radioisotopes of interest (tritium, carbon-14 [^{14}C], and iodine-129 [^{129}I]). The compliance levels for these radioisotopes are consistent with the current SDWA maximum contaminant levels (MCLs) of 20,000 picocuries per liter (pCi/L) for tritium, 2000 pCi/L for ^{14}C, and 1 pCi/L for ^{129}I. The laboratory-required MDC is 400 pCi/L for tritium, 5 pCi/L for ^{14}C, and 0.1 pCi/L for ^{129}I. The laboratory-required MDCs are also referred to as the laboratory-required detection limit (RDL) used in previous groundwater monitoring reports (DOE 2015c). The compliance levels and laboratory-required MDCs were used to establish the action levels for the site (Table 2). If an action level is exceeded, LM will provide the required notifications to NDEP within 90 days of receiving the laboratory analytical results. Table 2 provides the laboratory-required MDCs, compliance levels and MCLs, and action levels with the NDEP notification requirements.

4.0 Postclosure Monitoring and Results

The Closure Report (DOE 2018a) established the long-term postclosure monitoring program and inspection requirements for the site. The postclosure monitoring program is designed to (1) assess the effectiveness of the compliance boundary by monitoring for the radioisotopes of interest and (2) evaluate the effectiveness of monitoring locations within the groundwater flow system by monitoring water elevations to ensure that monitoring wells are located along the potential migration pathways. This includes annual site inspections to maintain the ICs and ensure site protectiveness. The long-term monitoring program will be reviewed periodically and revised as necessary to adequately track changes in radioisotope concentrations and stability of the flow system over time.

The postclosure monitoring program was initiated after NDEP approved the Closure Report in 2016 (Andres 2016). The 2018 sampling program was specified in the June 2018 environmental sampling notification letter that was provided to NDEP (DOE 2018b). Section 4.1 provides the results from the site inspection, and Sections 4.2 through 4.5 describe monitoring program results.

Table 2. Monitoring Network with Action Levels for Radioisotopes of Interest

Monitoring Wells / Piezometers	Action Levels for Radioisotopes of Interest					Lithologic Unit Monitored	
	Inside Contaminant Boundary	Outside Contaminant Boundary, but Inside Compliance Boundary			Outside Compliance Boundary		
	>MCL	>2× MDC	>0.5 MCL	>MCL	>2× MDC		
MV-1UPZ					Notify NDEP 3	Upper	Alluvium
MV-2UPZ					Notify NDEP 3		
MV-3UPZ		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
MV-4PZ		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
MV-5PZ		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
MV-6		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
UC-1-P-1SRC		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
UC-1-P-2SR (depth 780 ft)	Notify NDEP 1						
UC-1-P-2SR (depth 1200 ft)	Notify NDEP 1						
HTH-2					Notify NDEP 3		
HTH-1UPZ							
HTH-1LPZ						Lower	
MV-4		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
MV-5		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
UC-1-P-2SR (depth 1591 ft)	Notify NDEP 1					Chimney	
UC-1-P-2SR (depth 2192 ft)	NA						Volcanic
MV-1LPZ						Tuffaceous sediments	
MV-3LPZ							
MV-1					Notify NDEP 3	Densely welded tuff	
MV-2LPZ							
MV-2					Notify NDEP 3		
MV-3		Notify NDEP 1	Notify NDEP 2	Notify NDEP 3			
HTH-1RC					Notify NDEP 3		

Notes:
All notifications (by email or telephone call) shall be within 90 calendar days of receiving analytical data from laboratory.
Radioisotopes of interest are tritium, ^{14}C, and ^{129}I.
MCLs are SDWA maximum contaminant levels: 20,000 pCi/L for tritium, 2000 pCi/L for ^{14}C, and 1 pCi/L for ^{129}I.
>0.5 MCL are concentrations greater than 10,000 pCi/L for tritium, 1000 pCi/L for ^{14}C, and 0.5 pCi/L for ^{129}I.
MDC levels required by laboratory are 400 pCi/L for tritium, 5 pCi/L for ^{14}C, and 0.1 pCi/L for ^{129}I.
>2× MDC are concentrations greater than 800 pCi/L for tritium, 10 pCi/L for ^{14}C, and 0.2 pCi/L for ^{129}I.
Notify NDEP 1 indicates only notification; no action, is required.
Notify NDEP 2 indicates the sampling plan (sampling locations and frequency) should be modified in consultation with NDEP.
Notify NDEP 3 indicates a new strategy or path forward should be developed in consultation with NDEP (e.g., new monitoring wells may be required).
NA indicates no action required because the sample location is inside the contaminant boundary and has detections above the MCL.

4.1 Site Inspection and Maintenance Activities

Site inspections (also conducted as part of the postclosure inspection of CAU 417) are conducted annually to look for evidence of land use changes or significant land disturbances and to ensure that ICs are maintained and continue to be effective. This includes evaluating the site roads and inspecting the monitoring network well boxes, the concrete caps that cover the UC-3 and UC-4 boreholes, and the UC-1 monument plaque at surface ground zero (SGZ) for signs of damage, natural deterioration from weather, or vandalism. The annual site inspections were conducted in September 2017 as part of the water level monitoring event and in June 2018 as part of the annual sampling event. The UC-1 site features (roads, wellheads, and monument at SGZ) and concrete cap that covers the UC-3 borehole were all in good condition at the time of inspections. The concrete cap that covers the UC-4 borehole has some deterioration from weathering that is typical for the age of the concrete. The weathering is considered cosmetic, because a steel plate welded to the borehole casings beneath the concrete prevents access to the borehole. Appendix A provides photographs from the June 2018 inspection of the UC-1 monument at SGZ and the concrete caps that cover the UC-3 and UC-4 boreholes.

Additional inspection and maintenance activities and results are provided below:

- The State of Nevada Division of Water Resources website was accessed to determine if any new groundwater wells had been permitted within 5 miles of the UC-1 site. No new groundwater wells were permitted in the search area during this reporting period (NDWR 2019).
- The University of Nevada, Reno, website was accessed to determine if any oil and gas wells had been permitted within 5 miles of the UC-1 site. No oil and gas wells were permitted in the search area during this reporting period (UNR 2019).
- The LM public website was updated during this reporting period to include the updated fact sheet and revised Closure Report (DOE 2018a), which can be accessed at https://www.lm.doe.gov/CNTA/Sites.aspx.

4.2 Water Level Monitoring

Water depths are measured manually at all wells and PZs in the monitoring network (Table 3) during scheduled monitoring events and site inspections (September 2017 and June 2018) using an electric water level tool. Water depths are also recorded more frequently using pressure transducers to detect short-term and long-term pressure changes within the different hydrostratigraphic units. Water levels are measured according to the procedures specified in the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351), also called the Sampling and Analysis Plan (SAP). The well and PZ top-of-casing elevations are used to convert the water depths to water elevations, also referred to as hydraulic head in previous reports. The water elevations are used to monitor the quasisteady state of the groundwater system and to evaluate the effectiveness of the monitoring well network with respect to potential migration pathways. Hydrographs of the water elevations are maintained and evaluated for wells completed in the same lithologic unit, having similar depths, or having similar locations (inside the graben or outside the graben).

Table 3. Monitoring Network June 2018 Water Depths and Water Elevations

Monitoring Wells / Piezometers	Date Measured	Water Depth (ft)	TOC Elevation[a] (ft)	Water Elevation[a] (ft)	Lithologic Unit Monitored	
MV-1UPZ	6/26/2018	318.30	6069.98	5751.68	Upper	Alluvium
MV-2UPZ	6/26/2018	403.31	6190.66	5787.35	Upper	Alluvium
MV-3UPZ	6/26/2018	373.32	6167.75	5794.43	Upper	Alluvium
MV-4PZ	6/26/2018	276.15	6019.45	5743.30	Upper	Alluvium
MV-5PZ	6/26/2018	289.84	6040.85	5751.01	Upper	Alluvium
MV-6	6/26/2018	313.30	6053.84	5740.54	Upper	Alluvium
UC-1-P-1SRC	6/26/2018	282.42	6031.58	5749.16	Upper	Alluvium
HTH-2	6/26/2018	557.97	6026.05	5468.08	Upper	Alluvium
HTH-1UPZ	6/26/2018	544.37	6011.27	5466.90	Upper	Alluvium
HTH-1LPZ	6/26/2018	542.33	6011.31	5468.98	Lower	Alluvium
MV-4	6/26/2018	505.70	6019.57	5513.87	Lower	Alluvium
MV-5	6/26/2018	560.35	6,041.85	5481.50	Lower	Alluvium
UC-1-P-2SR	6/26/2018	452.90[b]	6080.51	5627.61[b]	Chimney	Alluvium
MV-1LPZ	6/26/2018	78.60	6069.91	5991.31	Tuffaceous sediments	Volcanic
MV-3LPZ	6/26/2018	210.95	6167.69	5956.74	Tuffaceous sediments	Volcanic
MV-1	6/26/2018	509.18	6070.57	5561.39	Densely welded tuff	Volcanic
MV-2LPZ	6/26/2018	415.34	6190.39	5775.05	Densely welded tuff	Volcanic
MV-2	6/26/2018	384.60	6190.66	5806.06	Densely welded tuff	Volcanic
MV-3	6/26/2018	603.41	6168.27	5564.86	Densely welded tuff	Volcanic
HTH-1RC	6/26/2018	486.05	6011.70	5525.65	Densely welded tuff	Volcanic

Notes:
Coordinate system used here is U.S. State Plane System 1927 (Nevada Central Zone), Vertical Datum, NGVD29.
[a] All elevations are corrected for true vertical depth corrected and reported in units of ft amsl.
[b] UC-1-P-2SR water level and water elevation are a composite of the chimney and alluvium in which it is perforated.

Abbreviation:
TOC = top of casing

4.3 Water Level Monitoring Results

Water depths were measured manually in the site wells and PZs, and the transducer data were downloaded on June 26, 2018. The water elevations are presented as hydrographs from 2009 through the present. Water depths collected using a water level tool appear as individual symbols, and water depths collected with transducers appear as lines because the data are recorded every few hours. The hydrographs (Figure 6 through Figure 9) are grouped by comparable monitored interval and location: alluvial aquifer southeast of the southeast-bounding graben fault, including well HTH-1RC in the upper volcanic section (Figure 6); alluvial aquifer within the graben fault, including piezometer MV-3UPZ (Figure 7); the volcanic section with open intervals near the detonation depth (Figure 8); and the volcanic section with open intervals below the detonation depth (Figure 9). Data gaps in the hydrographs are the result of transducers being removed for well-site activities or for the replacement of damaged transducers or cable. Abrupt changes in the data (e.g., Figure 7 data from MV-2UPZ in mid- and late 2009) are the result of imprecise readings at locations where manual water depth measurements are difficult to collect. The water elevations from wells and PZs completed in the upper alluvial unit were contoured using the water levels collected in June 2018 to provide a potentiometric surface within the graben (Figure 10). The water elevations are presented as hydrographs from when monitoring began in 2007 through June 2018 in Appendix B (Figures B-1 through B-4).

Figure 6 shows hydrographs from January 2009 through June 2018 of wells and PZs completed in the alluvium southeast of the graben along with well HTH-1RC (screened in the upper volcanic section below the alluvium). These data indicate that water levels in wells MV-4 and MV-5 have recovered from the 2010 aquifer testing and from the 2011 yearly sampling event during which several thousand gallons of water were removed. Low-flow bladder pumps were installed in wells MV-4 and MV-5 during the November 2013 sampling event to reduce the well purge volumes and the impact purging has on the water levels during sampling (DOE 2014). Water levels in well HTH-1RC have recovered from the recompletion in 2009. Before its recompletion, well HTH-1 had been perforated across its entire saturated section, and its water level was a composite of several hydrostratigraphic units. The recompletion isolated zones in the upper and lower alluvium (HTH-1UPZ and HTH-1LPZ) and in the volcanic section (HTH-1RC). HTH-1RC isolated a densely welded tuff unit above the detonation depth, but the original well casing remains open below an obstruction at 2812 ft (elevation of about 3200 ft amsl) to the original depth of 3704 ft (elevation of about 2300 ft amsl), allowing contribution from the volcanic section below the detonation zone (Figure 4). The water elevation in the volcanic section (HTH-1RC) is higher than water elevations in both the upper and lower alluvial piezometers (HTH-1UPZ and HTH-1LPZ). This observation confirms that an upward gradient from the volcanic section to the alluvium exists in this area, as had been indicated by flow logging performed by Desert Research Institute (DRI) in HTH-1 before the well's recompletion (DOE 2008). This hydrograph of water elevation is also provided in Appendix B as Figure B-1.

Figure 7 shows hydrographs from January 2009 through June 2018 of PZs and wells completed in the alluvium within the graben and northwest of the graben. Erratic water levels in upper piezometer MV-2UPZ (Figure 7) are attributed to damage during its installation. The lower water elevations observed after mid-2009 in the upper piezometers MV-1UPZ and MV-3UPZ are the results of attempts to further develop these PZs. The recompletion of well UC-1-P-1S resulted in a screened interval about 400 ft above the previous open interval and a roughly 7 to 8 ft decrease in water elevation (Figure 7 and Figure B-2 in Appendix B). The new completion is more isolated from the influence of deeper horizons where water elevations have been higher. The water elevations in the piezometers MV-4PZ and MV-5PZ (screened inside the graben) are approximately 250 ft higher than those in the MV-4 and MV-5 wells that are screened outside the graben to the southeast (Figure 6). Given these results, alluvial aquifer hydrographs were separated into two groups based on their screened location relative to the southeast-bounding graben fault. Water elevations from the MV-4 and MV-5 wells and PZs continue to support the conceptual model that the southeast-bounding graben fault acts as a barrier to flow. Figure B-2 in Appendix B provides the water elevations as hydrographs from when monitoring began in 2007 through June 2018.

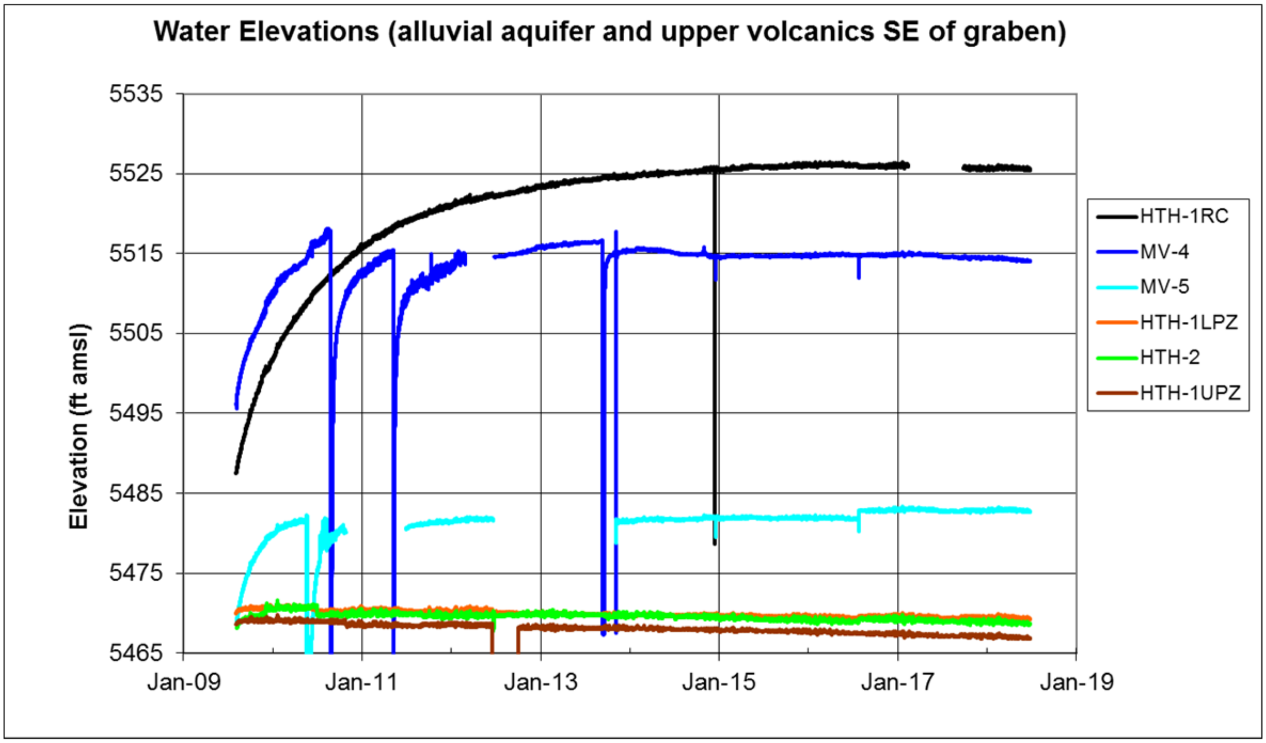

Figure 6. Water Elevations for the Alluvial Wells and Well HTH-1RC (Upper Volcanics) Southeast of the Down-Dropped Graben at the Screened Horizon

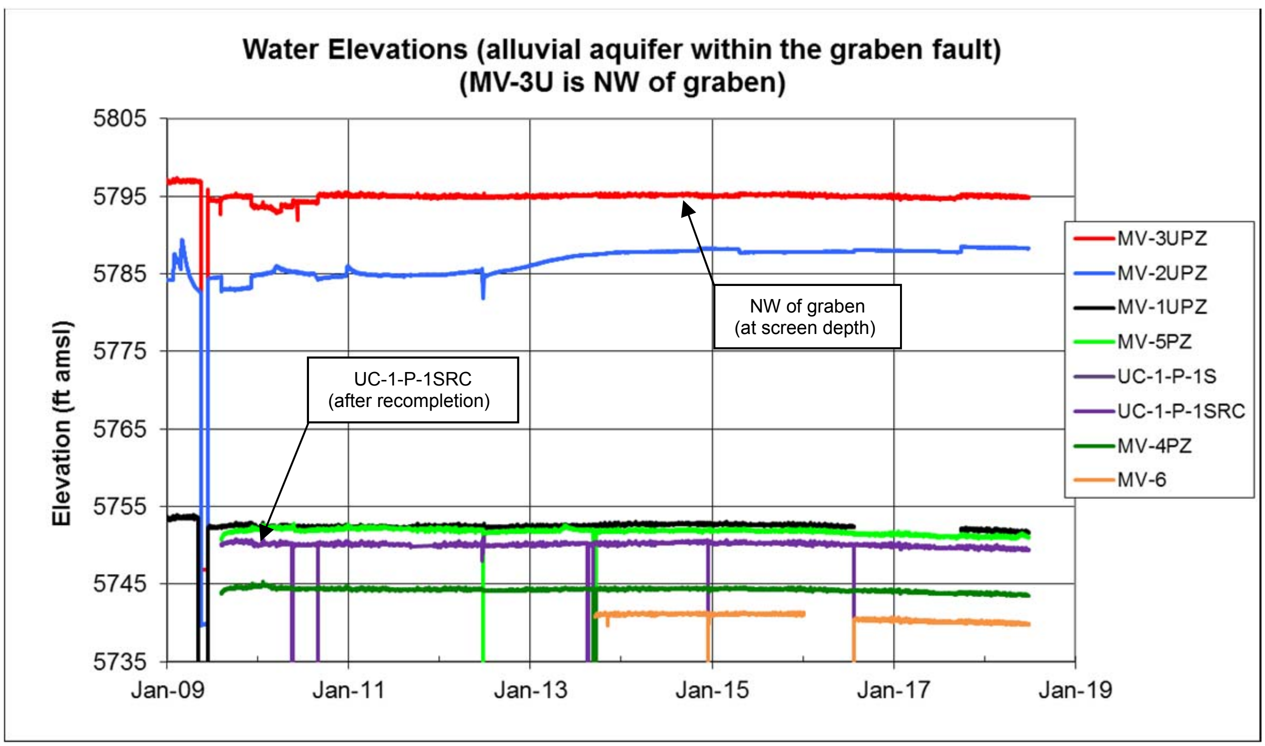

Figure 7. Water Elevations for the Alluvial Wells Northwest of the Southeast-Bounding Graben Fault

Figure 8 shows hydrographs from January 2009 through June 2018 of the well and PZs with open intervals near the detonation depth. Water elevations in the well and PZs at this depth have been declining since their installation in 2005; the exception is MV-1LPZ, which had a rising water elevation after installation until 2011. Water elevations in MV-2LPZ have been decreasing at about the same rate (about 5 ft per year) as the other wells and PZs screened in the volcanic section since 2012. The declining water elevations (highest observed in the volcanic section) are attributed to a slow release of the detonation-related pressure response that persists due to the low permeability of the volcanic section. The highly variable water levels in the MV-2LPZ (Figure 8) were investigated by DRI on August 5, 2008. DRI ran a temperature log, collected a bailed sample, and measured the depth of the LPZ. It was determined that sediment had filled MV-2LPZ to a depth 75 ft above the top of the screened interval. Additional development of this PZ in the summer of 2009 lowered the sediment fill to the top of the screened interval. Water elevations in MV-2LPZ appeared to recover in 2010 from the development, then steadily declined (at a decreasing rate) through 2011 and into 2012, when the water level dropped approximately 10 ft after well MV-2 was sampled. After this monitoring event, the water levels in MV-2LPZ recovered and then reverted to a decreasing trend. The proximity of the MV-2LPZ screened interval to the northwest-bounding graben fault is believed to be the cause of its erratic water levels. It is expected that water levels southeast of this fault (within the graben) are higher than water levels to the northwest, outside the graben. The abrupt water level increase (MV-2LPZ) in June 2010 followed by an abrupt decrease in June 2012 is the result of the installation (2010) and subsequent removal (2012) of a direct-read transducer with a ¼-inch cable. The transducer was placed more than 200 ft below water in case another sudden water level drop like the one in 2008 were to occur. The slow recovery of water levels in MV-2LPZ in response to what should be minor perturbations attests to the low permeability of the section. Figure B-3 in Appendix B provides the water elevations as hydrographs from when monitoring began in 2007 through June 2018.

Figure 9 shows hydrographs from January 2009 through June 2018 of wells with open intervals below the detonation depth and reentry well UC-1-P-2SR. The composite water level from UC-1-P-2SR (chimney and alluvium overlying the former cavity) is higher than in the densely welded tuff units below the detonation zone. The composite water elevation of 5628 ft amsl measured in June 2018 (Table 3) continues to increase, though at a long-term decreasing rate. Well UC-1-P-2SR has perforations as high as 1148 ft in the alluvium, and its water level is expected to eventually reach a steady-state elevation of approximately 5750 ft amsl (similar to other alluvial wells and PZs within the graben). Figure B-4 in Appendix B provides the water elevations as hydrographs from when monitoring began in 2007 through June 2018.

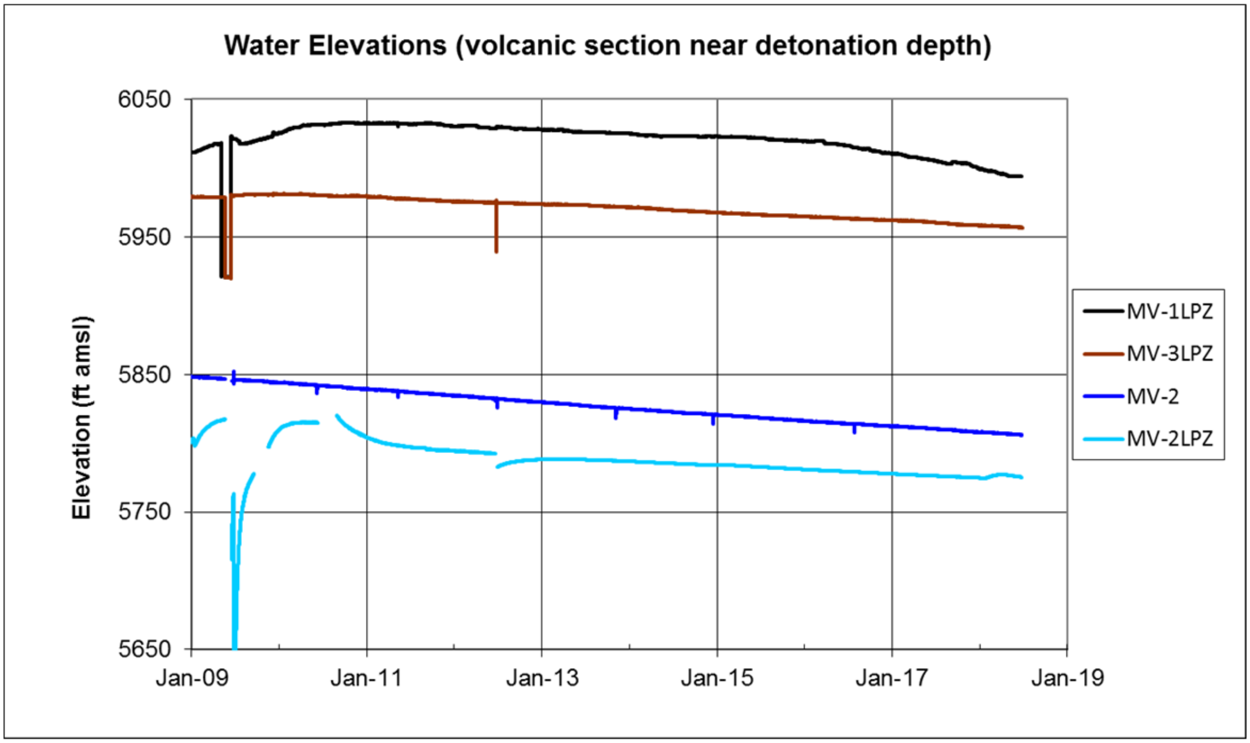

Figure 8. Water Elevations for the Well and Piezometers Screened in the Volcanic Section at or near the Depth of the Detonation

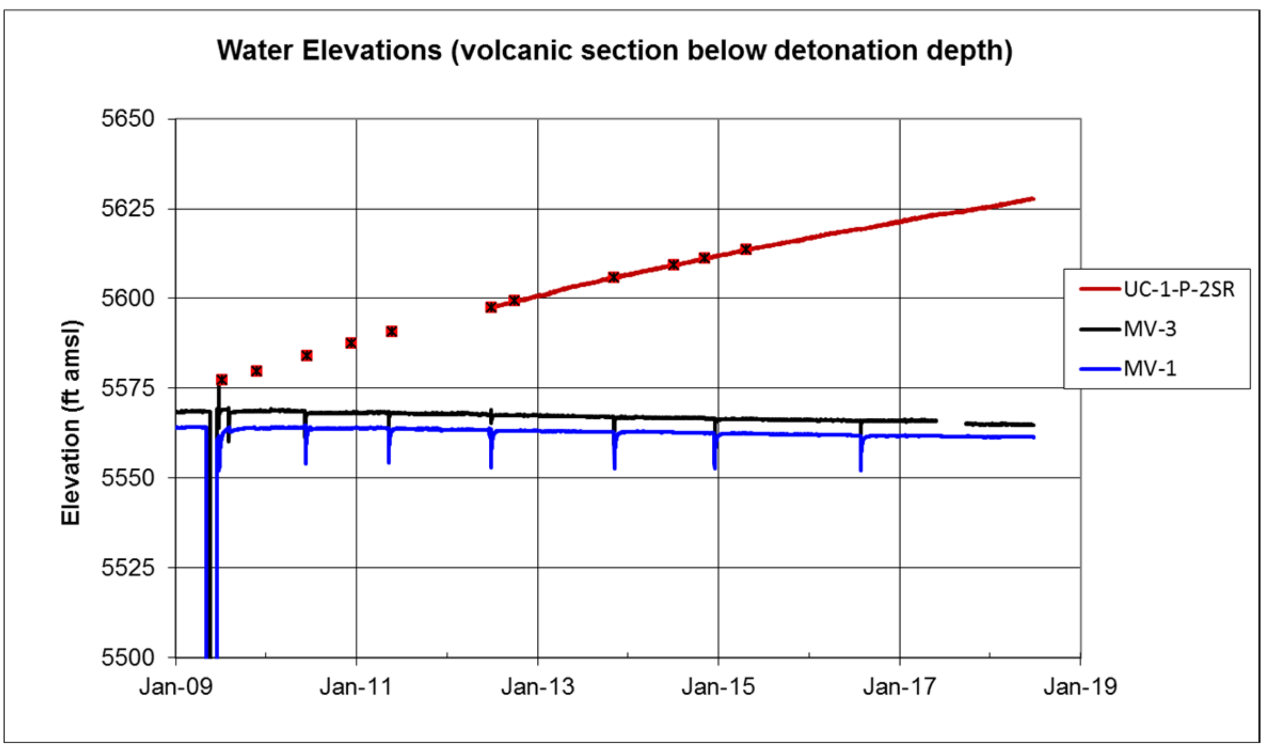

Figure 9. Water Elevations for the Wells Screened in the Volcanic Section Below the Detonation Depth
Note: Water elevations for reentry well UC-1-P-2SR [drilled into the chimney] are shown for reference.)

A potentiometric map of the upper part of the alluvial aquifer within the graben (Figure 10) was constructed using June 2018 water levels from MV-4PZ, MV-5PZ, MV-6, UC-1-P-1SRC, MV-1UPZ, and MV-2UPZ, all of which are screened at depths ranging from 600 to 1000 ft. Contouring of the potentiometric surface (Figure 10) was restricted to the area within the graben. Contours near SGZ are based on the composite water level from well UC-1-P-2SR. The interpretation seen in Figure 10 suggests that horizontal flow in the upper alluvium is toward the chimney near SGZ. Away from the chimney's influence, horizontal flow is east–southeast and likely deflected by the southeast-bounding graben fault that is acting as a barrier to flow. As drawn, the contours indicate a dip reversal between the chimney and MV-6 that could gradually disappear as water elevations recover in the alluvium above the detonation zone. Groundwater flow within the graben could eventually be east-southeast after water levels in reentry well UC-1-P-2SR recover. Depiction of groundwater flow directions within the graben has an inherent degree of uncertainty, given the structural complexity caused by the detonation and the limited data available within the graben.

4.4 Radioisotope Monitoring

The Closure Report (DOE 2018a) establishes the monitoring network and sampling frequency for the radioisotopes of interest. The monitoring network is designed to monitor both the most likely transport path (densely welded tuff) near and below the source zone and the most likely access path, the higher-permeability alluvial aquifer above the source zone. Since the alluvial unit is the most likely access path and has the highest groundwater velocities, the monitoring network wells completed in the alluvium are sampled more often than the wells completed in the low-permeability, densely welded tuff units. Site sampling is scheduled for every 2 years until 2020, when the sampling schedule becomes every 3 years. Water samples are collected according to procedures specified in the SAP. Discharge and handling of monitoring well purge water are conducted in accordance with the *Fluid Management Plan, Central Nevada Test Area Corrective Action Unit 443* (DOE 2009).

The radioisotopes of interest for the long-term postclosure monitoring program are tritium, ^{14}C, and ^{129}I (DOE 2018a). Water samples will be analyzed for tritium during each scheduled sampling event. Water samples collected in 2020 will also be analyzed for ^{14}C and ^{129}I. These radioisotopes will be included in the analytical suite every 12 years starting in 2020. Tritium is currently the primary radioisotope of concern because of its initial abundance and mobility. After a few hundred years, tritium (with a half-life of 12.3 years) will decay to insignificant levels, and the longer-lived radioisotopes, ^{14}C (with a 5730-year half-life) and ^{129}I (with a 1.57×10^7-year half-life), will become the primary focus of the long-term postclosure monitoring. The Closure Report established compliance levels and laboratory-required MDCs for the radioisotopes of interest (tritium, ^{14}C, and ^{129}I) that were used to establish action levels (Table 2) for the long-term postclosure monitoring program (DOE 2018a).

4.5 Radioisotope Results

Groundwater samples were collected from wells completed in the alluvium and volcanic section during the postclosure sampling events conducted June 26–27, 2018, and September 25, 2018 (Table 4). Well MV-5 could not be sampled during the June monitoring event because of a leak in the bladder pump. The bladder pump was replaced in MV-5, and a sample was collected on September 25, 2018. The monitoring wells MV-1, MV-2, MV-3, MV-4, MV-5, and HTH-1RC,

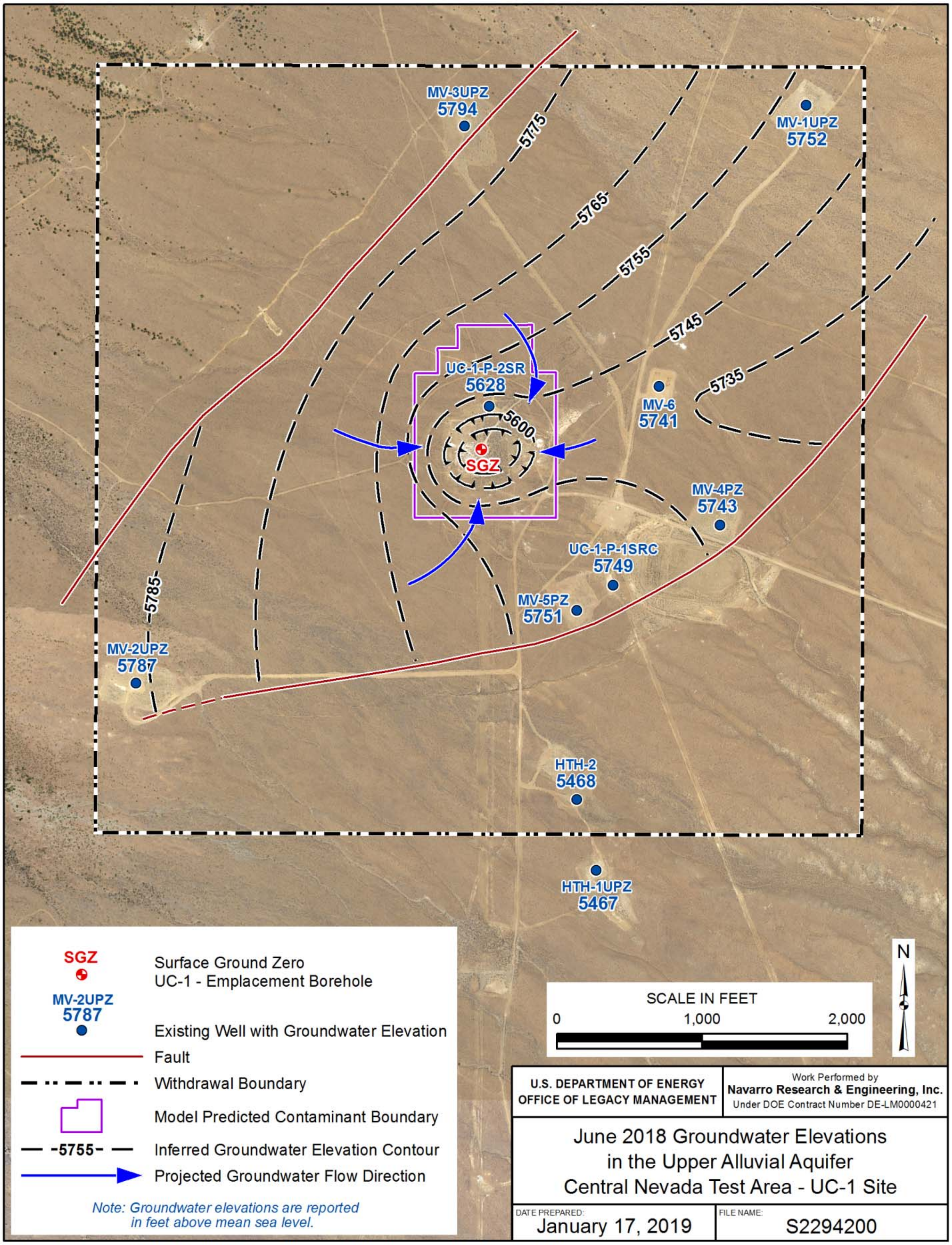

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Figure 10. June 2018 Groundwater Elevations in the Upper Alluvial Aquifer CNTA–UC-1 Site

are completed with bladder pumps and were purged to remove stagnant water from the pump tubing before sample collection. Monitoring wells MV-6 and UC-1-P-1SRC were purged before sampling using the dedicated electric submersible pumps. Field parameters (temperature, pH, and specific conductance) were allowed to stabilize before samples were collected. Table C-1 in Appendix C provides the field parameter measurements from the 2018 monitoring events.

Groundwater samples collected during the 2018 sampling events were analyzed for tritium. Laboratory analytical results from the sampling events indicate that tritium concentrations were below the laboratory-required MDC at the sampled locations (Table 4). The laboratory analytical results were validated in accordance with Section 5.0, “Validation of Laboratory Data,” in the *Environmental Data Validation Procedure* (LMS/PRO/S15870). All analyses were completed, and the samples were prepared and analyzed in accordance with accepted procedures that were based on the specified methods. The laboratory radiochemical MDC reported with these data are a priori estimates of the detection capability of a given analytical procedure, not an absolute concentration that can or cannot be detected. Table 4 presents 2018 laboratory results. A copy of the Data Validation Memorandum is maintained on the LM public website (Navarro 2018), which can be accessed at https://www.lm.doe.gov/CNTA/Sites.aspx. Laboratory analytical results collected during this and previous monitoring events are available on the GEMS website at https://gems.lm.doe.gov/#site=CNT.

Table 4. Monitoring Network June and September 2018 Laboratory Results

Monitoring Wells / Piezometers	Date Sampled	Tritium (pCi/L)	^{14}C (pCi/L)	^{129}I (pCi/L)	Lithologic Unit Monitored	
MV-1UPZ					Upper	Alluvium
MV-2UPZ						
MV-3UPZ						
MV-4PZ						
MV-5PZ						
MV-6	6/26/2018	<MDC/<MDC[a]	NS	NS		
UC-1-P-1SRC	6/26/2018	<MDC	NS	NS		
HTH-2						
HTH-1UPZ						
HTH-1LPZ					Lower	
MV-4	6/26/2018	<MDC	NS	NS		
MV-5	9/25/2018	<MDC	NS	NS		
UC-1-P-2SR					Chimney	
MV-1LPZ					Tuffaceous sediments	Volcanic
MV-3LPZ						
MV-1	6/26/2018	<MDC	NS	NS	Densely welded tuff	
MV-2LPZ						
MV-2	6/26/2018	<MDC	NS	NS		
MV-3	6/27/2018	<MDC	NS	NS		
HTH-1RC	6/26/2018	<MDC	NS	NS		

Notes:
Shaded cells were not sampled because they were not part of the sampling network for this scheduled sampling event as established in Table 2 of the Closure Report (DOE 2018a).
[a] Duplicate sample.

Abbreviations:
<MDC = below laboratory-required MDC (400 pCi/L for tritium, 5 pCi/L for ^{14}C, and 0.1 pCi/L for ^{129}I [DOE 2018a]).
NS = Not sampled because radioisotope was not part of the 2018 laboratory suite established in the Closure Report.

5.0 Summary and Recommendations

Site inspections were conducted in September 2017 and June 2018 as part of the annual site monitoring. At the time of inspection, the UC-1 site features (roads, wellheads, and UC-1 monument plaque at SGZ) all appeared to be in good condition, and no unusual ground disturbances were observed. The concrete cap that covers the UC-4 boreholes has some deterioration from weathering, typical for the age of the concrete, but remains protective. No groundwater wells or oil and gas well permits were granted within 5 miles of the UC-1 site during this monitoring period.

The sample analytical results indicate tritium was not detected above the laboratory-required MDC in all sampled wells in the monitoring network. These sample results, along with past results, support the determination that radioisotopes of interest have not migrated outside the compliance boundary. Water elevations continue to support the interpretations of flow directions and the adequacy of the monitoring network at the site. Water levels in the reentry well UC-1-P-2SR continue to recover from the dewatering effects of the detonation. The currently depressed water levels in this area direct groundwater flow in the alluvial aquifer near SGZ toward the chimney. In the volcanic section, water levels from well UC-1-P-2SR also indicate a downward gradient from the source zone to the densely welded tuff units below the detonation depth. The downward gradient could increase as water levels continue to recover in the chimney. Water level data from the PZ (screened inside the graben) and well (screened outside the graben) at the MV-4 and MV-5 locations continue to confirm that the southeast-bounding graben fault acts as a barrier to groundwater flow.

LM recommends the following:

- Conduct the annual site inspections as prescribed in the Closure Report.
- Conduct the postclosure groundwater sampling in 2020 as prescribed in the Closure Report.
- Complete the next Postclosure Groundwater Monitoring and Inspection Report (2018 through 2020) after the sampling in 2020 as prescribed in the Closure Report.

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Appendix A

Photographic Documentation

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Figure A-1. Concrete Cap that Covers the UC-3 Emplacement Borehole

Figure A-2. Concrete Cap that Covers the UC-4 Emplacement Borehole

Figure A-3. UC-1 Monument Plaque on the Emplacement Borehole Casing

Figure A-4. UC-1 Monument Plaque on the Emplacement Borehole Casing

Appendix B

Hydrographs of Water Elevation Data: 2007 Through the Present

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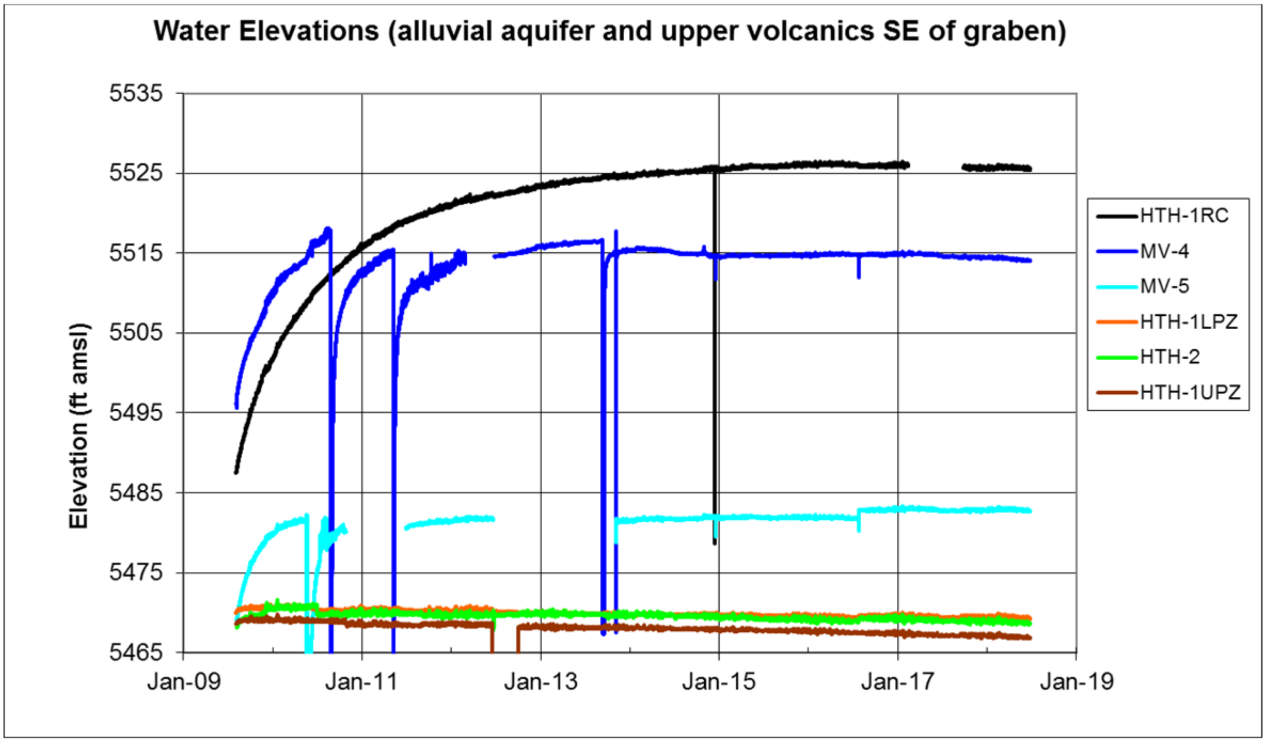

Figure B-1. Water Level Elevations for Alluvial Wells and Well HTH-1RC (upper volcanics) Southeast of the Down-Dropped Graben at the Screened Horizon

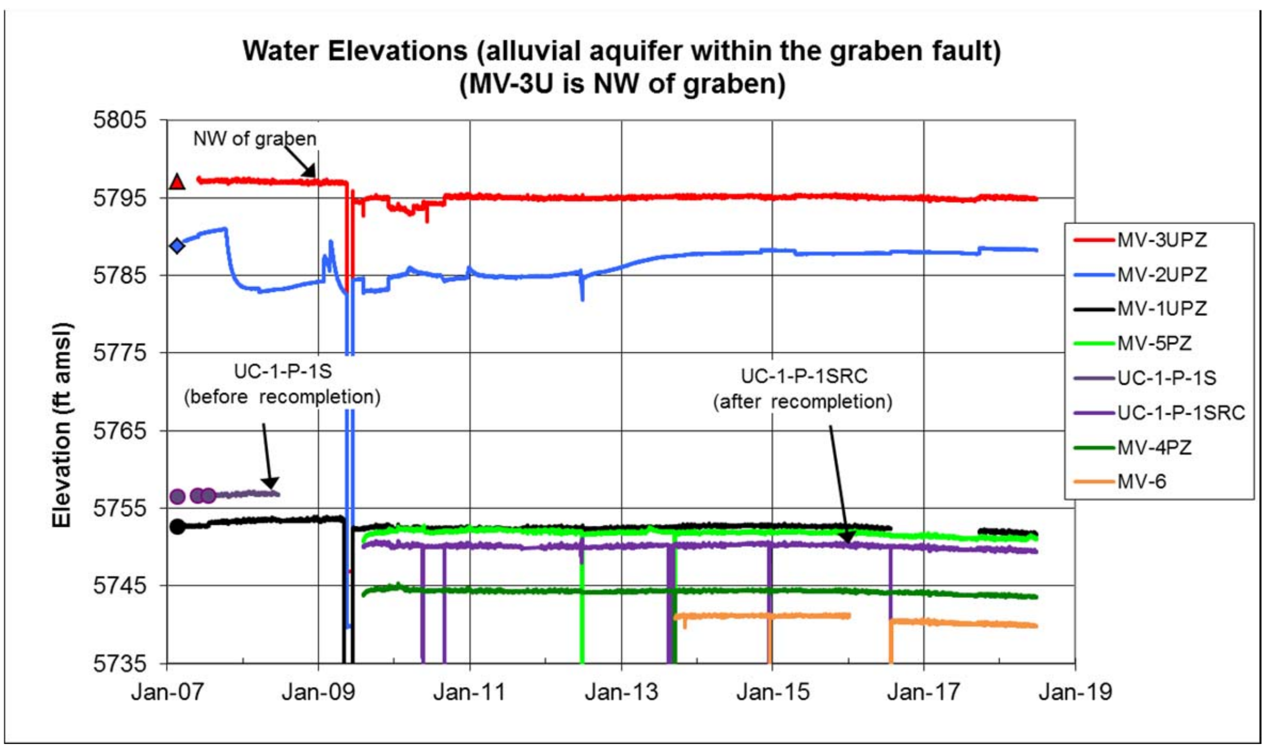

Figure B-2. Water Level Elevations for Alluvial Wells Northwest of the Southeast-Bounding Graben Fault

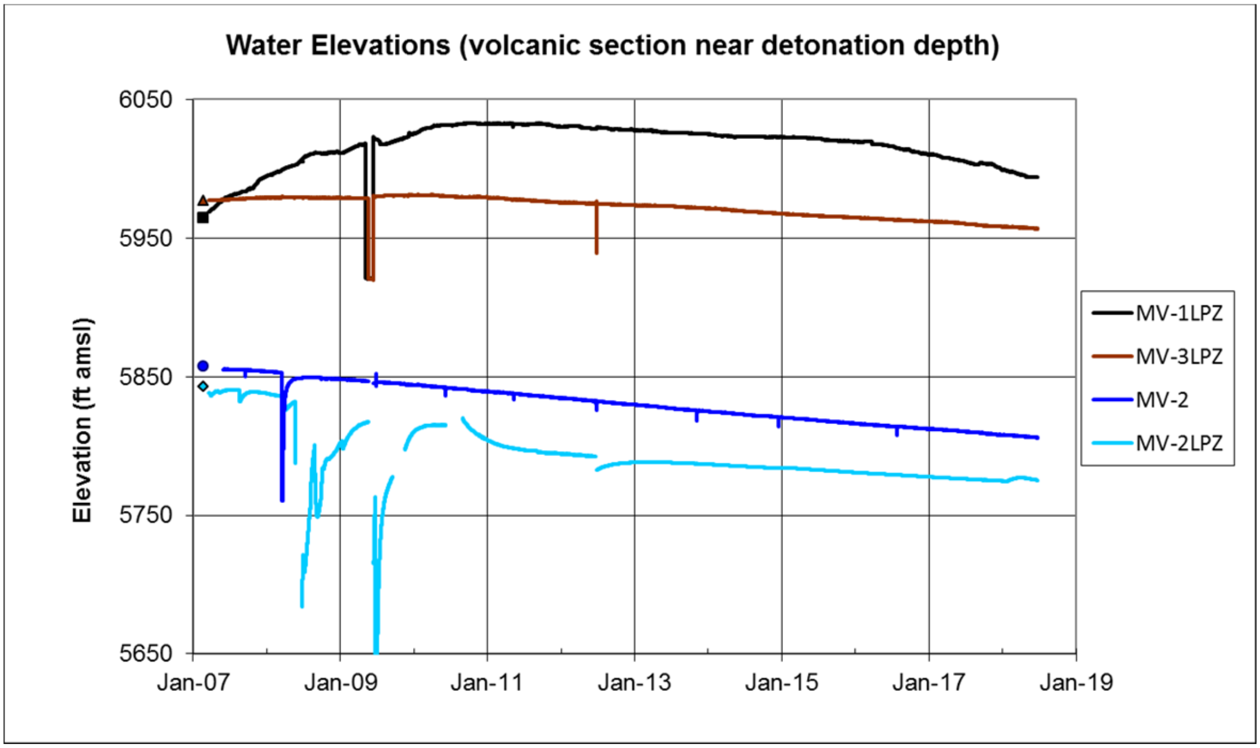

Figure B-3. Water Level Elevations for the Well and Piezometers Screened in the Volcanic Section at or near the Level of the Detonation

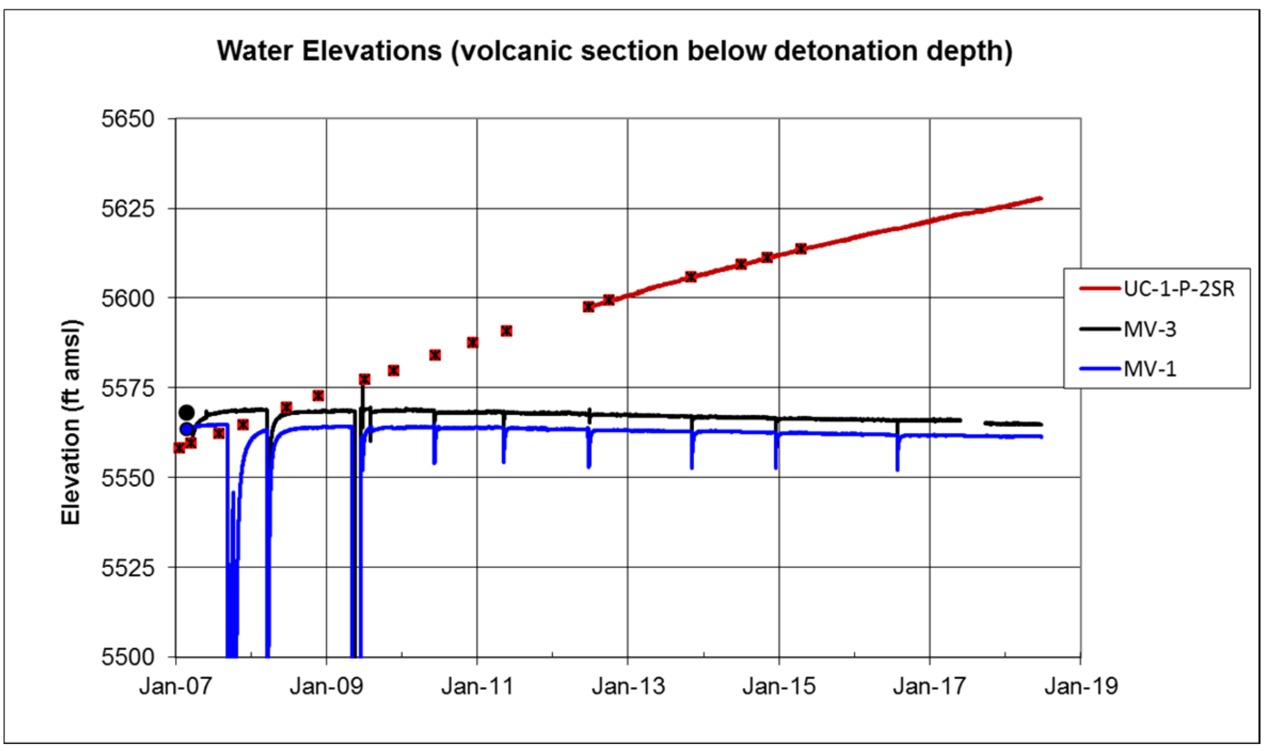

Figure B-4. Water Level Elevations for Wells Screened in the Volcanic Section Below the Level of the Detonation

Appendix C

Well Purge Data

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Table C-1. Monitoring Well Purge Data

Well Identification	Date Sampled	Purged Volume (gallons)	Temperature (°C)	pH (s.u.)	Specific Conductance (µmho/cm)
HTH-1RC	6/26/2018	6.5	18.8	8.3	600
MV-1	6/26/2018	9.2	19.4	9.7	681
MV-2	6/26/2018	7.7	19.5	10.7	1776
MV-3	6/27/2018	10.1	17.7	7.0	956
MV-4	6/26/2018	4.5	18.9	9.5	429
MV-5	9/25/2018	5.0	16.2	10.0	458
MV-6	6/26/2018	950	21.9	7.2	233
			22.2	7.3	232
			22.5	7.4	232
UC-1-P-1SRC	6/26/2018	500	22.8	7.2	328
			21.9	7.2	325
			21.9	7.3	326

Abbreviations:
µmho/cm = micromhos per centimeter
s.u. = standard unit

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Appendix D

NDEP Correspondence

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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

June 24, 2019

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

RE: Submittal of Draft 2018 Postclosure Groundwater Monitoring and Inspection Report, Central Nevada Test Area: Subsurface Corrective Action Unit (CAU) 443, Nevada Site *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 2018 Postclosure Groundwater Monitoring and Inspection Report for CAU 443.* The NDEP has no comments on the draft document and agrees with the Recommendations presented in Section 5.0. This letter serves as a Notice of Completion for the May 15, 2019 FFACO Milestone Deadline, *Draft 2018 Postclosure Groundwater Monitoring Report.*

If you have any comments or questions on the above, please contact me at 702-486-2850, ext. 232, or Mark McLane at ext. 226.

Sincerely,

Chris Andres

Christine D. Andres
Chief
Bureau of Federal Facilities

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