LMS/GNO/S08479

2011 Groundwater Monitoring and Inspection Report Gnome-Coach Site, New Mexico

February 2012

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Abbreviations

bgs	below ground surface
BSZ	bottom of screen zone
DOE	U.S. Department of Energy
DTW	depth to water
EPA	U.S. Environmental Protection Agency
ft	feet
LM	Office of Legacy Management
LTHMP	Long-Term Hydrologic Monitoring Program
pCi/L	picocuries per liter
SGZ	surface ground zero
TOC	top of casing
TSZ	top of screen zone

Executive Summary

Gnome-Coach was the site of a 3-kiloton underground nuclear test in 1961. Surface and subsurface contamination resulted from the underground nuclear testing, post-test drilling, and groundwater tracer test performed at the site. The State of New Mexico is currently proceeding with a conditional certificate of completion for the surface. As for the subsurface, monitoring activities that include hydraulic head monitoring and groundwater sampling of the wells onsite are conducted as part of the annual site inspection. These activities were conducted on January 19, 2011. The site roads, monitoring well heads, and the monument at surface ground zero were observed as being in good condition at the time of the site inspection. An evaluation of the hydraulic head data obtained from the site indicates that water levels in wells USGS-4 and USGS-8 appear to respond to the on/off cycling of the dedicated pump in well USGS-1 and that water levels in wells LRL-7 and DD-1 increased during this annual monitoring period. Analytical results obtained from the sampling indicate that concentrations of tritium, strontium-90, and cesium-137 were consistent with concentrations from historical sampling events.

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1.0 Introduction

This report presents the 2011 groundwater monitoring results collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Gnome-Coach, New Mexico, Site (Figure 1). Groundwater monitoring consisted of collecting hydraulic head data and groundwater samples from the wells onsite. Historically, the U.S. Environmental Protection Agency (EPA) had conducted these annual activities under the Long-Term Hydrologic Monitoring Program (LTHMP). LM took over the sampling and data collection activities in 2008 but continues to use the EPA Radiation and Indoor Environments National Laboratory in Las Vegas, Nevada, to analyze the water samples. This report summarizes groundwater monitoring and site investigation activities that were conducted at the site during calendar year 2011.

2.0 Site Location and Background

The site consists of 640 acres of federally withdrawn lands approximately 25 miles east of Carlsbad in Eddy County, New Mexico (Figure 1). The site was the location of the first underground nuclear test performed under the Plowshare Program by the U.S. Atomic Energy Commission, predecessor to DOE. The Plowshare Program was a research and development initiative started in 1958 to determine the technical and economic feasibility of peaceful applications of nuclear energy. The underground nuclear test conducted at the site was identified as Project Gnome and was performed on December 10, 1961. The test consisted of detonating a nuclear device with an estimated yield of 3 kilotons at a depth of 1,184 feet (ft) below ground surface (bgs) in a bedded salt deposit known as the Salado Formation. Immediately following the detonation, close-in stemming materials failed, and gasses from the cavity vented to the atmosphere through the access shaft and tunnel (Rawson et al. 1964). Post-test drilling operations and preparations for another underground nuclear test, identified as Coach, began shortly after the Project Gnome test. The Coach experiment was initially scheduled for 1963 but was canceled and never executed.

No additional underground nuclear detonations occurred at the site; however, in 1963, the U.S. Geological Survey conducted a groundwater tracer test using four dissolved radionuclides—tritium, iodine-131, strontium-90, and cesium-137—as tracers. The tracer test was conducted between wells USGS-4 and USGS-8 located west of the blast point, the surface projection of which is surface ground zero (SGZ) (Figure 2). Wells USGS-4 and USGS-8 are completed in the Culebra Dolomite Member of the Rustler Formation that lies above the Salado Formation. The Culebra Dolomite is a fractured carbonate aquifer of Permian age and is the most prolific aquifer near the site. For this reason, the Culebra aquifer is considered a critical transport pathway, not only for radionuclides used in the tracer test, but also for any detonation-related radionuclides that might be released to groundwater.

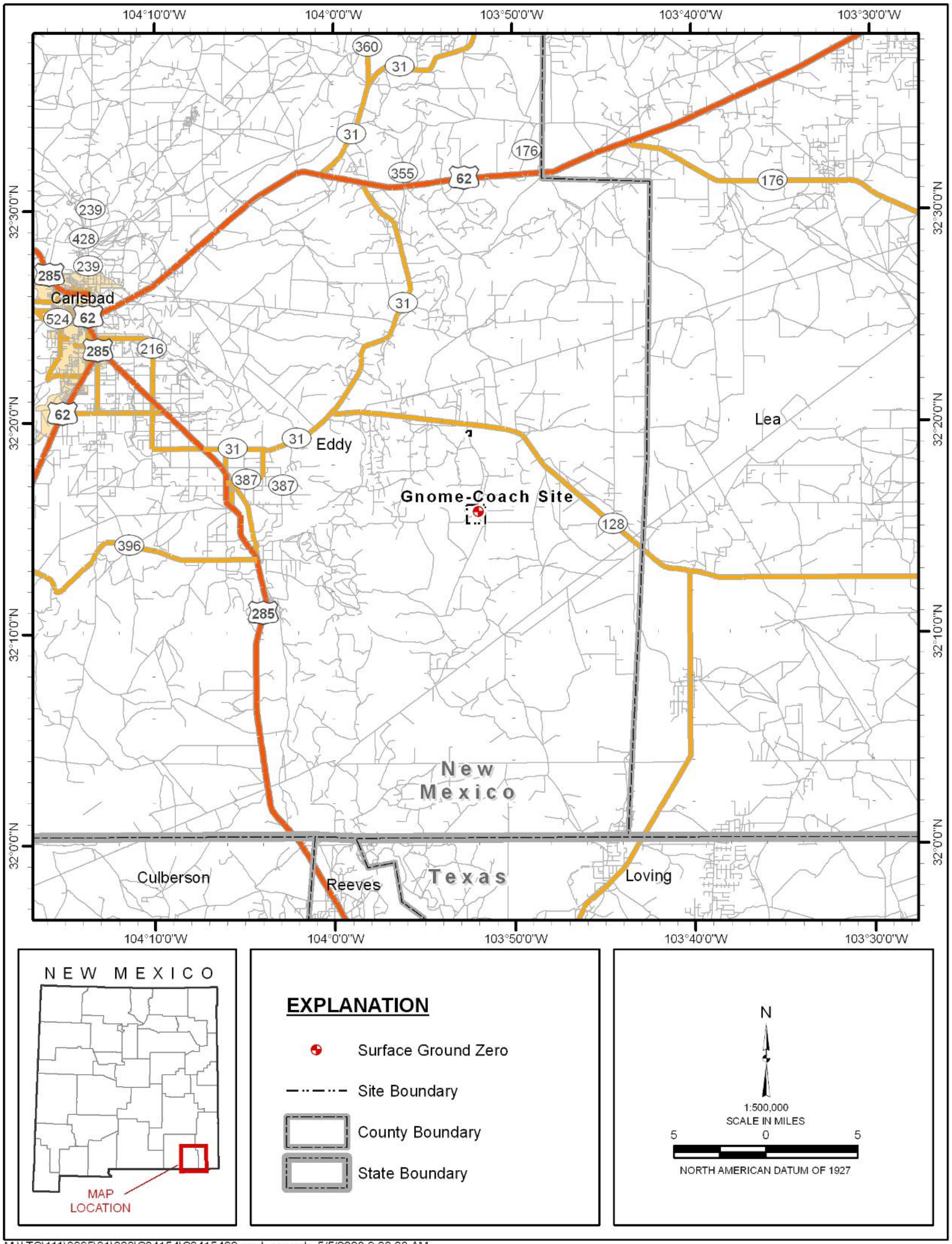

Figure 1. Gnome-Coach Site Location Map

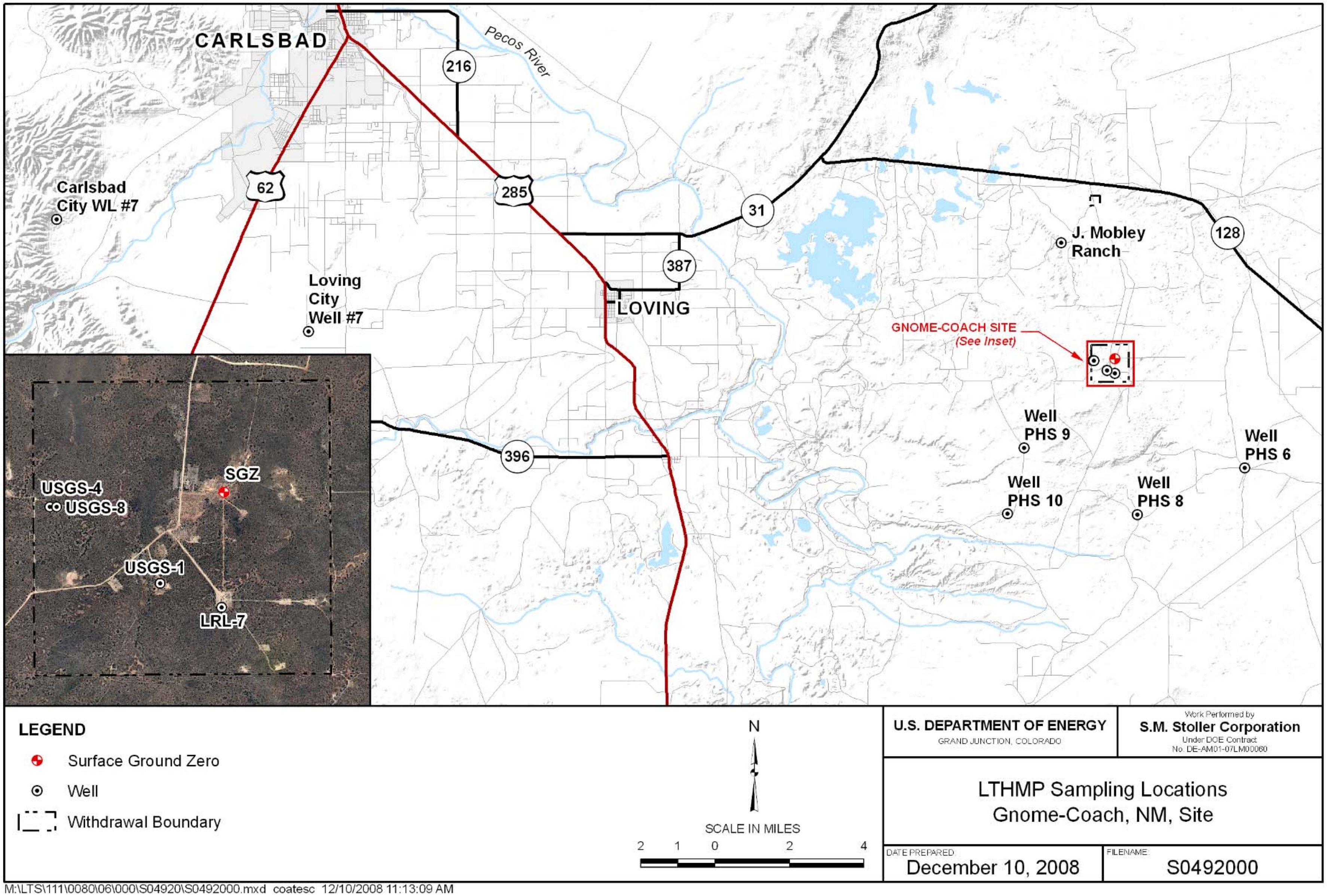

Figure 2. LTHMP Sampling Locations in 2009

2.1 Summary of Reclamation and Remediation Activities

Surface and subsurface contamination resulted from the underground nuclear testing, post-test drilling, and groundwater tracer test performed at the site. The original cleanup associated with the site was conducted between 1968 and 1969. During this phase of the cleanup, radioactive sludge from holding tanks and liquid from evaporation ponds were pumped into the test cavity, contaminated equipment and solid waste were disposed of in the emplacement shaft, uncontaminated buildings and equipment were moved offsite, and drill holes were plugged (except for those retained for the LTHMP) (REECO 1981). In 1972, an area reconnaissance revealed that cover material over a waste dump that remained from the post-test drilling operations was eroding and exposing contaminated material. The second major cleanup was conducted from 1977 to 1979 and included excavating contaminated soils from the waste dump and burying them in the emplacement shaft, removing concrete pads, performing general housekeeping activities, and conducting extensive post-cleanup sampling. During these operations, the test cavity and horizontal tunnel were filled to capacity, and remaining contaminated material was transported to the Nevada National Security Sites (formerly the Nevada Test Site) (REECO 1981).

In 1994, radiological contamination was identified on the surface and in the shallow subsurface (depth of 20 ft bgs) during a survey and sampling event conducted by EPA. The DOE National Nuclear Security Administration Nevada Site Office conducted a corrective action investigation to assess the extent of contamination detected at the site. The field investigation was performed from February through June 2002 and in May 2003. Soil samples were collected and analyzed for radiological and chemical constituents. The Corrective Action Investigation Report (DOE/NNSA 2004) for the site 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. A Completion Report, prepared in accordance with the Voluntary Remediation Program, recommended no further corrective actions, no use restrictions for the surface at the site, and the eventual goal of clean closure (DOE/NNSA 2005). The State of New Mexico is currently proceeding with a conditional certificate of completion for the surface at the site.

Subsurface corrective action activities have been limited at the site and have generally consisted of annual sampling and monitoring of groundwater as part of the LTHMP, which began in 1972. The purpose of the LTHMP was to ensure public safety, inform the public and news media, and document compliance with state and federal requirements (EPA 1972). Since 1972, locations used for long-term sampling have changed; some locations were abandoned or replaced, and new locations have been added. Samples collected from these locations have generally been analyzed for gamma-emitting radionuclides (using high-resolution gamma spectrometry), strontium-90, and tritium (using conventional and electrolytic enrichment methods). Table 1 shows well sample location information, including the distance and direction from SGZ, the formation monitored, and the year sampling began.

Table 1. LTHMP Sample Locations: 1972 to 2009

Sample Location	Distance and Direction from SGZ	Formation/Unit Monitored	First Year of Sampling	Comments
USGS-1	2,250 ft southwest	Culebra Dolomite	1972	Completed with pump and used by ranchers for livestock.
USGS-4	3,180 ft west	Culebra Dolomite	1972	Used in the 1963 tracer test.
USGS-8	3,060 ft west	Culebra Dolomite	1972	Used in the 1963 tracer test.
PHS-6	4.6 miles southeast	Gatuna Formation	1972	Completed with pump and used by ranchers for livestock.
PHS-8	4.3 miles south	Rocks of Triassic age	1972	Completed with pump and used by ranchers for livestock.
PHS-9	3.5 miles southwest	Gatuna Formation	1972	Completed with pump and used by ranchers for livestock.
PHS-10	5.15 miles southwest	Culebra Dolomite	1972	Completed with pump and used by ranchers for livestock.
DD-1	285 ft south	Salado Formation	1981	Reentry well drilled into the detonation cavity. Last sampled in 2005.
LRL-7	2,370 ft south	Salado Formation	1981	Drilled into a shaft constructed for the Coach underground test.
J. Mobley Ranch	3.4 miles north-northwest	Unknown	1993	Well screen interval and completion depth unknown. May monitor Culebra Dolomite.
Carlsbad City Well No. 7	28.7 miles west	Capitan Limestone	1972	Completed with pump. Used as a City supply well.
Loving City Well No. 7	21.7 miles west	Capitan Limestone	2006	Well screen interval and completion depth unknown. Used as a City supply well.
Loving City Well No. 2	13.2 miles west	Capitan Limestone	1972	Well plugged in 2005.
Malaga City Tap Water	12.2 miles west	Piped from Loving	1972	Last sampled in 1976.
Pecos River Pumping Station Well No. 1	15 miles south-southeast	Undifferentiated rocks of Tertiary and Quaternary age	1972	Last sampled in 1992.

Responsibility for the site was transferred from the DOE Office of Environmental Management to LM on October 1, 2006. After the transfer, LM evaluated the LTHMP and associated monitoring network. The purpose of the evaluation was to determine the effectiveness of the current monitoring network and determine future monitoring at the site. The evaluation considered feasible pathways for contaminant migration from the detonation zone and tracer test to surrounding receptors. Analytical results from more than 30 years of monitoring indicate that groundwater at sample locations outside the land-withdrawal boundary (Figure 1) were not impacted by nuclear-test-related contamination. For this reason, locations outside the land-withdrawal boundary have been excluded from future sampling, but wells within and near the boundary will continue to be monitored.

To enhance monitoring at the site, low-flow bladder pumps were installed in wells USGS-4, USGS-8, and LRL-7 in June 2008. The dedicated bladder pumps were installed to replace the previous sampling method that utilized a depth-specific bailer and to allow the collection of more representative samples utilizing the low-flow sampling method. Pressure transducers were also installed in the onsite monitoring wells in 2008 and 2009 to obtain hydraulic head data for continued evaluation of the site. Results of the hydraulic head monitoring are provided in Section 4.2.

Geophysical well logging was conducted in the onsite monitoring wells USGS-4, USGS-8, and USGS-1 in April 2010. The well logging was conducted to obtain borehole deviation data from wells USGS-1 and USGS-4, natural gamma data from wells USGS-4 and USGS-8, and down-hole 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 flow directions and gradients at the site. The natural gamma data provide geologic information that can be used to correlate with other wells in the area. Data obtained from the video logs suggest that the casings are in generally good condition for their age. Data obtained from the well logging supports the long-term monitoring at the site. The 2010 Groundwater Monitoring and Inspection Report summarizes the well logging results (DOE 2011).

3.0 Geology and Hydrology

The 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 extensive studies required to locate the Waste Isolation Pilot Plant approximately 8 miles north-northeast of the site. The basin deposits dip gently to the east and southeast, though in places the bedding is almost flat. During the late Permian Period, a warm shallow sea in the region provided ideal environments for reef development, which blocked seawater circulation. As the seawater began to evaporate, brines were formed, and crystalline salts precipitated and accumulated on the basin floor. As a result, the site area is underlain by several thousand feet of limestone, dolomite, gypsum, halite, anhydrite, and potassium salts (potash). The Salado Formation, in which the Gnome detonation took place, is a 2,500-ft-thick bed of halite that formed during the Permian Period. The Salado Formation is virtually impermeable due to the plastic nature of the salt under pressure.

Overlying the Salado Formation are five thin-bedded members of the Rustler Formation. This formation includes the Culebra Dolomite Member, which was the subject of extensive study during the location and siting phases of the Waste Isolation Pilot Plant. Above the Culebra Dolomite is the Tamarisk Anhydrite Member, which is overlain by the Magenta Dolomite. The uppermost member of the Rustler Formation is the Forty-Niner Member, a mixture of gypsum and anhydrite. The youngest Permian sequences in the site area are the thin, red, sedimentary rocks of the Dewey Lake Redbeds. At the site, about 200 ft of Permian-age anhydrites, mudstones, and dolomites separate the Culebra Dolomite from younger overlying formations.

The Culebra Dolomite is a widespread, laterally continuous, fractured carbonate aquifer that is approximately 30 ft thick and is encountered at a depth of approximately 490 ft bgs at the site. The groundwater within the Culebra generally moves through fractures and is of poor quality because of high concentrations of dissolved solids (Mercer 1983). The Culebra is the most prolific aquifer near the site, and despite the poor water quality, it is a source of water for ranchers who maintain livestock throughout the area.

4.0 Groundwater Monitoring and Inspection Results

Groundwater monitoring and site inspection activities conducted on January 19, 2011, consisted of a site inspection, hydraulic head monitoring, and groundwater sampling. The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PLN/S04351) is used to guide the quality assurance/quality control of the annual sampling and monitoring program. The analytical results obtained from the annual sampling were validated in accordance with the *Environmental Procedures Catalog* (LMS/PRO/S04325), "Standard Practice for Validation of Laboratory Data." All samples were analyzed using accepted procedures that were based on the specified methods. The laboratory radiochemical minimum detectable concentration reported with these data is 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 Package is maintained in the LM records and is available upon request. The following sections summarize results obtained from these activities.

4.1 Site Inspection Results

A site inspection was conducted as part of the annual monitoring in January 2011. The inspection included observing roads, monitoring well heads, and inspecting the monument at SGZ for any signs of damage, natural deterioration from weather, or vandalism. All roads, all well heads, and the monument were observed as being in good condition at the time of the inspection.

4.2 Hydraulic Head Monitoring and Results

Water levels in site wells (USGS-1, USGS-4, USGS-8, LRL-7, and DD-1) are recorded every 3 hours by pressure transducers. On January 19, 2011, the depth to water was measured in all wells, except DD-1, using a water level tape. A water level was not obtained from DD-1 because the well is completed in the detonation cavity and access is restricted. The January 19, 2011, water level measurements were used to convert the transducer data to water depths and to resolve a shift in the data that resulted from the logging of wells USGS-4 and USGS-8 in April 2010. A flow meter was installed in the water supply well USGS-1 in April 2010 to measure pumping flow rates. The flow meter was downloaded during the January 2011 monitoring event, and the data indicated that the flow meter had stopped working approximately 4.5 days after it had been installed and that the solar panel used to power the data logger for the flow meter had been removed. The average flow rate for the period of operation was approximately 5 gallons per minute. Table 2 presents the water level data and groundwater elevations obtained in 2011, along with the zone of completion and the hydrostratigraphic unit monitored for the wells.

Table 2. Gnome-Coach Site Water Levels

Well	Date	DTW (ft)[a]	TOC Elevation (ft)	TSZ Elevation (ft)	BSZ Elevation (ft)	Formation/Unit Monitored	Groundwater Elevation (ft)
USGS-1[c]	01/19/2011	434.00	3,425.78	2,907.78[b]	2,875.78[b]	Culebra Dolomite	2,991.87[b]
USGS-4	01/19/2011	426.22	3,415.25	2,943.22[b]	2,909.70[b]	Culebra Dolomite	2,993.86[b]
USGS-8	01/19/2011	419.65	3,412.96	2,949.96[b]	2,917.96[b]	Culebra Dolomite	2,993.31[b]
LRL-7	01/19/2011	468.51	3,442.42	2,654.42	2,128.42	Salado Formation	2,973.91
DD-1	01/19/2011	NM	3,398.18	NM	NM	Salado Formation	NM

BSZ = bottom of screen zone, uncased/open interval, or perforated interval in feet above mean sea level
DTW = depth to water (all measurements obtained from north top of casing)
NM = not measured
TOC = top of casing elevation in feet above mean sea level
TSZ = top of screen zone, uncased/open interval, or perforated interval in feet above mean sea level
[a] Depth to water has not been corrected for true vertical depth.
[b] Elevation has been corrected for true vertical depth (at the water level depth, the deviation correction for USGS-1 is 0.09 ft; USGS-4 is 4.83 ft; USGS-8 did not deviate from vertical, so no correction is required).
[c] Well USGS-1 has a dedicated submersible pump that was operating at the time of the measurement.

The transducers were downloaded as part of the annual monitoring event in January 2011. All transducers, with the exception of DD-1, were downloaded again in August 2011. The head data are plotted with time as hydrographs shown in Figure 3 and Figure 4. The hydrographs are grouped according to each well's open interval and formation monitored. Head data collected using a water level tape appear as individual symbols, and data collected with transducers appear as lines. Figure 3 shows the hydrographs for the wells (USGS-1, USGS-4, and USGS-8) completed in the Culebra Dolomite. These data indicate that water levels in well USGS-1 recover approximately 2 ft when the dedicated pump in this well cycles off. Small water level changes in wells USGS-4 and USGS-8 also appear to be related to the pumping of well USGS-1. Figure 4 shows the hydrographs for the wells (LRL-7 and DD-1) completed in the Salado Formation. These data indicate that water levels in well LRL-7 did not fully recover from the annual sampling events conducted in January and that water levels increased in well DD-1. It should be noted that hydraulic head data from wells USGS-1, USGS-4, and USGS-8 have been corrected to true vertical depth. For reference, the borehole deviation data obtained from well USGS-4 requires a correction of 4.83 feet to obtain true vertical depth (DOE 2011). Borehole deviation data are currently not available for wells DD-1 and LRL-7, so groundwater elevations depicted in Figure 4 are approximate.

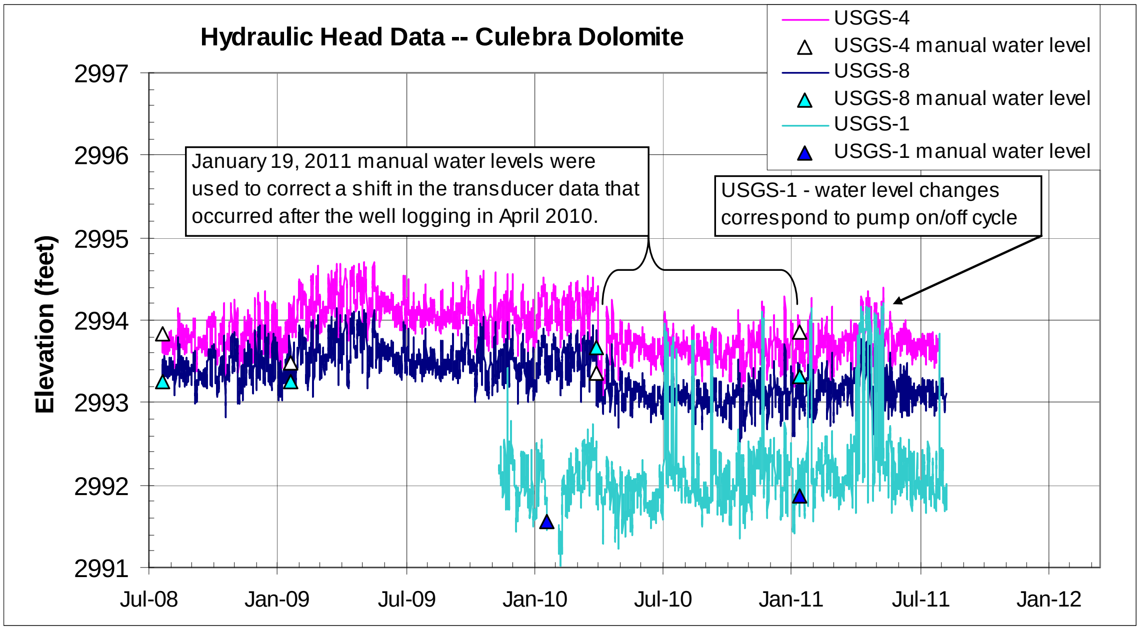

Figure 3. Hydrograph Showing Water Elevations in Wells USGS-1, USGS-4, and USGS-8

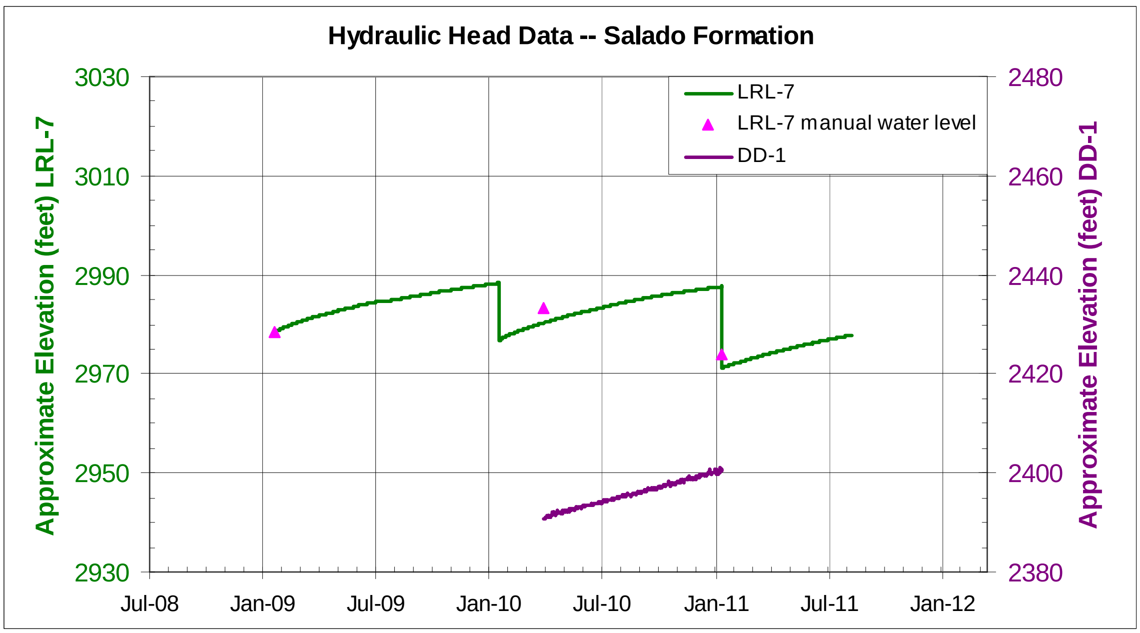

Figure 4. Hydrograph Showing Water Elevations in Wells DD-1 and LRL-7

4.3 Groundwater Sampling and Results

Groundwater samples were collected from wells USGS-1, USGS-4, USGS-8, and LRL-7 on January 19, 2011. A sample was not collected from well DD-1 because it is completed in the detonation cavity and the presence of contamination is well documented. Samples were also not collected from the offsite locations because of the distance (several miles) from the site. Monitoring wells USGS-4, USGS-8, and LRL-7 were sampled using dedicated low-flow submersible bladder pumps. The tubing inlets of the bladder pumps are located in the screened or open interval to allow water to be collected directly from the adjacent geologic formation. This limits the volume of purge water to the volume of water in the pump tubing, and the low flow rates minimize mixing with stagnant water in the well bore. No purge water was discharged on the ground during the sampling. The sample collected from well USGS-1 was collected as a grab sample because the pump was operating at the time of the sampling. Samples were analyzed for gamma-emitting radionuclides (using high-resolution gamma spectrometry), strontium-90, and tritium (using conventional methods). An additional sample was collected from well USGS-1 to be analyzed for tritium, using the electrolytic enrichment method, but it was not analyzed because the EPA Laboratory no longer offers that service.

Analytical results obtained from the 2011 monitoring event indicate that contaminant concentrations in onsite wells USGS-4, USGS-8, and LRL-7 were consistent with previous analytical results. Concentrations in well LRL-7 are the result of contamination from waste disposal during the site cleanup, and concentrations in wells USGS-4 and USGS-8 are the result of radionuclides injected during the tracer test in 1963. Cesium-137 concentrations in samples collected from wells USGS-8 and LRL-7 and tritium concentrations in samples collected from well LRL-7 during the 2008 through 2011 sampling events were higher than concentrations measured in 2007. The increased concentrations are due to changes in the sampling method that was implemented after the 2007 monitoring event, in which dedicated low-flow bladder pumps were installed. No analytical results were obtained for enriched tritium because the EPA Laboratory no longer provides that service. Table 3 lists the analytical results from the wells that were sampled during the January 2011 sampling event.

Table 3. Gnome-Coach Site Groundwater Sample Analytical Results

Sample Location	Collection Date	Tritium (pCi/L)	Enriched Tritium (pCi/L)	Cesium-137 (pCi/L)	Strontium-90 (pCi/L)	Formation/Unit Monitored
USGS-1	01/19/2011	<150	NA	<2.2	<3.6	Culebra Dolomite
USGS-1 (duplicate)	01/19/2011	<150	NA	<2.4	<1.1	Culebra Dolomite
USGS-4	01/19/2011	11,300	NA	<2.4	2,650	Culebra Dolomite
USGS-8	01/19/2011	21,200	NA	150	3,650	Culebra Dolomite
LRL-7	01/19/2011	3,910	NA	134	<29	Salado Formation

NA = not analyzed
pCi/L = picocuries per liter

Charts 1 through 7 in Appendix A show temporal plots of radionuclide concentrations (1972 through 2011) in samples collected at wells LRL-7, USGS-4, and USGS-8. Concentration results are plotted on a semilogarithmic scale. All sample results, including nondetects, are plotted. As indicated in the figures, many results from sampling events before the late 1980s had no reported detection limit. For interpretation purposes, relatively high concentrations (i.e., concentrations significantly higher than detection limits associated with subsequent sampling) should be considered detections.

5.0 Conclusions

The site roads, monitoring well heads, and the monument at SGZ were observed as being in good condition at the time of the site inspection in January 2011. An evaluation of the hydraulic head data obtained from the site indicates that water levels in wells USGS-4 and USGS-8 (Figure 3) appear to respond to the on/off cycling of the dedicated pump in well USGS-1. More data are needed, however, to evaluate the effect pumping has on the hydraulic system. Water levels in well LRL-7 (Figure 4) do not fully recover from the annual sampling events; this is not unexpected because the well is screened in the very-low-permeability Salado Formation. Data from the transducer in well DD-1 (Figure 4) indicate that water levels have increased during this monitoring period. Analytical results obtained from the annual sampling in 2011 indicate that concentrations of tritium, strontium-90, and cesium-137 were consistent with concentrations from historical sampling events.

6.0 References

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Appendix A

Well Concentration Plots

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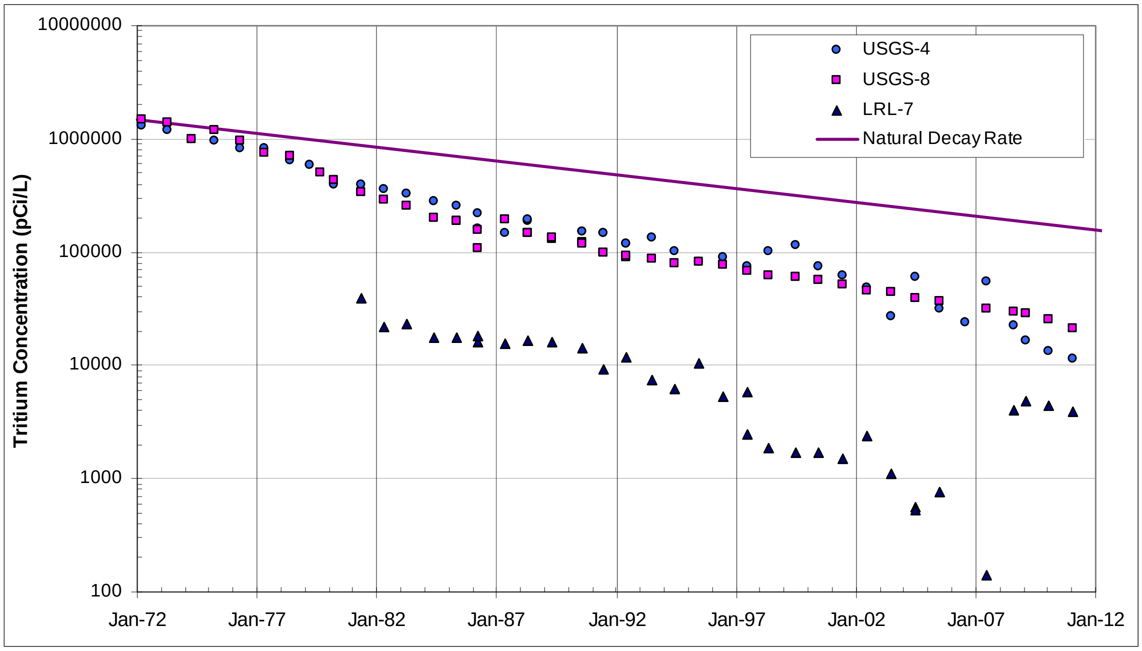

Chart 1. Tritium Concentrations at Wells USGS-4, USGS-8, and LRL-7

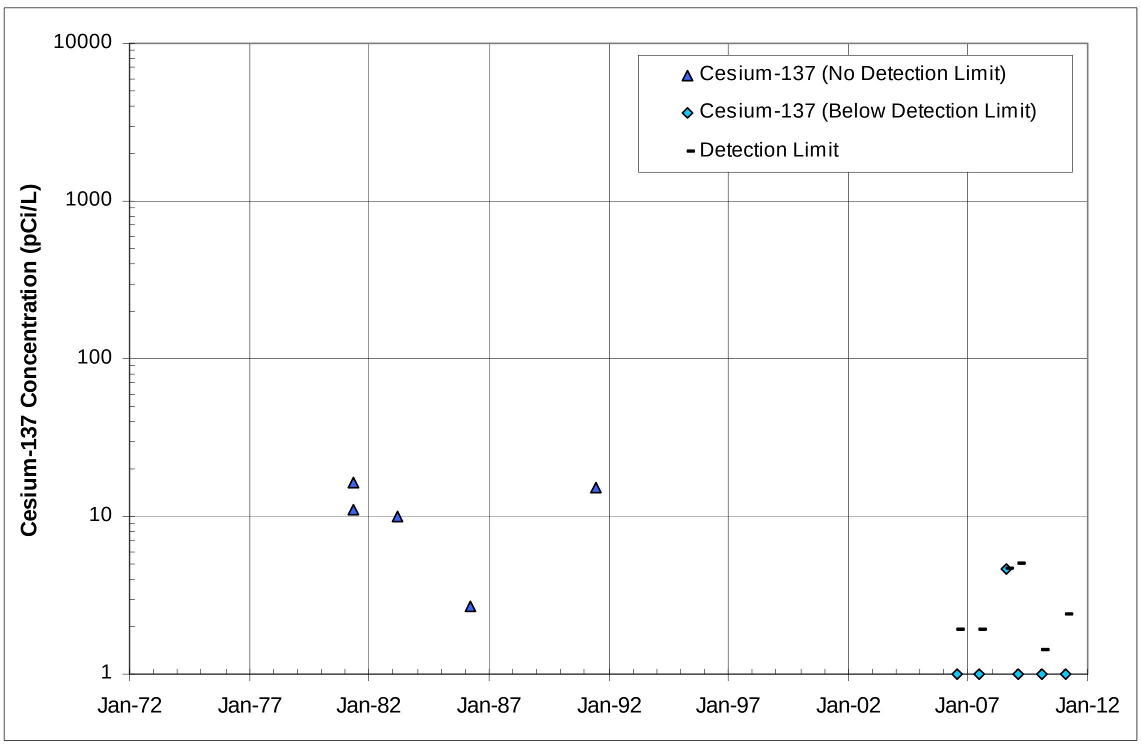

Chart 2. Cesium-137 Concentrations at Well USGS-4

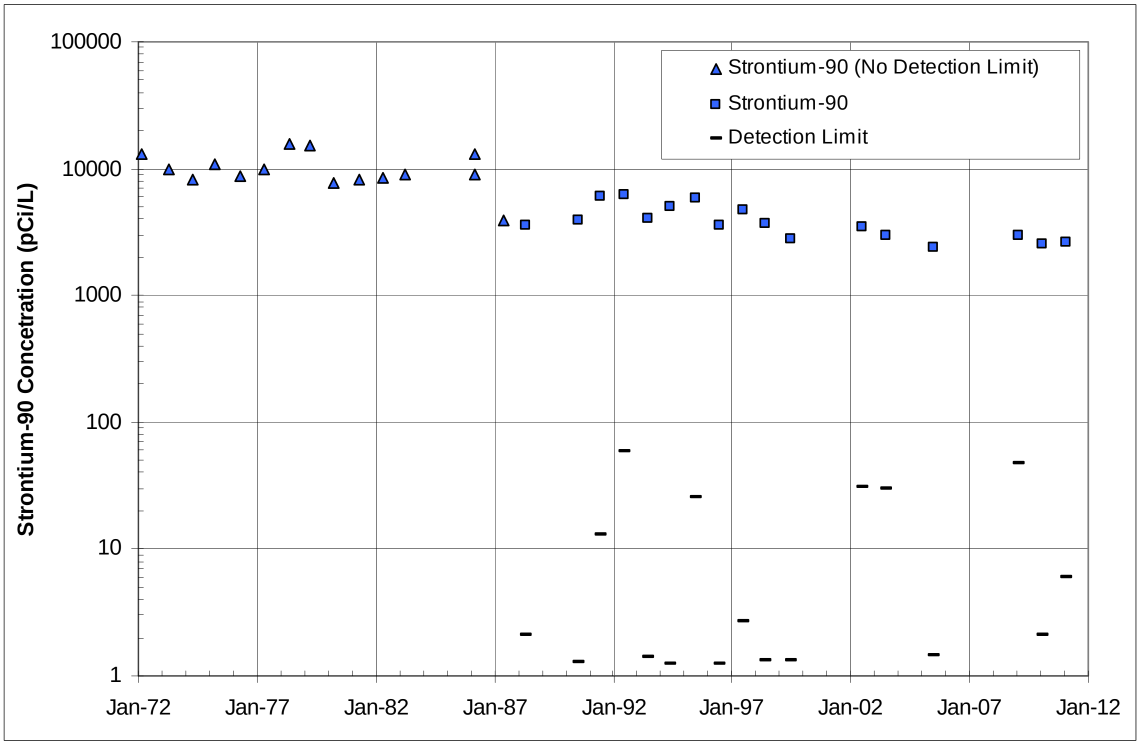

Chart 3. Strontium-90 Concentrations at Well USGS-4

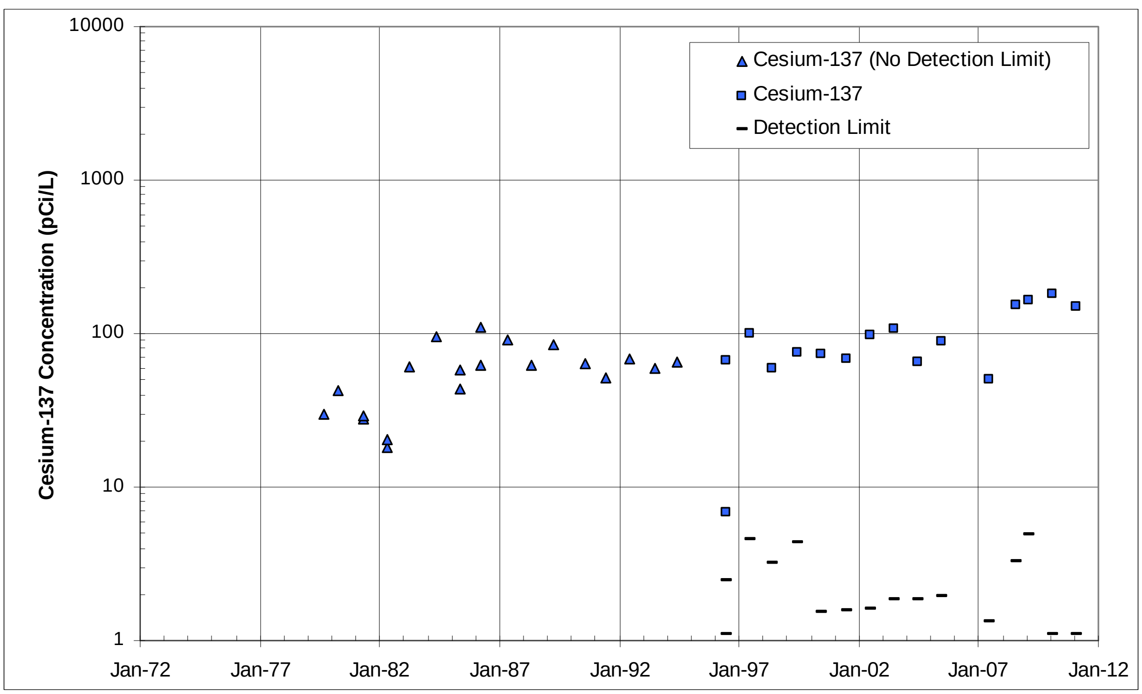

Chart 4. Cesium-137 Concentrations at Well USGS-8

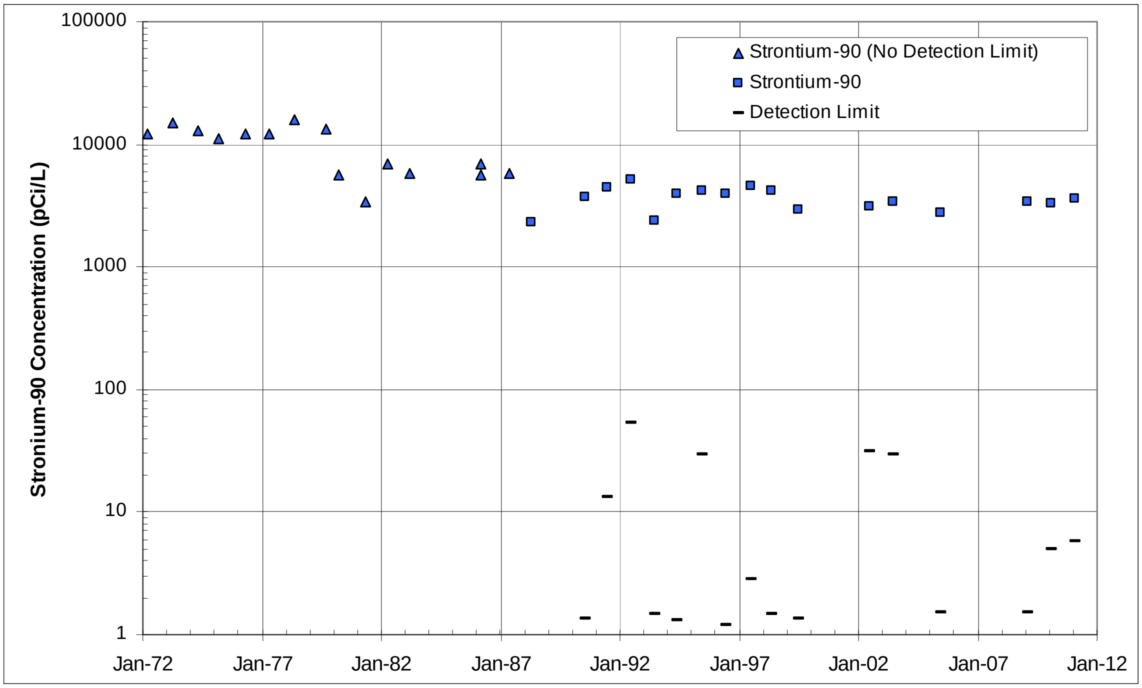

Chart 5. Strontium-90 Concentration at Well USGS-8

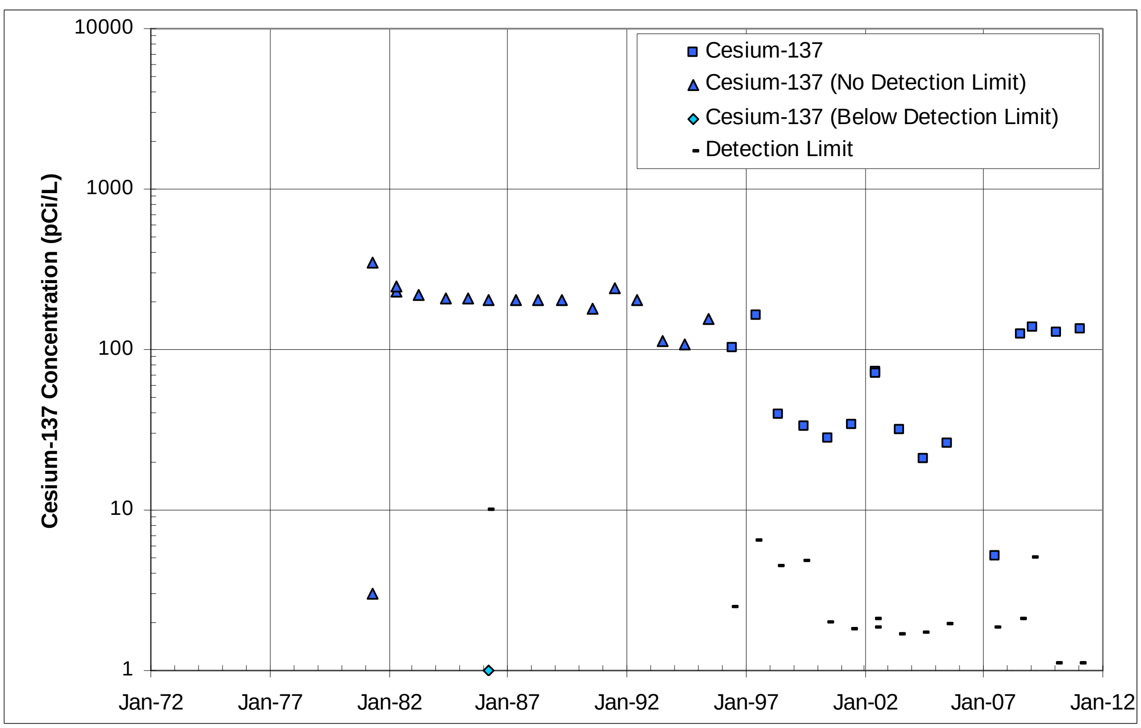

Chart 6. Cesium-137 Concentration at Well LRL-7

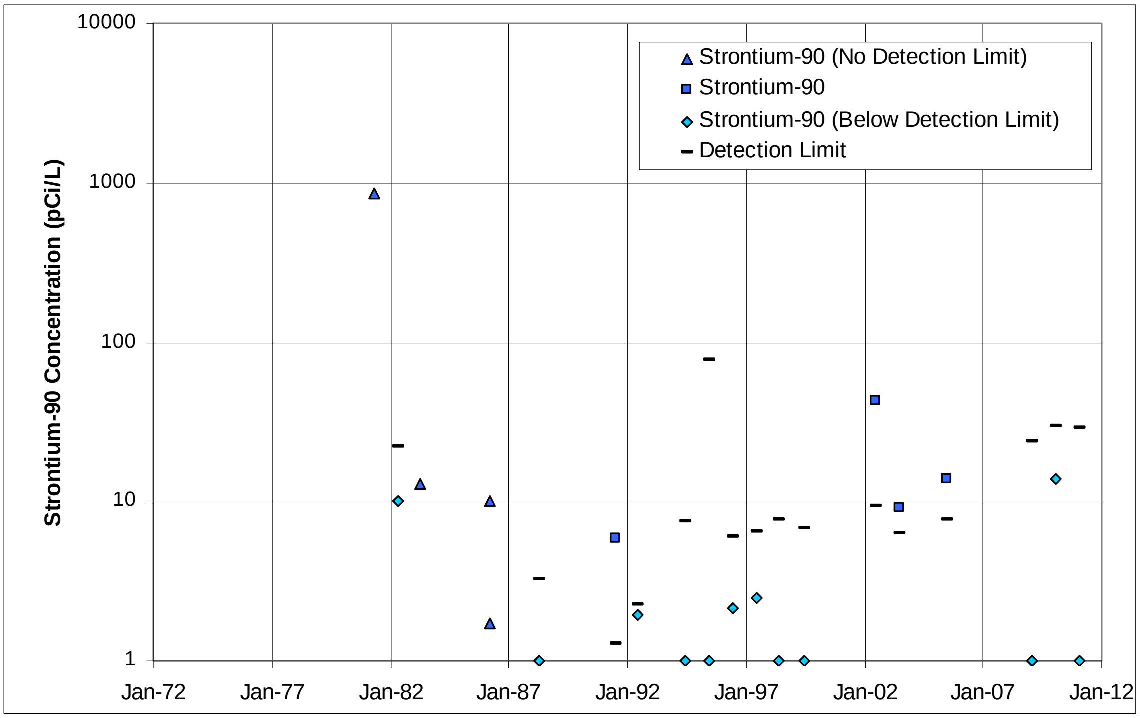

Chart 7. Strontium-90 Concentrations at Well LRL-7

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