LMS/GNO/49972

2024 Groundwater Monitoring and Inspection Report Gnome-Coach, New Mexico, Site

April 2025

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Abbreviations

API	American Petroleum Institute
BHL	bottom-hole location
BLM	U.S. Bureau of Land Management
^{137}Cs	cesium-137
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
IC	institutional control
LM	Office of Legacy Management
LMS	Legacy Management Support
LTHMP	Long-Term Hydrologic Monitoring Program
LTS&M Plan	Long-Term Surveillance and Maintenance Plan
m/d	meters per day
NMIMT	New Mexico Institute of Mining and Technology
pCi/L	picocuries per liter
SHL	surface-hole location
^{90}Sr	strontium-90
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

Executive Summary

The Gnome-Coach, New Mexico, Site in southeastern New Mexico was the location of an underground nuclear test in 1961 and a groundwater tracer test in 1963 that resulted in residual radionuclide contamination. The Long-Term Surveillance and Maintenance Plan for the site describes the U.S. Department of Energy Office of Legacy Management (LM) plan for monitoring groundwater (radiochemical sampling and water-level measurements), inspecting the site, maintaining site institutional controls, evaluating and reporting data, and documenting site records and data management processes. These activities are reported annually, and this report summarizes the results from the September 2023 to August 2024; it includes the site inspection and annual sampling that were completed on January 30, 2024. Observations made during the reporting period indicate that the institutional controls remain protective of the site.

The monitoring well network consists of three wells completed in the Culebra Dolomite (wells USGS-1, USGS-4, and USGS-8) and two wells completed in the Salado Formation (wells DD-1 and LRL-7). Groundwater elevation data from the Culebra wells (USGS-1, USGS-4, and USGS-8) continue to support a regional groundwater flow direction that is generally toward the south but is influenced locally by the pumping in well USGS-1. Groundwater elevations in the Culebra wells, which had been decreasing overall since monitoring began in 2008, stabilized in 2020 and have generally remained stable through this reporting period that ended in August 2024. The decrease in the overall groundwater elevation is likely due to an increase in oil and gas well drilling that uses groundwater from the Culebra Aquifer as part of the drilling and hydrologic fracturing process. Groundwater elevation data from well LRL-7, which monitors the Coach drift, continue to indicate that water levels have stabilized from the well's last sampling event in 2011. Water levels in reentry well DD-1, which monitors the detonation cavity, continue to rise at a rate averaging about 11 feet per year. Water levels in wells LRL-7 and DD-1 might not be representative of the Salado Formation and are likely influenced by remnant pressure effects associated with the detonation, the plastic nature of the Salado Formation, and past disposal activities.

Samples were collected from wells USGS-1, USGS-4, and USGS-8 (completed in the Culebra Dolomite) on January 30, 2024, to monitor radionuclide concentrations associated with the tracer test. Laboratory radiochemical results were consistent with previous results. Samples were not collected from wells DD-1 and LRL-7 (completed in the Salado Formation) because these wells are not scheduled for annual sampling due to the limited potential for contaminant migration in the Salado Formation. Copies of this report are sent to the individuals on the distribution list provided as Appendix C, and the report is available on the LM public website at https://www.energy.gov/lm/gnome-coach-new-mexico-site.

1.0 Introduction

This report presents the groundwater monitoring and site inspection data collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Gnome-Coach, New Mexico, Site (Figure 1). The site was the location of an underground nuclear test in 1961 and a radionuclide groundwater tracer test in 1963 that resulted in residual radionuclide contamination in the groundwater and postdetonation features that require long-term oversight. Long-term responsibility for the site was transferred from the DOE National Nuclear Security Administration Nevada Site Office to LM on October 1, 2006. The Long-Term Surveillance and Maintenance Plan (LTS&M Plan) for the site describes LM's plan for monitoring groundwater, inspecting the site, maintaining institutional controls (ICs), evaluating and reporting data, and documenting the site's records and data management processes (DOE 2016b). This report summarizes the results of the groundwater monitoring and site inspection activities conducted during the September 2023 to August 2024 reporting period. The purpose of these activities is to monitor the groundwater and ensure that the ICs are protective of the site and of human health and the environment. This report and the LTS&M Plan are available on the LM public website at https://www.energy.gov/lm/gnome-coach-new-mexico-site. Data collected during this and previous monitoring events (including laboratory results and water-level data) are available on the Geospatial Environmental Mapping System (GEMS) website at https://gems.lm.doe.gov/#site=GNO.

2.0 Site Location and Background

The Gnome-Coach site is approximately 25 miles southeast of Carlsbad in Eddy County, New Mexico (Figure 1). The U.S. Atomic Energy Commission, a predecessor agency to DOE, acquired the site through a land withdrawal from the U.S. Bureau of Land Management (BLM) in the early 1960s for underground nuclear testing through the Plowshare Program (AEC 1962). The Plowshare Program was a research and development initiative started in 1957 to determine the technical and economic feasibility for peaceful applications of nuclear energy. The withdrawal comprises two parcels of land totaling approximately 680 acres. The larger parcel (640 acres) is where the underground nuclear test and radionuclide tracer test occurred and is identified as the Gnome-Coach site in Section 34 within Township 23 South, Range 30 East. The smaller parcel (40 acres) was used for observation during the underground test and is identified as the observation area in Section 10, Township 23 South, Range 30 East. The focus of this report is the 640-acre parcel identified as the Gnome-Coach site (Figure 1).

The purpose of the underground nuclear test, identified as Project Gnome, was to study the possibility of converting the energy from nuclear detonations into electricity, investigate the production and retrieval of radioisotopes, measure neutron activation cross sections of specific isotopes, collect data on the characteristics of nuclear explosions in salt formations, and collect data for use in future Plowshare Program projects (AEC 1962). Preparation for the test began in 1958 and involved multiple agencies. The U.S. Geological Survey (USGS) installed several wells and boreholes to assess the geologic and hydrologic conditions at the site (Section 2.1). The site was determined suitable for the experiment, and a 10-foot (ft)-diameter vertical emplacement shaft was excavated to a depth of 1216 ft (Figure 2). A horizontal drift (Gnome drift) was mined from the bottom of the shaft, extending 1116 ft to the northeast, ending in a hook shape that was completed in the Salado Formation. The hook shape was designed for placement of the nuclear device and was intended to be self-sealing following the detonation that occurred at a depth of 1184 ft on December 10, 1961. The nuclear device had a reported yield of 3 kilotons (DOE 2015b). Immediately following the detonation, close-in stemming materials failed, and gases from the detonation cavity vented to the atmosphere through the Gnome drift and the emplacement shaft (AEC 1962). The emplacement shaft was cleared, and a new drift was excavated after the detonation to inspect the effects of the detonation. The cavity that resulted from the detonation has well-documented dimensions confirmed by scientists who entered the cavity 5 months after the test in May 1962 (Figure 3). Posttest drilling operations and preparations for another underground nuclear test, identified as Project Coach, began shortly after the Gnome test. The emplacement shaft was restored and deepened to a depth of 1284 ft, and a second horizontal drift—the Coach drift—was mined 1945 ft southeast from the shaft (AEC 1969). The Coach experiment was initially scheduled for 1963 but was canceled, and there were no additional underground nuclear detonations at the site. The site is still referred to as the Gnome-Coach site. Figure 2 is a map showing the site and site features (monitoring wells, emplacement shaft, and the Project Gnome monument). Figure 3 is a cross section that shows these units with the emplacement shaft, the Gnome drift, and the cavity that resulted from the nuclear detonation.

In 1963, USGS conducted a groundwater tracer test in the Culebra Dolomite, a fractured carbonate aquifer that is the most prolific aquifer near the site (Figure 3) and is at a depth of approximately 500 ft near the site. The tracer test was designed to estimate the dispersion coefficient and effective porosity of the Culebra Aquifer for evaluating the potential movement of radionuclides (Beetem and Angelo 1964). Wells USGS-4 and USGS-8 were used for the tracer test and are approximately 3100 ft west of the Project Gnome monument, which is directly above the detonation cavity and signifies surface ground zero (Figure 2). Water from the extraction well (USGS-4) was mixed with four dissolved radionuclides (tritium, iodine-131, strontium-90 [^{90}Sr], and cesium-137 [^{137}Cs]), and the solution was pumped into the injection well (USGS-8). The tracer test experiment was performed in two separate phases over 21 days in February and March 1963. Samples were collected at the extraction well (USGS-4) during the test to record the arrival and concentration of each tracer.

2.1 Geology and Hydrology

The Gnome-Coach site is in the northwestern part of the Delaware Basin, a deep, oval, sedimentary basin 75 miles wide and 135 miles long in southeastern New Mexico. The geology and hydrology of this basin are well studied because of oil and gas exploration, mining, and the presence of the Waste Isolation Pilot Plant (WIPP) approximately 8.5 miles north-northeast of the site (measured from the approximate center of each withdrawal boundary). The basin lithology comprises crystalline sedimentary rocks overlain by evaporites that were deposited during the late Permian Period, when a warm, shallow sea was blocked from seawater circulation. As the seawater evaporated, the transition from a deep marine environment (limestone and dolomite) to a shallow marine and later dry environment (gypsum, halite, anhydrite, and potassium salts [potash]) resulted in several thousand feet of deposits accumulating on the basin floor. The basin deposits and the lithostratigraphic units they compose are almost flat to gently dipping to the east and southeast near the Gnome site (USGS 1962).

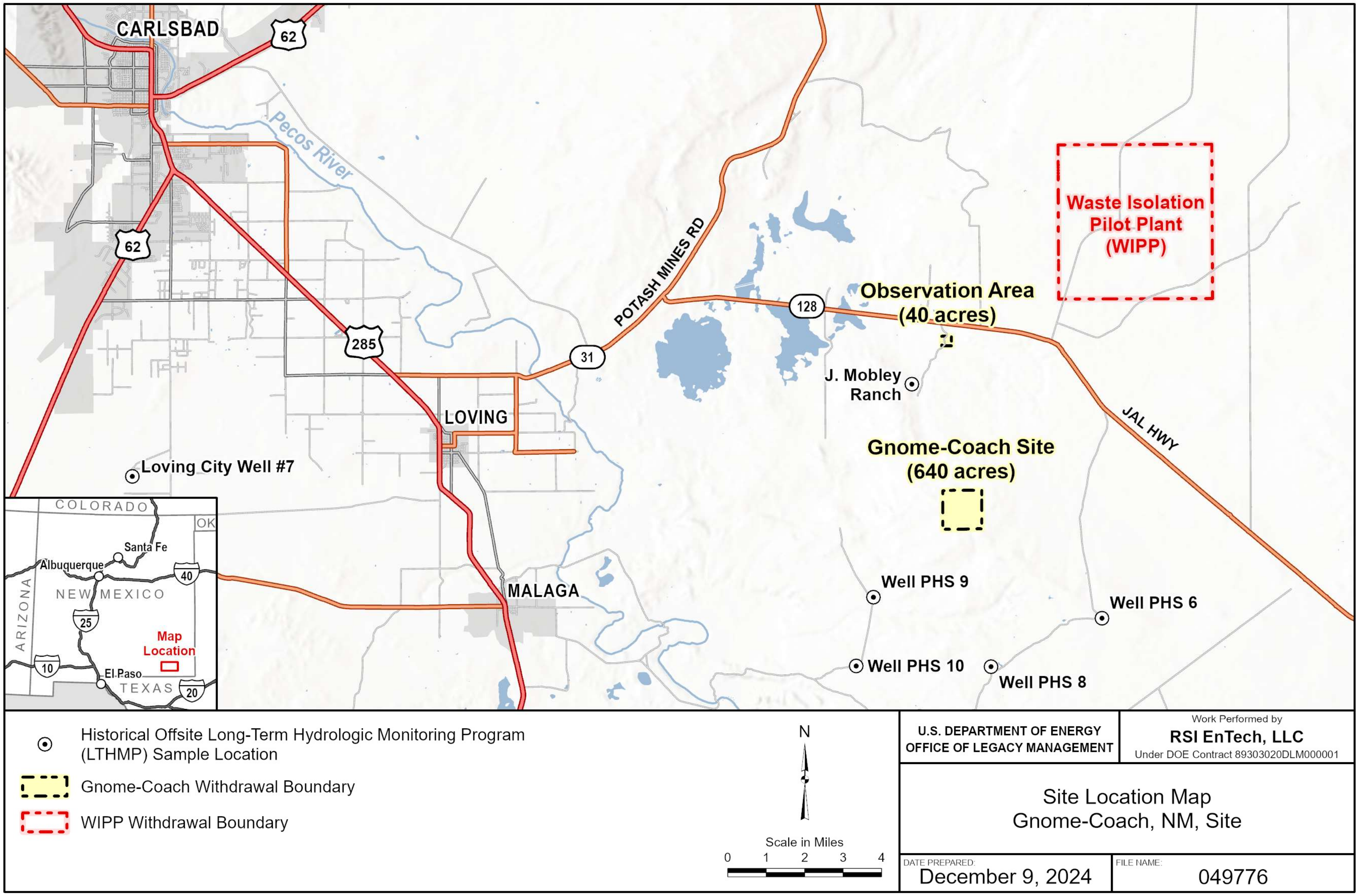

Figure 1. Location Map for the Gnome-Coach, New Mexico, Site

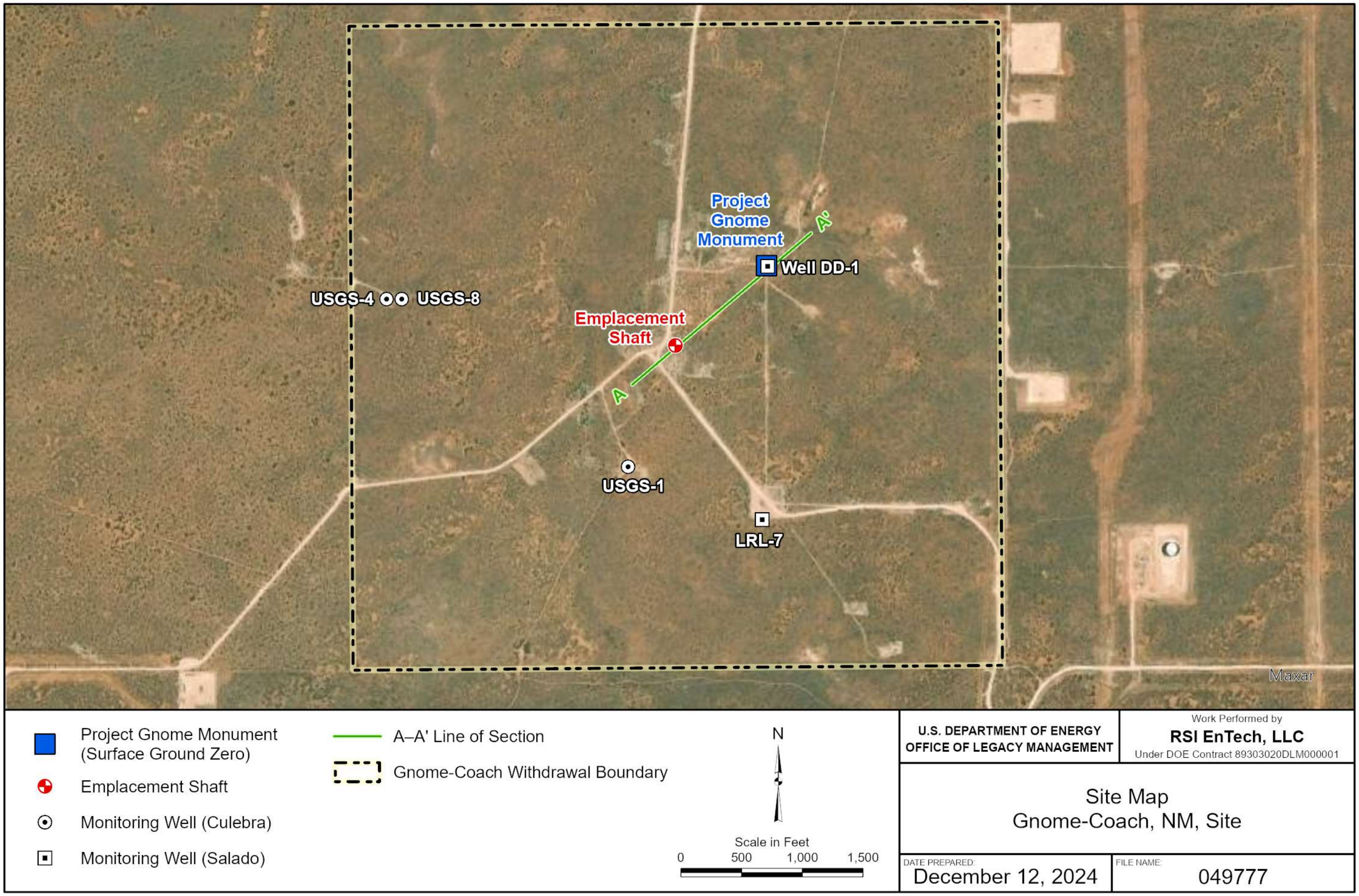

Figure 2. Site Map for the Gnome-Coach, New Mexico, Site

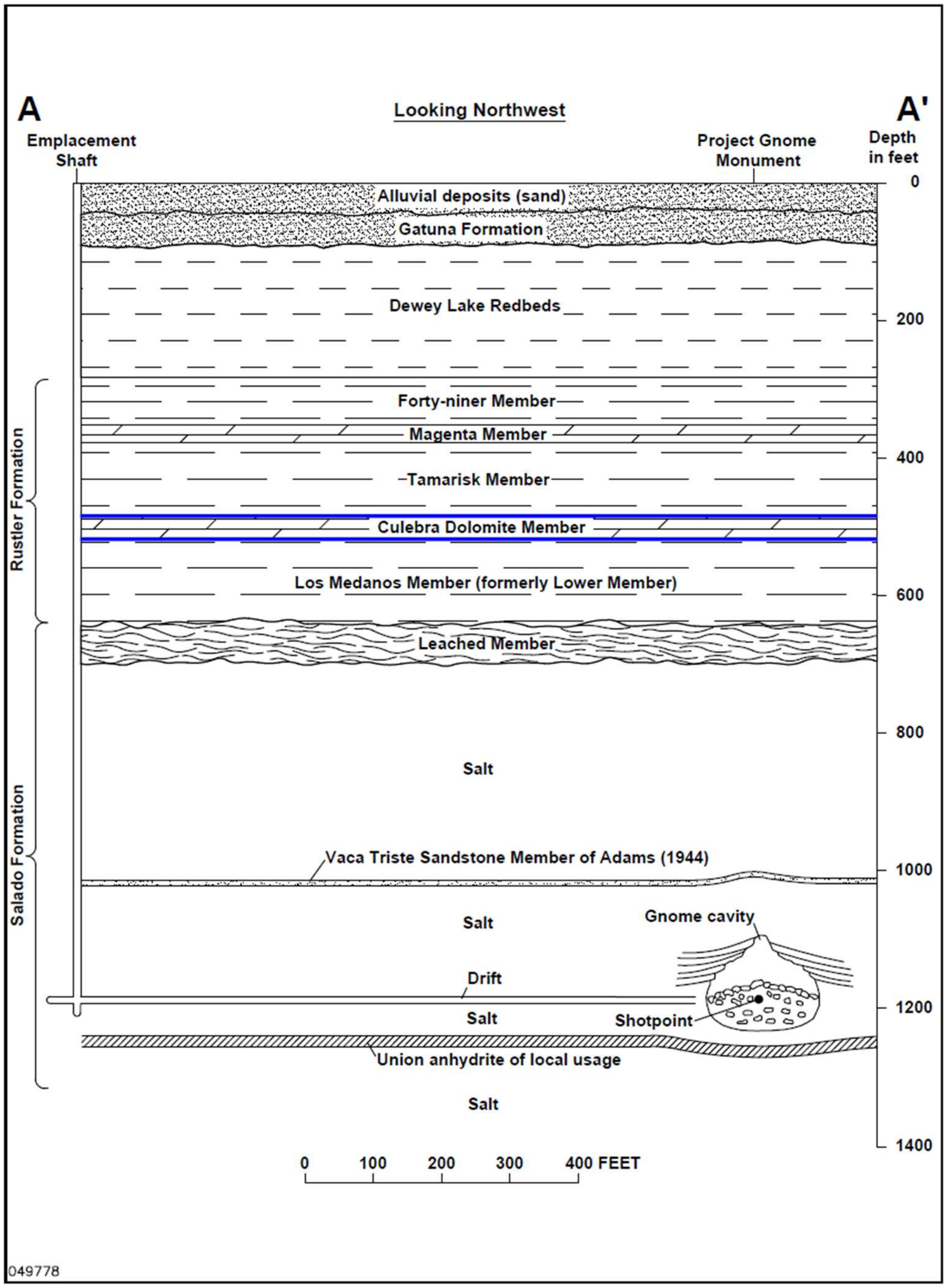

Figure 3. Stratigraphic Cross Section at the Gnome-Coach, New Mexico, Site

The lithostratigraphic units beneath the Gnome site were defined during the pretest drilling and mining of the emplacement shaft (Figure 3). The Salado Formation, in which the detonation took place, is an approximately 1500 ft thick bed of halite with potassium minerals and minor amounts of sandstone, siltstone, shale, anhydrite, and gypsum that formed at the site during the Permian Period (USGS 1968). Overlying the Leached Member at the top of the Salado Formation are five thinly bedded members of the Rustler Formation (Figure 3). In ascending order, these are the Lower Member (now referred to as the Los Medanos Member), which primarily consists of clay and silt with some gypsum and anhydrite; the Culebra Dolomite Member; the Tamarisk Member, which consists of anhydrite and gypsum; the Magenta Member, which consists of silty dolomite; and the Forty-Niner Member, a mixture of gypsum and anhydrite. The youngest Permian sequences in the site area are the thinly bedded siltstones of the Dewey Lake Redbeds Formation. Overlying the Dewey Lake Redbeds Formation are the Gatuna Formation, which was deposited after the Permian Period, and the alluvial sand deposits, which are Quaternary deposits (USGS 1968).

The Culebra Dolomite Member of the Rustler Formation is a widespread, laterally continuous, fractured carbonate aquifer in which the radionuclide tracer test took place. It is approximately 30 ft thick and is present at depths ranging from approximately 460 to 515 ft at the site (Figure 3). The Culebra is the most prolific aquifer near the site; despite the poor water quality associated with high concentrations of dissolved solids (Mercer 1983), ranchers access it to provide water to their livestock throughout the area. Water-level data collected from wells completed in the Culebra (wells USGS-1, USGS-4, and USGS-8) (Figure 2) before and after the underground test indicate that the Culebra Aquifer is confined (under artesian conditions) at the site. These data (historical and recent) also indicate that the aquifer is sensitive to pressure changes. Water-level responses were seen in the observation wells (USGS-1 and USGS-4) immediately following the underground nuclear test (USGS 1962). More recently, wells USGS-4 and USGS-8 have responded to changes in the pumping of groundwater from well USGS-1 (DOE 2017). Groundwater within the Culebra Aquifer moves through fractures in the dolomite, which is fairly permeable at the site, with hydraulic conductivities measuring approximately 4 meters per day (m/d) (USGS 1971). The hydraulic conductivity decreases to the northeast near the WIPP facility, ranging from 0.27 m/d to 2.7×10^{-3} m/d (DOE 2012b). It is reported that groundwater flow within the Culebra Aquifer near the WIPP facility is generally to the south (DOE 2012a).

The Salado Formation, in which the nuclear detonation took place, is characterized as a regional aquiclude because of the hydraulic properties of the bedded halite within the formation (DOE 2012b). The plastic nature of salt under pressure of its own weight and that of overlying units results in movement over time that closes openings (fractures and void spaces) within the deposit, making any continuous movement of water through the formation highly unlikely. Permeability testing conducted in the Salado Formation near the WIPP facility measured hydraulic conductivities that were less than 6.5×10^{-9} m/d (DOE 2012b). The low permeability, low porosity, and plastic nature of salt are characteristics that supported the determination that the bedded halite of the Salado Formation is an optimal geologic material to host a nuclear waste repository (SNL 1997). These same characteristics also limit the transport potential of any residual contamination associated with the Gnome detonation cavity, and the assumption is that the detonation cavity and drifts will close over time. Fluids associated with the Salado Formation occur mainly as small fluid inclusions in the halite crystals. Fluids also occur between crystal boundaries (interstitial fluid) of the massive crystalline salt formation; there are fluids in clay seams and anhydrite beds. Wastes were mixed with water and injected through well DD-1 into the detonation cavity for disposal during surface cleanup activities (Section 2.2). Fluid levels in the detonation cavity are monitored by the reentry well DD-1 and in the Coach drift by well LRL-7, both of which are completed in the Salado Formation.

2.2 Summary of Reclamation and Remediation Activities

Cleanup of the surface and shallow subsurface contamination resulting from the underground nuclear testing, posttest drilling, and groundwater tracer test was conducted in 1968 and 1969. A second major cleanup was conducted from 1977 to 1979 (REECo 1981). During this phase of the cleanup, liquid waste was pumped into the cavity through existing boreholes, contaminated material was disposed of in the emplacement shaft and the Coach drift through existing drill holes, uncontaminated equipment was moved offsite, and boreholes were plugged except for those retained for use as groundwater monitoring wells (AEC 1969). While conducting a survey and sampling event in 1994, the U.S. Environmental Protection Agency (EPA) identified radiological contamination on the surface and in the shallow subsurface. The DOE National Nuclear Security Administration Nevada Site Office conducted a corrective action investigation to assess the extent of contamination at the site. The field investigations were performed from February to June 2002 and in May 2003. Contamination identified during the field investigation was excavated and disposed of offsite. A postremediation surface radiological survey identified areas having radiological concentrations above background, but none of the concentrations were above the action levels determined to be safe for the public. The corrective action investigation report (DOE and NNSA 2004) summarizes the results of the investigation. After discussions with the State of New Mexico, it was decided that the site would be administered under the Voluntary Remediation Program. DOE prepared a completion report in accordance with the Voluntary Remediation Program (DOE and NNSA 2005) and a Conditional Certificate of Completion, which documents that surface remediation activities have been completed in accordance with the Voluntary Remediation Program (Schoeppner 2014).

Subsurface activities have consisted of annual sampling and monitoring of groundwater as part of the Long-Term Hydrologic Monitoring Program (LTHMP). EPA began the LTHMP in 1972 (EPA 1972) and conducted the sampling until 2008 when LM assumed responsibility for sampling. In 2009, LM evaluated the LTHMP to assess the effectiveness of the monitoring network (Figure 1) and to determine future monitoring at the site. The evaluation considered potential transport pathways for contaminant migration from the detonation zone and tracer test area to surrounding receptors. Samples collected from these locations have generally been analyzed for gamma radiation-emitting radionuclides (using high-resolution gamma radiation spectrometry), ^{90}Sr, and tritium (using conventional and electrolytic enrichment methods). Analytical results from more than 30 years of monitoring indicate that groundwater at sample locations outside the land-withdrawal boundary (Figure 1) was not impacted by contamination related to nuclear tests. For this reason, starting in 2010, groundwater monitoring focused on monitoring wells within the site boundary (Figure 2). Table 1 lists the monitoring wells in the network, the purpose for monitoring, the unit monitored, and the frequency for monitoring (sampling and water levels).

Table 1. Gnome-Coach Site Monitoring Well Network

Well Identification	Purpose for Monitoring	Formation/ Unit Monitored	Monitoring Frequency	
			Sampling	Water Level
USGS-1[a]	Point of access	Culebra Dolomite	Annual	Annual
USGS-4	Tracer test			
USGS-8				
LRL-7	Coach drift	Salado Formation	Every 10 years, or as needed	
DD-1	Detonation cavity			

Note:
[a] This well has been used since the early 1980s as a point of diversion to provide water for livestock belonging to area ranchers under the BLM water right C01901.

Low-flow bladder pumps were installed in wells USGS-4, USGS-8, and LRL-7 in June 2008 to enhance monitoring at the site. The dedicated bladder pumps were installed to replace the previous sampling method that used a depth-specific bailer and to allow the collection of samples using the low-flow sampling method. Pressure transducers were also installed in the onsite monitoring wells in 2008, 2009, and 2010 to monitor water-level changes. Geophysical well logging was conducted in onsite wells USGS-1, USGS-4, and USGS-8 in April 2010. The well logging was conducted to obtain borehole deviation data from wells USGS-1 and USGS-4, natural gamma radiation data from wells USGS-4 and USGS-8, and downhole video logs from wells USGS-4 and USGS-8. The borehole deviation data allow measured depths to be corrected to true vertical depths to support the calculation of groundwater elevations at site wells that deviate from vertical. The gamma ray logs provide geologic information that can be used to correlate with other wells in the area. The video log images suggest that the well casings were generally in good condition. The 2010 groundwater monitoring and inspection report (DOE 2011) summarizes the well-logging results.

A seismic reflection survey was conducted at the site in early 2011. Seven seismic reflection profiles totaling approximately 13.9 miles were acquired to assist in the interpretation of subsurface conditions (geology and hydrogeology) at and near the site. The survey was designed to image the upper few thousand feet of the section, which includes the Culebra Dolomite (at a depth of about 475 ft at wells USGS-4 and USGS-8) and the detonation (at a depth of 1184 ft) within the Salado Formation. A check-shot survey was acquired in well USGS-4 to calibrate the seismic profiles to the subsurface lithology. Significant features identified that would influence groundwater flow were areas of collapse in the evaporites overlying the Salado Formation and possible faults that cross the site. The seismic survey results are summarized in the 2012 groundwater monitoring and inspection report (DOE 2013).

Well boxes were installed at wells USGS-4, USGS-8, LRL-7, and DD-1 in 2012 and 2013 to improve wellhead security at the site. This resulted in modifications to the USGS-4 and USGS-8 wellheads. The USGS-1 wellhead was also modified in 2013 to repair damage received from a water truck (DOE 2013). The wellhead modifications established new measuring points on the top of the casing for measuring depth to groundwater in these wells. To account for these modifications, the monitoring wells were surveyed by a registered land surveyor in 2014 to provide northings and eastings with new top-of-casing elevations. The wellhead survey data are summarized in the 2014 groundwater monitoring and inspection report (DOE 2015a).

Repairs were made to the wellhead of reentry well DD-1, and a totalizing flowmeter was installed at well USGS-1 in January 2015. Repairs to well DD-1 were necessary because of vandalism in July 2014 (DOE 2016a). The flowmeter was installed in the flow system of water-supply well USGS-1 to monitor total gallons removed from the well. Signs were also installed at the site in April 2015 to inform the public that ground-disturbing activities are not allowed at the site without permission from LM (DOE 2016a). These signs were installed near the emplacement shaft, near well USGS-1, and around the site perimeter. The signs fulfill a requirement of the Conditional Certificate of Completion issued by the New Mexico Environment Department in 2014. LM’s plan for monitoring and inspecting the site and maintaining the site ICs is outlined in the LTS&M Plan for the site (DOE 2016b). The 2015 groundwater monitoring and inspection report documents repairs made to well DD-1 (DOE 2016a).

The totalizing flowmeter installed at well USGS-1 was removed before the February 2022 sampling event by an unknown third party who installed a new flowmeter at a new location at well USGS-1. The flowmeters have been difficult to maintain because the relatively high salt content (total dissolved solids) causes buildup on flowmeter parts over time. The new flowmeter had extensive salt buildup and indicated that only 0.34 acre-foot of water had been removed from February 8 through October 6, 2022, which indicates that the flowmeter was not functioning (DOE 2023). There are no plans to maintain a new flowmeter at well USGS-1.

3.0 Groundwater Monitoring and Inspection Results

Groundwater monitoring and inspections are conducted to look for changes at the site and obtain time-series data (radiochemical and water levels) to identify trends and maintain LM's understanding of the groundwater flow system in accordance with the LTS&M Plan (DOE 2016b). These activities include working with local agencies and frequently monitoring public websites to maintain ICs and ensure protectiveness of the site (Section 3.1). The field activities, which were conducted on January 30, 2024, included inspecting the site (Section 3.1), measuring depth to groundwater and downloading data from pressure transducers (Section 3.2), and collecting groundwater samples (Section 3.3). The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2024c) outlines procedures used to guide the quality assurance/quality control of the annual sampling and monitoring program. These procedures incorporate standards and guidance from EPA, DOE, and ASTM International. The site inspection and monitoring results are summarized in the following sections.

3.1 Site Inspection and Results

Gnome-Coach site lands are under federal jurisdiction and are administered by BLM. The site was withdrawn on October 26, 1961, from all forms of appropriation associated with mining laws and leasing through Public Land Order 2526 (Volume 26 *Federal Register* page 10279 [26 FR 10279]), which prohibits future oil and gas leasing or mineral claims at the site. The ICs and associated restrictions are documented in the LTS&M Plan for the site (DOE 2016b). To maintain protectiveness of the site, the restrictions specific to ground-disturbing activities were provided to BLM (as shape files) for inclusion in BLM's database to increase the visibility of restrictions and prevent inadvertent intrusion. These restrictions allow BLM to make surface improvements with provisions for avoiding surface features (emplacement shaft, buried debris, salt muck, and monitoring wells) that remain at the site. LM monitors these surface features and drilling activities in the sections surrounding the site to ensure that those activities do not impact the site (Figure 4). LM's duties include inspecting the site for evidence of land use changes or significant land disturbances. LM also evaluates site roads and inspects the well network, warning signs (that ground-disturbing activity is prohibited), the concrete cap that covers the emplacement shaft, and the monument for signs of damage, natural deterioration from weather, or vandalism. Figure 4 shows the site (Section 34) and surrounding sections that are monitored for drilling activity.

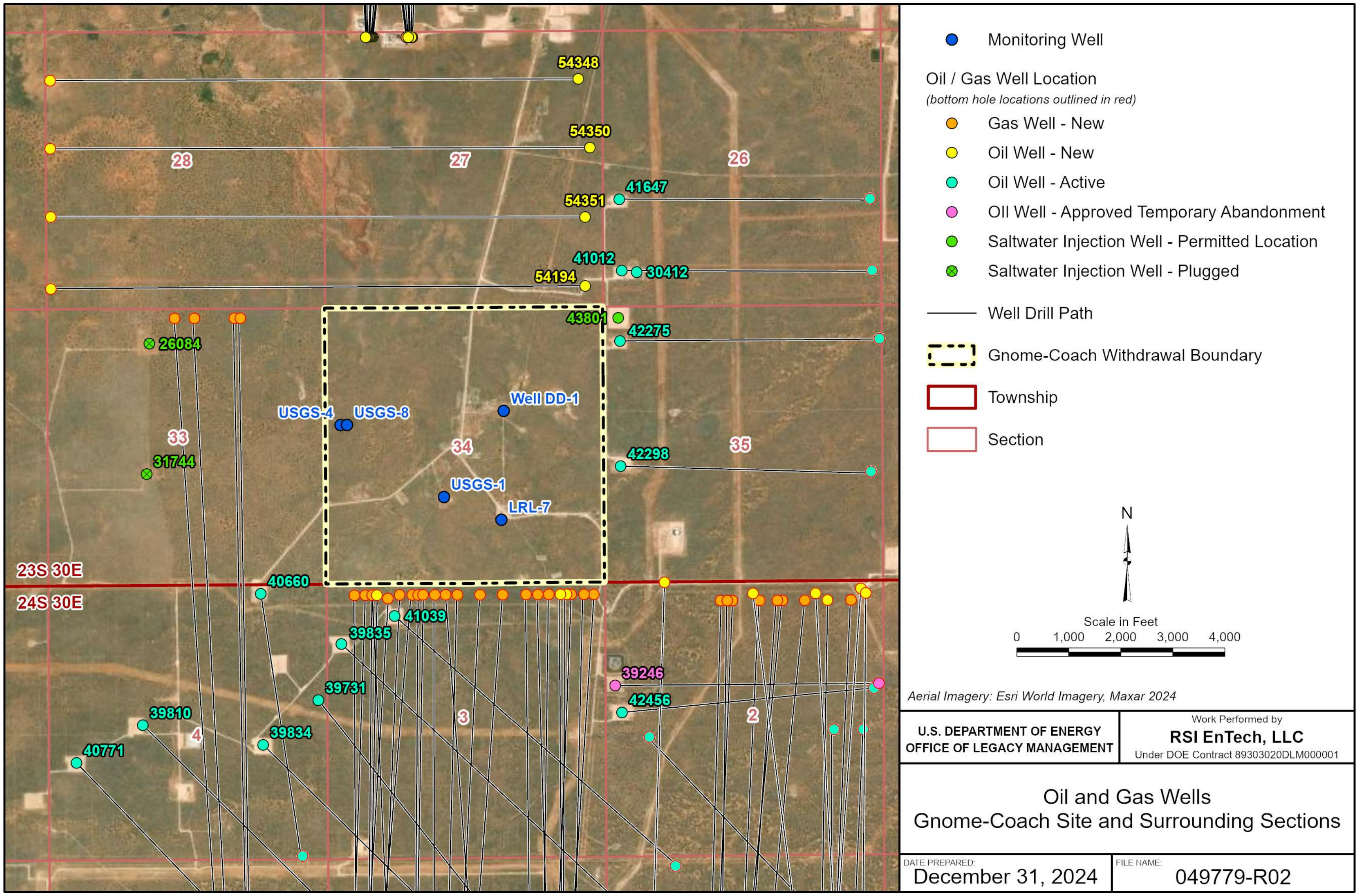

Figure 4. Sections Surrounding the Gnome-Coach, New Mexico, Site

The site inspection for this reporting period was performed on January 30, 2024. At the time of the inspection, the site wells, roads, concrete cap, and monument at surface ground zero were in good condition, and no land use changes or significant land disturbances were observed. One sign was replaced at the west end of the emplacement shaft, and the remaining signs onsite and around the perimeter of the site were observed as being in good condition. Appendix A provides photographs of some of the surface features at the site.

On April 3, 2023, the Legacy Management Support (LMS) contractor was informed that the submersible electric pump in well USGS-1 had been dropped in the well while the rancher that maintains the pump was conducting routine pump maintenance activities. The pump was attached to approximately 200 ft of discharge pipe when it was dropped in the well. LMS staff notified contractors with the Sandia National Laboratories, and they were able to remove the pressure transducer from well USGS-1 on April 4, 2023. On April 28, the LMS contractor was informed that the rancher had installed a new pump and discharge piping in well USGS-1, but during the installation, approximately 400 ft of 2-inch PVC water access pipe that was used to contain the pressure transducer had been dropped in the well. The rancher that maintains the pump is planning to remove the PVC water access pipe, pump, and pump discharge pipe that remain in the well. LM is working with the rancher to complete these activities and allow for the reinstallation of a new PVC water access tube.

Additional inspection activities and the results are as follows:

- The New Mexico Office of the State Engineer website was accessed to determine whether any new groundwater extraction wells had been permitted in the nine sections in and surrounding the site (Figure 4). There were no new groundwater extraction well permits in the referenced sections during this reporting period (OSE 2024).
- The New Mexico Oil Conservation Division website was accessed to determine whether any new oil and natural gas well applications had been permitted for wells having a planned surface-hole location (SHL) or bottom-hole location (BHL) within nine sections surrounding the site (Figure 4). Oil and gas wells in this area are initially drilled vertically until they near the target depth, where they build angle until the wellbore is horizontal. The wells are targeting the Brushy Canyon and Bone Spring Formations for oil and the Wolfcamp Formation for natural gas. Typically, the horizontal or lateral part of the well in the targeted formation is hydraulically fractured to increase formation permeability and stimulate production. The target depths range from 7600 to 10,500 ft for oil production and from 11,000 to 12,500 ft for natural gas production. The shallowest targeted interval is more than 6000 ft deeper than the depth of the nuclear test (1184 ft). A total of 16 applications were approved to drill natural gas (13) and oil (3) wells, and a total of 38 applications (27 from the 2023 reporting period and 11 from previous years) were removed or cancelled in the sections surrounding the site during this reporting period (OCD 2024). All 13 of the permitted natural gas wells have planned SHLs within Sections 14 and 23 of Township 24 South, Range 30 East, which are approximately 3 to 4 miles southeast of the site. The laterals of these wells will extend to planned BHLs within Section 2, Township 24 South, Range 30 East, southeast of the site. The three oil wells permitted during this reporting period have planned SHLs in Section 27, Township 23 South, Range 30 East and laterals that will extend to planned BHLs in Section 28. The one saltwater injection well in Section 35 (American Petroleum Institute [API] number 30-015-43801) that was issued a permit during the 2016 reporting period (DOE 2017) has not been drilled. The well pad has been constructed, and it was planned for saltwater disposal at a depth of 16,500 ft when

installed (Figure 4). The planned SHLs and BHLs for the 16 new applications to drill do not impact Section 34, so the ICs continue to be protective of the site.

- The New Mexico Institute of Mining and Technology (NMIMT) website was accessed to obtain data on seismic events that occurred during this reporting period. In the past, these data were obtained from the USGS Earthquake Hazards Program, but NMIMT maintains a more detailed database for seismic events that occur in southeast New Mexico and west Texas, utilizing an array of nine seismic stations near the WIPP site. According to this database, there were 178 seismic events having magnitudes of 2.0 or greater recorded during a period between November 8, 2023, and August 31, 2024. Of the 178 seismic events, 2 had magnitudes greater than 4.0 (4.49 and 4.06), and 13 had magnitudes greater than 3.0 and less than 3.9. The remaining 163 events ranged in magnitudes between 2.0 and 2.9. Of these 163 seismic events, a total of 13 were identified within 25 miles of the site (NMIMT 2024). These seismic events all had magnitudes between 2.0 and 2.9, with the largest magnitude (2.73) being approximately 18 miles south-southeast from the site on January 4, 2024 (Figure 5). Seismic events having magnitudes between 3.0 and 3.9 may be felt at the surface but do not result in any damage to surface structures. Seismic events having magnitudes between 2.0 and 2.9 are not felt at the surface (USGS 2023).
- The LM public website has been updated to show that the site is now managed by LM under the Plowshare/Vela Uniform/Weapons-Related Program (formally the Nevada Offsites Program). This does not change how the site is managed but provides better alignment with the program in which the test was conducted (Plowshare) at the site. The site documents page was updated to include the 2023 groundwater monitoring and inspection report (DOE 2024a).

The LM public website is routinely updated to allow the public and stakeholders to access the most current site information. LM also monitors the above-mentioned public websites (for water well drilling and extraction, oil and natural gas well drilling, saltwater or wastewater injection, and seismic activity) to assess any potential impacts these activities may have at the site. The hydraulic fracturing process used to stimulate oil and gas production uses millions of gallons of water for each well, much of which flows back during production as produced water. The produced water (a combination of fracturing water and formation water) is brine and is typically disposed of as saltwater or wastewater in injection wells. The two injection wells in Section 33 (API numbers 30-015-26084 and 30-015-31744) that were abandoned in February 2018 were used to dispose of saltwater and wastewater from 2001 through 2013. These wells injected wastewater at depths ranging from 8000 to 14,500 ft (OCD 2024). It has been documented in Oklahoma that injection wells in the state caused earthquakes as great as magnitude 4.5 (damaging some surface structures) before regulations were enacted to limit injection rates and pressures. In recent years, the number of seismic events in southeast New Mexico and west Texas has increased. This increase, which started in 2019, has been attributed to increased oil and gas drilling and disposal of wastewater through injection wells within the Delaware Basin (NMBGMR 2021). LM will continue to monitor these activities for any potential impacts to the site.

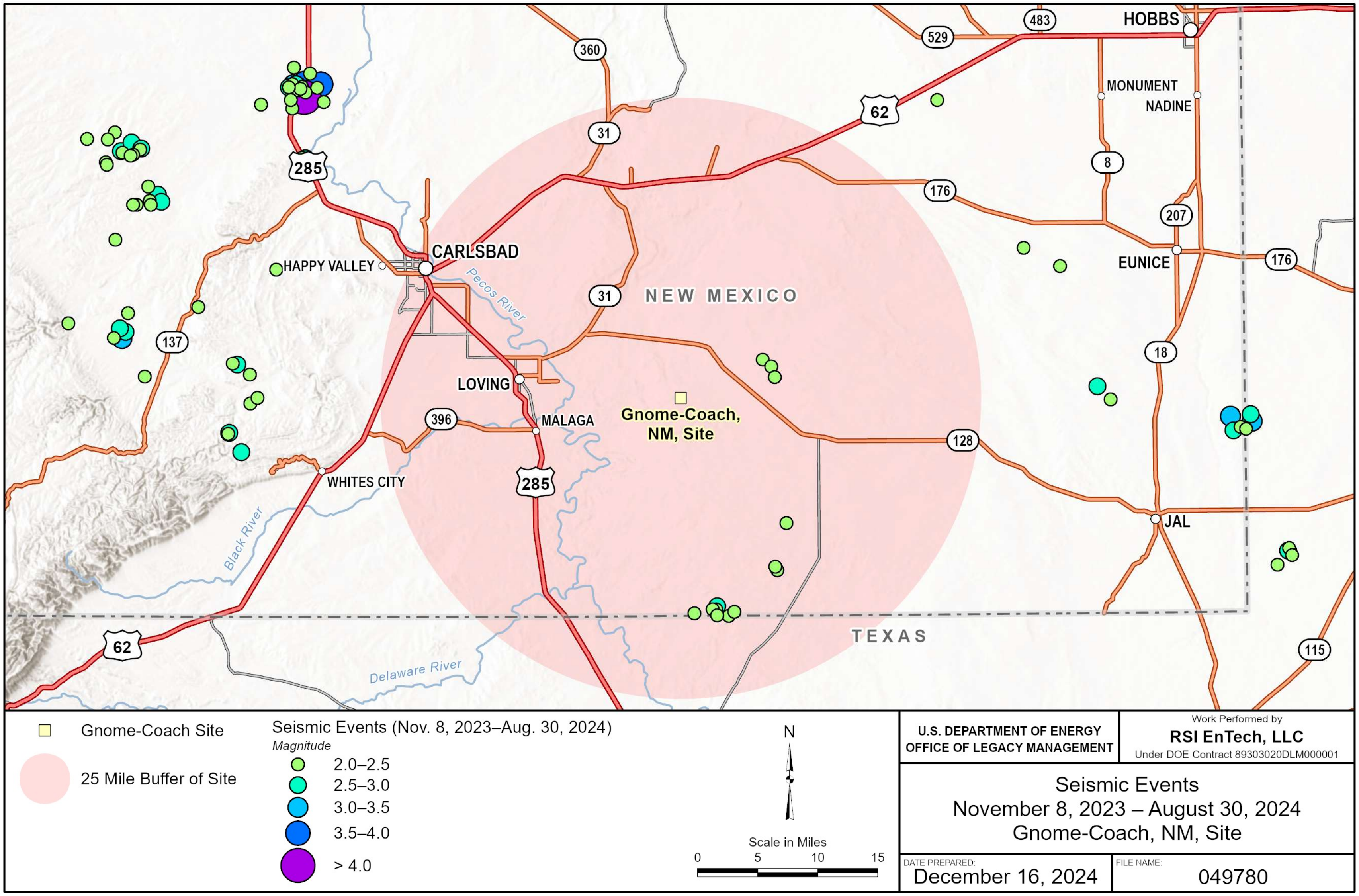

Figure 5. Seismic Activity Surrounding the Gnome-Coach, New Mexico, Site

3.2 Water-Level Monitoring and Results

The monitoring well network consists of three wells completed in the Culebra Dolomite (wells USGS-1, USGS-4, and USGS-8) and two wells completed in the Salado Formation (wells DD-1 and LRL-7). LM began monitoring water levels in these wells in 2008 shortly after assuming responsibility for the site. This includes manually measuring the depth to water in all monitoring wells using a water-level indicator during site visits. Water levels in the Culebra wells are recorded more frequently using pressure transducers to evaluate short-term and long-term water-level changes in the aquifer. Water levels in the Salado wells are no longer recorded using pressure transducers because high-salinity water limits transducer life, and no short-term variations in water levels were observed by previous transducer data. Table 2 presents the depth-to-water data that were measured during the site inspection, along with the top-of-casing elevations, top and bottom screen-zone elevations, groundwater elevations, and the formations monitored for the wells. The top-of-casing elevations are documented in the U.S. State Plane, Zone New Mexico East coordinate system with the vertical data based on the North American Vertical Datum of 1988 and the horizontal data based on the North American Datum of 1983. This coordinate system was implemented in the 2020 groundwater monitoring report (DOE 2021).

Table 2. Gnome-Coach Site Monitoring Well Network Water Levels

Well	Date	DTW (ft)[a]	TOC Elevation (ft amsl)	TSZ Elevation (ft amsl)	BSZ Elevation (ft amsl)	Formation/ Unit Monitored	Groundwater Elevation (ft amsl)
USGS-1	1/30/2024	NM[b]	3428.72	2909[c]	2877[c]	Culebra Dolomite	NM[b,c]
USGS-4	1/30/2024	432.62	3415.84	2942[c]	2909[c]		2989.65[c]
USGS-8	1/30/2024	425.41	3413.37	2949[c]	2917[c]		2987.96[c]
LRL-7	1/30/2024	465.63	3444.64	2655[d]	2129[d]	Salado Formation	2979.01[d]
DD-1	1/30/2024	874.72	3399.53[e]	2261[d]	U/NM		2524.81[d]

Notes:
The TOC elevations are provided in the U.S. State Plane, Zone New Mexico East coordinate system with vertical data based on NAVD 88 and horizontal data based on NAD 83 (DOE 2015a).
[a] DTW has not been corrected for true vertical depth.
[b] Well USGS-1 has a dedicated submersible pump that was not operating at the time of the water level measurement.
[c] Elevation has been corrected for true vertical depth. (At the current water-level depths, the deviation correction for USGS-1 is 0.09 ft; the deviation correction for USGS-4 is 4.96 ft; and no correction is required for USGS-8 because it did not deviate from vertical.)
[d] Elevations for LRL-7 and DD-1 have not been corrected for true vertical depth because borehole deviation data are not available for these wells.
[e] TOC elevation is estimated because of repairs to the wellhead after the well was vandalized in 2014 (DOE 2016a).

Abbreviations:
BSZ = bottom of screen zone, uncased/open interval, or perforated interval in ft amsl
DTW = depth to water (all measurements obtained from north top-of-casing)
ft amsl = feet above mean sea level
NAD 83 = North American Datum of 1983
NAVD 88 = North American Vertical Datum of 1988
NM = not measured
TOC = top-of-casing elevation in ft amsl (NAVD 88)
TSZ = top of screen zone, uncased/open interval, or perforated interval in ft amsl
U/NM = unknown or not measured (the construction and open intervals of reentry well DD-1 are unknown)

The transducers in wells USGS-4 and USGS-8 were downloaded and water levels measured manually in all site wells except well USGS-1 on January 30, 2024 (Table 2). A transducer is not installed in well USGS-1, and the water level could not be measured in this well because the PVC water access tube was dropped in the well during pump maintenance activities in April 2023 (DOE 2024a). The pump in well USGS-1 cycles on and off to provide water to the nearby tank that supplies water to livestock. The volume of water in the tank is maintained by a float switch, which activates the pump in well USGS-1 to supply water to the tank at a rate of approximately 15 gallons per minute. When the pump cycles on, water levels in well USGS-1 drop by approximately 5 ft. The transducers in wells USGS-4 and USGS-8 were downloaded again in August 2024.

Manual water levels measured in January 2024 (Table 2) were used along with the top-of-casing elevations to convert the transducer data to groundwater elevations; these are presented as hydrographs to show data from the time monitoring began in 2008. The hydrographs are grouped according to each well's open interval and formation monitored (Figure 6 and Figure 8). A shorter time interval of the Culebra well hydrographs are shown to highlight specific groundwater responses in Figure 7. Groundwater elevations from manual water-level measurements are shown as individual data point symbols, and transducer data appear as lines. These data were corrected for the specific gravity of water for each screened unit. The specific gravity of water from Culebra-screened wells is approximately 1.0035, and the specific gravity of water from Salado-screened wells is approximately 1.15. Borehole deviation data are available for wells USGS-1, USGS-4, and USGS-8, so groundwater elevation data from these wells include a correction for true vertical depth (Figure 6 and Figure 7). Borehole deviation data are not available for wells DD-1 and LRL-7, so groundwater elevations from these wells are approximate (Figure 8).

Groundwater elevation data were evaluated with the historical data to assess changes in the groundwater flow system. The hydrographs for wells USGS-1, USGS-4, and USGS-8 (completed in the Culebra Dolomite) are shown in Figure 6. Groundwater elevation data from the Culebra wells continue to support a regional groundwater flow direction that is generally toward the south but is locally influenced by pumping from well USGS-1. These data also continue to show that pumping from well USGS-1 produces an almost immediate water-level drawdown response in wells USGS-4 and USGS-8, which are approximately 2350 ft northwest of well USGS-1 (Figure 6). Groundwater elevations have generally been decreasing in the Culebra wells since monitoring began in 2008 (Figure 6) but stabilized in 2020 and have generally remained stable through this reporting period that ended in August 2024. The exception is a brief decline between 2022 and 2023 that may be attributed to an increase in oil and gas activity and pumping of water from the Culebra Dolomite to support the increased drilling. The Culebra Dolomite is a highly fractured and transmissive unit, and a slight increase or decrease in groundwater elevation could be attributed to changes in pumping demands on this water bearing zone. Figure 7 is the hydrograph showing groundwater elevations for the Culebra wells during this reporting period.

Fluid levels in the detonation cavity are monitored by well DD-1 and in the Coach drift by well LRL-7; both wells are in the Salado Formation. The hydrograph for wells DD-1 and LRL-7 is shown in Figure 8. The water elevations in these wells are likely not indicative of the Salado Formation because of their connection to the large unnatural openings and their use for disposal of liquid waste during site cleanup activities in the late 1960s and 1970s. Water elevations in well LRL-7 (primary vertical axis) have stabilized, are no longer rising, and have recovered from the last sampling event in January 2011. Water elevations in well DD-1 (secondary vertical axis) continue to rise at a rate of approximately 11 ft per year. Factors that influence water levels in wells LRL-7 and DD-1 include the slow refilling of the detonation cavity by the limited groundwater flow within the Salado Formation, remnant pressure effects associated with the detonation, the plastic nature of the Salado Formation, and injections of liquefied waste material associated with past disposal activities. Water elevations from wells DD-1 and LRL-7 are approximate because borehole deviation data are not available for these wells (Figure 8).

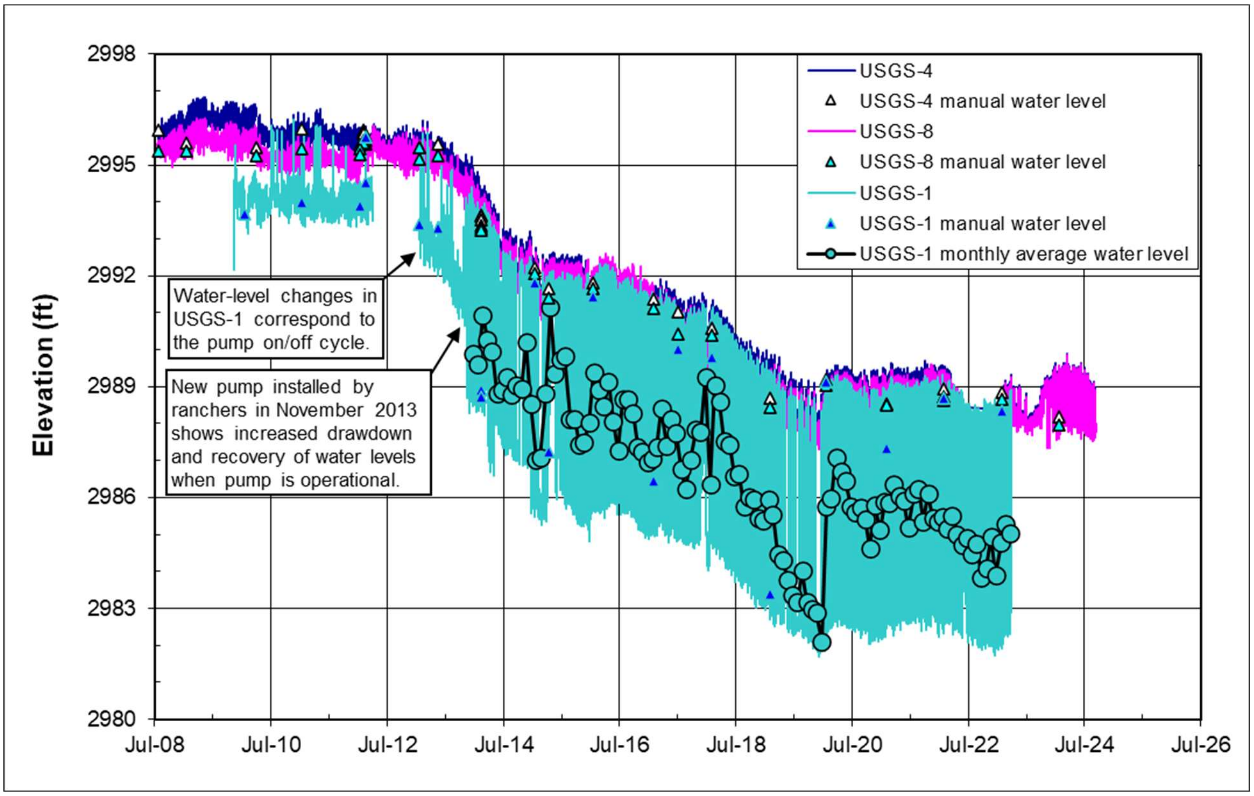

Figure 6. Groundwater Elevations in Culebra Wells, 2008 Through 2024

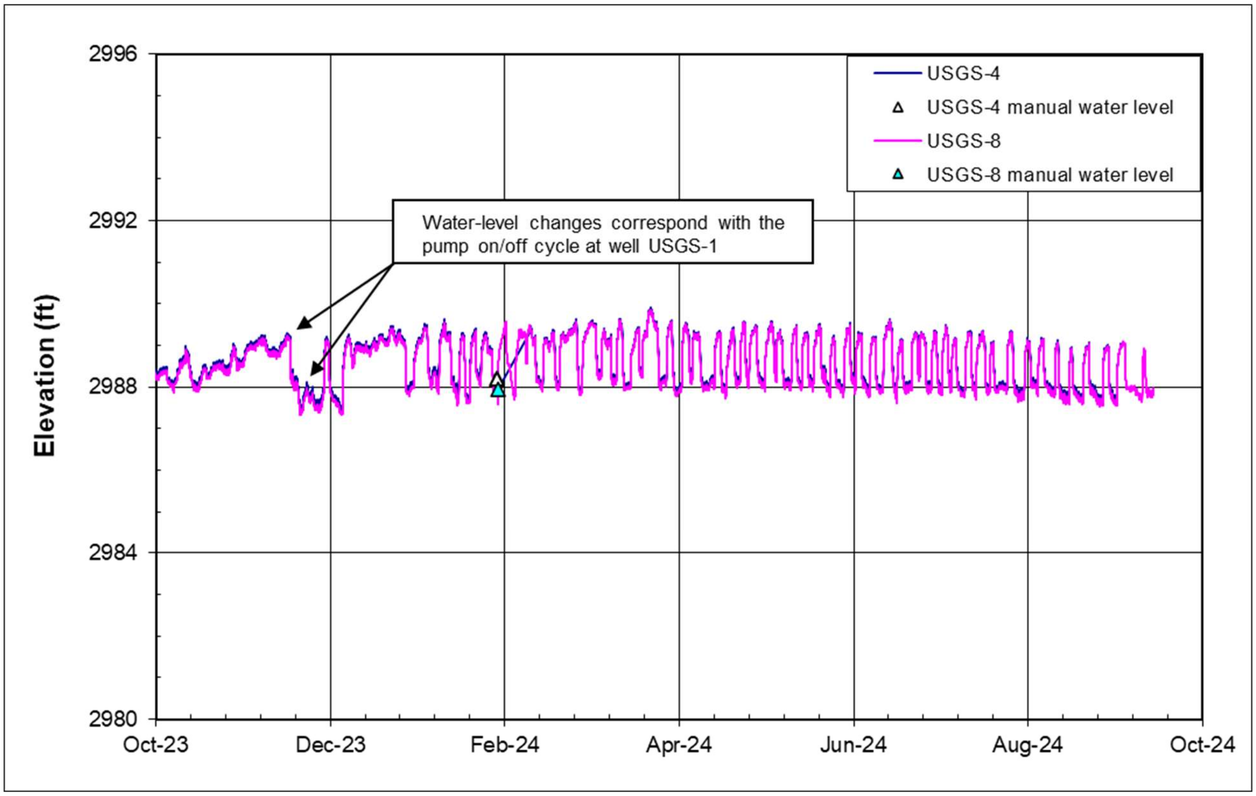

Figure 7. Groundwater Elevations in Culebra Wells, 2024 Reporting Period

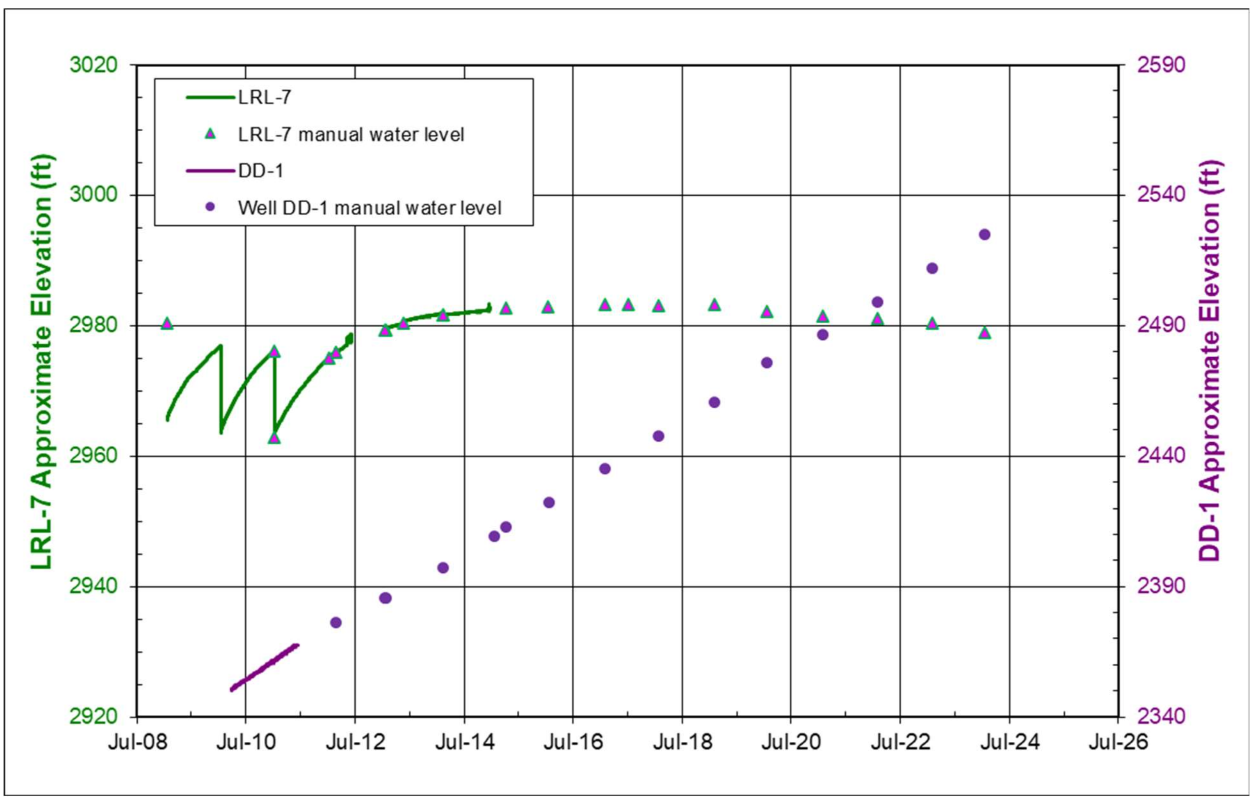

Figure 8. Groundwater Elevations in Reentry Wells DD-1 and LRL-7, 2008 Through 2024

3.3 Groundwater Sampling and Results

The well network is designed to monitor the sources of radionuclide contamination (underground nuclear test and tracer test) and the point of access (well USGS-1), and samples are collected to identify trends in the data. The monitoring of these wells was initiated in 1972. The monitoring wells completed in the Culebra Dolomite (wells USGS-1, USGS-4, and USGS-8) are sampled annually for the radionuclides of interest (tritium, ^{137}Cs, and ^{90}Sr) used during the tracer test in 1963. Iodine-131 was also used during the tracer test, but it is no longer present at the site because of its short half-life (8 days). Wells completed in the Salado Formation (wells LRL-7 and DD-1) are sampled less frequently because of the low permeability of the Salado Formation and limited potential for transport.

Monitoring wells USGS-1, USGS-4, and USGS-8 were sampled on January 30, 2024. Wells DD-1 and LRL-7 were not sampled during the 2024 reporting period but are planned for sampling in 2027. The samples from well USGS-1 were collected as grab samples using the dedicated pump that fills the nearby water tank. The samples from wells USGS-4 and USGS-8 were sampled using dedicated high pressure bladder pumps. Samples were analyzed for gamma radiation-emitting radionuclides (using high-resolution gamma radiation spectrometry), ^{90}Sr, and tritium (using conventional methods). The laboratory analytical results were validated in accordance with the *Environmental Data Validation Procedure* (DOE 2024b). Samples were analyzed using accepted procedures based on specified methods. The laboratory radiochemical minimum detectable concentrations reported with these data are an estimate of the predicted detection capability of a given analytical procedure not an absolute concentration that can or cannot be detected. A copy of the data validation memo is available on request.

Laboratory radiochemical results from the 2024 monitoring event continue to trend lower, consistent with previous results (Table 3). Sample results with a less-than symbol (<) indicate concentrations that are below the laboratory minimum detectable concentration. Table 3 presents a summary of laboratory radiochemical results from 2016 through 2024 for comparison.

Table 3. Radiochemical Analytical Results 2016–2024

Sample Location	Collection Date	Tritium (pCi/L)	Tritium Enriched Method (pCi/L)	^{137}Cs (pCi/L)	^{90}Sr (pCi/L)	Formation/ Unit Monitored
USGS-1	1/27/2016	<364	<2.91	<6.08	<0.974	Culebra Dolomite
	2/7/2017	<357	<3.1	<4.92	1.78[a]	<0.85	
	7/12/2017	<365	NA	NA	<0.69	
	2/6/2018	<344	<2.8	<2.67	<0.852	
	2/12/2019	<130	NA	<6.0	<0.57	
	1/28/2020	<110	NA	<4.1	<0.65	
	2/9/2021	<160	NA	<3.6	<0.50	
	2/9/2021[b]	<160	NA	<5.2	<0.50	
	2/9/2021	<160	NA	<3.6	<0.50	
	2/8/2022	<160	NA	<4.6	<0.68	
	2/7/2023	<443	NA	<2.6	1.35[c]	
	1/30/2024	<337	NA	<6.45	<0.962	
USGS-4	1/27/2016	5,240	NA	<6.03	1420	Culebra Dolomite
	2/7/2017	4,470	NA	<3.09	1050	
	2/6/2018	4,102	NA	<2.55	1906	
	2/6/2018[b]	NA	NA	<2.77	1828	
	2/12/2019	4,070	NA	<7.8	2260	
	1/28/2020	3,700	NA	<6.2	2100	
	2/9/2021	2,920	NA	<5.7	1910	
	2/8/2022	NS	NS	NS	NS	
	2/7/2023	3,439	NA	<2.66	1240[c]	
	1/30/2024	1,820	NA	<5.87	1210	
	1/30/2024[b]	1,740	NA	<6.12	1140	
USGS-8	1/27/2016	16,400	NA	142	2410	Culebra Dolomite
	1/27/2016[b]	16,100	NA	166	2270	
	2/7/2017	11,300	NA	149	1640	
	2/7/2017[b]	11,600	NA	141	1670	
	2/12/2019	10,500	NA	142	3260	
	2/12/2019[b]	11,000	NA	127	3310	
	1/28/2020	10,600	NA	145	3280	
	1/28/2020[b]	10,000	NA	136	3250	
	2/9/2021	9,120	NA	110	3010	
	2/8/2022	NS	NS	NS	NS	
	2/7/2023	7,360	NA	96	2138[c]	
	2/7/2023[a]	7,075	NA	117	2301[c]	
	1/30/2024	5,830	NA	143	2210	

Notes:
[a] Indicates the sample was reanalyzed because the result was suspected to be a laboratory error (DOE 2018).
[b] Indicates a field duplicate sample.
[c] Indicates J flag, biased high, result estimated.

Abbreviations and symbols:
NA = not analyzed
NS = not sampled
pCi/L = picocuries per liter
< = below the laboratory minimum detectable concentration

Figures B-1 through B-7 in Appendix B show temporal plots of radionuclide concentrations (1972–2024) in samples collected from wells LRL-7, USGS-4, and USGS-8 to support trend analysis. Sample results from well USGS-1 are not included because concentrations of tritium (using conventional methods), ^{90}Sr, and ^{137}Cs have not been detected above the laboratory minimum detectable concentration in this well since monitoring began in 1972. The detection of ^{90}Sr (1.78 picocuries per liter [pCi/L]) in the February 2017 and February 2023 (1.35 pCi/L) samples collected from well USGS-1 are attributed to laboratory error (DOE 2018) and results that are biased high or estimated by the laboratory (DOE 2024a), respectively. Concentrations are plotted on a semilogarithmic scale, and all sample results are plotted, including results below the laboratory minimum detectable concentration. Several results from sampling events before the late 1980s had no reported detection limit, as shown in the charts. For interpretation purposes, relatively high concentrations (i.e., concentrations significantly higher than detection limits associated with subsequent sampling) should be considered detections. The natural decay rates for tritium (12.3-year half-life), ^{90}Sr (28.8-year half-life), and ^{137}Cs (30.2-year half-life) have been included on the charts for reference. The increases in tritium concentrations in samples collected from well LRL-7 (Figure B-1) and ^{137}Cs concentrations in samples collected from wells USGS-8 and LRL-7 (Figure B-4 and Figure B-6) after the 2007 sampling event are attributed to changes in the sampling method. Before 2008, EPA collected samples using a depth-specific bailer. Starting in 2008, LM collected samples from dedicated bladder pumps using the low-flow sampling method. Tritium concentrations in samples collected from well USGS-4 (Figure B-1) continue to decrease at a rate that is greater than the natural decay rate for tritium.

4.0 Summary and Conclusions

The site inspection and annual sampling were conducted on January 30, 2024. At the time of the inspection, the signs onsite and around the site perimeter were observed to be in good condition, as were the roads, wellheads, concrete cap, and Project Gnome monument. A review of the public websites that monitor drilling activity indicated that no new wells were drilled (oil wells, injection wells, or groundwater extraction wells). The New Mexico Oil Conservation Division approved 16 new applications to drill in surrounding sections of the site, and no permits were received or approved to drill onsite. Therefore, the ICs continue to be protective of the site. A search of seismic events indicated that 13 events having magnitudes between 2.0 and 2.73 occurred within 25 miles of the site. The frequency of these events has increased in southeast New Mexico and west Texas since 2019. This increase has been attributed to increased oil and gas drilling and disposal of wastewater through deep injection wells within the Delaware Basin.

The groundwater elevation data from the Culebra wells continue to support a regional groundwater flow direction that is generally toward the south but is influenced locally by the pumping in well USGS-1. This pumping produces an almost immediate water-level drawdown response in wells USGS-4 and USGS-8. Groundwater elevations have generally been decreasing in the Culebra wells since monitoring began in 2008 but stabilized in 2020 and have generally remained stable through this reporting period that ended in August 2024. The exception is a brief decline between 2022 and 2023 that may be attributed to an increase in oil and gas activity and pumping of water from the Culebra Dolomite to support the increased drilling. The oil and gas well industry uses groundwater from the Culebra Dolomite as part of the drilling and hydrologic fracturing process. Groundwater elevation data from well LRL-7, which monitors the Coach drift, indicate that water levels have recovered and stabilized from the well's last sampling event in January 2011. Water levels in reentry well DD-1, which monitors the detonation cavity, continued to rise at a rate of approximately 11 ft per year. Water levels in wells LRL-7 and DD-1 might not be representative of the Salado Formation and are likely influenced by remnant pressure effects associated with the detonation, the plastic nature of the Salado Formation, and past disposal activities.

Samples were collected from wells USGS-1, USGS-4, and USGS-8 on January 30, 2024. Wells DD-1 and LRL-7 (completed in the Salado Formation) were not sampled during the 2024 reporting period but are planned for sampling in 2027. Laboratory results for the samples collected from wells USGS-1, USGS-4, and USGS-8 were consistent with previous results and continue to trend lower. Copies of this report are sent to the individuals on the distribution list provided as Appendix C, and a copy is available on the LM public website at https://www.energy.gov/lm/gnome-coach-new-mexico-site.

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Appendix A

Photographic Documentation

Photograph A-1. Looking East at the Monument and Well DD-1 at the Gnome-Coach, New Mexico, Site

Photograph A-2. Looking East at the Concrete Cap that Covers the Project Gnome Emplacement Shaft and the Sign that Notifies the Public of No Excavating or Digging Without Permission

Photograph A-3. Looking East at the Concrete Cap that Covers the Project Gnome Emplacement Shaft

Photograph A-4. Well USGS-1 After Sampling on January 30, 2024

Appendix B

Well Concentration Plots

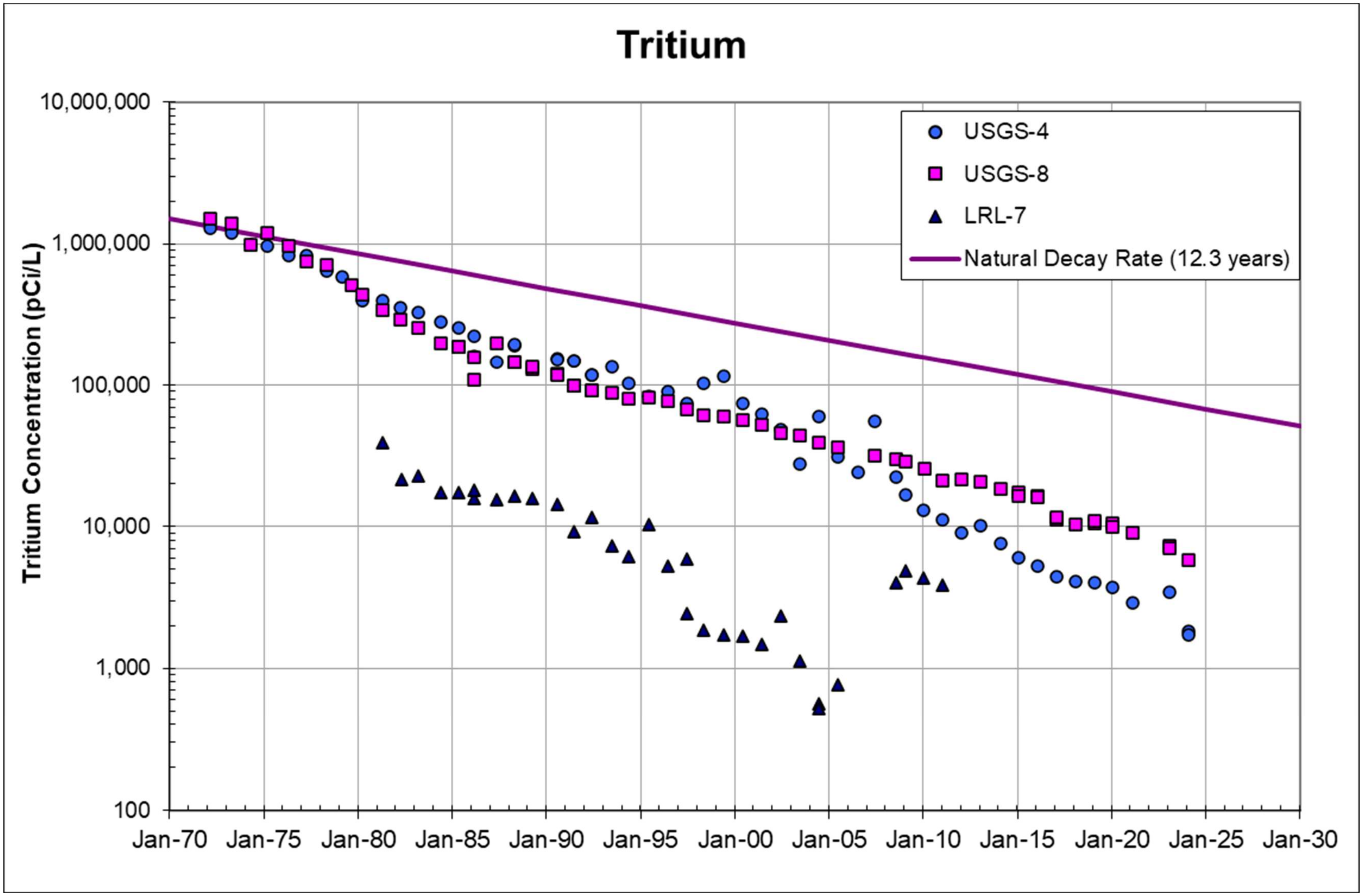

Figure B-1. Tritium Concentrations at Wells USGS-4, USGS-8, and LRL-7

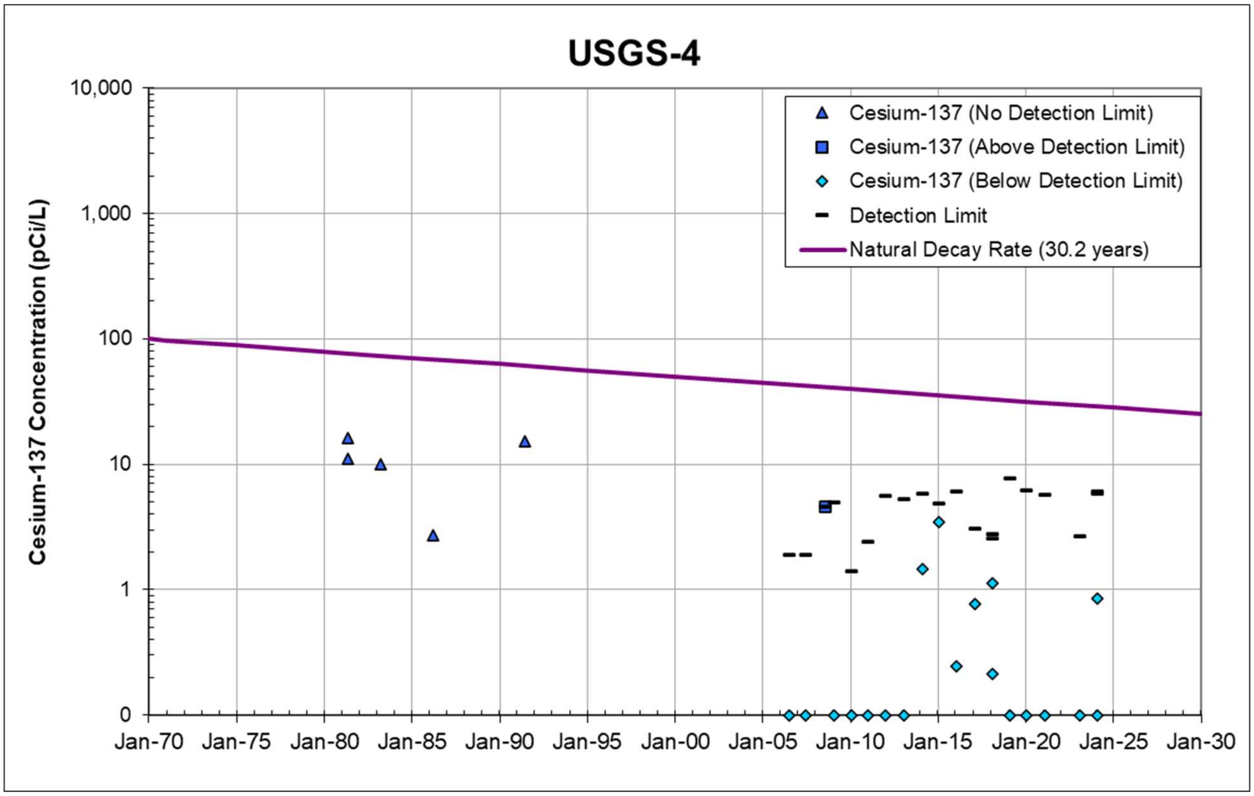

Figure B-2. Cesium-137 Concentrations at Well USGS-4

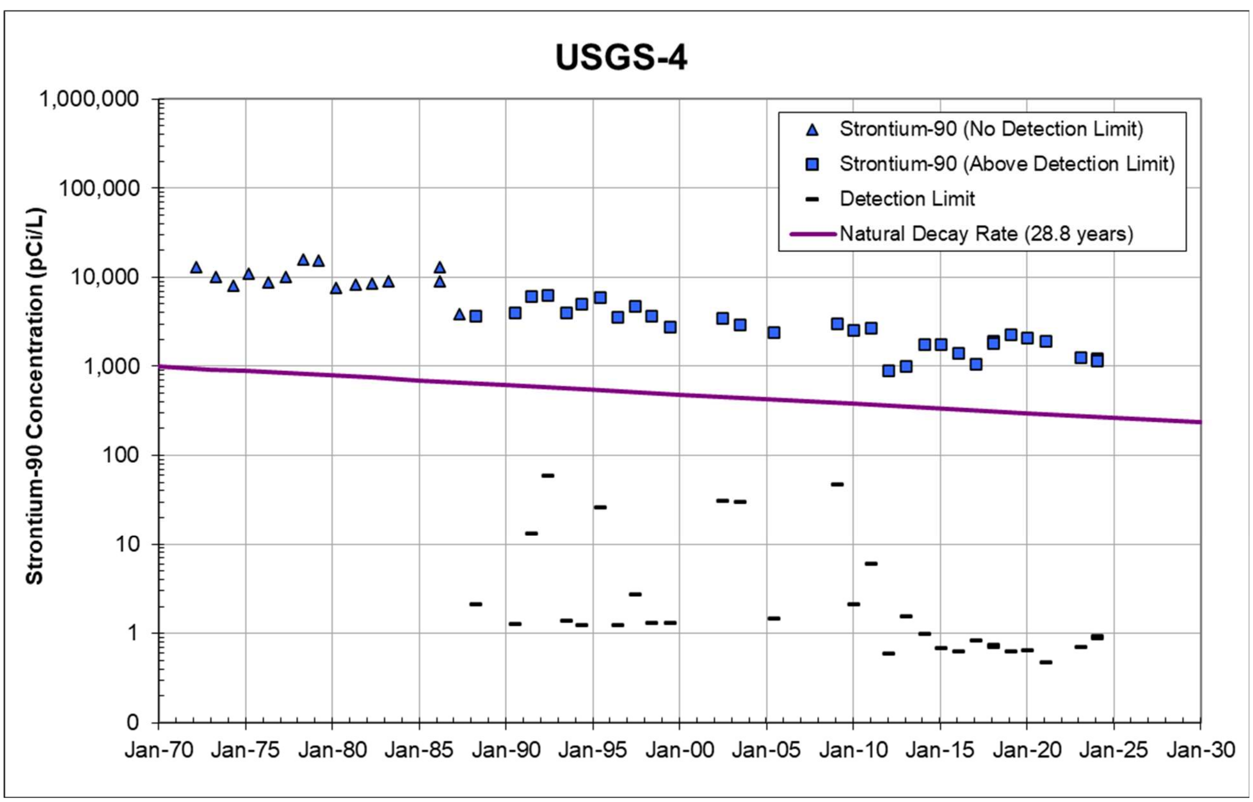

Figure B-3. Strontium-90 Concentrations at Well USGS-4

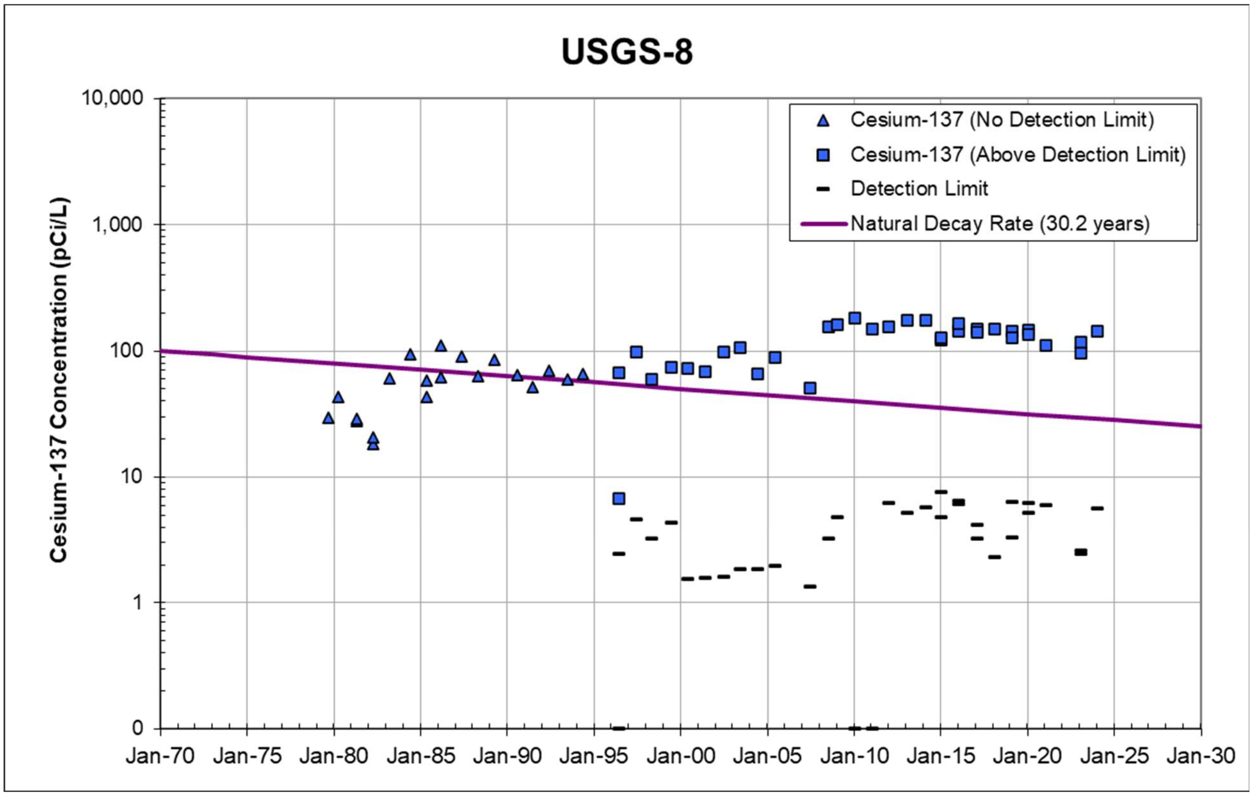

Figure B-4. Cesium-137 Concentrations at Well USGS-8

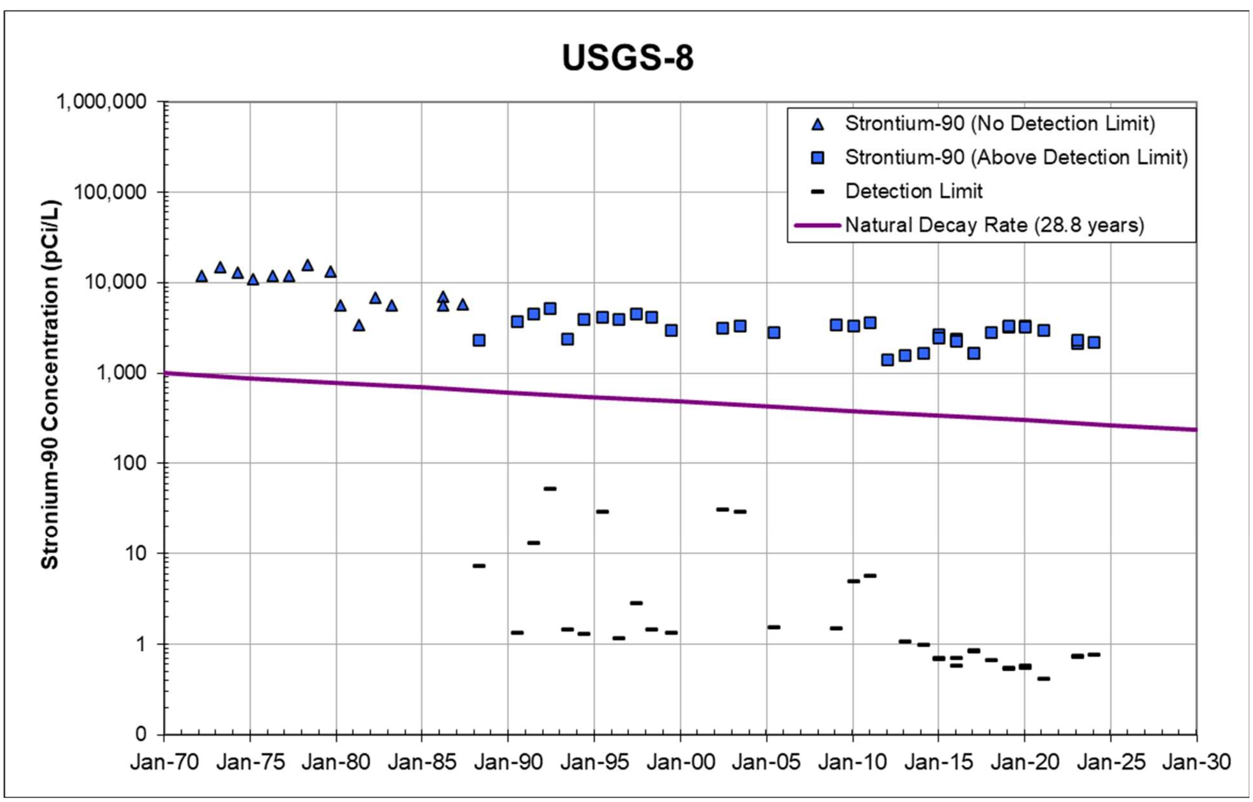

Figure B-5. Strontium-90 Concentrations at Well USGS-8

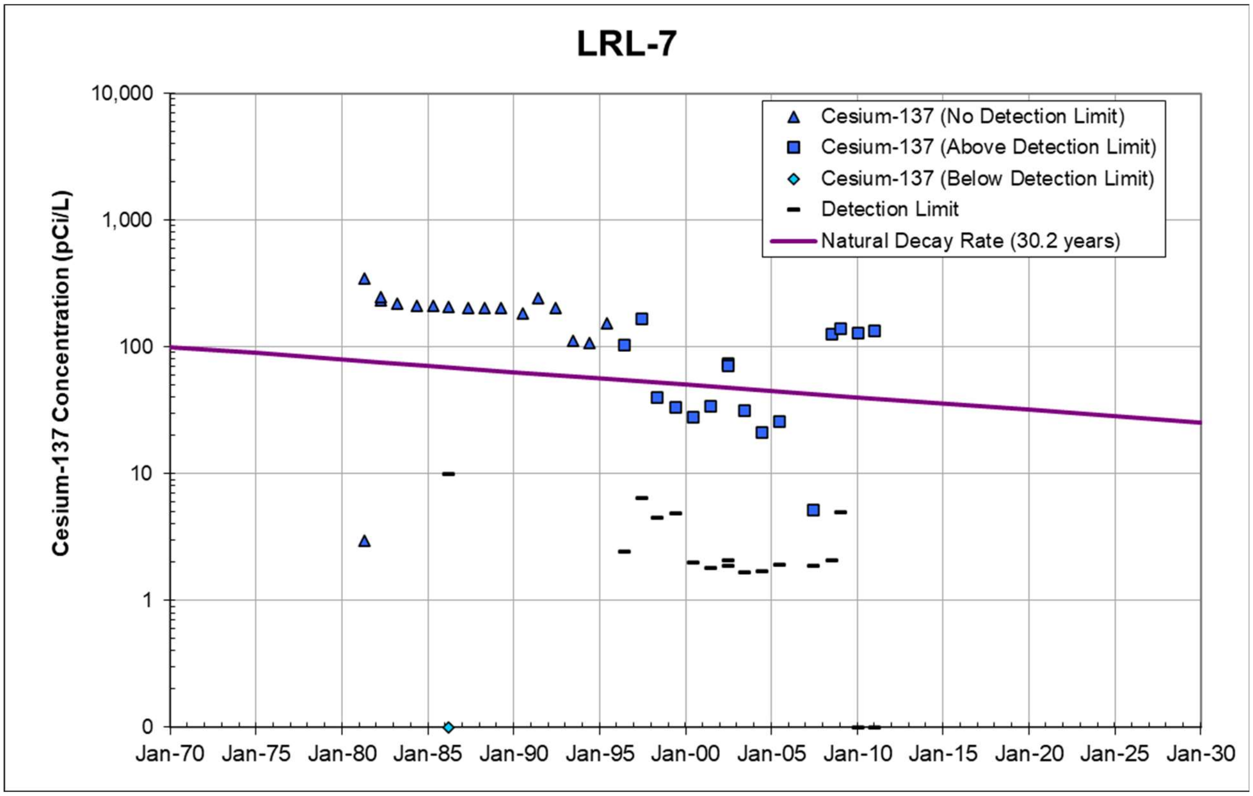

Figure B-6. Cesium-137 Concentrations at Well LRL-7

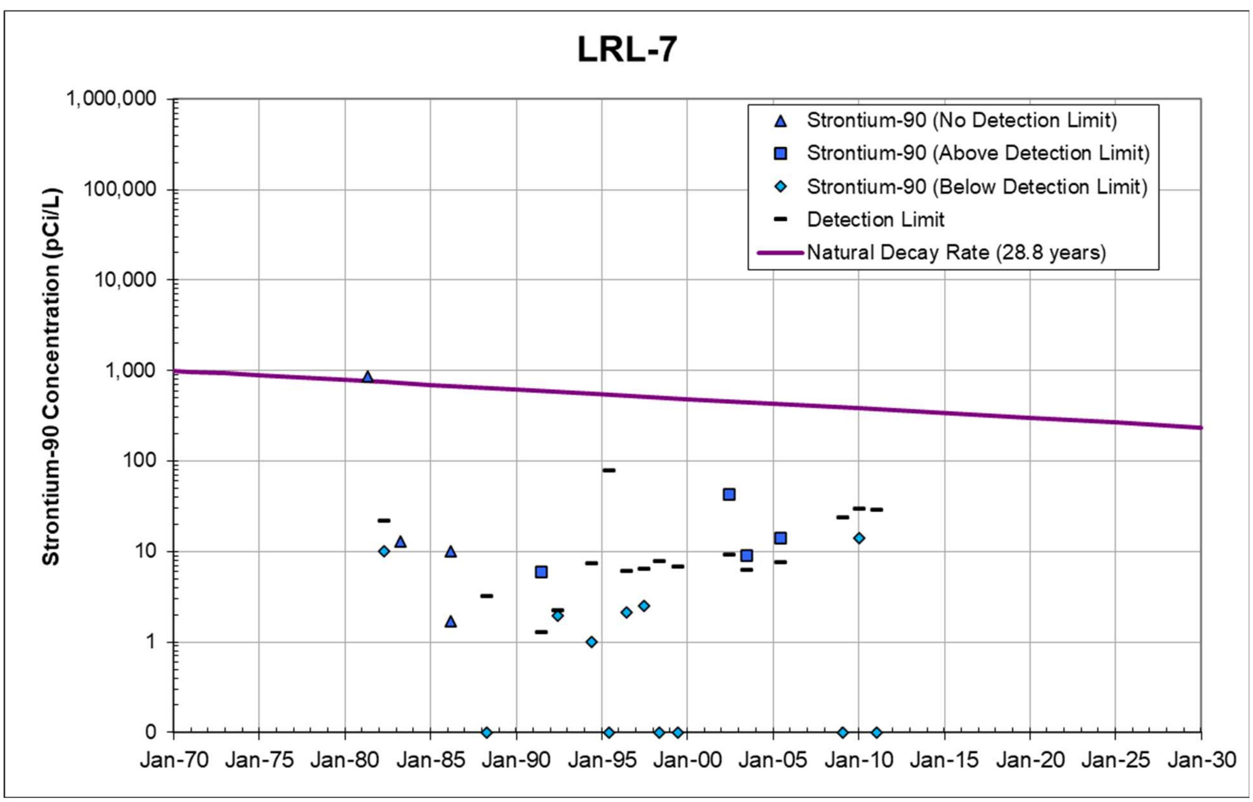

Figure B-7. Strontium-90 Concentrations at Well LRL-7

Appendix C

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