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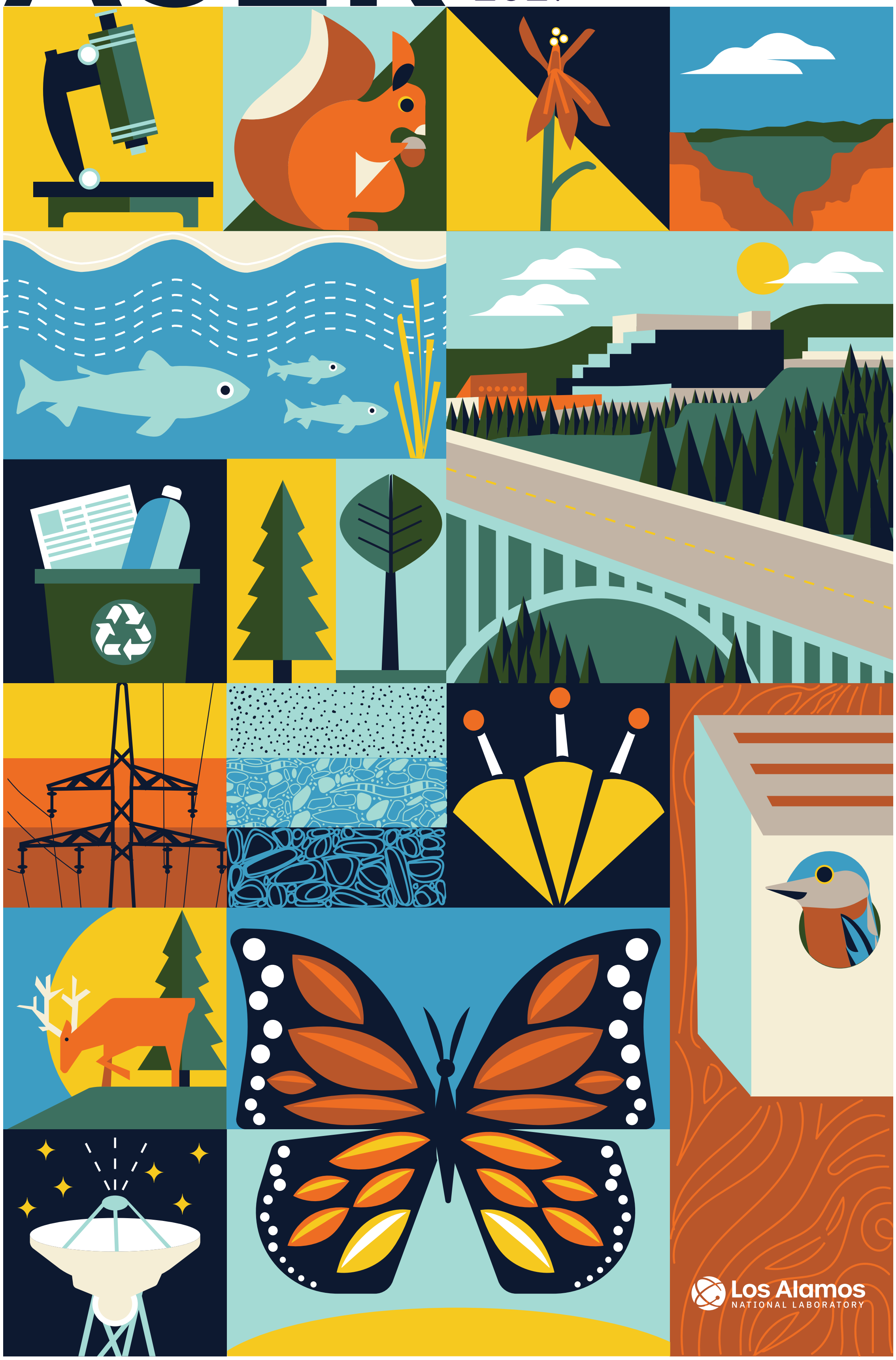

Los Alamos
NATIONAL LABORATORY

LOS ALAMOS NATIONAL LABORATORY
GOVERNING POLICY FOR THE ENVIRONMENT

- We are committed to act as stewards of our environment to achieve our mission in accordance with all applicable environmental requirements.
- We set continual improvement objectives and targets, measure and document our progress, and share our results with our workforce, sponsors, and public.
- We reduce our environmental risk through legacy cleanup, pollution prevention, and long-term sustainability programs.

ANNUAL SITE ENVIRONMENTAL REPORT FOR 2021
LA-UR-22-29103
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Los Alamos National Laboratory
2021 Annual Site Environmental Report

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Los Alamos
NATIONAL LABORATORY

Abstract

Los Alamos National Laboratory's (LANL's or the Laboratory's) annual site environmental reports are prepared each year by the Laboratory's environmental organizations as required by U.S. Department of Energy Order 231.1B, Administrative Change 1, *Environment, Safety, and Health Reporting*, and Order 458.1, Administrative Change 4, *Radiation Protection of the Public and the Environment*.

The chapters in this report discuss our success in complying with environmental laws, regulations, and orders (Chapter 2, Compliance Summary); how we manage the Laboratory's environmental performance (Chapter 3, Environmental Programs and Analytical Data Quality); how we monitor for air emissions of radioactive materials and climate conditions (Chapter 4, Air Quality); how we monitor for effects of Laboratory operations on groundwater quality (Chapter 5, Groundwater Protection); how we monitor the movement of chemicals and radionuclides by storm water runoff and the levels of chemicals and radionuclides in deposited sediment (Chapter 6, Watershed Quality); how we monitor for the presence, levels, and effects of chemicals and radionuclides in plants, animals, soil, and vegetation (Chapter 7, Ecosystem Health); and, finally, what radionuclide dose or risk from chemical exposure members of the public may experience as a result of Laboratory operations (Chapter 8, Public Dose and Risk Assessment).

This report follows plain language guidelines as required for federal agencies by the Plain Language Act of 2010. More information about plain language can be found at http://www.plainlanguage.gov. We have substantially reduced the use of acronyms and abbreviations and are using active voice and personal pronouns.

We hope you find this report useful. If you have questions or suggestions to improve this report or if you want copies of the *Annual Site Environmental Report Summary*, please contact us at ASER@lanl.gov or call the LANL Public Affairs Office at (505) 667-7000.

This report, its supplemental tables, and the *Annual Site Environmental Report Summary* are available at https://environment.lanl.gov/environmental-report.

Table of Contents

Table of Figures

Table of Tables

Table of Tables

Chapter Authors and Contributors

Abstract
Leslie Hansen

Executive Summary
Leslie Hansen

1.0 Introduction
David Bruggeman
Kari Garcia
Leslie Hansen
Ben Sutter
Brent Thompson
Kenneth Waight III
Marjorie Wright

2.0 Compliance Summary
Candie Arellano
Ben Bateman
David Bruggeman
Christine Bullock
Alethea Banar
Aaron Dailey
Emily Day
Sean Dolan
Mike Erickson
David Fuehne
Robert Gallegos
Ellen Gammon
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Tim Goering
Sarah Gould
Jennifer Griffin
Jeff Holland
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Scot Johnson
Patrick Kennedy
Ashley Kowalewski
Frazer Lockhart
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Alan Madsen
Christian Maupin
Avril Millensted
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Bruce Robinson
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Karla Sartor
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Roz Sereda
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Jenna Stanek
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Daria Cuthbertson
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Jenna Stanek
Charles Hathcock
Michael McNaughton
Brent Thompson
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Mary Jo Chastenet
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Jamie Gerard
Michael McNaughton
Jeffrey Wicker

Executive Summary

Los Alamos National Laboratory (LANL or the Laboratory) is located in Los Alamos County in north-central New Mexico, approximately 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe. The Laboratory's mission is to solve national security challenges through scientific excellence. Environmental stewardship and compliance are core values of operations at the Laboratory. Part of that commitment includes reporting on the Laboratory's environmental performance.

A public use trail on Los Alamos National Laboratory property in White Rock Canyon

This site environmental report

- characterizes the Laboratory's environmental performance, including effluent releases, environmental monitoring, and estimated radiological doses to the public and the environment;
- summarizes environmental occurrences and responses;
- confirms compliance with environmental standards and requirements;
- highlights significant programs and efforts; and
- describes property clearance activities in accordance with U.S. Department of Energy (DOE) Order 458.1.

LANL has changed substantially since it was founded in 1943. Undoubtedly, the future will continue to bring significant changes to the Laboratory mission and operations. Regardless of these changes, we are committed to operating the site sustainably.

The Laboratory's Governing Policy on Environment

We are committed to act as stewards of our environment to achieve our mission in accordance with all applicable environmental requirements. We set continual improvement objectives and targets, measure and document our progress, and share our results with our workforce, sponsors, and the public. We reduce our environmental risk through legacy cleanup, pollution prevention, and long-term sustainability programs.

Environmental stewardship requires an active management system to provide environmental policy, planning, implementation, corrective actions, and management review. We use an Environmental Management System to accomplish this. The Laboratory has been certified to the International Organization for Standardization's 14001 standard for the Environmental Management System since April 2006.

The chapters in this report discuss a range of topics: our success in complying with environmental laws, regulations, and orders (Chapter 2, Compliance Summary); how we manage the Laboratory's environmental performance (Chapter 3, Environmental Programs and Analytical Data Quality); how we monitor for air emissions of radioactive materials and climate conditions (Chapter 4, Air Quality);

how we monitor for effects of Laboratory operations on groundwater quality (Chapter 5, Groundwater Protection); how we monitor the movement of chemicals and radionuclides by storm water runoff and the levels of chemicals and radionuclides in deposited sediment (Chapter 6, Watershed Quality); how we monitor for the presence, levels, and effects of chemicals and radionuclides in plants, animals, soil, and vegetation (Chapter 7, Ecosystem Health); and finally, what radionuclide dose or risk from chemical exposure members of the public may experience as a result of Laboratory operations (Chapter 8, Public Dose and Risk Assessment).

2021 Environmental Performance Summary

Our environmental performance can be summarized as follows (see Chapters 2 and 3).

- The Laboratory operated under 18 different types of environmental permits and legal orders (Table 2-21 in Chapter 2).
- Mixed wastes managed under the Laboratory's Site Treatment Plan decreased by approximately 85 cubic yards for mixed low-level waste and 96 cubic yards for mixed transuranic waste.
- The Laboratory was fully in compliance with its Clean Air Act, Title V Operating Permit emission limits.
- We discharged approximately 113 million gallons of liquid effluents from seven permitted outfalls. Four permitted outfalls had no discharge. Six of the 807 outfall samples collected (1.0 percent) exceeded eight effluent quality limits in the outfall permit (Table 2-6 in Chapter 2).
- In fiscal year 2021, we reported to the New Mexico Environment Department 15 instances of a contaminant detected in groundwater at a location where the contaminant had not been previously detected above a standard or screening level (Table 2-12 in Chapter 2).
- Two areas of the regional aquifer at the Laboratory have groundwater contaminants that are of sufficient concentration and extent to warrant actions, such as interim measures, further characterization, and potential remediation under the 2016 Compliance Order on Consent: RDX contamination in the vicinity of Technical Area 16 and chromium contamination beneath Sandia and Mortandad canyons. Interim measures to control the chromium plume boundary are ongoing (Chapter 5).
- One environmental occurrence was reported under DOE Order 232.2, Occurrence Reporting and Processing of Operations Information, related to the exceedance of a permit limit at Outfall 051.
- The Laboratory had six inspections or audits conducted by regulating agencies or external auditors in 2021, including its second triennial review of compliance with permits and related regulatory requirements (Table 2-19 in Chapter 2).
- We made 11 reports of unplanned nonradioactive liquid releases to the New Mexico Environment Department (Table 2-20 in Chapter 2).
- Radiological doses to the public from Laboratory operations were less than 1 millirem per year, and health risks are indistinguishable from zero.

2021 Environmental Program Highlights

During 2021, programs comprising the Laboratory's Environmental Management System reported the following new initiatives or highlights.

- The Laboratory's Pollution Prevention Program led an initiative to develop a LANL Vulnerability Assessment and Resilience Plan for addressing impacts of climate change on operations and funded a sulfur hexafluoride gas reclamation unit.
- The New Mexico Environment Department, the DOE, the Laboratory, and Amigos Bravos (a nonprofit organization that works on water-related issues) reached an agreement to reclassify several stream segments on Laboratory property, resulting in increased water quality protections for an additional three miles of surface waters within LANL's boundaries.
- A Manhattan Project–era magazine for explosives at Technical Area 16 that is part of the Manhattan Project National Historical Park was rehabilitated, and a Manhattan Project–era bomb hauler truck used at Los Alamos was donated to the Park.
- The New Mexico Environment Department granted certificates of completion for 13 remedial sites in fiscal year 2021. Of the remaining sites, 134 are deferred because of ongoing operations, and 896 have investigations or corrective actions either in progress or pending.

2021 Environmental Monitoring Highlights

During 2021, we completed the following.

- The Laboratory operated 43 environmental air-monitoring stations and conducted stack monitoring at 10 facilities to measure levels of airborne radiological materials. During 2021, the radioactive emissions from all Laboratory sources amounted to less than 1 percent of the regulatory limit, and concentrations of airborne radioactive material measured in ambient air samples were below the applicable concentration levels for environmental compliance.
- We analyzed groundwater samples for per- and polyfluoroalkyl substances (PFAS) compounds in 2020 and 2021. Pueblo and Los Alamos canyons were the only locations with results exceeding the screening level of 70 nanograms per liter. In Pueblo Canyon, samples with results exceeding the screening level were collected in alluvial, intermediate depth, and regional aquifer wells.
- The 2021 results of the storm water and base flow sampling fell within the ranges observed in the previous 10 years, and the sediment sampling results continued to verify that sediment transport observed in Laboratory canyons generally results in lower concentrations of Laboratory-released chemicals in the new sediment deposits than previously existed in a given stream reach.
- The Laboratory completed its triennial sampling of surface soil and vegetation from onsite, perimeter, and background locations, as well as its annual sampling of soil, sediment, vegetation, and wildlife around facilities. In most soil, sediment, plant, and animal samples from onsite and perimeter locations, radionuclides and chemicals were not detected, had levels similar to background, or had levels below the screening levels that may be harmful to biota. Surveys confirmed the presence of Mexican spotted owls in two locations on Laboratory property.
- The 2020 biota dose assessment confirms previous assessments and shows no harmful effects to the biota populations at LANL from Laboratory radioactive materials.

An additional summary of this report prepared by students can be found in the *Los Alamos National Laboratory Annual Site Environmental Report Summary*. The full report and the summary are available on the Laboratory's website at https://environment.lanl.gov/environmental-report.

Chapter 1: Introduction

Los Alamos National Laboratory (the Laboratory) was established in 1943. As Project Y of the Manhattan Project, the Laboratory's objective during World War II was to design and build the world's first atomic bombs. Surrounded by the diverse communities of Northern New Mexico and employing approximately 15,000 people, the Laboratory continues today with a mission to solve national security challenges. Figure 1-1 is a photo of Technical Area 3, which contains the administrative headquarters for the Laboratory and several key facilities.

Figure 1-1. Looking southwest at Los Alamos National Laboratory's Technical Area 3, which includes the National Security Sciences Building and the Strategic Computing Complex.

Contents

Background and Purpose

Background

In March 1943, during World War II, a small group of scientists came to Los Alamos, New Mexico, for Project Y of the Manhattan Project. Their goal was to develop the world's first atomic bombs. By 1945, more than 3,000 civilian and military personnel were working at Los Alamos Laboratory.

The Laboratory's original mission to design, develop, and test nuclear weapons has broadened and evolved over time. The current mission is to solve national security challenges through simultaneous excellence.

The Los Alamos Laboratory was established by the U.S. Army Corps of Engineers. In 1946, the U.S. Atomic Energy Commission took charge of Los Alamos Laboratory, and in 1947, Los Alamos Laboratory became Los Alamos Scientific Laboratory. Thirty years later, in 1977, the U.S. Department of Energy (DOE) became the federal agency in control. Los Alamos Scientific Laboratory underwent its final name change in 1981, becoming Los Alamos National Laboratory (LANL or the Laboratory). The National Nuclear Security Administration, a semiautonomous agency within DOE, has overseen the management and operating contract for the Laboratory since 2000.

From 1943 through May 2006, the Laboratory was operated by the Regents of the University of California. In June 2006, Los Alamos National Security, LLC took over as the contractor responsible for managing and operating the Laboratory. In 2014, DOE decided to separate the cleanup of legacy waste from the management and operating contract. Legacy waste cleanup work was transitioned to a bridge contract under DOE's Office of Environmental Management in October 2015. A new contractor, Newport News Nuclear BWXT–Los Alamos, LLC (N3B), became responsible for legacy waste cleanup operations in April 2018. Triad National Security, LLC (Triad) was awarded the most recent management and operating contract for the Laboratory and began managing the Laboratory in November 2018. Currently, both the National Nuclear Security Administration and DOE's Office of Environmental Management maintain field offices in Los Alamos, New Mexico.

Purpose

This document is a consolidated site environmental report and fulfills the annual reporting requirements of the National Nuclear Security Administration and DOE's Office of Environmental Management under DOE Orders 231.1B Chg 1, Environment, Safety, and Health Reporting, and 458.1 Chg 3, Radiation Protection of the Public and the Environment.

In this document, "we" refers to the people who work at Los Alamos National Laboratory, including employees of DOE and contractor organizations.

As part of the Laboratory's commitment to protecting the environment, we monitor and report on how Laboratory activities affect the environment. The objectives of this annual report are to

- characterize the site's environmental performance, including effluent discharges, air emissions, environmental monitoring, and estimated radiological doses to the public from releases of radioactive materials;

- summarize environmental occurrences and responses;
- document compliance with environmental standards and requirements;
- highlight significant programs and efforts; and
- summarize property clearance activities.

The chapters in this report discuss our compliance with environmental laws, regulations, and orders (Chapter 2, Compliance Summary); how we manage the Laboratory's environmental performance and assure the quality of data from analysis of environmental samples (Chapter 3, Environmental Programs and Analytical Data Quality); how we monitor for air emissions of radioactive materials and for weather conditions (Chapter 4, Air Quality); how we monitor for effects of Laboratory operations on groundwater quality (Chapter 5, Groundwater Protection); how we monitor the movement of chemicals and radionuclides in storm water runoff and sediment (Chapter 6, Watershed Quality); how we monitor for the presence, levels, and effects of chemicals and radionuclides in plants, animals, soil, and vegetation (Chapter 7, Ecosystem Health); and finally, what radioactive dose or risk from chemical exposure that members of the public may experience as a result of Laboratory operations (Chapter 8, Public Dose and Risk Assessment).

Environmental Setting

Location and Demographics

Los Alamos National Laboratory is located in Los Alamos and Santa Fe counties, in north-central New Mexico, approximately 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe (see Figure 1-2). The Laboratory sits on the Pajarito Plateau at the eastern edge of the Jemez Mountains. The Sierra de los Valles range of the Jemez Mountains is directly west of the Laboratory, and White Rock Canyon, containing the Rio Grande, is east. The Pajarito Plateau is a series of mesas separated by east-west trending canyons. Mesa tops range in elevation from approximately 7,800 feet on the western side to about 6,200 feet on the eastern side.

The Laboratory property is about 40 square miles. This property includes areas with active operations and some additional DOE properties, such as a proposed land transfer tract in Rendija Canyon (labeled "DOE" in Figure 1-2). The land surrounding the Laboratory is largely undeveloped. Large tracts of land north, west, and south of the site are managed by the Santa Fe National Forest, the U.S. Bureau of Land Management, Bandelier National Monument, and Los Alamos County. The town of Los Alamos borders the Laboratory to the north. The Pueblo de San Ildefonso and the town of White Rock border the Laboratory to the east. Santa Clara Pueblo is north of the Laboratory but does not share a border (see Figure 1-2).

New Mexico's 2021 population was 2,117,877 people (Census 2022a). The estimated population within a 50-mile radius of Los Alamos based on 2020 census data was 453,808 people (CIESIN 2022). The counties with substantial land area within 50 miles of the Laboratory are Los Alamos, Santa Fe, Sandoval, and Rio Arriba. The estimated racial and ethnic composition of the population within these counties, based on the latest available data from the U.S. Census Bureau's American Community Survey (2016–2020), is shown in Table 1-1 (Census 2022b). Figure 1-3 shows municipalities and tribal properties within 50 miles of the Laboratory.

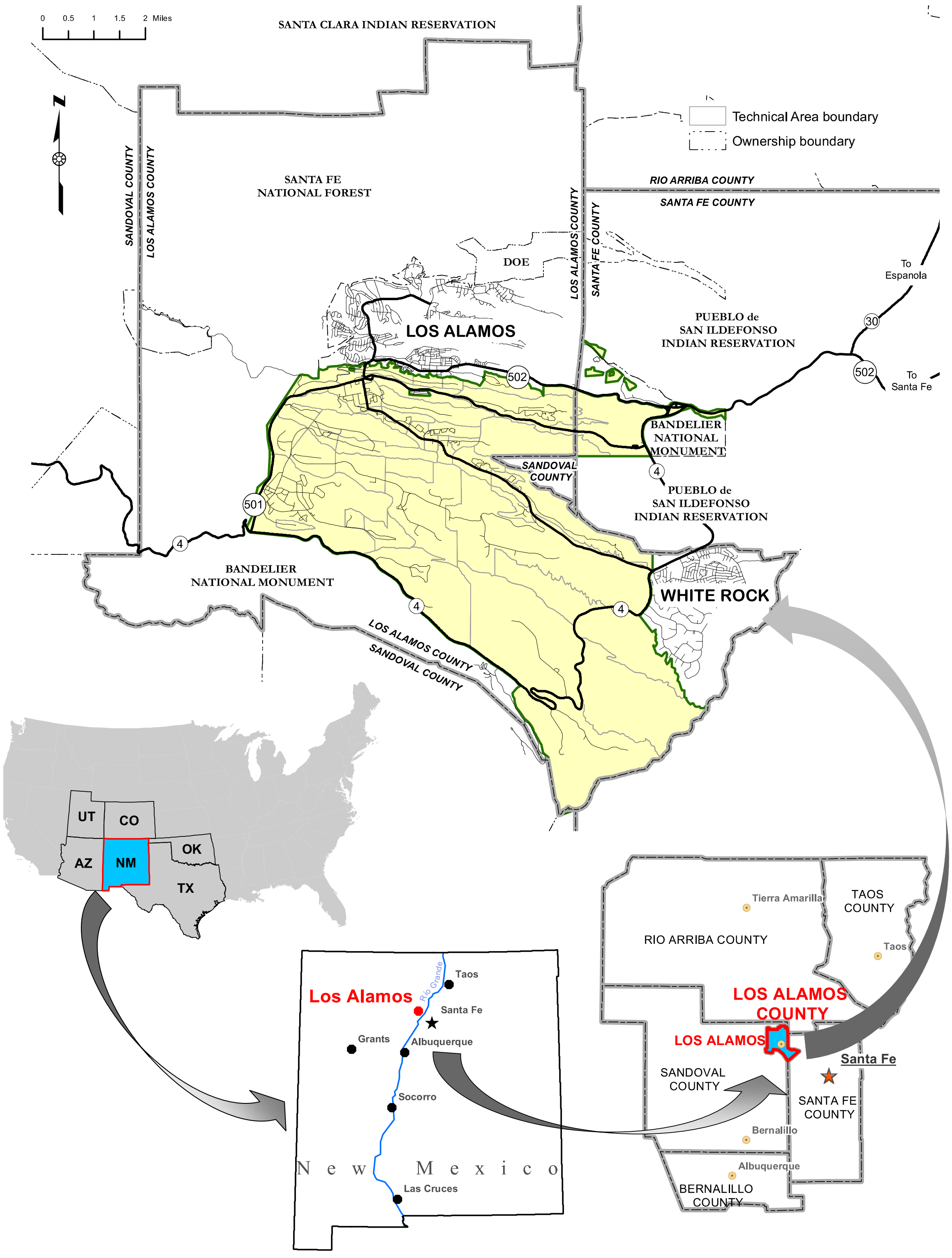

Figure 1-2. Regional location of Los Alamos National Laboratory (in yellow)

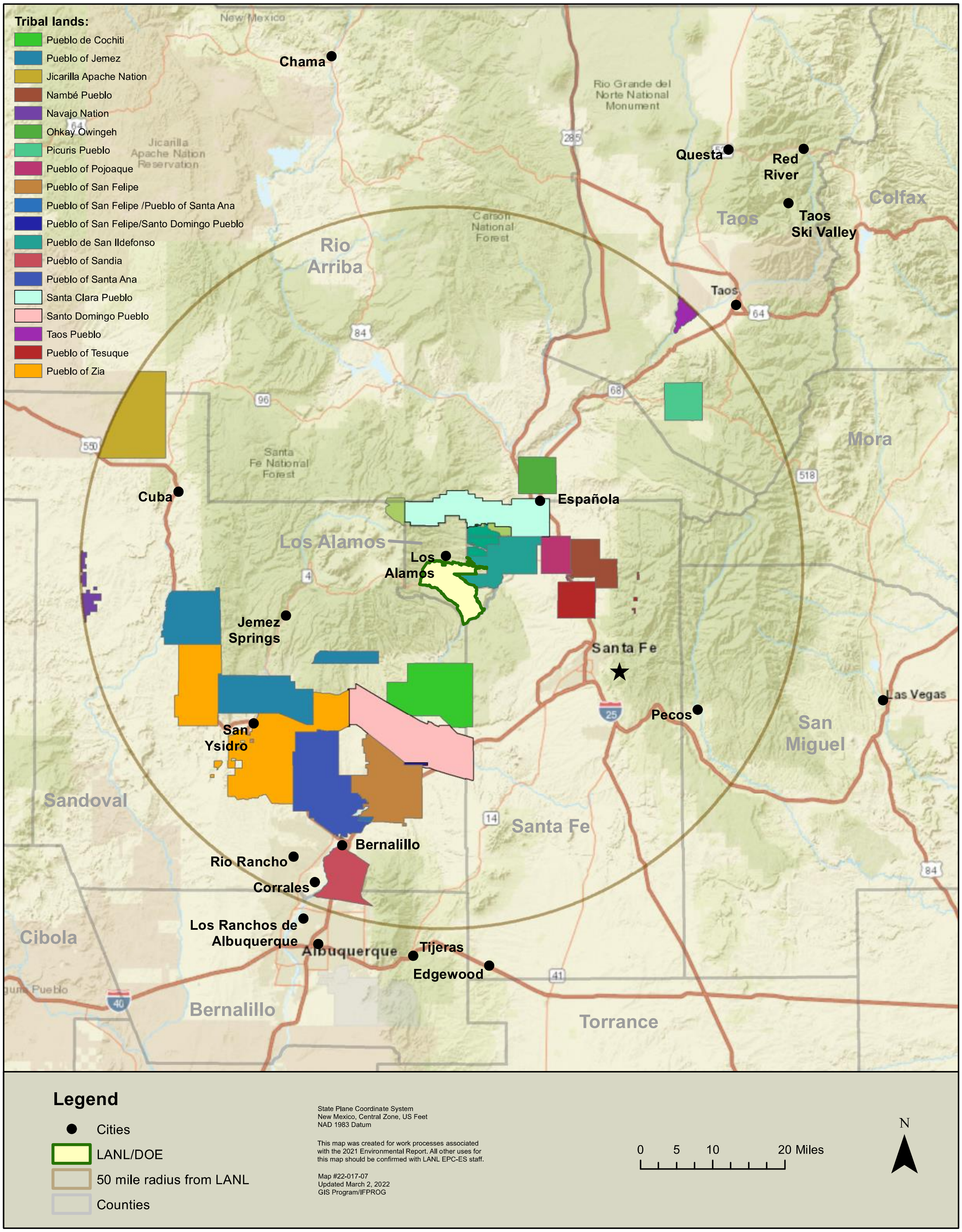

Figure 1-3. Municipalities and tribal properties within a 50-mile radius of the Laboratory

Table 1-1. Estimated Racial and Ethnic Composition of the Population Within Los Alamos, Santa Fe, Sandoval, and Rio Arriba Counties, 2016–2020 (Census 2022b)

Race	Number of People
White alone	253,983
Black or African American alone	5,525
American Indian and Alaska Native alone	29,076
Asian alone	5,371
Some other race alone	32,078
Two or more races	27,178
Ethnicity	**Number of People**
Hispanic or Latino, of any race	165,344
Not Hispanic or Latino	187,867

Geology

The Los Alamos National Laboratory site lies along a continental rift called the Rio Grande Rift. Continental rifts occur where tectonic plates in the earth's crust move apart. A rift allows magma to rise near the earth's surface, and volcanoes are common features xof rifts. The Jemez Mountains are the remnants of a cluster of volcanos. Many of the rock formations that make up the Pajarito Plateau come from materials expelled during volcanic eruptions.

The mesas of the Pajarito Plateau are mostly composed of Bandelier Tuff. Tuff is a type of soft rock that forms from hardened volcanic ash. The Bandelier Tuff is more than 1,000 feet thick in the western part of the plateau and thins to about 260 feet thick on the eastern edge of the plateau above the Rio Grande. On the western side of the Pajarito Plateau, the Bandelier Tuff overlaps the Tschicoma Formation of the Jemez Mountains. The Tschicoma Formation is an older rock layer of volcanic dacite. Eastward near the Rio Grande, the Puye Formation, a layer of sand and gravel that underlies the Bandelier Tuff, becomes visible in places. The Puye Formation can store groundwater. Basalt rocks originating from the Cerros del Rio volcanoes east of the Rio Grande mix with the Puye Formation along the river and extend beneath the Bandelier Tuff in places.

The Santa Fe Group sediment formations lie below the Puye Formation and Bandelier Tuff. These formations extend between the Jemez and Sangre de Cristo Mountains and are more than 3,300 feet thick in places. The Santa Fe Group contains a large volume of groundwater and is the regional aquifer for this area.

Rifts are associated with faults, which are fractures between two blocks of rocks. The rift boundary in the Los Alamos area consists of a local master fault and three subsidiary faults, known as the Pajarito fault zone. Past and present studies at the Laboratory investigate the earthquake hazards associated with these faults (Lee 2018).

Climate

Los Alamos County has a semiarid climate, meaning that more water is lost from the soil and plants through evaporation and transpiration than is received as annual precipitation. Annual temperatures and amounts of precipitation vary across the county because of the 5,000-foot change in elevation and the complex topography.

Four distinct seasons occur in Los Alamos County. Winters are generally mild with occasional snow storms. Spring is the windiest season. Summer is the rainy season with frequent afternoon thunderstorms. Fall is typically dry, cool, and calm.

On average, winter temperatures range from 30°F to 50°F during the day and from 15°F to 25°F during the night. The Sangre de Cristo Mountains to the east of the Rio Grande act as a barrier to wintertime arctic air masses, making the occurrence of subzero temperatures rare. On average, summer temperatures range from 70°F to 88°F during the day and from 50°F to 59°F during the night.

The rainy season begins in early July and ends in early September. Afternoon thunderstorms form in the summer as moist air from the Pacific Ocean and the Gulf of Mexico lifts over the Jemez Mountains and then often moves eastward across the Laboratory. These thunderstorms produce short, heavy downpours and an abundance of lightning. Local lightning density is estimated at 15 strikes per square mile per year.

The average annual precipitation (which includes both rain and the water equivalent of snow, hail, and any other frozen precipitation) is about 17 inches. The average annual snowfall is about 43 inches.

The complex topography of the Pajarito Plateau influences local wind patterns. Daytime winds in the Los Alamos area are predominantly from the south, as heated daytime air moves up the Rio Grande valley. Nighttime winds on the Pajarito Plateau are lighter and more variable than daytime winds and are typically from the west, a result of prevailing upper-level winds from the west and the downslope flow of cooled mountain air.

See the Meteorology section in Chapter 4, Air Quality, for more information.

Hydrology

Surface water on the Laboratory occurs primarily as ephemeral flow, associated with individual rain storms and lasting from only a few hours to days, or intermittent flow, associated with events like snow melt and lasting from only a few days to weeks. Some springs on the edge of the Jemez Mountains supply water year-round to western sections of some canyons on Laboratory property, but the amount of water is not enough to maintain surface flows across the plateau to the eastern Laboratory boundary.

Groundwater in the Los Alamos area occurs in three modes: (1) water in the near-surface sediments in the bottoms of some canyons (alluvial groundwater), (2) water in underground porous rock layers underlain by a more solid rock layer and therefore perched above the regional aquifer (intermediate-perched groundwater), and (3) water in the regional aquifer.

The regional aquifer is the only aquifer in the area with enough water to serve as a municipal water supply. The source of most water added to the regional aquifer appears to be rain and snow that fall on the Jemez Mountains. A secondary source is local infiltration of water in canyon bottoms on the Pajarito Plateau (Birdsell et al. 2005). Groundwater from the regional aquifer beneath the Laboratory discharges into the Rio Grande through springs in White Rock Canyon.

Biological Resources

The Pajarito Plateau is biologically diverse, partly because of the dramatic 5,000-foot elevation change from the Rio Grande up to the top of the Jemez Mountains and partly because of the many steep canyons that dissect the area. The major types of vegetation in this area include the following: (1) juniper woodlands with scattered piñon (*Pinus edulis*) trees between 5,300 and 7,500 feet in elevation, covering large portions of the mesa tops and south-facing canyon slopes at the lower elevations; (2) ponderosa pine (*Pinus ponderosa*) woodlands on the western portion of the plateau between 6,200 and 8,700 feet in elevation; (3) mixed-conifer woodlands and forests between 6,200 and 9,900 feet in elevation, overlapping the ponderosa pine community both in the deeper canyons and on north-facing canyon slopes and extending onto the slopes of the Jemez Mountains; (4) grasslands at all elevations, ranging from blue grama grass near the Rio Grande to montane grasses above 8,100 feet; and (5) shrublands at all elevations but especially associated with areas severely burned by wildfire (Hansen et al. 2018). Local wetlands and riparian areas also enrich the diversity of plants and animals found on the plateau.

Frequent drought conditions throughout New Mexico since 1998 have resulted in the loss of many forest and woodland trees. Between 2002 and 2005, more than 90 percent of the mature piñon trees in the Los Alamos area died from a combination of drought stress and bark beetle infestation (Breshears et al. 2005). Many mature ponderosa pine and other conifer trees in the area also have died. This mortality of forest trees is projected to continue into the 2050s (Williams et al. 2013).

Two major wildfires have affected the Laboratory: the Cerro Grande Fire in 2000 and the Las Conchas Fire in 2011. Both fires resulted in loss of forest trees on the slopes of the Jemez Mountains west of the Laboratory and were followed by large flash floods that caused extensive soil erosion and some infrastructure damage. A 1,000-year storm event in September 2013 also resulted in flooding and damage.

Cultural Resources

Surveys of approximately 90 percent of the DOE land in Los Alamos County have identified more than 1,900 prehistoric and historic cultural sites. Nearly 79 percent of the sites were constructed and used by Ancestral Pueblo people during the thirteenth, fourteenth, and fifteenth centuries. However, evidence suggests human activity from the Paleoindian Period (16,000–8,000 BC) through the Historic Period (seventeenth century–present). Cultural resource specialists at the Laboratory document and evaluate these cultural sites for their eligibility on the National Register of Historic Places.

The Laboratory itself also is associated with events of national significance in recent history. We have evaluated over 300 buildings and structures at the Laboratory used during the Manhattan Project (1943–1945) and the Cold War historical period (1945–1990) for listing in the National Register of Historic Places. Of these, 171 buildings have been declared eligible.

Established in 2014, the Manhattan Project National Historical Park, managed by the National Park Service, includes units at Hanford, Washington; Oak Ridge, Tennessee; and Los Alamos. Nine buildings associated with the design and assembly of The Gadget (the atomic bomb tested at Trinity Site in southern New Mexico in July 1945), the Little Boy weapon (the atomic bomb detonated over Hiroshima, Japan, near the end of World War II in August 1945), and the Fat Man weapon (the atomic bomb detonated over Nagasaki, Japan, near the end of World War II in August 1945) are part of the Manhattan Project National Historical Park at Los Alamos National Laboratory. Eight additional Laboratory buildings and structures, identified in the park legislation, are considered eligible for inclusion in the park.

Laboratory Activities and Facilities

The mission of the Laboratory is to solve national security challenges through simultaneous excellence—in nuclear security; mission-focused science, technology and engineering; mission operations; and community relations. Mission focus areas include

- nuclear deterrence and stockpile stewardship,
- protecting against nuclear threats,
- emerging threats and opportunities, and
- energy security solutions.

The Laboratory property is organized into 49 technical areas, which contain buildings, experimental areas, support facilities, roads, and utility rights-of-way (see

Figure 1-4 and Appendix C, Descriptions of Technical Areas and their Associated Programs). Developed areas account for less than half of the total land area; many portions of the Laboratory act as buffer areas for security, safety, and possible future expansion. The Laboratory has about 897 buildings, trailers, and transportable buildings containing 8.2 million square feet under roof (LANL 2020).

At the end of 2021, 13,626 people were employed by the primary contractors at the Laboratory and an additional 960 people were employed by staff augmentation and protective force subcontractors. The LANL-affiliated workforce resides predominantly in Los Alamos, Santa Fe, Rio Arriba, Bernalillo, Sandoval, and Taos counties and includes regular workers, temporary workers, and students.

The DOE's National Nuclear Security Administration issued a site-wide environmental impact statement for continued operation of the Laboratory in May 2008 (DOE 2008). In the 2008 Site-Wide Environmental Impact Statement, the Laboratory identified 15 facilities as being key for evaluating the potential environmental impacts of continued operation (see Table 1-2 and Figure 1-4). Activities in the key facilities represent the majority of environmental impacts associated with Laboratory operations.

The remaining Laboratory facilities were identified as non-key facilities. Examples of non-key facilities include the Nonproliferation and International Security Center; the National Security Sciences Building, which is the main administration building; and the Technical Area 46 sewage treatment facility.

Table 1-2. Key Facilities

Facility	Technical Areas
Plutonium Facility Complex	55
Chemistry and Metallurgy Research (CMR) Building	03
Sigma Complex	03
Materials Science Laboratory (MSL)	03
Target Fabrication Facility	35
Machine Shops	03
Nicholas C. Metropolis Center for Modeling and Simulation	03
High Explosives Processing (HEP) Facilities	08, 09, 11, 16, 22, 37
High Explosives Testing (HET) Facilities	14, 15, 36, 39, 40
Los Alamos Neutron Science Center (LANSCE)	53
Biosciences Facilities (formerly Health Research Laboratory)	03, 16, 35, 43, 46
Radiochemistry Facility	48
Radioactive Liquid Waste Treatment Facility (RLWTF)	50
Solid Radioactive and Chemical Waste Facilities	50, 54, 60, 63
Weapons Engineering Tritium Facility (WETF)	16

In April 2018, the DOE’s National Nuclear Security Administration published a supplemental analysis that reviewed changes at the Laboratory and evaluated the adequacy of the 2008 Site-Wide Environmental Impact Statement in analyzing anticipated impacts from LANL operations from 2018 through 2022 (DOE 2018). The supplemental analysis indicated that the environmental impacts occurring from 2008 through 2017 and those projected for 2018 through 2022 have not substantially changed from the impacts projected in the Site-Wide Environmental Impact Statement Record of Decision and are bounded by the analyses presented in the 2008 Site-Wide Environmental Impact Statement.

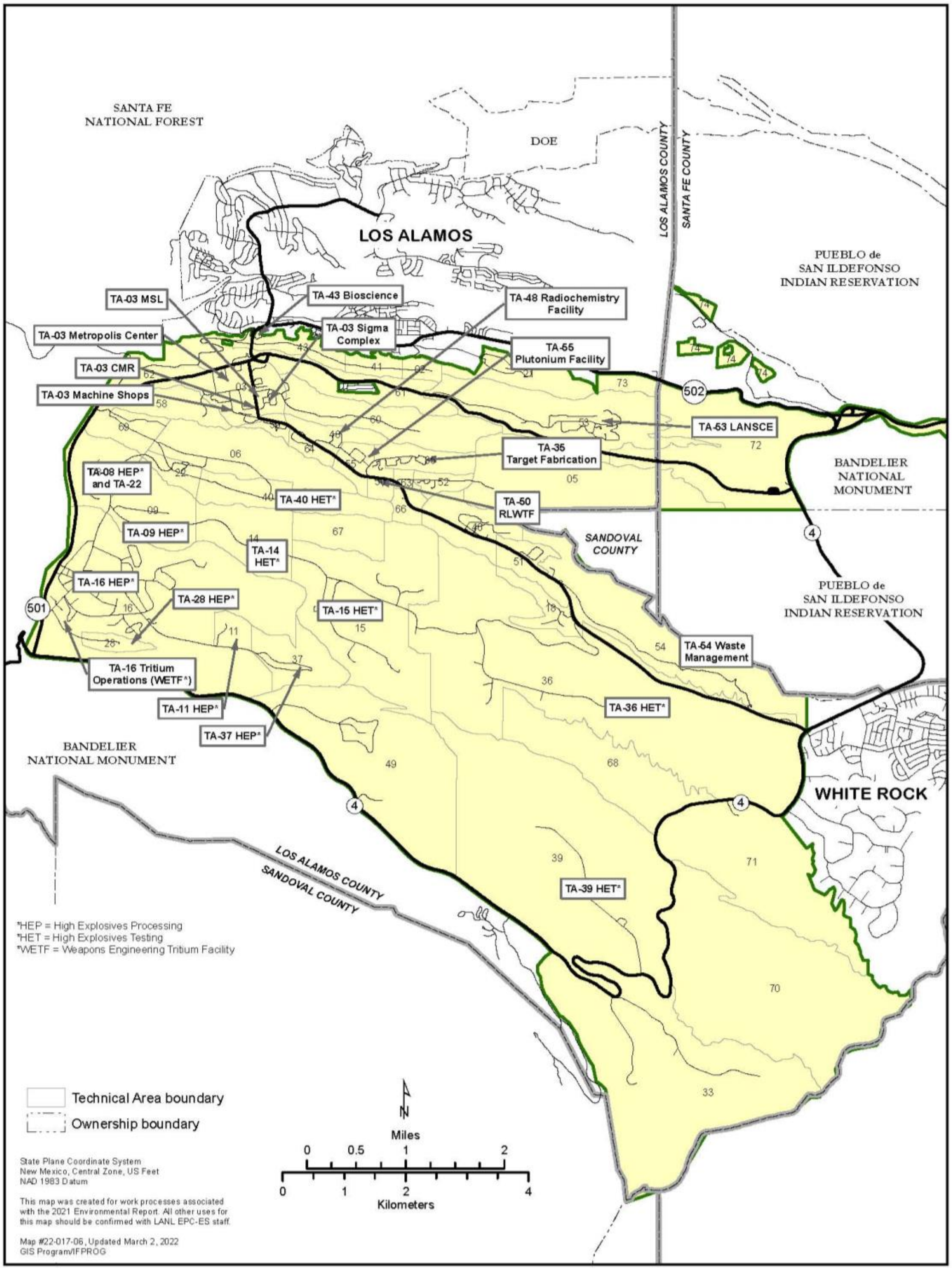

Figure 1-4. Technical Areas (TAs) and key facilities of the Laboratory

Workforce Location Changes

In 2020, the Laboratory responded to the COVID-19 pandemic with changes in some Laboratory operations. The Laboratory was identified as an essential business, and it never shut down. However, the Laboratory workforce was directed to work from home as much as possible starting in mid-March 2020. During 2020, well over half of the employees working on any given day worked at offsite locations.

The “normal operations with maximized telework” status continued for Laboratory employees for much of 2021. In addition, the Laboratory’s management and operating contractor leased new office space in Santa Fe, New Mexico, and developed a work locations procedure to allow managers to approve staff to be onsite, hybrid (perform work both onsite and offsite), telework (primarily work offsite but within a two-hour ground commute of LANL), or remote (work offsite more than a two-hour ground commute from LANL), depending on the needs of the organization. During 2021, 1,172 employees participated in a pilot telework program.

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Chapter 2: Compliance Summary

Compliance with environmental laws and orders is part of Los Alamos National Laboratory's (LANL's or the Laboratory's) environmental stewardship. This chapter provides a summary of the Laboratory's compliance with these laws and orders during 2021, including compliance with permit conditions and limits, inspections, notices of violations, occurrences, and accomplishments. Below is a partial list of the environmental laws and Department of Energy (DOE) Orders that apply to the Laboratory. A table summarizing the Laboratory's permits and compliance orders and a table listing the LANL facilities in the U.S. Environmental Protection Agency Enforcement and Compliance History Online database are provided at the end of this chapter.

Radiation Protection

- DOE Order 458.1, Radiation Protection of the Public and the Environment
- Clean Air Act – Radionuclide National Emission Standards for Hazardous Air Pollutants

Waste Management

- DOE Order 435.1, Radioactive Waste Management
- Resource Conservation and Recovery Act
- Federal Facility Compliance Act

Air Quality

- Clean Air Act
- New Mexico Air Quality Control Act

Water Quality

- Clean Water Act
- New Mexico Water Quality Act
- Energy Independence and Security Act

Natural and Cultural Resources

- National Environmental Policy Act
- National Historic Preservation Act
- Endangered Species Act
- Migratory Bird Treaty Act
- Floodplain, Wetland, and Invasive Species Executive Orders

Other Environmental Protections

- Toxic Substances Control Act
- Federal Insecticide, Fungicide, and Rodenticide Act
- New Mexico Pesticide Control Act
- DOE Order 231.1B, Environment, Safety, and Health Reporting

- DOE Order 231.2, Occurrence Reporting and Processing of Operations Information
- Emergency Planning and Community Right-to-Know Act
- DOE Order 436.1, Departmental Sustainability

Contents

Introduction

Environmental laws are designed to protect human health and the environment by

- regulating the handling, transportation, and disposal of materials;
- regulating impacts to biological and cultural resources, air, and water; and
- requiring analysis of the environmental impacts of new operations.

This chapter provides a summary of our compliance with state and federal environmental regulations and permits and DOE environmental orders during 2021, including inspections, notices of violations, and accomplishments. A table summarizing the Laboratory's environmental permits and legal orders is provided at the end of this chapter.

Radiation Protection

DOE Order 458.1 Chg 4, Radiation Protection of the Public and the Environment

DOE Order 458.1 directs DOE facilities to keep radiological doses to the public and the environment as low as reasonably achievable and to monitor for routine and non-routine releases of radioactive materials. The order requires DOE sites to do the following:

- Ensure the radiological dose to the public from their site activities does not exceed 100 millirem in any given year.
- Comply with the order's dose limits for wildlife and plants.
- Notify the public about any radiation doses resulting from operations.
- Use radiological limits authorized by the DOE to evaluate property that has the potential to contain residual radioactivity (for example, surplus equipment, waste shipped for disposal off site, or land parcels transferred to new owners) before releasing it to ensure that the dose does not exceed 25 millirem per year above background for real estate or 1 millirem per year above background for moveable items.

Estimated Maximum Possible Radiological Dose to the Public

During 2021, the estimated maximum radiological dose to a member of the public from Laboratory operations was less than 1 millirem, and radiation doses to wildlife and plants were below the annual DOE dose limits (McNaughton et al. 2022). Details of the Laboratory's annual radiological dose estimates for the public are presented in Chapter 8 and estimates for wildlife and plants are presented in Chapter 7.

Property Released from the Laboratory

Real Estate

We did not convey or transfer any land parcels during 2021.

Recycled Metals

Metals that have been exposed to ionizing radiation during Laboratory operations (potentially activated) are evaluated for levels of radioactivity before being released for recycling. About 68 tons of potentially activated metal were recycled in 2021 from the Los Alamos Neutron Science Center's accelerator operations. Releases from the Los Alamos Neutron Science Center were evaluated using the protocol in the Multi-Agency Radiation Survey and Assessment for Materials and Equipment manual and were independently reviewed by DOE. However, releases from Technical Area 21 met the criteria for unrestricted radiological release under Title 10, Part 835 of the Code of Federal Regulations, *Occupational Radiation Protection*, and DOE Order 458.1.

Portable Property

Laboratory staff survey smaller personal property items (for example, tools and furniture) from radiologically controlled areas on an on-demand basis. These items typically remain on site and, once cleared, their use is unrestricted. The policies and procedures for releasing these items comply with Title 10, Part 835 of the Code of Federal Regulations, Occupational Radiation Protection.

N3B surveyed and released personal property throughout 2021 as part of ongoing environmental remediation, waste packaging, and shipping operations. Eight mixed low-level waste, 26 low-level waste, and 33 transuranic waste shipments were prepared and released for offsite disposal.

N3B provided radiological screening and sampling to confirm the presence or absence of soil radiological contamination at Los Alamos County land parcels A-8-b and A-16-a adjacent to Technical Area 21. N3B remediated these land parcels by potholing hotspots where the presence of contamination was confirmed.

Establishment and Use of Authorized Limits

Pre-Approved Authorized Limits for radionuclides in soils are evaluated every year to determine if an update is needed. Triad implemented new DOE pre-approved authorized limits for volumetric contamination in 2021.

Waste Management Summary

Management of wastes generated by LANL operations is a crucial component of our compliance with environmental laws and is discussed in the next several sections. Table 2-1 summarizes radiological and hazardous wastes generated at LANL and their current disposal pathways. The callout box below explains some waste types.

What are the types of radioactive waste?

Transuranic Waste – Waste is classified as transuranic waste when the activity of alpha-emitting transuranic radionuclides with half-lives of 20 years or more (such as plutonium, cesium, and strontium) is greater than 100 nanocuries per gram of waste.

Mixed Transuranic Waste –Transuranic waste along with at least one component defined as hazardous under the Resource Conservation and Recovery Act.

High-Level Waste – The highly radioactive waste resulting from the reprocessing of spent nuclear fuel, transuranic waste, or tailings from the milling of uranium or thorium ore.

Low-Level Waste – Contains added radioactivity but does not contain high-level waste. It also does not contain any waste defined as hazardous under the Resource Conservation and Recovery Act.

Mixed Low-Level Waste – Low-level waste along with at least one waste defined as hazardous under the Resource Conservation and Recovery Act.

Table 2-1. LANL Waste Types and Disposal Methods

Waste Type	Method for Disposal	2021 Disposal Amount
Solid Transuranic Waste and Solid Mixed Transuranic Waste	The Laboratory sends solid transuranic and mixed transuranic wastes off site to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, when the transuranic or mixed transuranic waste meets the plant's waste acceptance criteria. Some transuranic and mixed transuranic waste is stored at LANL while waiting for an acceptable disposal pathway to be identified.	375 cubic meters
Solid Low-Level Radioactive Waste	The Laboratory sends solid low-level radioactive waste off site to licensed treatment, storage, and disposal facilities. These sites include the Nevada Nuclear Security Site, operated by the DOE, and commercial facilities operated by Energy Solutions (Clive, Utah), Perma-Fix Northwest, Inc. (Richland, Washington), and Waste Control Specialists (Andrews County, Texas).	4,622 cubic meters
Liquid Radioactive Waste	The Laboratory treats liquid radioactive waste on site at the Radioactive Liquid Waste Treatment Facility in Technical Area 50. The treated water is either evaporated or released at permitted outfall 051.	1,065,051 liters
Solid Hazardous Waste	The Laboratory sends solid hazardous waste off site for treatment and disposal at licensed treatment, storage, and disposal facilities. In 2021, these included Veolia North America (Henderson, Colorado) and Clean Harbors (Clive, Utah).	40,398 kilograms
Solid Mixed Low-Level Waste	The Laboratory sends solid mixed low-level waste off site to licensed treatment, storage, and disposal facilities. In 2021, these sites included Energy Solutions (Clive, Utah), Perma-Fix of Florida, Inc. (Gainesville, Florida), and Waste Control Specialists (Andrews County, Texas). Some mixed low-level waste is treated at one of the licensed treatment, storage, and disposal facilities to meet land disposal restrictions and is then disposed of at the Nevada Nuclear Security Site.	285 cubic meters

Waste Type	Method for Disposal	2021 Disposal Amount
Sanitary Solid Waste	The Laboratory sends sanitary solid waste, such as its office and cafeteria trash, to the Los Alamos County Eco Station for transfer to municipal landfills. Los Alamos County operates this transfer station and is responsible to the State of New Mexico for obtaining all related permits for these activities.	1,611 tons
Liquid Sanitary Waste	The Laboratory treats liquid sanitary waste onsite at the Sanitary Wastewater Treatment Plant. Treated water is reused in Laboratory cooling towers and is ultimately released at permitted outfall 001.	806,398 gallons
PCB Wastes*	Waste containing polychlorinated biphenyls (PCBs), including transformers and objects contaminated with at least 50 parts per million PCBs, were sent to U.S. Environmental Protection Agency–authorized treatment and disposal facilities, including Clean Harbors (Clive, Utah) and Veolia North America (Henderson, Colorado).	2,514 kilograms
Asbestos Waste**	Waste containing asbestos is deposited at any of several waste disposal sites operated in accordance with Title 40, Part 61, Section 154 of the Code of Federal Regulations.	178 cubic meters

**This total includes waste containing only PCBs. If a waste with PCBs also contains hazardous or low-level waste, the amount of that waste is captured in the other category.*

***This total includes waste containing only asbestos. If a waste with asbestos also contains hazardous or low-level waste, the amount of that waste is captured in the other category.*

Radioactive Wastes

DOE Order 435.1 Chg 1, *Radioactive Waste Management*

Laboratory operations using nuclear materials generate four types of radioactive wastes: low-level radioactive waste (also called low-level waste), mixed low-level waste, transuranic waste, and mixed transuranic waste. Radioactive waste generated during Laboratory operations must (1) meet Laboratory onsite storage requirements, and (2) meet requirements for transportation to and disposal at the final facility. All aspects of radioactive waste generation, storage, and disposal are regulated by DOE Order 435.1 Chg 1, *Radioactive Waste Management*, and DOE Manual 435.1-1.

Onsite Low-Level Radioactive Waste Disposal

Material Disposal Area G at Technical Area 54 (Area G) is the only active waste disposal facility at the Laboratory. Operations began at Area G in 1957 and included the disposal of low-level radioactive waste, certain infectious waste containing radioactive materials, asbestos-containing material, PCBs, and temporary storage of transuranic waste. Mixed low-level waste and mixed transuranic waste have been stored in surface structures at Area G. The capacity to dispose of low-level waste at Area G is very limited; waste is accepted for disposal only under special circumstances and with prior authorization. In 2021, N3B disposed of 106 cubic yards of low-level waste in Area G.

Planning for the closure of Area G has been underway since 1992. We are working with the New Mexico Environment Department Hazardous Waste Bureau under the 2016 Compliance Order on Consent to develop and implement corrective measures for the solid waste management units at Area G. Environmental monitoring at Area G includes (1) a direct-penetrating radiation thermoluminescent dosimeter monitoring network (Chapter 4); (2) an environmental air station monitoring network (Chapter 4); (3) a groundwater monitoring network (Chapter 5); and (4) periodic soil, vegetation, and small mammal sampling (Chapter 7). Table 2-2 provides the 2021 status of the DOE low-level waste disposal facility management process for Area G.

Table 2-2. DOE Low-Level Waste Disposal Facility Management Status for Area G

Management Process Phase	Status
Performance Assessment/ Composite Analysis	Revision 4 was approved in 2009 (LANL 2008). The annual determination of adequacy for 2020 was published in April 2021.
Closure Plan	Plan issued in 2009 (LANL 2009).
Performance Assessment/ Composite Analysis Maintenance Program	Revised Plan issued in 2021 (Neptune 2021a). Updated analyses and modeling of erosion, cliff retreat, and infiltration were completed during 2020 (Neptune 2021b, Neptune 2021c).
Disposal Authorization Statement	Revision 2 was issued November 15, 2018. This revision identifies the DOE Environmental Management Field Office in Los Alamos as the responsible field office.

Hazardous Wastes

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act regulates wastes from generation to disposal. Hazardous wastes include all solid wastes that are (1) listed as hazardous by the U.S. Environmental Protection Agency (listed wastes); (2) ignitable, corrosive, reactive, or toxic (characteristic wastes); or (3) batteries, pesticides, lamp bulbs, or contain mercury. Mixed radioactive waste (also called mixed waste) is listed as hazardous, and characteristic hazardous waste is commingled with radioactive waste. Under the Resource Conservation and Recovery Act, facilities that treat, store, or dispose of hazardous wastes, including mixed radioactive wastes, must obtain a permit from their regulatory authority.

LANL’s Hazardous Waste Facility Permit

The State of New Mexico is authorized by the U.S. Environmental Protection Agency to administer its hazardous waste management program and issue and enforce hazardous waste facility permits. On November 8, 1989, the New Mexico Environment Department issued the first LANL Hazardous Waste Facility Permit for the storage and treatment of hazardous and mixed radioactive waste at the Laboratory. The permit includes requirements that allow for the storage and sometimes the treatment of hazardous and mixed radioactive wastes at 27 separate hazardous waste management units (sites) at the Laboratory. The permit also contains requirements for waste management, sampling, reporting, inspection, training, waste minimization, preparedness and prevention, and emergency and contingency planning. The permit requires the Laboratory to post certain information for public review in an electronic information repository (electronic public reading rooms). The permit is issued to the DOE (through its field offices, the National Nuclear Security Administration Los Alamos Field Office and the DOE-Environmental Management Los Alamos Field Office), the management and operating contractor, Triad, and the legacy waste cleanup contractor, N3B.

On June 29, 2020, the Laboratory submitted an application to the New Mexico Environment Department to renew and modify the 2010 LANL Hazardous Waste Facility Permit. This renewal application consisted of the LANL General Part A Permit Application, Revision 10, and the Part B Renewal Permit Application. On March 23, 2021, the New Mexico Environment Department issued an Administratively Incomplete Determination for the permit renewal application and gave the Laboratory 60 days to respond. The New Mexico Environment Department later extended the response date to July 22, 2021. The Laboratory provided a response with additional information and supporting documents to complete the permit renewal application on July 21, 2021. The New Mexico Environment Department continued to review the application through 2021.

What do these waste terms mean?

Treatment – Any process that changes the physical, chemical, or biological characteristics of a waste to minimize its threat to the environment.

Storage – Temporary holding of waste before the waste is treated, disposed of, or stored somewhere else. A **storage unit** stores hazardous waste. Examples include tanks, containers, drip pads, and containment buildings.

Disposal – Discharge, deposit, injection, or placing of any waste on or in the land or water. A disposal facility is any site where the waste is intentionally placed and where it will remain.

Remediated Waste – Waste that has undergone treatment.

Permit Modifications, Reports, and Other Activities

The Hazardous Waste Facility Permit sometimes needs modification to address new information, changes in a facility, or changes in regulatory requirements. The three classes of modifications consist of minor modifications (Class 1 and Class 2) and major modifications (Class 3). Notices of all proposed permit modifications are published in a newspaper of general circulation, and for most types of permit modifications the notices include a request for public comment before Agency approval. Notices of approvals of permit modifications are mailed to members of the public who sign up for a LANL facility mailing list maintained by the New Mexico Environment Department.

One administrative Class 1 modification request was submitted in July 2021 to keep the permit current with routine changes to the facility and its operations. The permit modification request involved changes to the Contingency Plan in Attachment D, in which the contacts for the Primary and Alternate Incident Response Commanders were updated. The administrative Class 1 permit modification was approved on September 14, 2021.

Another Class 1 modification request was submitted in August 2021 to add a waste treatment process at Technical Area 54, Pad 11, Dome 375. New Mexico Environment Department approved this modification on October 18, 2021.

Triad and N3B coordinated to send demolition activity notifications to the New Mexico Environment Department for the quarters ending in March, June, September, and December in 2021. One fiscal year 2020 notification was also sent for the Laboratory covering all relevant demolition activities from October 1, 2020, to September 30, 2021. The fiscal year notification was submitted to the New Mexico Environment Department along with the December 2021 quarterly report. Annual waste minimization reporting, responses to requests for information from the New Mexico Environment Department, and annual electronic public reading room training were also coordinated between Triad and N3B.

A closure certification report was submitted in February 2020 documenting closure activity at the Technical Area 16-399 Burn Tray. In November 2020, the New Mexico Environment Department issued a disapproval letter for the Technical Area 16-399 Burn Tray closure certification. In response, a report was submitted to the New Mexico Environment Department in March 2021 with revised risk assessment evaluations. The New Mexico Environment Department issued a second disapproval letter with comments on May 25, 2021. After integrating the New Mexico Environment Department's comments into the risk assessment and discussion with the New Mexico Environment Department technical staff, it was determined that further soil removal was the best path forward to achieve clean closure. On August 3, 2021, the New Mexico Environment Department approved the proposed path forward.

From January 2021 through December 2021, four soil vapor monitoring reports were submitted in accordance with the permit requirements for the Technical Area 63 Transuranic Waste Facility.

Inspections, Noncompliances, and Notices of Violation

The LANL Hazardous Waste Facility Permit requires that the Laboratory provide advance written notice to the New Mexico Environment Department of any changes to any permitted unit or activity that may result in a noncompliance with the permit, and it requires verbal and written reports of the discovery of any noncompliance that may endanger human health or the environment. Instances of permit noncompliances that do not threaten human health or the environment, such as an exceedance of a storage holding time, are compiled and reported annually to the New Mexico Environment Department as required by the permit. The Laboratory submitted the fiscal year 2021 noncompliance report to the New Mexico Environment Department in December 2021. None of the following identified releases or incidents of noncompliance posed a potential threat to human health or the environment.

During the reporting period (October 1, 2020, through September 30, 2021), two releases were within or from a permitted unit under operational control of Triad. The reported releases included water overflow from a water valve left in the open position and water leakage from an eyewash station not completely closed after the monthly maintenance check.

Triad reported 10 instances of noncompliance with the LANL Hazardous Waste Facility Permit. Reported instances included notification not made within the required 10 days, container labeling, lapse in repair to asphalt in permitted unit, inspection report not completed weekly as required owing to the area being closed off, and failure to update the operating record for one container that had been shipped. Seven of the instances of noncompliance were identified by internal assessments conducted by hazardous waste management experts, and these were promptly corrected. Three instances of noncompliance were identified during an external triennial review of environmental regulatory compliance and operations.

N3B reported 10 instances of noncompliance with the LANL Hazardous Waste Facility Permit. Reported instances included improper labeling, containers with free liquids not on secondary containment pallets, improper drum stacking, missing and faded warning signs, missing spill kit, peeling of secondary containment sealant in several domes, a crack redeveloped in the floor of one dome, storm water intrusion underneath the perimeter curb in one dome, and inconsistencies with the completion/use of Inspection Report Forms. N3B personnel conducted weekly inspections to identify noncompliance with the Permit in the legacy waste cleanup program. These noncompliances have been corrected or are in the process of correction to compliant configurations with the exception of five containers with liquids. The five containers with liquids cannot immediately be placed on secondary containment because the action is not allowed by the approved nuclear evaluation of the safety of the situation. However, multiple compensatory measures are in use, including daily inspection and the use of absorbent socks/pads around each container.

The New Mexico Environment Department conducted its annual compliance inspection from October 25 through 28, 2021. The New Mexico Environment Department has not yet issued its Compliance Evaluation Inspection Report and Findings for the 2020 or the 2021 annual compliance inspections.

Settlement Agreement and Stipulated Final Order

On January 22, 2016, DOE, National Nuclear Security Administration, Los Alamos National Security, LLC (the previous management and operating contractor for the Laboratory), and the State of New Mexico signed a Settlement Agreement for resolution of potential penalties associated with the drum of transuranic waste that resulted in a 2014 contamination event at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. The settlement agreement includes five supplemental environmental projects, which the National Nuclear Security Administration and the Laboratory implemented. Below are the 2021 activities on the remaining supplemental environmental projects. The Watershed Enhancement Project and Surface Water Sampling Project are now complete.

1. Road Improvement Project – Improve routes at the Laboratory used for the transportation of transuranic waste to the Waste Isolation Pilot Plant.

   No activities in 2021.

2. Triennial Review Project – Conduct an independent, external triennial review of environmental regulatory compliance and operations.
   The second triennial review was conducted in 2021 by Parson's Enterprise Construction Management Services, and a final report was made public by posting to the Electronic Public Reading Room in September 2021.

3. Potable Water Line Replacement Project – Replace aging potable water lines and install metering equipment for Laboratory potable water systems.
   Approval of the final certification of this Supplemental Environmental Project by the New Mexico Environment Department is anticipated in 2022.

The 2016 Compliance Order on Consent

The 2016 Compliance Order on Consent (modified in 2017; available at https://www.env.nm.gov/hazardous-waste/lanl) is a settlement agreement between the New Mexico Environment Department and DOE addressing cleanup of legacy wastes. It supersedes the Compliance Order on Consent issued in 2005. The order guides and governs the ongoing cleanup of legacy waste at the Laboratory through an annual work planning process. Campaigns are planned using risk-based criteria to group, prioritize, and implement corrective actions. The annual planning process allows revisions to cleanup campaigns based on actual work progress, changed conditions, and funding.

The Laboratory has two types of legacy waste corrective action sites: (1) Solid Waste Management Units and (2) Areas of Concern. Solid Waste Management Units are areas where solid wastes were spilled or disposed of. Examples of these units include certain septic tanks, firing sites, landfills, sumps, and areas that historically received liquid effluents from outfalls. Areas of Concern are areas that may have received a hazardous waste or hazardous constituents through soil movement or the flow of liquid wastes from Laboratory facilities. Examples include canyon bottoms downstream from historical outfalls.

As of October 1, 2021, the Laboratory had 1,405 corrective action sites listed in Appendix A of the 2016 Compliance Order on Consent. During fiscal year 2021, three sites received certificates of completion with controls, 10 sites received certificates of completion without controls, and no sites were changed to a deferred status. Therefore, at the end of fiscal year 2021, 88 corrective action sites had certificates of completion with controls, 287 had certificates of completion without controls, and 134 sites were deferred until they no longer had active operations. The remaining 896 Solid Waste Management Units and Areas of Concern had investigations or corrective actions (or both) either in progress or pending.

The Compliance Order on Consent also addresses remediation of groundwater-containing contaminants that resulted from Laboratory operations. Groundwater remediation activities are discussed in detail in Chapter 5, Groundwater Protection.

During fiscal year 2021 we submitted the following documents to the New Mexico Environment Department Hazardous Waste Bureau as part of the Consent Order deliverables:

- six investigation reports,
- seven Periodic Monitoring Reports for five groundwater monitoring groups,
- one annual update on the Integrated Facility Groundwater Monitoring Program,
- one annual update for Los Alamos/Pueblo Canyon Sediment Monitoring,
- one report on the Sandia Canyon wetland performance,
- two biennial erosion control inspection reports,
- three investigation work plans and three investigation reports for investigation work set forth under the Consent Order, and
- two Corrective Measures Study/Corrective Measures Implementation progress reports.

Facility Groundwater Monitoring Program

The LANL Hazardous Waste Permit requires the permittees (DOE, Triad, and N3B) to conduct groundwater monitoring for all regulated units subject to the groundwater monitoring requirements of Title 40, Part 264, Subpart F of the Code of Federal Regulations and subject to corrective action under Permit Section 11.2.

Currently, all groundwater monitoring is conducted under the Interim Facility-Wide Groundwater Monitoring Plan (N3B 2021), which is updated annually and fulfills the groundwater monitoring requirements of the Compliance Order on Consent. While the Consent Order is in effect, the groundwater monitoring requirements of the Consent Order fulfill the groundwater monitoring requirements under the LANL Hazardous Waste Permit.

Groundwater monitoring activities conducted under the Interim Facility-Wide Groundwater-Monitoring Plan and monitoring results are discussed in Chapter 5, Groundwater Protection.

Mixed Wastes

Federal Facility Compliance Act

The Federal Facility Compliance Act requires federal facilities that generate or store mixed radioactive and hazardous wastes to submit a Site Treatment Plan that includes a schedule for developing capacities and technologies to treat all mixed waste. In October 1995, the State of New Mexico issued a Federal Facility Compliance Order to the Laboratory requiring a Site Treatment Plan for mixed radioactive and hazardous wastes.

While identifying treatment and disposal options for the mixed waste inventory, the Laboratory's Site Treatment Plan allows the Laboratory to store accumulated mixed waste at permitted storage units for more than one year, which is otherwise prohibited by the Land Disposal Restrictions provision of the Resource Conservation and Recovery Act. The Site Treatment Plan provides enforceable time periods in which the facility is required to treat or otherwise meet land disposal restriction requirements for the accumulated waste.

The Laboratory updates its Site Treatment Plan every year. An annual report describes the amount of mixed waste that has been stored at LANL under the plan provisions during the previous fiscal year and the amount shipped to approved Treatment, Storage, and Disposal Facilities. The Site Treatment Plan Report must be submitted to the New Mexico Environment Department on March 31 each year and contains data from the previous fiscal year (October 1 to September 30).

During the fiscal year 2021, mixed low-level waste covered under the Site Treatment Plan decreased from 285 cubic yards (218 cubic meters) to 200 cubic yards (153 cubic meters). This change was due to offsite shipments of 135 cubic yards (103 cubic meters), administrative adjustments of 35 cubic yards (27 cubic meters), and the addition of 14 cubic yards (11 cubic meters) of new waste.

During the fiscal year 2021, the mixed transuranic waste covered under the Site Treatment Plan decreased from approximately 2059 cubic yards (1574 cubic meters) to 1963 cubic yards (1501 cubic meters). This change was due to 322 cubic yards (246 cubic meters) shipped to the Waste Isolation Pilot Plant, administrative adjustments of 161 cubic yards (123 cubic meters), and 68 cubic yards (52 cubic meters) of new waste.

Volumes of mixed waste managed under the Site Treatment Plan at the Laboratory during fiscal year 2021 are provided in Table 2-3. These waste volumes may be adjusted slightly by reconciliation during the New Mexico Environment Department review of the Site Treatment Plan update. Approved Site Treatment Plan updates are available at http://www.env.nm.gov/hazardous-waste/lanl-ffco-stp/.

Table 2-3. Approximate Volumes of Mixed Wastes Stored and Shipped Off Site for Treatment and/or Disposal under LANL's Site Treatment Plan by the Management and Operating Contractor (Triad) and the Legacy Waste Cleanup Contractor (N3B) during Fiscal Year 2021

LANL Contractor	Volume of mixed wastes stored at LANL under the Site Treatment Plan	Volume of mixed wastes shipped off site under the Site Treatment Plan
Mixed Low-Level Waste		
Triad	14 cubic yards (11 cubic meters)	17 cubic yards (13 cubic meters)
N3B	186 cubic yards (142 cubic meters)	118 cubic yards (90 cubic meters)
Mixed Transuranic Waste		
Triad	255 cubic yards (195 cubic meters)	77 cubic yards (59 cubic meters)
N3B	1,708 cubic yards (1,306 cubic meters)	245 cubic yards (187 cubic meters)

Other Wastes

Toxic Substances Control Act

The Toxic Substances Control Act addresses the production, import, use, and disposal of specific chemicals, including PCBs. The Laboratory is responsible for record keeping and reporting the import or export of small quantities of chemicals used for LANL research activities and the disposal of PCB-containing substances. PCB-containing substances include: (1) dielectric fluids, (2) solvents, (3) oils, (4) waste oils, (5) heat-transfer fluids, (6) hydraulic fluids, (7) slurries, (8) soil, and (9) materials contaminated by spills.

Laboratory staff conducted 20 Toxic Substances Control Act reviews for chemicals imported or exported by the Laboratory's Property Management Group Customs Office in 2021. These reviews are to ensure certain chemical compounds follow the Toxic Substance Control Act requirements before being imported or exported out of the country. These shipments were all properly categorized, and the chemical compound samples were sent to collaborative researchers in other countries.

Air Quality and Protection

Clean Air Act

Title V Operating Permit

Under the Clean Air Act, the Laboratory is regulated as a major source of air pollutants based on its potential to emit nitrous oxides, carbon monoxide, and volatile organic compounds. The Laboratory has a Clean Air Act Title V Operating Permit and is required to keep air emissions of regulated pollutants below permit limits. In 2019, we submitted a five-year Title V renewal application. The Laboratory continues to operate under its existing Title V Operating permit until a final renewal permit is issued. This permitting action is summarized as follows:

- The current Title V Operating Permit has an expiration date of February 27, 2020. We were required to submit a Title V renewal application 12 months before the expiration date. We submitted the renewal application on February 26, 2019. The New Mexico Environment Department issued a draft renewal permit in 2020 and solicited public comments. The New Mexico Environment Department Air Quality Bureau anticipates issuing a new operating permit in mid-2022. In the meantime, LANL continues to operate under the existing Title V Operating permit, under the "Permit Shield" provisions of Title 20 Chapter 2 Part 70 Section 400 of the New Mexico Administrative Code.

The Laboratory annually certifies its compliance with the conditions of its Title V Operating Permit and reports any permit deviations to the New Mexico Environment Department. Deviations occur when any permit condition is not met. In 2021, no deviations were reported for the Laboratory.

Table 2-4 summarizes the Laboratory's emissions data and provides a list of the major sources of these air pollutants at the Laboratory.

Table 2-4. Calculated Emissions of Regulated Air Pollutants Reported to the New Mexico Environment Department in 2021

Emission Unit	Pollutants (tons)					
	Nitrous Oxides	Sulfur Oxides	Particulate Matter	Carbon Monoxide	Volatile Organic Compounds	Other Hazardous Air Pollutants
Asphalt plant	0	0	0	0	0	0
Technical Area 3 power plant (3 boilers)	8.93	0.12	1.18	6.16	1.14	0.29
Technical Area 3 power plant (combustion turbine)	23.41	1.62	3.15	4.87	1.02	0.64
Research and development chemical use	n/a*	n/a	n/a	n/a	6.83	5.65
Degreaser	n/a	n/a	n/a	n/a	0.035	0.035
Data disintegrator	n/a	n/a	0.38	n/a	n/a	n/a
Stationary standby generators†	2.42	0.08	0.09	0.58	0.10	0.001
Miscellaneous small boilers	19.86	0.12	1.59	15.90	1.14	0.38
Permitted generators (11 units)	2.10	0.06	0.11	2.08	0.25	0.001
TOTAL	56.72	1.98	6.50	29.59	10.52	7.01
Permit Limits (tons/year)	245	150	120	225	200	120

**n/a = not applicable*

† The stationary standby generators are no longer sources in the Laboratory's Title V permit. However, they are included in this table for comparison with previous annual site environmental reports.

The Laboratory's emissions in 2021 were significantly lower than the permit limits; for example, nitrogen oxide emissions were approximately 23 percent of the permit limit, carbon monoxide emissions were 13 percent of the permit limit, and particulate matter emissions were 5 percent of the permit limit. No emissions in excess of permit limits occurred from any of the permitted sources.

Figure 2-1 depicts a five-year history of pollutant emissions at the Laboratory. Emissions from 2017 through 2021 remained relatively constant.

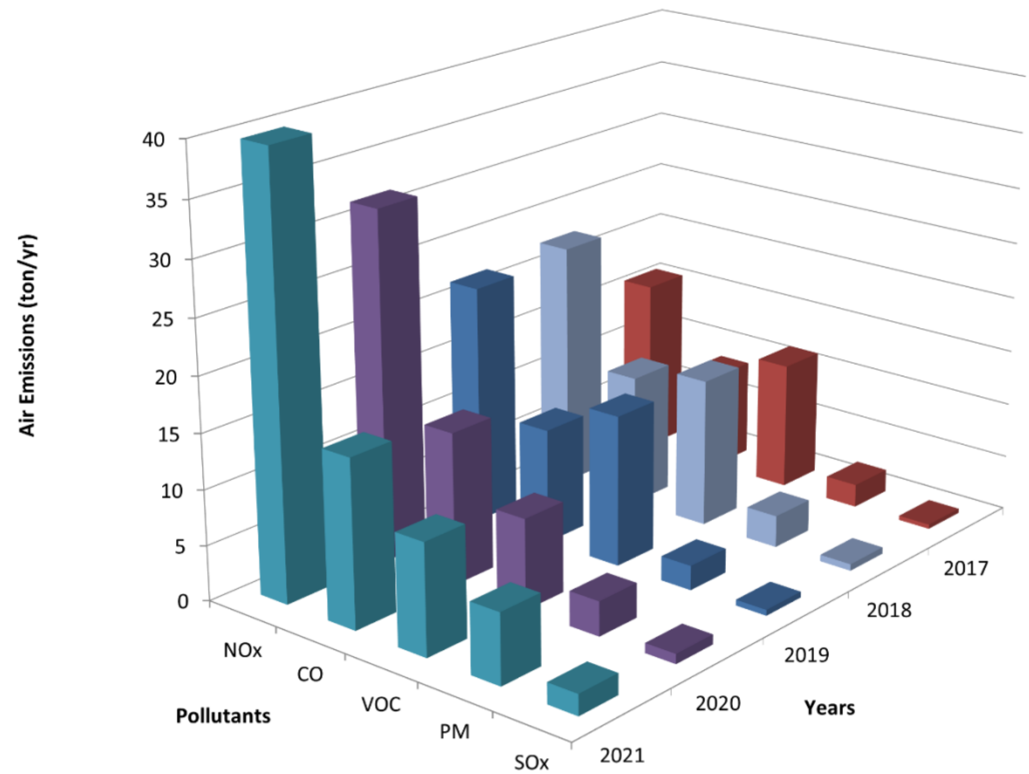

Figure 2-1. LANL criteria pollutant emissions from 2017 through 2021. These totals do not include small boilers or standby generators.

Management of Refrigerants and Halons under Title VI – Stratospheric Ozone Protection and the American Innovation and Manufacturing Act

Title VI of the Clean Air Act regulates chemicals known to deplete the ozone layer in our atmosphere, such as halons, chlorofluorocarbons, and hydrochlorofluorocarbons, as well as other non-ozone-depleting chemicals such as hydrofluorocarbons. These chemicals are primarily used as refrigerants, solvents, propellants, and foam-blowing agents. The regulations prohibit the Laboratory from knowingly venting or otherwise releasing into the environment any of these chemicals during maintenance, service, repair, or disposal of refrigeration equipment (such as air conditioners, refrigerators, chillers, or freezers) or fire-suppression systems. All technicians who work on refrigeration equipment at the Laboratory are certified by the U.S. Environmental Protection Agency. The Laboratory is working to remove refrigeration equipment that uses ozone-depleting substances and replace it with equipment using more environmentally friendly refrigerants listed as acceptable under the U.S. Environmental Protection Agency's Significant New Alternatives Program. In 2021, 2,380 pounds of refrigerant were sent off site for disposal. Of that amount, 793 pounds were hydrochlorofluorocarbons, 1,192 pounds were hydrofluorocarbons, and 395 pounds were mixed refrigerant. Additionally, the Laboratory has one remaining fire-suppression system that uses halon.

Regulation of Airborne Radionuclide Emissions under the Radionuclide National Emission Standards for Hazardous Air Pollutants

Emissions of airborne radionuclides are regulated under the Radionuclide National Emission Standards for Hazardous Air Pollutants, which sets a dose limit of 10 millirem per year to any member of the public for air emissions. The estimated maximum dose of air emissions to a member of the public in 2021 was 0.50 millirem, less than 1 percent of the limit allowed by the Clean Air Act regulations (See Chapter 8, Public Dose and Risk Assessment).

Asbestos Notifications

The Asbestos National Emission Standards for Hazardous Air Pollutants require the Laboratory to provide advance notice to the New Mexico Environment Department Air Quality Bureau for large renovation jobs that involve asbestos and for all demolition projects. The standards also require that facilities conducting activities involving asbestos mitigate visible airborne emissions and properly package and dispose of all asbestos-containing wastes. In 2021, 19 large renovation and demolition projects were completed by Triad. Advance notification to the New Mexico Environment Department was submitted for each of these projects. All other asbestos waste was properly packaged and disposed of at approved landfills. N3B did not complete any large renovation or demolition projects in 2021.

New Mexico Air Quality Control Act

New Source Reviews

The State of New Mexico requires that new or modified sources of emissions be evaluated to determine whether they (1) do not require a construction permit because they are exempted under the New Mexico Administrative Code (“exempted”), (2) do not produce sufficient emissions to require a construction permit (“no permit required”), (3) require a notice of intent to construct, or (4) require a construction permit. In 2021, LANL submitted to the New Mexico Environment Department Air Quality Bureau two air permit applications and one exemption notice as follows:

- In May 2021, LANL filed an exemption notice with the New Mexico Environment Department for 30 exempt sources, described as fuel-burning equipment used solely for heating buildings for personal comfort or for producing hot water for personal use and that use gaseous fuel rated at, less than, or equal to five million British Thermal Units per hour.
- In October 2021, an application was filed with the New Mexico Environment Department for equipment substitution at LANL’s existing asphalt plant. A new asphalt plant will be installed in the same location as the existing asphalt plant. The new equipment will replace the existing asphalt plant equipment, which falls under the General Construction Permit “substitution of equipment” category. The existing asphalt plant was decommissioned and dismantled in 2021.
- In December 2021, LANL submitted an application for a modification of the construction permit for beryllium machining at the LANL Target Fabrication Facility at Technical Area 35, Building 213. The requested revision is to New Source Review Permit No. 632,

issued on December 26, 1985. New Source Review Permit No. 632 has not been previously revised.

Surface Water Quality and Protection

Clean Water Act

The primary goal of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The Act requires National Pollutant Discharge Elimination System permits for several types of effluent and storm water discharges. The permits below contain specific chemical, physical, and biological criteria and management practices the Laboratory must meet when discharging water. The U.S. Environmental Protection Agency, Region 6, provides and enforces the Laboratory's Clean Water Act permits. The New Mexico Environment Department certifies the permits as protective of waters of the state and performs some compliance inspections and monitoring on behalf of the U.S. Environmental Protection Agency.

LANL's National Pollutant Discharge Elimination System Industrial and Sanitary Point-Source Outfall Permit (Outfall Permit)

The Laboratory's current National Pollutant Discharge Elimination System Industrial and Sanitary Point-Source Outfall Permit NM0028355 [Outfall Permit] became effective on October 1, 2014, with final modifications implemented May 2015. The permit includes one sanitary and 10 industrial outfalls that discharge into four watersheds in the region, with the amount of discharge varying from year to year (See Table 2-5).

Table 2-5. Volume of Effluent Discharged from Permitted Outfalls in 2021

Outfall No.	Building No.	Description	Canyon Receiving Discharge	2021 Discharge (gallons)
03A048	53-963/978	Los Alamos Neutron Science Center cooling tower	Los Alamos	31,874,400
051	50-1	Technical Area 50 Radioactive Liquid Waste Treatment Facility	Mortandad	235,929
04A022*	3-2238	Sigma emergency cooling system	Mortandad	736,272
03A160	35-124	National High Magnetic Field Laboratory cooling tower	Mortandad	0
03A181	55-6	Plutonium Facility cooling tower	Mortandad	2,993,804
13S	46-347	Sanitary wastewater system plant	Sandia	0
001	3-22	Power plant (includes treated effluent from sanitary wastewater system plant)	Sandia	65,195,500
03A027	3-2327	Strategic Computing Complex cooling tower	Sandia	0
03A113	53-293/952	Los Alamos Neutron Science Center cooling tower	Sandia	285,400
03A199	3-1837	Laboratory Data Communications Center	Sandia	12,175,000
05A055	16-1508	High Explosives Wastewater Treatment Facility	Water	0
			2021 Total:	113,496,305

** This outfall's designation was changed from 03A022 to 04A022 in the October 2014 permit renewal to reflect only emergency cooling water and roof drain/storm water discharges to the outfall (cooling tower blowdown was diverted to the sanitary wastewater system plant).*

The Laboratory's current Outfall Permit requires weekly, monthly, quarterly, yearly, and term sampling of the effluents (treated wastewater) released to the environment to demonstrate compliance with the permit's water quality limits. The sampling results are compared to the permit limits and are reported every month in a Discharge Monitoring Report to the U.S. Environmental Protection Agency and the New Mexico Environment Department. Additionally, any engineering changes or flow changes that would affect quality or quantity of the effluents are reported in a Notice of Planned Change to the U.S. Environmental Protection Agency and the New Mexico Environment Department.

Laboratory personnel collected 807 samples in 2021 from Outfalls 001, 03A048, 03A113, 03A181, 03A199, 04A022, and 051. Eight of these samples (1.0 percent) indicated an exceedance of a permit limit (See Table 2-6). Each exceedance was addressed immediately by correcting the cause or ceasing the discharge until corrective actions could be implemented that would return the effluent to compliance. Outfalls 13S, 03A027, 03A160, and 05A055 did not discharge in 2021.

Table 2-6. Exceedances at National Pollutant Discharge Elimination System Permitted Industrial and Sanitary Outfalls in 2021

Outfall No.	Parameter	Date	Permit Limit (milligrams/liter)	Result (milligrams/liter)	Corrective Action
001	Copper, Dissolved Daily Max	6/24/2021	0.0073	0.0618	Operations identified cooling tower cleaning operations to be the source of copper. Monitoring those operations for copper was implemented.
001	PCB Daily Average	6/29/2021	0.00000064	0.00000113	Adjusted chemicals at the water treatment plant. Operations samples collected 7/12/21, 7/16/21, 8/9/21, and 8/23/21 indicated PCB concentration below the permit limit.
001	PCB Daily Max	6/29/2021	0.00000064	0.00000113	
001	Temperature 6T3	8/08/2021	20°C	Exceeded 20°C for at least 6 hours, 3 days in a row with a max temp of 21.7°C	Resumed cooling of Sanitary Effluent Reclamation Facility effluent before discharge.
051	Total Residual Chlorine Daily Max	8/10/2021	0.011	0.19	Discharge was stopped to determine the cause of the exceedance. The exceedance is believed to be a false positive from an out-of-date reagent used by the facility's onsite laboratory. The Environmental compliance group will perform all future analysis for pH and total residual chlorine on compliance samples.
04A022	Total Residual Chlorine Daily Max	9/20/2021	0.011	0.02	Personnel closed a partially open city water valve that was open and causing the sump to overflow to the outfall.

Outfall No.	Parameter	Date	Permit Limit (milligrams/ liter)	Result (milligrams/ liter)	Corrective Action
051	Chemical Oxygen Demand Daily Average	9/14/2021	125	155	Chemical Oxygen Demand samples in October and November were well below the permit limit. The cause of the exceedance remains undetermined.
051	Chemical Oxygen Demand Daily Max	9/14/2021	125	155	Chemical Oxygen Demand samples in October and November were well below the permit limit. The cause of the exceedance remains undetermined.

The Laboratory has been working on projects to identify and reduce PCBs in water discharged to Outfall 001. Efforts have included cleaning out PCBs in upstream sumps, tanks, cleanouts, and manholes. We have also optimized the treatment process at the sanitary wastewater system treatment plant to reduce PCBs in its effluent.

The current National Pollutant Discharge Elimination System Permit NM002835 expired on September 30, 2019, and was administratively continued on October 22, 2019, by the U.S. Environmental Protection Agency. The National Pollutant Discharge Elimination System permit and regulations require the permittees to submit a reapplication to the U.S. Environmental Protection Agency 180 days before the expiration of the existing permit. The Laboratory submitted a permit reapplication on March 26, 2019, and the U.S. Environmental Protection Agency issued a draft permit for public comment on November 30, 2019. A public hearing was held on January 15, 2020, and the public comment period was extended to November 2, 2020. On November 15, 2020, the Laboratory requested that the U.S. Environmental Protection Agency reopen the comment period to allow the permittees to address comments submitted by a coalition of citizen groups. The comment period was reopened at the end of January 2021 and additional comments were submitted at the end of March 2021. LANL received its new National Pollution Discharge Elimination System Permit NM0028355 in March 2022.

National Pollutant Discharge Elimination System General Permit for Discharges of Storm Water from Construction Sites (Construction General Permit)

The National Pollutant Discharge Elimination System General Permit for Discharges of Storm Water from Construction Sites (Construction General Permit) regulates storm water discharges from construction sites covering one or more acres, or projects less than one acre that are part of a common plan of development. Laboratory compliance with the Construction General Permit includes developing storm water pollution prevention plans, conducting site inspections during construction and implementing corrective actions when necessary. Upon completion of each project, a notice of termination is submitted to the U.S. Environmental Protection Agency to terminate permit coverage. A storm water pollution prevention plan describes the project activities, site conditions, best management practices for sediment and erosion control, and permanent control measures, such as storm water detention ponds, required for reducing pollutants in storm water discharges. LANL staff inspect the location and condition of storm water controls during construction and identify corrective actions if needed.

Construction projects at LANL did not stop during the COVID-19 pandemic. Work continued and inspections were completed following the Centers for Disease Control and Prevention guidelines and LANL policies for ensuring work to be done safely and following COVID-safe practices.

In 2021, Triad was responsible for 35 storm water pollution prevention plans and performed 830 inspections, with 95.3 percent of inspections fully compliant. The DOE directly contracted one project at LANL with a storm water pollution prevention plan in 2021, which received a final inspection for Notice of Termination in July 2021.

National Pollutant Discharge Elimination System Multi-Sector General Permit for Storm Water Discharges Associated with Industrial Activities (Multi-Sector General Permit)

The Multi-Sector General Permit authorizes the discharge of storm water and allowable non-storm water associated with specific industrial activities and their associated facilities. Industrial activities conducted at the Laboratory and covered under the Multi-Sector General Permit include: (1) metals fabrication, (2) vehicle and equipment maintenance, (3) hazardous waste treatment and storage, (4) recycling activities, (5) warehousing activities, and (6) asphalt manufacturing. The purpose of the Multi-Sector General Permit is to minimize offsite migration of pollutants in storm water. The U.S. Environmental Protection Agency issued a new National Pollutant Discharge Elimination System Multi-Sector General Permit on February 19, 2021, which became effective on March 1, 2021. The 2021 Multi-Sector General Permit has some new terms and conditions relative to past Multi-Sector General Permits.

The Multi-Sector General Permit requires permittees to take actions to minimize pollutant discharges and meet the permit's effluent limitations, including minimizing exposure of materials to storm water, good housekeeping, maintenance activities, spill prevention and response, and employee training. The permit also requires permittees to conduct facility inspections and visual assessments of industrial storm water discharges and take corrective actions or "Additional Implementation Measures" as needed. Additional Implementation Measures are a new feature of the 2021 Multi-Sector General Permit. There are three levels of Additional Implementation Measures, prescribing sequential and increasingly robust storm water controls.

Under the 2021 Multi-Sector General Permit, the Laboratory is required to monitor storm water for the following types of water quality parameters at the frequency and durations listed:

- Indicator Parameters – monitored quarterly for the duration of the permit.
- Benchmark Parameters – monitored quarterly in year 1 and year 4 of the permit unless an Additional Implementation Measure–triggering event occurs, requiring continued quarterly monitoring until results indicate a return to baseline status. A benchmark exceedance means the reported concentration of the identified parameter exceeded an industry sector–specific benchmark value specified in the Multi-Sector General Permit. Benchmark values are not permit limits.
- Effluent Limitations Guidelines – monitored annually for the duration of the permit.
- Impaired Waters – monitored annually in year 1 and year 4 of the permit unless a parameter is detected, requiring continued annual monitoring until the parameter is not detected. An impaired waters exceedance means that the value exceeds a New Mexico surface water quality standard, as provided in *Standards for Interstate and Intrastate Surface Waters*, Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code.

Depending on the type of exceedance that occurs, an exceedance can trigger corrective action (Effluent Limitations Guidelines exceedance) or an Additional Implementation Measure response (benchmark exceedance). Both require evaluation of potential sources and either follow-up action or documentation of why no action is required.

Additional Implementation Measures are triggered by an exceedance of a benchmark that can occur two ways: (1) the average of four quarterly results exceeds the benchmark value, or (2) the average of fewer than four quarterly results is mathematically certain to exceed the benchmark value. Once a facility is authorized to discharge under the Multi-Sector General Permit, it is considered within a baseline status for all benchmark water quality parameters applicable to the facility. If a benchmark limit is exceeded, triggering Additional Implementation Measures, the operator must implement the appropriate controls and continue quarterly monitoring for the exceeding parameter until the average of four additional quarterly results fall below the benchmark value, resulting in a return to baseline status. An exceedance of a benchmark value that triggers Additional Implementation Measures is not considered a permit violation.

Responsibilities for Multi-Sector General Permit compliance at the Laboratory are identified by Permit Tracking Number and Operator in Table 2-7.

Table 2-7. Multi-Sector General Permit Tracking Numbers by Operator and Covered Industrial Activity

Permit Tracking No.	Industrial Activities Covered	Responsible Operator	Operator Role	Date Permit Coverage Began
NMR050011	Technical Area 54 Maintenance Facility West	N3B	Environmental Management Legacy Cleanup	June 2021
NMR050012	Technical Area 54 Areas G and L	N3B	Environmental Management Legacy Cleanup	June 2021
NMR050013	Metal fabrication, vehicle and equipment maintenance, recycling activities, electricity generation, warehousing activities, and asphalt manufacturing	Triad National Security, LLC	National Nuclear Security Administration Management and Operations and Management	June 2021

As the Laboratory's Multi-Sector General Permit implementation and compliance are operator-specific, annual compliance activities are reported separately for each operator.

Management and Operating Contractor (Triad) Compliance Summary

In 2021, Triad operated under the 2015 Multi-Sector General Permit from January 1 to June 24 and, following authorization from the U.S. Environmental Protection Agency, under the 2021 Multi-Sector General Permit from June 25 onward. Eight facilities operated by Triad are permitted under the 2021 Multi-Sector General Permit. Storm water monitoring is conducted year-round.

All corrective actions associated with exceedances recorded in 2021 have been completed. In 2021, Triad staff completed the following tasks as part of the Multi-Sector General Permit compliance:

- 92 inspections of storm water controls,
- one annual inspection at each site having “no exposure” status,
- collection of 65 samples,
- 274 inspections of ISCO® automated sampler equipment,
- 51 inspections of single stage samplers at substantially identical discharge points (discharge points that discharge storm water from the same source and with the same control measures and amount of storm water runoff per unit area),
- 10 visual inspections at nine monitored discharge points,
- 20 visual inspections at ten substantially identical discharge points, and
- 123 corrective actions including
    - 18 control measures maintained, repaired, or replaced,
    - 69 corrective actions to remedy control measures inadequate to meet non-numeric effluent limits,
    - one corrective action from change in facility operations requiring change in control measures, and
    - 35 corrective actions to address unauthorized releases (spills) or discharges.

By meeting permit-defined criteria, we were able to discontinue monitoring as summarized in Table 2-8. Monitoring for these Impaired Waters parameters was discontinued because they were not detected in storm water samples during year 1 of the permit.

Table 2-8. 2021 Parameters with Discontinued Monitoring until Permit Year 4

Monitoring Type	Parameter	Discharge Point(s)
Impaired Waters	Mercury, total	031
Impaired Waters	Total Aroclors	022, 026, 031, 032, 042, 075, 076, 077

Table 2-9 summarizes the exceedance of quarterly benchmarks for Triad’s National Pollutant Discharge Elimination System Multi-Sector General Permit.

Table 2-9. 2021 Exceedances of the Management and Operating Contractor’s National Pollutant Discharge Elimination System Multi-Sector General Permit Quarterly Benchmarks

Discharge Point	Exceeded Parameters	Date Exceeded
	Nitrate plus Nitrite Nitrogen	
022	✓ Additional Implementation Measure Level 1	12/24/2021

NOTES: A benchmark exceedance means the reported concentration of the identified parameter in a representative quarterly storm water sample exceeded an industry sector-specific benchmark value specified in the Multi-Sector General Permit. Benchmark values are not permit limits.

Legacy Cleanup Contractor (N3B) Compliance Summary

Two Laboratory facilities (Technical Area 54, Areas G and L and Maintenance Facility West) subject to N3B control are permitted under the 2021 Multi-Sector General Permit. Both facilities received authorization to discharge under the 2021 Multi-Sector General Permit in June 2021, and monitoring under that permit began on August 1, 2021. Monitoring of storm water discharges at N3B-permitted facilities occurs between April 1 and November 30 each year.

Compliance Summary

The following tasks were completed by N3B during 2021 as part of Multi-Sector General Permit compliance:

- Four routine facility inspections were conducted at each Multi-Sector General Permit–covered facility.
- 38 quarterly visual inspections of storm water discharges from monitored outfalls/substantially identical discharge points were completed.
- Annual Impaired Waters monitoring samples were collected from all six monitored outfalls (five at Technical Area 54 Areas G and L and one at Maintenance Facility West).
- Seven quarterly benchmark samples were collected from five monitored outfalls at Technical Area 54, Areas G and L.
- Nine corrective actions were initiated to address needed maintenance or in response to storm water exceedances of benchmark values or a New Mexico surface water quality standard.
- Employee training in accordance with Part 2.1.2.8 of the Multi-Sector General Permit was conducted.
- Annual Impaired Waters samples were collected from four monitored outfalls at Technical Area 54, Areas G and L and Maintenance Facility West.

2021 was N3B's first year of monitoring these facilities under the 2021 Multi-Sector General Permit. Table 2-10 summarizes exceedances of Impaired Waters parameters and benchmark values in storm water samples collected in 2021 from N3B-controlled facilities.

Table 2-10. 2021 Exceedances of the N3B's National Pollutant Discharge Elimination System Multi-Sector General Permit Benchmark Values or Impaired Waters Parameters*

N3B Facility	Monitored Discharge Point	Exceedance							Sample Date(s)
		Benchmarks				Impaired Waters			
		Total Cadmium	Dissolved Cadmium	Total Selenium	Chemical Oxygen Demand	Adjusted Gross Alpha	Total Recoverable Aluminum	Dissolved Copper	
Technical Area 54 Maintenance Facility West	049	n/a	n/a	n/a	n/a	✓	✓	✓	8/2/2021
Technical Area 54 Areas G and L	050	✓	✓		✓		n/a	n/a	10/26/21
Technical Area 54 Areas G and L	051	✓		✓		✓	✓		8/22/2021
Technical Area 54 Areas G and L	069				✓	✓		✓	8/2/2021, 10/26/2021 (Chemical Oxygen Demand only)
Technical Area 54 Areas G and L	072				✓		n/a	n/a	8/22/2021

NOTES: A benchmark exceedance means the reported concentration of the identified parameter in a representative quarterly storm water sample exceeded an industry sector-specific benchmark value specified in the Multi-Sector General

Permit. Benchmark values are not permit limits. An impaired waters exceedance means the reported concentration of the identified parameter in a representative storm water sample exceeded a receiving water segment-specific New Mexico surface water quality standard as provided in Standards for Interstate and Intrastate Surface Waters, *Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code. n/a indicates monitoring for the specified parameter is not applicable to the corresponding outfall.*

LANL's Individual Permit Authorization to Discharge under the National Pollutant Discharge Elimination System (from Solid Waste Management Units and Areas of Concern) (Storm Water Individual Permit)

The Individual Permit Authorization to Discharge under the National Pollutant Discharge Elimination System (Storm Water Individual Permit) authorizes discharges of storm water from certain Solid Waste Management Units and Areas of Concern (hereafter called sites) at the Laboratory. The permit lists 405 sites that must be managed to remain in compliance with its terms and conditions. The objective is to prevent storm water runoff from transporting pollutants of concern from these sites to surface waters. Pollutants of concern potentially occurring at these sites include metals, organic chemicals, high explosives, and radionuclides.

The U.S. Environmental Protection Agency issued the original permit in 2010 and it has been administratively continued. A new draft permit was issued by the U.S. Environmental Protection Agency in November 2019 for public comment; a public hearing was conducted October 2020. In November 2020, the New Mexico Environment Department issued a state certification of the Storm Water Individual Permit. We submitted a petition for review of the state certification to the New Mexico Secretary of the Environment and comments on the state certification to the U.S. Environmental Protection Agency and the New Mexico Environment Department in December 2020 and January 2021. On December 30, 2021, a settlement agreement was signed by the New Mexico Environment Department and the permittees regarding the state certification.

The Storm Water Individual Permit has technology-based requirements for storm water control. Technology-based requirements means that storm water controls reflecting best industry practices, considering their availability, economic achievability, and practicability, are required at each of the 405 permitted sites. Examples of controls used to manage storm water under the Storm Water Individual Permit include retention berms and coir logs. These storm water controls are routinely inspected and are maintained as needed. The permit required LANL to install baseline controls at all 405 sites. These were completed and certified to the U.S. Environmental Protection Agency by 2011.

The 405 sites have been grouped into 250 small sub-watersheds, called site monitoring areas, for permit monitoring. Specific locations within each of the site monitoring areas are used to sample the storm water runoff from the sites.

If target action levels of pollutants, which are based on the New Mexico surface water quality standards, are exceeded in the storm water samples, corrective action and additional controls called "enhanced controls" are installed. Additional storm water sampling is required and is referred to as "corrective action monitoring." Site monitoring areas where we have not collected sufficient storm water samples to evaluate the target action levels, for example, because of a lack of local rainfall, are referred to as being in "extended baseline monitoring."

If all control measures have been installed and the results of sampling confirm that all pollutants of concern for a site-monitoring area are below the target action levels, the Laboratory certifies to the U.S. Environmental Protection Agency that the corrective actions are complete for the sites in that site monitoring area.

If all the storm water control measures have been installed, but the Laboratory cannot demonstrate that all results are below target action levels (for example, if natural background concentrations at the site are above the target action levels), the Laboratory can request that a site be placed in alternative compliance. For a site placed in alternative compliance, the corrective action is completed under an individual site compliance schedule determined by the U.S. Environmental Protection Agency.

In summary, the process of complying with the Storm Water Individual Permit can be broken down into five steps: (1) installation and maintenance of control measures, (2) storm water sampling to determine effectiveness of control measures, (3) additional corrective action if a target action level is exceeded, (4) reporting results of fieldwork and monitoring to the U.S. Environmental Protection Agency and the New Mexico Environment Department, and (5) certification of corrective action complete or requests for alternative compliance to the U.S. Environmental Protection Agency.

2021 Accomplishments

Despite the COVID-19 related impacts in 2021, we completed the following tasks to comply with the requirements of the Storm Water Individual Permit:

- Published an update to the 2020 Site Discharge Pollution Prevention Plan, which identified pollutant sources, described control measures, and defined monitoring at all permitted sites.
- Published the “Storm Water Individual Permit Annual Report for Reporting Period January 1–December 31, 2020,” which presents the compliance status for all permitted sites, activities conducted, and milestones accomplished to comply with the Storm Water Individual Permit.
- Completed 1,424 inspections of storm water controls at the 250 site monitoring areas.
- Completed 884 sampling equipment inspections.
- Conducted storm water monitoring at 138 site monitoring areas.
- Collected extended baseline confirmation samples at two site monitoring areas.
- Collected corrective action confirmation monitoring samples at 17 site monitoring areas.
- Installed 22 additional control measures at 16 site monitoring areas.
- Held two public meetings as required by the Storm Water Individual Permit.
- Submitted analytical results following certification of enhanced controls at 34 site/site monitoring area combinations.
- Submitted analytical results following certification of a no-exposure condition at four site/site monitoring areas combinations.
- Submitted certification of enhanced controls at 20 site/site monitoring area combinations.
- Submitted certification of complete corrective action following a certificate of completion from the New Mexico Environmental Department at one site/site monitoring area combination.
- Continued to support the Storm Water Individual Permit reapplication effort.

For more information on surface water quality at the Laboratory, see Chapter 6, Watershed Quality.

Table 2-11 summarizes the exceedance of target action levels for storm water samples collected in 2021 for the Storm Water Individual Permit.

Table 2-11. 2021 Exceedances of LANL's National Pollutant Discharge Elimination System Storm Water Individual Permit Target Action Levels

Site Monitoring Area (SMA)	Parameter	Type of Exceedance	Number of Exceedances	Total Number of Samples Taken	Sample Date(s)
CDB-SMA-1	Aluminum	maximum target action level	1	1	08/03/2021
	Copper	maximum target action level	1	1	
	Gross alpha	average target action level	1	1	
	Total PCB	average target action level	1	1	
CDV-SMA-7	Gross alpha	average target action level	1	1	08/26/2021
CHQ-SMA-0.5	Gross alpha	average target action level	1	1	08/03/2021
	Total PCB	average target action level	1	1	
CHQ-SMA-1.02	Copper	maximum target action level	2	2	05/31/2021 08/03/2021
	Gross alpha	average target action level	2	2	
	Total PCB	average target action level	2	2	
CHQ-SMA-6	Copper	maximum target action level	2	2	05/31/2021 07/25/2021
	Gross alpha	average target action level	2	2	
F-SMA-2	Aluminum	maximum target action level	1	1	08/26/2021
	Copper	maximum target action level	1	1	
	Gross alpha	average target action level	1	1	
	Selenium	maximum target action level	1	1	
M-SMA-13	Aluminum	maximum target action level	1	1	08/26/2021
	Copper	maximum target action level	1	1	
PJ-SMA-3.05	Copper	maximum target action level	1	1	07/27/2021
	Gross alpha	average target action level	1	1	
PJ-SMA-5	Copper	maximum target action level	1	1	05/30/2021
PJ-SMA-9	Copper	maximum target action level	1	1	07/27/2021
PJ-SMA-11	Copper	maximum target action level	2	2	06/27/2021 08/26/2021
	Gross alpha	average target action level	2	2	
PJ-SMA-11.1	Copper	maximum target action level	1	1	08/26/2021
	Gross alpha	average target action level	1	1	
PJ-SMA-19	Gross alpha	average target action level	1	1	08/22/2021
	Total PCB	average target action level	1	1	
PT-SMA-2	Copper	maximum target action level	1	1	08/26/2021
	Gross alpha	average target action level	1	1	
PT-SMA-4.2	Gross alpha	average target action level	1	1	08/22/2021
S-SMA-6	Copper	maximum target action level	1	1	08/26/2021
	Gross alpha	average target action level	1	1	
	Lead	maximum target action level	1	1	
STRM-SMA-4.2	Copper	maximum target action level	1	1	07/27/2021
	Silver	maximum target action level	1	1	
T-SMA-1	Aluminum	maximum target action level	1	1	08/26/2021
	Copper	maximum target action level	1	1	
	Gross alpha	average target action level	1	1	
	Selenium	maximum target action level	1	1	
	Total PCB	average target action level	1	1	
W-SMA-7.8	Gross alpha	average target action level	1	1	05/30/2021
W-SMA-11.7	Aluminum	maximum target action level	1	1	08/26/2021

Site Monitoring Area (SMA)	Parameter	Type of Exceedance	Number of Exceedances	Total Number of Samples Taken	Sample Date(s)
	Gross alpha	average target action level	1	1	

** The maximum target action level is the target for individual maximum values recorded at a site, and the average target action level is the target for the geometric mean of applicable monitoring results at a site. Target action levels are benchmarks, not permit limits.*

Aboveground Storage Tank Program

The Laboratory's Aboveground Storage Tank Program manages compliance with the requirements of the U.S. Environmental Protection Agency under the Clean Water Act and with the New Mexico Administrative Code regulations administered by the New Mexico Environment Department's Petroleum Storage Tank Bureau. The Laboratory manages 11 registered aboveground storage tank systems and manages 17 Spill Prevention, Control, and Countermeasure plans.

Because of the COVID-19 pandemic there were no formal onsite compliance inspections by the Petroleum Storage Tank Bureau in 2021. However, a New Mexico Environment Department Petroleum Storage Tank Bureau inspector conducted two site visits to oversee tank system maintenance and repair work. In 2021, a new Petroleum Storage Tank Bureau regulation requiring third-party testing of alarms, sensors, spill prevention, and control devices came into effect and LANL met this requirement for its aboveground storage tank systems. LANL is working with the Petroleum Storage Tank Bureau to develop a permanent closure plan for an aboveground fuel storage tank that has been out of service since 2013.

Federal regulations administered by the U.S. Environmental Protection Agency require Spill Prevention, Control, and Countermeasure plans for facilities with aboveground storage tank systems and regulated oil-filled equipment. In 2021, Laboratory staff completed amendments to two plans, began updates to two plans, and began preparing two new plans owing to planned increases in oil storage at two facilities. Laboratory staff conducted all annual and monthly inspections for the facilities as required.

Clean Water Act Section 404/401 Permits

Section 404 of the Clean Water Act requires that the Laboratory receive verification from the U.S. Army Corps of Engineers that proposed projects within perennial or intermittent watercourses comply with Clean Water Act nationwide permit conditions. Effective June 22, 2020, ephemeral streams are no longer considered by the U.S. Army Corps of Engineers for Section 404 compliance under the 2020 Navigable Water Protection Rule.

Section 401 of the Clean Water Act requires states to certify that Section 404 permits issued by the U.S. Army Corps of Engineers comply with state water quality standards. The New Mexico Environment Department reviews Section 404/401 permit applications and issues separate Section 401 certification letters, which may include additional requirements to meet state stream standards for individual Laboratory projects.

Section 404/401 verifications and certifications that were issued or active at the Laboratory in 2021 are listed in Summary of Permits and Legal Orders section at the end of this chapter.

The Energy Independence and Security Act: Storm Water Management Practices

Section 438 of the Energy Independence and Security Act of 2007 establishes storm water runoff requirements for federal development and redevelopment projects. Any federal project over 5,000 square feet that alters the flow of water over the surface of the ground must implement low-impact development controls to maintain water temperatures, flow rates, flow volumes, and durations that were present before development. Examples of appropriate controls include vegetated swales, infiltration basins, permeable pavement, vegetated strips, rain barrels, and cisterns. The goal is to manage runoff through infiltration, evapotranspiration, or harvest and reuse.

The Laboratory identifies projects for Section 438 compliance through the permits and requirements identification process and excavation permitting. LANL's Environmental Protection and Compliance Division is responsible for implementing Section 438 compliance. Staff work with internal and subcontractor design and construction personnel to meet the requirements. Section 438 guidance is published in the LANL Engineering Standards Manual.

In 2021, four projects were completed that required Energy Independence and Security Act compliance. As part of their Section 438 compliance, the Technical Area 3 Building 2643 Parking Garage Project, Technical Area 50 Building 305 Parking Garage Project, Technical Area 3 Multi-Use Office Building Project, and Technical Area 55 Asphalt Pad Project used swales, detention/infiltration basins, and revegetation to manage storm water discharge. All Energy Independence and Security Act requirements for these projects were completed in 2021.

New Mexico Water Quality Act: Surface Water Protection

Under the New Mexico Water Quality Act, the New Mexico Water Quality Control Commission adopts standards for surface waters of the state. *Standards for Interstate and Intrastate Surface Waters*, Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code, defines designated surface water uses for the state, sets water quality criteria to protect those uses, and provides an anti-degradation policy. The Laboratory's National Pollutant Discharge Elimination System permits, along with any dredge and fill activities approved under Section 404 of the Clean Water Act, must be certified by the New Mexico Environment Department to ensure New Mexico water quality standards are met. In 2021, during the Triennial Review, the Water Quality Control Commission considered changes to the Laboratory's surface water classifications based on studies conducted by LANL and the New Mexico Environment Department. The changes, formally adopted by the Water Quality Control Commission in March of 2022, added three miles of streams to more protective aquatic life uses.

Additionally, under Section 303(d) of the Clean Water Act, the New Mexico Environment Department determines which stream reaches (delineated as assessment units) within the state are impaired for the assessment units' designated use(s). The New Mexico Environment Department uses the Laboratory's surface water monitoring data in developing its list of impaired waters for the assessment units on Laboratory property. The discharge limits and monitoring requirements in the Laboratory's National Pollutant Discharge Elimination System permits are determined, in part, by the impairment status of affected water courses. In 2021, most assessment units at the Laboratory were sometimes listed as impaired because of naturally occurring substances. See Chapter 6, Watershed Quality, for more information.

Groundwater Quality and Protection

Safe Drinking Water Act

The Los Alamos County Department of Public Utilities supplies water for Los Alamos, White Rock, the Laboratory, and Bandelier National Monument. The Department issues an annual drinking water quality report, as required by the Safe Drinking Water Act. The 2021 report is available at https://www.losalamosnm.us/common/pages/DisplayFile.aspx?itemId=18583904. For 2021, the drinking water quality for Los Alamos met all U.S. Environmental Protection Agency regulations.

New Mexico Water Quality Act: Groundwater Quality Standards

In FY 2021, we reported to the New Mexico Environment Department 15 instances of a contaminant detected in groundwater at a location where the contaminant had not been previously detected above a standard or screening level (See Table 2-12). The standards and screening levels for this reporting requirement include: (1) the New Mexico Environment Department Soil Screening Levels Summary Table A-1 Values for Tap Water, (2) the New Mexico Water Quality Control Commission groundwater standards, and (3) the U.S. Environmental Protection Agency maximum contaminant levels.

Table 2-12. 2021 Locations with First-Time Groundwater Quality Standard or Screening Level Exceedances

Parameter Name	Location (well or spring)	Groundwater Zone	Sample Date	Result	Standard or Screening Level Value	Units	Type of Standard or Screening Level
Nitrosodimethylamine [N-]	R-69 S2	Regional Aquifer	03/09/2021	0.00835	0.00491	µg/L	New Mexico Environment Department Tap Water Screening Level[a]
Nitrosodimethylamine [N-]	R-68	Regional Aquifer	03/09/2021	0.00628	0.00491	µg/L	New Mexico Environment Department Tap Water Screening Level
Nitrosodimethylamine [N-]	R-69 S1	Regional Aquifer	03/09/2021	0.0110	0.00491	µg/L	New Mexico Environment Department Tap Water Screening Level
Perfluorohexanesulfonic acid	LAUZ-1	Alluvial	06/09/2021	284	70	ng/L	New Mexico Environment Department Tap Water Screening Level
Perfluorooctanesulfonic acid	LAUZ-1	Alluvial	06/09/2021	113	70	ng/L	New Mexico Environment Department Tap Water Screening Level
Perfluorooctanoic acid	LAUZ-1	Alluvial	06/09/2021	123	70	ng/L	New Mexico Environment Department Tap Water Screening Level
Nickel	LAOI-7	Perched-Intermediate	08/11/2021	502	200	µg/L	New Mexico Groundwater Standard[b]
RDX	Bulldog Spring	Perched-Intermediate Spring	09/14/2021	11.8	9.66	µg/L	New Mexico Environment Department Tap Water Screening Level
Nitrosodiethylamine[N-]	R-69 S2	Regional Aquifer	09/21/2021	0.0341	0.00167	µg/L	New Mexico Environment Department Tap Water Screening Level
Benzo(a)anthracene	R-55 S1	Regional Aquifer	10/15/2021	0.314	0.12	µg/L	New Mexico Environment Department Tap Water Screening Level
Chromium[c]	CRPZ-1	Regional Aquifer	11/04/2021	72.5	50	µg/L	New Mexico Groundwater Standard

Parameter Name	Location (well or spring)	Groundwater Zone	Sample Date	Result	Standard or Screening Level Value	Units	Type of Standard or Screening Level
Chromium[c]	CrPZ-2a	Regional Aquifer	11/10/2021	239	50	µg/L	New Mexico Groundwater Standard
Chromium[c]	CRPZ-3	Regional Aquifer	11/09/2021	300	50	µg/L	New Mexico Groundwater Standard
Chromium[c]	CRPZ-4	Regional Aquifer	11/10/2021	92.5	50	µg/L	New Mexico Groundwater Standard
Chromium[c]	CRPZ-5	Regional Aquifer	11/22/2021	411	50	µg/L	New Mexico Groundwater Standard

[a] New Mexico Environment Department Soil Screening Levels Summary Table A-1 Values for Tap Water ("Risk Assessment Guidance for Site Investigations and Remediation") published June 2019.
[b] New Mexico Water Quality Control Commission groundwater standards published December 21, 2018.
[c] Regional aquifer piezometers in the Chromium Investigation monitoring group area were recently incorporated to be sampled as part of the Interim Facility-Wide Groundwater Monitoring Plan for the 2022 Monitoring Year (See section 3.3 of the Monitoring Year 2022 Interim Facility-Wide Groundwater Monitoring Plan). This result was from the first sampling under this plan and therefore now qualifies for reporting under the Monthly Notification of Groundwater Data mechanism. Previous sampling of the piezometers provided screening level results and those values or trends generally conform with this reported result.
Note: µg/l = micrograms per liter; ng/l = nanograms/liter New Mexico Ground Water Standard.

New Mexico Water Quality Act: Groundwater Discharge Regulations

Under the New Mexico Water Quality Act, the New Mexico Water Quality Control Commission sets regulations for liquid discharges onto or below ground surfaces to protect groundwater. The New Mexico Environment Department enforces the groundwater discharge regulations and may require a facility that discharges effluents to submit a discharge plan and obtain a permit. In 2021, the Laboratory had four discharge permits and one discharge permit application pending a decision. Sample results are compared to the standards and screening levels presented in the New Mexico Water Quality Act: Groundwater Quality Standards section and are reported to the New Mexico Environment Department.

Technical Area 46 Sanitary Wastewater System Plant Discharge Permit DP-857

On December 16, 2016, the Laboratory was issued a renewal and modification for Discharge Permit DP-857, which applies to combined effluent discharges from the Technical Area 46 Sanitary Wastewater System plant, the Sanitary Effluent Reclamation Facility, and the Sigma Mesa evaporation basins.

The permit requires quarterly, semi-annual, and/or annual sampling of (1) the Sanitary Wastewater System Plant's treated water, (2) effluent from National Pollutant Discharge Elimination System Outfalls 001, 03A027, and 13S (outfalls that can discharge water from the sanitary wastewater system plant), (3) water collected in the Sigma Mesa evaporation basins, and (4) groundwater from wells located in Sandia Canyon. In 2021, one sample collected from National Pollutant Discharge Elimination Outfall 001 exceeded the tap water screening guidance level for bromodichloromethane, a disinfection byproduct. A downgradient intermediate well, SCI-1, was monitored quarterly for bromodichloromethane in 2021, but this compound was not detected in any samples collected. No inspections of Discharge Permit DP-857 facilities were conducted in 2021.

Domestic Septic Tank Disposal Systems Discharge Permit DP-1589

On July 22, 2016, the New Mexico Environment Department issued Discharge Permit DP-1589 to the Laboratory for discharges from septic tank disposal systems. These septic systems (a combined septic tank and leach field) are in remote areas of the Laboratory where access to the sanitary wastewater system plant's collection system is not practicable. There are currently six active septic tank disposal systems at the Laboratory.

Discharge Permit DP-1589 requires monitoring and inspections for the Laboratory's septic tank disposal systems. These actions include, but are not limited to, the following: (1) routine septic tank sampling, (2) septic tank water-tightness testing, (3) annual pumping and septic tank inspection, and (4) inspection of the leach field disposal system.

The permit conditions require semi-annual and annual sampling of water from active septic tank disposal systems. In 2021, the following exceedances of groundwater standards were detected: the Technical Area 33-0375 septic tank exceeded for total nitrogen, iron, and phenol, and the Technical Area 33-0179, Technical Area 39-0132, and Technical Area 58-0052 septic tanks each exceeded for total nitrogen. All results were reported to the New Mexico Environment Department. No inspections of Discharge Permit DP-1589 facilities were conducted in 2021.

Technical Area 50 Radioactive Liquid Waste Treatment Facility Discharge Plan and Permit Application DP-1132

The Laboratory first submitted a discharge plan and permit application for the Radioactive Liquid Waste Treatment Facility at Technical Area 50 in 1996. After a process involving an updated permit application and several permit hearings and permit actions, the New Mexico Environment Department's Ground Water Quality Bureau posted Public Notice of Draft DP-1132, which includes financial assurance provisions, on December 17, 2021, for public review and comment. Beginning in 2018, the New Mexico Environment Department granted 120-day Temporary Permissions for discharges while the permitting process continues. The Temporary Permissions require the Laboratory to implement operational, monitoring, and closure actions through work plans for certain units and/or systems at the Radioactive Liquid Waste Treatment Facility. Examples of these actions are (1) monthly and quarterly sampling of treated effluent; (2) quarterly and annual groundwater monitoring at seven alluvial, perched-intermediate, and regional aquifer wells; (3) the installation of a soil moisture monitoring system beneath the Technical Area 52 solar evaporation tank; and (4) the removal from service of seven tanks that do not have secondary containment. In 2021, bromodichloromethane and pentachlorophenol were detected above applicable groundwater standards or tap water screening guidance levels at National Pollutant Discharge Elimination Outfall 051. No compliance inspections were conducted in 2021. All groundwater monitoring well samples met groundwater quality standards except for detections of nitrate and perchlorate at MCOI-6. More information about well sampling results is presented in Chapter 5, Groundwater Protection.

Land Application of Treated Groundwater Discharge Permit DP-1793

In 2015 the New Mexico Environment Department issued Discharge Permit DP-1793 to the Laboratory for the discharge of treated groundwater by land application (spraying treated groundwater onto the surface of the ground). On April 30, 2018, operational responsibility for DP-1793 was transferred to N3B. Activities involving land application of treated groundwater include well pumping tests, aquifer tests, and well rehabilitation. Under the permit, individual work plans must be submitted for each land application project. Work plans are posted to the Laboratory's Electronic Public Reading Room for a 30-day public comment period. Each work plan addresses how groundwater will be treated so that constituent concentrations are less than 90 percent of the New Mexico groundwater standards before discharge.

The term of DP-1793 was five years, which ended in 2020. To continue operations under DP-1793, a renewal application was submitted on January 29, 2020. The Laboratory continues to operate under the DP-1793 permit until a final renewal permit is issued by the New Mexico Environment Department Ground Water Quality Bureau.

Injection of Treated Groundwater into Class V Underground Injection Control Wells Discharge Permit DP-1835

On August 31, 2016, the New Mexico Environment Department Ground Water Quality Bureau issued Discharge Permit DP-1835 for the injection of treated groundwater into six Class V underground injection control wells in Mortandad Canyon. On July 21, 2017, the New Mexico Environment Department Ground Water Control Board approved minor updates to DP-1835. On April 30, 2018, operational responsibility for DP-1835 was transferred to N3B. To continue operations, a renewal application was submitted on June 4, 2021. The Laboratory continues to operate under the existing Discharge Permit DP-1835 permit until a final renewal permit is issued by the New Mexico Environment Department Ground Water Control Board.

Hazardous Waste Facility Permit Groundwater Activities

The Hazardous Waste Facility Permit contains requirements for groundwater monitoring of operational facilities. During 2021, groundwater monitoring completed under the 2016 Compliance Order on Consent met this requirement. Chapter 5, Groundwater Protection, provides more details on groundwater monitoring activities and monitoring results in 2021.

Compliance Order on Consent Groundwater Activities

In 2021, the Laboratory performed groundwater protection activities in accordance with the New Mexico Environment Department under the Compliance Order on Consent.

Activities included sampling and testing groundwater from wells and springs for general monitoring of groundwater quality, characterizing a chromium groundwater plume and an RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) groundwater plume, and implementing an interim measure to control migration of the chromium groundwater plume.

The goal of the chromium interim measure is to control migration of the chromium plume while the Laboratory assesses the approach for the final remediation of the plume. In 2021, interim measure operations included (1) withdrawing chromium-contaminated groundwater from the regional aquifer using extraction wells (referred to as CrEX wells, for chromium extraction), (2) treating the water using ion exchange to remove the chromium, and (3) injecting the treated groundwater back into the regional aquifer using injection wells (referred to as CrIN wells, for chromium injection). During 2021, we pumped from all five extraction wells (CrEX-1, CrEX-2, CrEX-3, CrEX-4, and CrEX-5), and injected treated water into all five injection wells (CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5).

More information is available in Chapter 5, Groundwater Protection.

Other Environmental Statutes and Orders

National Environmental Policy Act

The National Environmental Policy Act requires federal agencies to consider the environmental impacts of proposed activities, operations, and projects. The DOE has analyzed the impacts of LANL operations and activities in a Site-Wide Environmental Impact Statement (DOE 2008a). The Records of Decision for the Site-Wide Environmental Impact Statement (DOE 2008b, DOE 2009) describe the operations and activities the DOE has approved and any required mitigations.

Laboratory staff specializing in the National Environmental Policy Act review proposed projects to determine if associated impacts have been analyzed in the 2008 Site-Wide Environmental Impact Statement for the Continued Operation of Los Alamos National Laboratory or other existing National Environmental Policy Act documents.

In 2021, staff reviewed approximately 1,060 proposed projects. Those projects or activities that do not have coverage under existing documents require new or additional analyses. Laboratory projects that required additional National Environmental Policy Act analyses in 2021 are explained below.

- In April 2021, the DOE/National Nuclear Security Administration issued a public notice regarding its intent to prepare an environmental assessment (DOE 2021a) to upgrade the Laboratory's electrical power capacity by constructing and operating a new 115-kilovolt power transmission line and by improving LANL's existing electrical infrastructure. The proposed transmission line would originate at Public Service Company of New Mexico's Norton Substation, located on public lands managed by the U.S. Department of Interior, Bureau of Land Management. The proposed transmission line would proceed southwesterly crossing the Caja del Rio public land managed by the U.S. Department of Agriculture, Santa Fe National Forest, ultimately spanning White Rock Canyon onto DOE/National Nuclear Security Administration-managed lands at LANL. On May 6, 2021, a virtual public scoping meeting was held with the public comment period ending on May 21, 2021. The Environmental Assessment is being drafted.

Five Los Alamos National Laboratory projects were categorically excluded from further DOE National Environmental Policy Act review in 2021:

- Construction and Operation of a Light Manufacturing Facility to support the Isotope Production Program at Los Alamos National Laboratory (CX-270609)
- Domestic Atmospheric Radiation Measurement Campaigns (CX-270611)
- Leasing Laboratory Space (CX-270620)
- Leasing Property (CX-270530)
- Decommissioning and Demolition Project at Technical Area 41, Los Alamos National Laboratory, Los Alamos County, New Mexico (CX-270542).

National Historic Preservation Act

The National Historic Preservation Act of 1966, as amended, requires federal agencies to consider the effects of their activities on historic properties, including archaeological sites and historic buildings, and requires a mitigation plan for any adverse effects to the properties. LANL's Cultural Resources Management Plan (LANL 2017a) describes the Laboratory's process for complying with the National Historic Preservation Act and other cultural resources laws and regulations, and its strategy for managing cultural resources.

In 2021, N3B archaeologists reviewed six Environmental Remediation projects to assist in legacy waste cleanup at the Laboratory. They also assisted Triad archaeologists in recording cavates in Technical Area 54 for the National Park Service Vanishing Treasures program. N3B archaeologists coordinated with Triad to write reports for consultation with the State Historic Preservation Office and the National Park Service regarding soil samples at Manhattan Project historic buildings.

In fiscal year 2021, Triad archaeologists supported 17 projects by conducting historic property surveys or verifying results from previous surveys. Additionally, archaeologists completed an archaeological site update review and conducted a literature and map search for two areas in Colorado in which a DOE/LANL atmospheric and environmental monitoring project is being conducted.

Artifacts excavated from Laboratory property are curated at the Museum of Indian Arts and Culture, located in Santa Fe, New Mexico. Owing to the COVID-19 pandemic no annual inspection of the museum took place during 2020 or 2021. The annual inspection is expected to resume in 2022. The focus of the annual inspections is to ensure compliance with regulations for the preservation and curation of artifacts from archaeological sites. These inspections are required under Curation of Federally Owned and Administered Archaeological Collections, Title 36 Part 79 of the Code of Federal Regulations.

Triad historic buildings staff supported 21 Laboratory projects by performing inspections and research on the historical use of the buildings using the LANL National Security Research Center, documents available through the public reading room, and historical photographs. Staff conducted archival documentation for five projects impacting historic buildings at Technical Area 16 and Technical Area 43. Staff also conducted interior and exterior photography of Technical Area 22 Building 1 for the potential adaptive reuse, rehabilitation, and restoration of this historic building. Historic buildings staff also participated in surveillance and maintenance evaluations for the most significant historic properties located at the Laboratory, including the 17 buildings and structures that are either included in the Manhattan Project National Historical Park or that are eligible for the park (See Chapter 3).

Cultural resources staff continue to conduct consultations with the Accord Pueblos (Pueblo de San Ildefonso, Santa Clara Pueblo, Pueblo of Jemez, and Pueblo de Cochiti) regarding the identification and preservation of traditional cultural properties, human remains, and sacred objects in compliance with the National Historic Preservation Act and the Native American Graves Protection and Repatriation Act.

Endangered Species Act

The Endangered Species Act requires federal agencies to protect federally listed, threatened, or endangered species, including their habitats. We implement these requirements through the Habitat Management Plan (LANL 2017b).

The Laboratory contains habitat for three federally listed species: the southwestern willow flycatcher (*Empidonax traillii extimus*), the Jemez Mountains salamander (*Plethodon neomexicanus*), and the Mexican spotted owl (*Strix occidentalis lucida*). Two other federally listed species occur near the Laboratory: the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) and the western distinct population segment of the yellow-billed cuckoo (*Coccyzus americanus*). The southwestern willow flycatcher, yellow-billed cuckoo, and New Mexico meadow jumping mouse have not been observed on Laboratory property. In addition, several federal species of concern and state-listed species potentially occur within the Laboratory (Berryhill et al. 2020, BISON-M 2021; Table 2-13).

Table 2-13. Threatened, Endangered, and Other Sensitive Species Occurring or Potentially Occurring at the Laboratory

Scientific Name	Common Name	Protected Status*	Potential to Occur†
Empidonax traillii extimus	Southwestern willow flycatcher	E, NME, S1	Moderate
Mustela nigripes	Black-footed ferret	E	Low
Strix occidentalis lucida	Mexican spotted owl	T, NMS	High

Scientific Name	Common Name	Protected Status*	Potential to Occur†
Coccyzus americanus	Yellow-billed cuckoo (western distinct population segment)	T, NMS	Low
Zapus hudsonius luteus	New Mexico meadow jumping mouse	E, NME, S1	Low
Haliaeetus leucocepahlus	Bald eagle	NMT, S1	High
Cynanthus latirostris magicus	Broad-billed hummingbird	NMT, S1	Low
Amazilia violiceps	Violet-crowned hummingbird	NMT, S1	Low
Gila Pandora	Rio Grande chub	NMS	Moderate
Plethodon neomexicanus	Jemez Mountains salamander	E, NME	High
Falco peregrinus	Peregrine falcon	NMT	High
Accipiter gentiles	Northern goshawk	NMS	High
Lanius ludovicianus	Loggerhead shrike	NMS	High
Vireo vicinior	Gray vireo	NMT	High
Myotis ciliolabrum melanorhinus	Western small-footed myotis bat	NMS	High
Myotis volans interior	Long-legged bat	NMS	High
Euderma maculatum	Spotted bat	NMT	High
Corynorhinus townsendii pallescens	Townsend's pale big-eared bat	NMS	High
Nyctinomops macrotis	Big free-tailed bat	NMS	High
Bassariscus astutus	Ringtail	NMS	High
Vulpes	Red fox	NMS	Moderate
Lilium philadelphicum var. andinum	Wood lily	NME	High
Cypripedium calceolus var. pubescens	Greater yellow lady's slipper	NME	Moderate
Mentzelia springeri	Springer's blazing star	FSS	Moderate
Cynomys gunnisoni	Gunnison's prairie dog	NMS	Moderate
Danaus plexippus	Monarch Butterfly	**	High
Strix occidentalis lucida	Mexican spotted owl	T, NMS	High

*E = Federal Endangered; T = Federal Threatened; NME = New Mexico Endangered; NMT = New Mexico Threatened; NMS = New Mexico Sensitive Taxa (informal); S1 = Heritage New Mexico: Critically Imperiled in New Mexico; FSS = Forest Service Sensitive Species; **Warranted but precluded by higher priorities December 15, 2020.*
† Low = No known habitat exists at the Laboratory. Moderate = Habitat exists, though the species has not been recorded recently. High = Habitat exists, and the species occurs at the Laboratory.

We review proposed projects to determine if they have the potential to affect federally listed species or their habitats. In 2021, Triad biologists reviewed 688 excavation permits, 306 project profiles in the permits and requirements identification system, 20 minor siting proposals, and 20 storm water pollution prevention plans for potential impacts to threatened or endangered species. N3B subject matter experts reviewed 26 excavation permits and six project profiles in the permits and requirements identification system. If there is a potential for impacts, biologists work with project personnel to either modify the project to avoid the impacts or to prepare a biological assessment for consultation with the U.S. Fish and Wildlife Service. In 2021, we prepared one biological assessment to analyze the impacts to listed species (LANL 2021a). We did not find any projects out of compliance with endangered species protection requirements in 2021.

We also conducted surveys for the Mexican spotted owl, southwestern willow flycatcher, and Jemez Mountains salamander. In 2021, Mexican spotted owls were found on Laboratory property in the same nesting locations as past years. Male Mexican spotted owls were heard on multiple surveys, but no successful breeding was confirmed. Southwestern willow flycatchers were not found during surveys, but one willow flycatcher of unknown subspecies was recorded during bird banding operations. One Jemez Mountains salamander was found on a survey of LANL lands.

Migratory Bird Treaty Act

Under the Migratory Bird Treaty Act, it is unlawful “by any means or manner to pursue, hunt, take, capture [or] kill” any migratory birds except as permitted by regulations issued by the U.S. Fish and Wildlife Service. As part of the Laboratory’s Migratory Bird Treaty Act compliance, we review projects for potential impacts to migratory birds and conduct bird population monitoring projects. These efforts support DOE’s commitment to “promote monitoring, research, and information exchange related to migratory bird conservation and program actions that may affect migratory birds…” as stated in the September 12, 2013, Memorandum of Understanding between the DOE and the U.S. Fish and Wildlife Service.

In project reviews, Laboratory biologists provide specific comments for projects that have the potential to affect migratory birds, their eggs, or nestlings. In general, projects that remove vegetation that may contain bird nests are scheduled before or after the bird nesting season. In 2021, we did not find any projects out of compliance with migratory bird protection requirements.

In 2021, we continued annual breeding season and winter surveys for birds in all major habitat types and continued monitoring nest box use by birds. As part of a long-term monitoring project at two open detonation sites and one open burn site, our point count surveys and nest box monitoring results continue to suggest that operations at these sites are not negatively affecting bird populations. In addition, biologists continued to capture and band birds during the breeding season in Sandia Canyon, to monitor breeding bird populations, and during fall migration in Pajarito Canyon, to monitor use of Laboratory lands by migrating birds.

Floodplain and Wetland Executive Orders

We comply with Executive Order 11988, *Floodplain Management*, and Executive Order 11990, *Protection of Wetlands*, by preparing floodplain and wetland assessments for projects in floodplains or wetlands. In 2021, three floodplain assessments were prepared: one was for a fire risk mitigation project around an explosives testing site in Potrillo Canyon (Technical Area 36); one was for a heating, ventilation, and air conditioning unit installation (Technical Area 39); and one was for installation of a three-strand smooth wire operational boundary fence around the High Explosive Transfer Facility (Technical Area 8). No violations of the DOE floodplain/wetland environmental review requirements were recorded.

Invasive Species Executive Order

In accordance with Executive Order 13751, *Safeguarding the Nation from the Impacts of Invasive Species*, we identify invasive species and treat isolated invasive plant species populations. Larger, well-established populations of some species like Siberian elm (*Ulmus pumila*), Russian olive (*Elaeagnus angustifolia*), and saltcedar (*Tamarix ramosissima*) are removed opportunistically, in conjunction with other construction projects. Developing an invasive species best management practices document is a mitigation requirement of the Finding of No Significant Impact for the Final Supplemental Environmental Assessment for the Wildfire Hazard Reduction and Forest Health Improvement Program at Los Alamos National Laboratory, Los Alamos, New Mexico, and planning for the effort is underway. We have developed a software application for electronic devices that allows users to identify and mark the locations of invasive plant species at the Laboratory to track spread and plan for future removals. A current list of invasive species known to occur at LANL is presented below in Table 2-14.

Table 2-14. List of Common Names and Latin Names of Invasive Species Known to Occur at LANL

Common Name	Latin Name
Giant leopard slug	*Limax maximus*
Eurasian collared dove	*Streptopelia decaocto*
European starling	*Sturnus vulgaris*
Bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
Cheatgrass	*Bromus tectorum*
Dalmatian toadflax	*Linaria dalmatica*
Field bindweed	*Convolvulus arvensis*
Jointed goatgrass	*Aegilops cylindrica*
Kochia	*Kochia scoparia*
Leafy spurge	*Euphorbia esula*
Lehmann lovegrass	*Eragrostis lehmanniana*
Mullein	*Verbascum spp.*
Myrtle spurge	*Euphorbia myrsinites*
Nodding plumeless thistle	*Carduus nutans*
Oxeye daisy	*Leucanthemum vulgare*
Puncturevine	*Tribulus terrestris*
Redtop	*Agrostis gigantea*
Rough cocklebur	*Xanthium strumarium*
Russian knapweed	*Acroptilon repens*
Russian olive	*Elaeagnus angustifolia*
Russian thistle	*Salsola kali*
Saltcedar	*Tamarix ramosissima*
Scotch cottonthistle	*Onopordum acanthium*
Siberian elm	*Ulmus pumila*
Smooth brome	*Bromus inermis*
Teasel	*Dipsacus spp.*
Tree of heaven	*Ailanthus altissima*
Whitetop	*Cardaria draba*
Yellow salsify	*Tragopogon dubius*

Executive Order 14008, Tackling the Climate Crisis at Home and Abroad

Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, set a goal of conserving 30 percent of land and water by 2030, among other goals. The DOE submitted its first conservation action plan under the America the Beautiful Initiative associated with this executive order in December 2021, with the following focus areas:

- Create More Parks and Safe Outdoor Opportunities in Nature-Deprived Communities;
- Support Tribally Led Conservation and Restoration Priorities;
- Expand Collaborative Conservation of Fish and Wildlife Habitats and Corridors;
- Increase Access for Outdoor Recreation;
- Incentivize and Reward the Voluntary Conservation Efforts of Fishers, Ranchers, Farmers and Forest Owners;
- Create Jobs by Investing in Restoration and Resilience; and
- Other Activities Supportive of the America the Beautiful Initiative.

Laboratory plans and programs that supported the DOE's conservation action plan in 2021 included:

- Los Alamos National Laboratory Trails Program (LANL 2015) (https://www.lanl.gov/environment/protection/trails/index.php) and Trails Management Plan
- Los Alamos National Laboratory Pollinator Protection Plan (LANL 2021b) and pollinator protection actions
- Sensitive Species Best Management Practices Source Document (LANL 2020a)
- Migratory Birds Best Management Practices Source Document for Los Alamos National Laboratory (LANL 2020b) and migratory bird monitoring (see Chapters 3 and 7)
- Invasive species monitoring
- Collaborative monitoring of mountain lions with the National Park Service.

In July 2021, interim implementation guidance for the Justice40 Initiative was released as a new requirement of Executive Order 14008. The aim of this initiative is to secure environmental justice and spur economic opportunity for disadvantaged communities that have been historically marginalized and overburdened by pollution and underinvestment in housing, transportation, water and wastewater infrastructure, and health care. The Justice40 initiative provides guidance on how certain federal investments might be made toward a goal that 40 percent of the overall benefits from federal investments flow to disadvantaged communities. The Environmental Management – Los Alamos Field Office was selected as one of five Department of Energy pilot programs to implement this requirement of the Executive Order. Deliverables include:

- Communication Plan;
- Stakeholder Engagement Plan;
- Implementation Plan; and
- Benefits Calculation Methodology.

Federal Insecticide, Fungicide, and Rodenticide Act; New Mexico Pesticide Control Act; and National Pollutant Discharge Elimination System Pesticide General Permit

Two laws and one nationwide Clean Water Act permit regulate how the Laboratory uses and reports on its use of pesticides (chemicals that destroy plant, fungal, or animal pests). The

Federal Insecticide, Fungicide, and Rodenticide Act regulates the distribution, sale, and use of pesticides. The New Mexico Pesticide Control Act regulates (1) licensing and certification of pesticide workers, (2) record keeping, (3) equipment inspection, (4) application of pesticides, and (5) storage and disposal of pesticides. The National Pollutant Discharge Elimination System Pesticide General Permit requires annual reporting of pesticide use to the U.S. Environmental Protection Agency. The Environmental Protection Agency issued a new National Pollutant Discharge Elimination System Pesticide General Permit in 2021, which is effective until October 31, 2026.

In 2021, pesticide usage was reported to the U.S. Environmental Protection Agency in accordance with the National Pollutant Discharge Elimination System Pesticide General Permit. Table 2-15 shows the amounts of pesticides the Laboratory used in 2021.

Table 2-15. Pesticides Used by LANL in 2021

Herbicide	Amount
Velossa	79.84 gallons
Ranger Pro Herbicide	40.57 gallons
Axxe Broad Spectrum Herbicide	1.86 gallons
Insecticide	**Amount**
Maxforce Complete Brand Granular Insect Bait	1.291 pounds
PT Wasp Freeze II and Hornet Insecticide	0.159 pounds
Summit B.T.I. Briquets	1 briquette
Virkon S	.00066 gallons
Water Treatment Chemical	**Amount**
Garratt-Callahan Formula 314-T	456 pounds
Garrett-Callahan Formula 316	5 pounds 15 ounces

DOE Order 231.1B, Environment, Safety, and Health Reporting

DOE Order 231.1B, Environment, Safety, and Health Reporting, requires the timely collection and reporting of information on environmental issues that could adversely affect the health and safety of the public and the environment at DOE sites. This report fulfills DOE Order 231.1B requirements to publish an annual site environmental report.

The intent of this report is to

- characterize site environmental management performance, including effluent releases, environmental monitoring, types and quantities of radioactive materials emitted, and radiological doses to the public;
- summarize environmental occurrences and responses reported during the calendar year;
- confirm compliance with environmental standards and requirements;
- highlight significant programs and efforts, including environmental performance indicators, performance measures programs, or both; and
- summarize property clearance activities.

The Laboratory began environmental monitoring in 1945 and published the first comprehensive environmental monitoring report in 1970. Current and past reports are available at https://environment.lanl.gov/environmental-report.

Emergency Planning and Community Right-to-Know Act

The Emergency Planning and Community Right-to-Know Act requires emergency plans for more than 360 hazardous substances if they are present at a facility in amounts above specified thresholds. We are required to notify state and local officials and the community under this Act about the following items: (1) changes at the Laboratory that might affect the local emergency plan or if the Laboratory's emergency planning coordinator changes; (2) leaks, spills, and other releases of listed chemicals into the environment if these releases exceed specified quantities; (3) the annual inventory of the quantities and locations of hazardous chemicals above specified thresholds present at the facility; and (4) total annual releases to the environment of listed chemicals that exceed specified thresholds. Table 2-16 identifies community and emergency planning reporting the Laboratory performed in 2021.

Table 2-16. Status of Emergency Planning and Community Right-to-Know Act Reporting in 2021

Emergency Planning and Community Right-to-Know Act Section	Description of Reporting	Status (Yes, No, or Not Required)
Section 302–303	Planning notification	Not required
Section 304	Extremely hazardous substance or hazardous substance release notification	Not required
Section 311–312	Material safety data sheet/Hazardous chemical inventory	Yes
Section 313	Toxics release inventory reporting	Yes

For Section 313 reporting, the listed chemical that met the criteria for reporting in 2021 was lead. The largest use of reportable lead was from offsite waste transfers. Table 2-17 summarizes the reported releases in 2021. There are no compliance violations associated with this use or release of lead.

Table 2-17. Summary of 2021 Total Annual Releases under Emergency Planning and Community Right-to-Know Act, Section 313

Reported Release	Lead (pounds)
Air emissions	4.18
Water discharges	0.24
Onsite land disposal (firing range)	1,465
Offsite waste transfers	12,299

DOE Order 232.2A, Occurrence Reporting and Processing of Operations Information

DOE Order 232.2A, Occurrence Reporting and Processing of Operations Information, requires reporting of abnormal events or conditions that occur during facility operations. An "occurrence" is one or more events or conditions that may adversely affect workers, the public, property, the environment, or the DOE mission. In 2021, Triad had one reportable environmental occurrence (See Table 2-18). N3B did not have any reportable environmental occurrences in 2021.

Table 2-18. 2021 Environmental Occurrences

Title	Description and Comments	Status
Discharge to Outfall 051 Exceeded Regulatory Limit for Total Residual Chlorine	On August 10, 2021, during a planned National Pollutant Discharge Elimination System discharge to Outfall 051 from the Radioactive Liquid Waste Treatment Facility, sample results indicated that the total residual chlorine level was 19 parts per billion, which exceeded the regulatory limit of 11 parts per billion. Exceeding regulatory limits requires a non-standard report to an outside agency. The discharge was stopped when the exceedance was discovered. Required notifications were made. There was no impact to the health and safety of personnel, the program, or the environment.	Closed

DOE Order 436.1, Departmental Sustainability

The purpose of this DOE order is to ensure that the DOE carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges. As directed by this order, the Laboratory adopted an Environmental Management System and prepares and implements an annual Site Sustainability Plan. LANL's Environmental Management System and Site Sustainability Plan are discussed in detail in Chapter 3.

Inspections and Audits

Table 2-19 lists the environmental inspections conducted by regulating agencies and external auditors at the Laboratory during 2021.

Table 2-19. Environmental Inspections and Audits Conducted at LANL during 2021

Date	Purpose	Performing Entity
3/2–4/2021 and 10/26–28/2021	Environmental Management System Surveillance Audits, covering clauses of the International Standards Organization 14001:2015 standard	NSF International
5/24-26/2021	Carlsbad Field Office Annual Recertification	Environmental Protection Agency, Carlsbad Field Office
10/7/2021	Waste Control Specialists Annual Recertification Audit at N3B	Waste Control Specialists
10/25–28/2021	Annual Audit and Resource Conservation and Recovery Act Permit Site Inspections	New Mexico Environment Department Hazardous Waste Bureau

Date	Purpose	Performing Entity
9/23/2021	New Mexico Environment Department Title VI inspection, including the asphalt plant, internal combustion/generators, data disintegrator, and evaporative sprayers.	New Mexico Environment Department Air Quality Bureau
6/21–28/2021	Second independent Triennial Review to assess Los Alamos National Laboratory's compliance with permits and related regulatory requirements within six areas: • Storm water discharge associated with the Storm Water Individual Permit; • Storm water discharge associated with industrial activities; • Industrial and sanitary point-source outfall wastewater; • Spills; • Hazardous waste; and • New Mexico solid waste.	Parsons (DOE 2021b).

Unplanned Releases

Air Releases

In 2021, there were no unplanned air releases.

Liquid Releases

Triad reported 11 unplanned liquid releases to the New Mexico Environment Department in 2021, as required by the New Mexico Water Quality Control Commission regulations, and N3B reported one unplanned liquid release (See Table 2-20). Corrective actions were taken for all liquid releases and were communicated to the New Mexico Environment Department Ground Water Quality Bureau.

Table 2-20. 2021 Unplanned Reportable Liquid Releases

Material Released	Number of Instances	Approximate Total Release (gallons)
Potable Water	4	64,700
Sanitary Wastewater	2	420
Radioactive Liquid Waste Treatment Facility Treated Effluent	2	3,505
Sanitary Effluent Blended Water	1	200
Non-PCB Mineral Oil	1	50
High Explosive Wastewater	1	500
Well purge water (N3B)	1	70

Site Resilience

Updated in 2018, the National Climate Assessment explains what current and future climate change is likely to mean for the United States (Gonzalez et al. 2018). Predictions are made for temperature, precipitation (including snowpack), and wildland fires. DOE Order 436.1, Departmental Sustainability, directs the Laboratory to determine how its facilities and operations can mitigate risks associated with climatic factors, such as increasing temperatures and increasing wildland fire risk, and to identify the types of facilities/operations that could be impacted.

In 2015, we began tracking climatic risk indices relating to temperature, precipitation, wind, indicator species, and storm water flow. These indices will assist us in identifying when actions are necessary to protect facilities and operations. Below are the results of indices that were available in 2021.

Temperature

Temperature data have been collected in Los Alamos since 1910. Long-term trends in annual average temperatures are reported in the Meteorological Monitoring section of Chapter 4 and are shown in Figure 2-2. The temperatures between 1960 and 2000 had no trend. The years 2001–2010 were approximately 1.5°F warmer than the previous 40 years, and the years 2011–2018 were approximately 3°F warmer than the 1960–2000 averages. Seven of the last eight years had an annual average temperature greater than 50°F. When average temperatures are broken down into summer and winter minimums and maximums, the summer minimum temperatures (See Figure 2-3) demonstrate the strongest increasing trend from 1990 onward (an increase of approximately 4°F).

Changes in temperature can also be assessed by changes in the number of cooling and heating degree days. The number of cooling and heating degree days is used to estimate the annual power usage needed to heat or air condition buildings. A cooling degree day represents a one-degree increase in the average daily temperature above 65°F. As an example, if the average daily temperature was 80°F, that day would represent 15 cooling degree days. Heating degree days are calculated in the same way from the number of degrees an average daily temperature is below 65°F. Shown in Figure 2-4, cooling degree days have been increasing since 1990, while heating degree days have been decreasing (See Figure 2-5). Thus, less energy has been needed to heat buildings, but more energy has been needed to cool them.

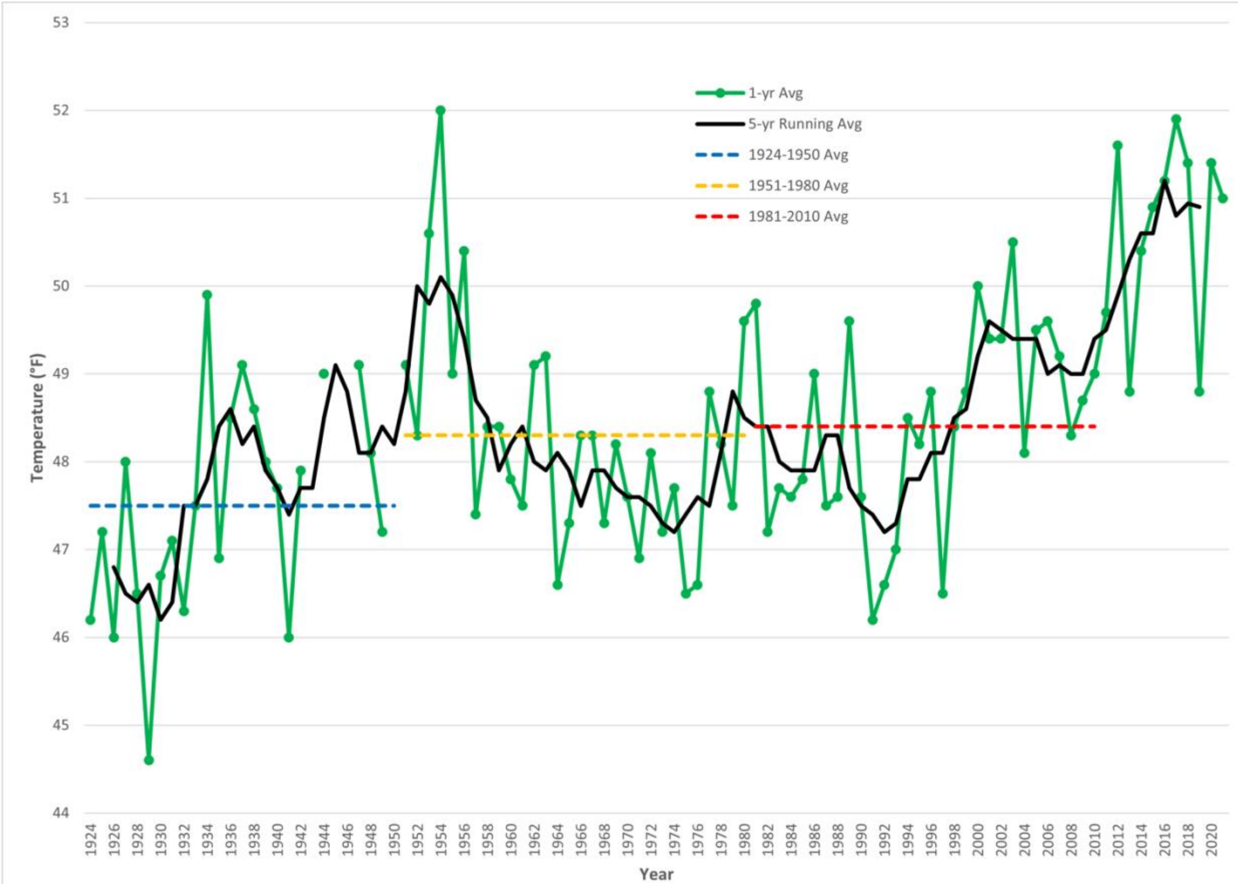

Figure 2-2. Annual average temperatures for Los Alamos. The dashed lines represent long-term climatological average temperatures, the black line represents the five-year running average temperature, and the green line represents the one-year average.

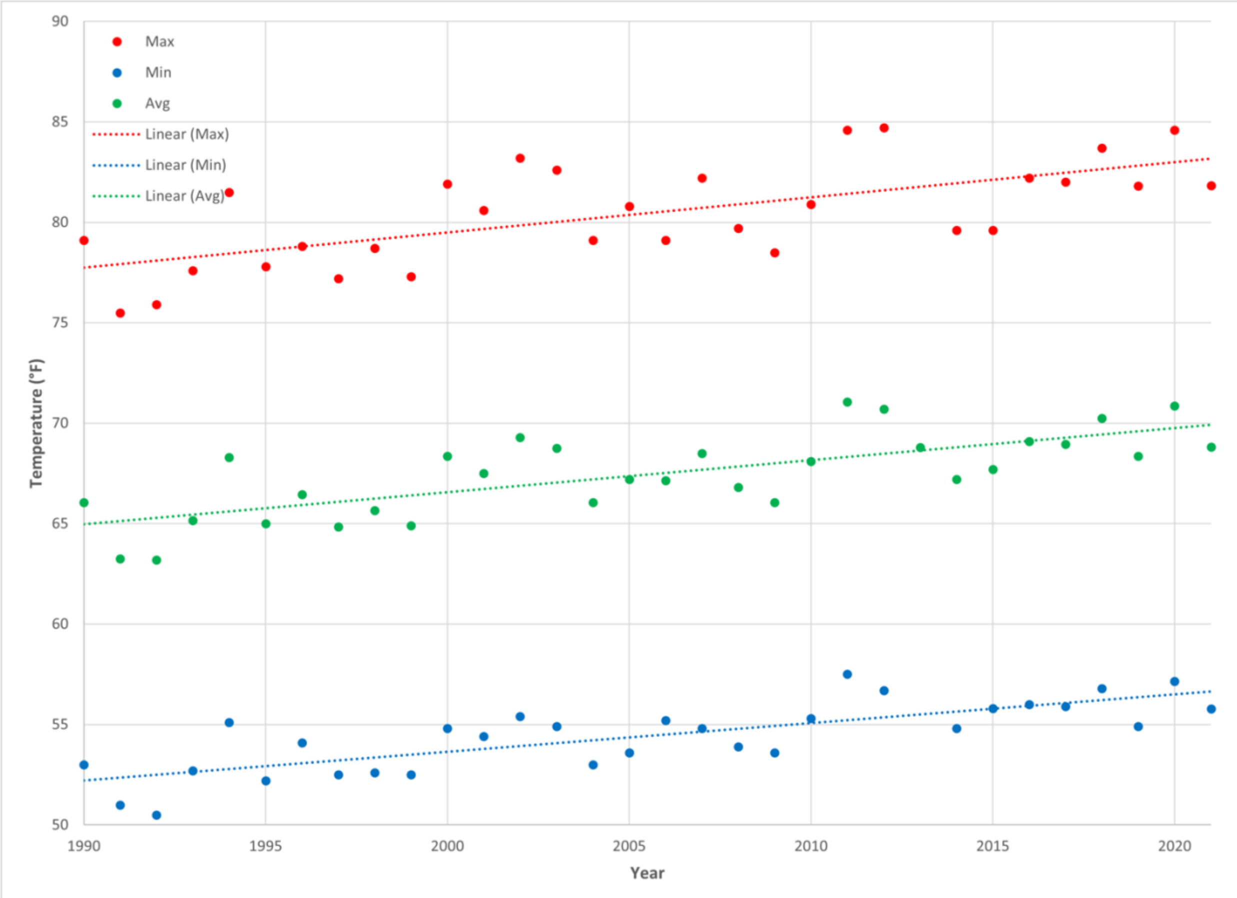

Figure 2-3. Average summer (June, July, August) Los Alamos temperatures. The dashed lines represent the trend line for maximum, minimum, and average summer temperatures, which show summer temperatures have been continuously increasing since 1990.

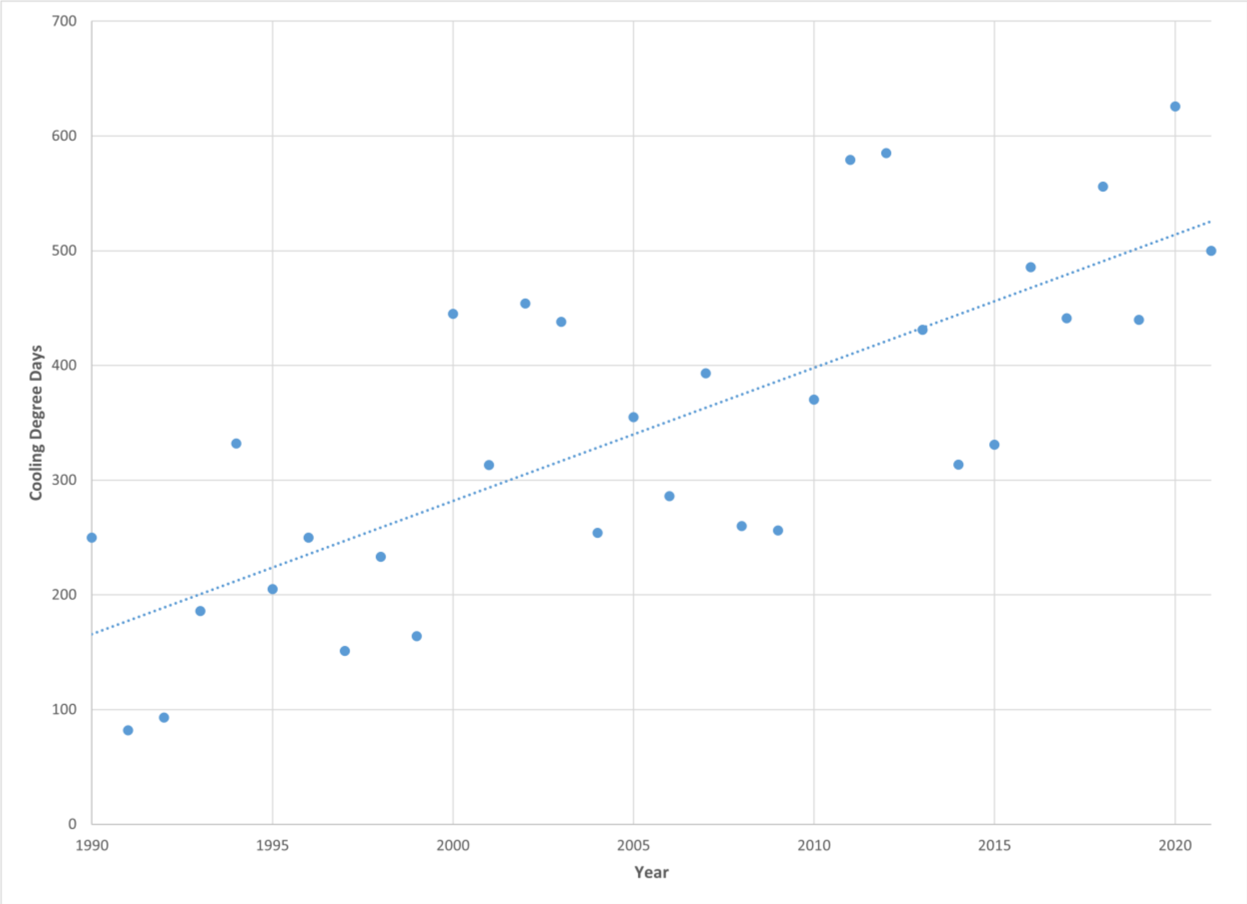

Figure 2-4. Los Alamos cooling degree days per year. The dashed line represents the trend line for cooling degree days, which shows cooling degree days have increased, resulting in more energy needed to cool buildings.

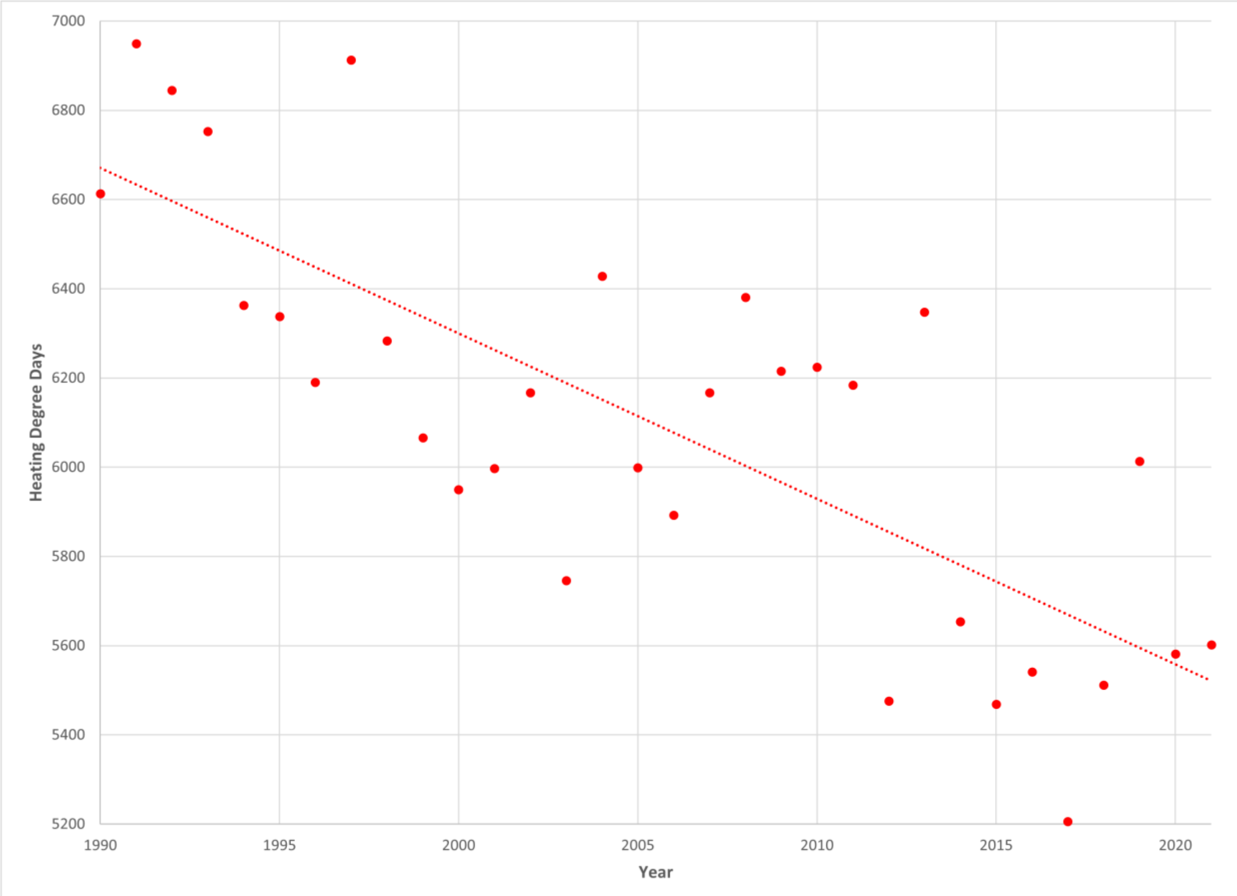

Figure 2-5. Los Alamos heating degree days. The dashed line represents the trend line for heating degree days, which shows heating degree days have decreased, resulting in less energy needed to heat buildings.

Wind Speed

The annual average wind speed measured at the Laboratory's meteorological tower of record at Technical Area 6 has increased approximately 20 percent from 1994 to 2014 (See Figure 2-6). Since 2015, the annual average wind speed has not shown such an increase, as speeds have remained around 2.9 meters per second. Although not shown here, the monthly average wind speed during the spring months (windiest months) shows an increase by approximately 1 meter per second. Winds are produced by low- and high-pressure weather systems that move across New Mexico. Near the ground's surface, wind speeds are also influenced by the type of vegetation present (for example, forests versus grasslands). Our current hypothesis is that the extensive loss of trees in the local area caused by wildfires, drought, and bark beetle infestations has led to a decrease in the amount of wind resistance provided by trees, allowing wind speeds near the surface to increase. There is no trend in the annual peak gusts recorded at Technical Area 6 since 1990 (Kelly et al. 2015).

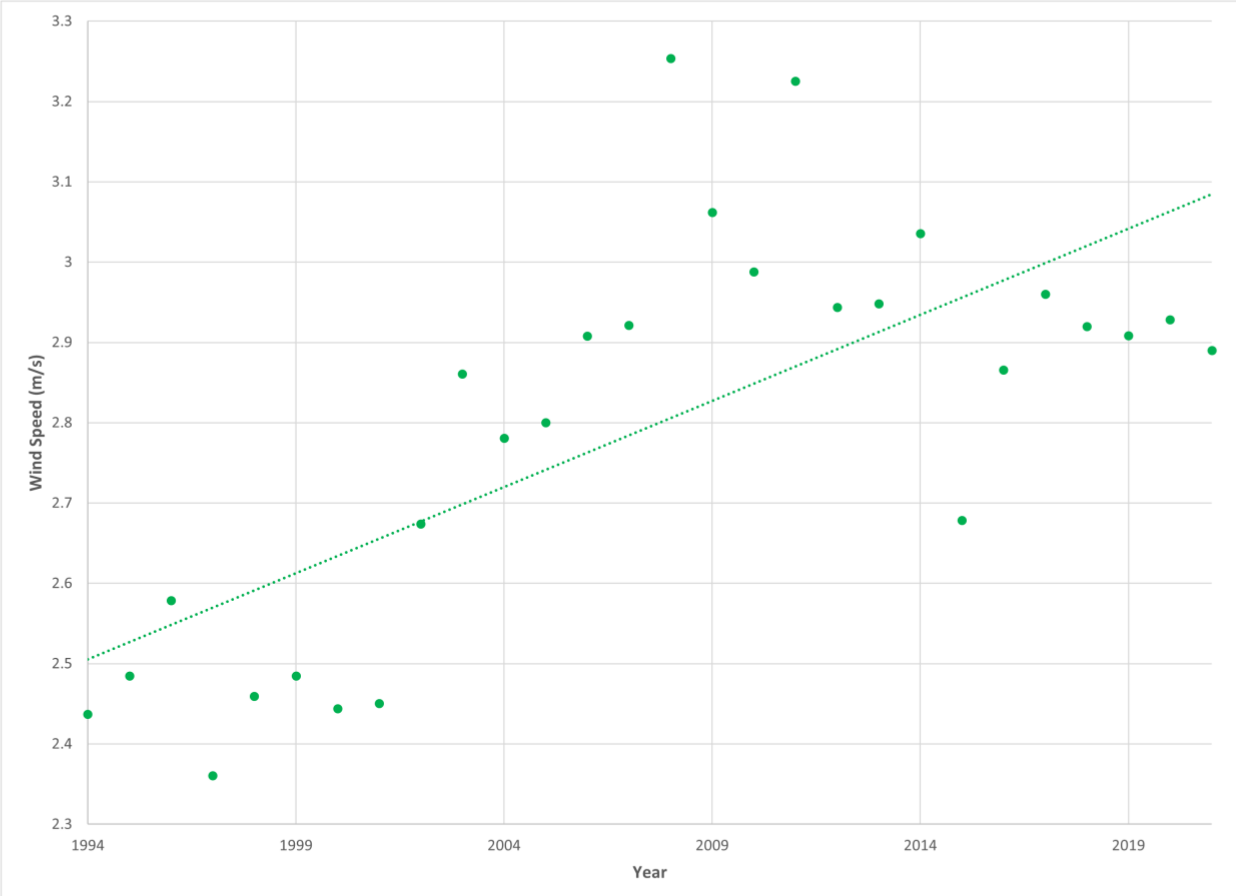

Figure 2-6. Technical Area 6 annual average wind speed at 12 meters above the ground. The dashed line represents the trend line for wind speed, which shows the annual average wind speed has been increasing since 1994.

Annual Red Flag Warnings

The National Weather Service issues Red Flag Warnings when critical weather conditions may result in extreme fire behavior. The National Weather Service began recording the number of Red Flag Warnings per year for the Los Alamos area in 2012 (See Figure 2-7). Red Flag Warnings have increased over the past four years, but since 2012, there has not been a trend. Some Laboratory operations, including explosives testing, are restricted on days with Red Flag Warnings.

If the following weather conditions occur simultaneously for three or more hours, a Red Flag Warning can be issued:

- sustained winds at or above 20 miles per hour,
- relative humidity less than 15 percent, and
- above average temperatures.

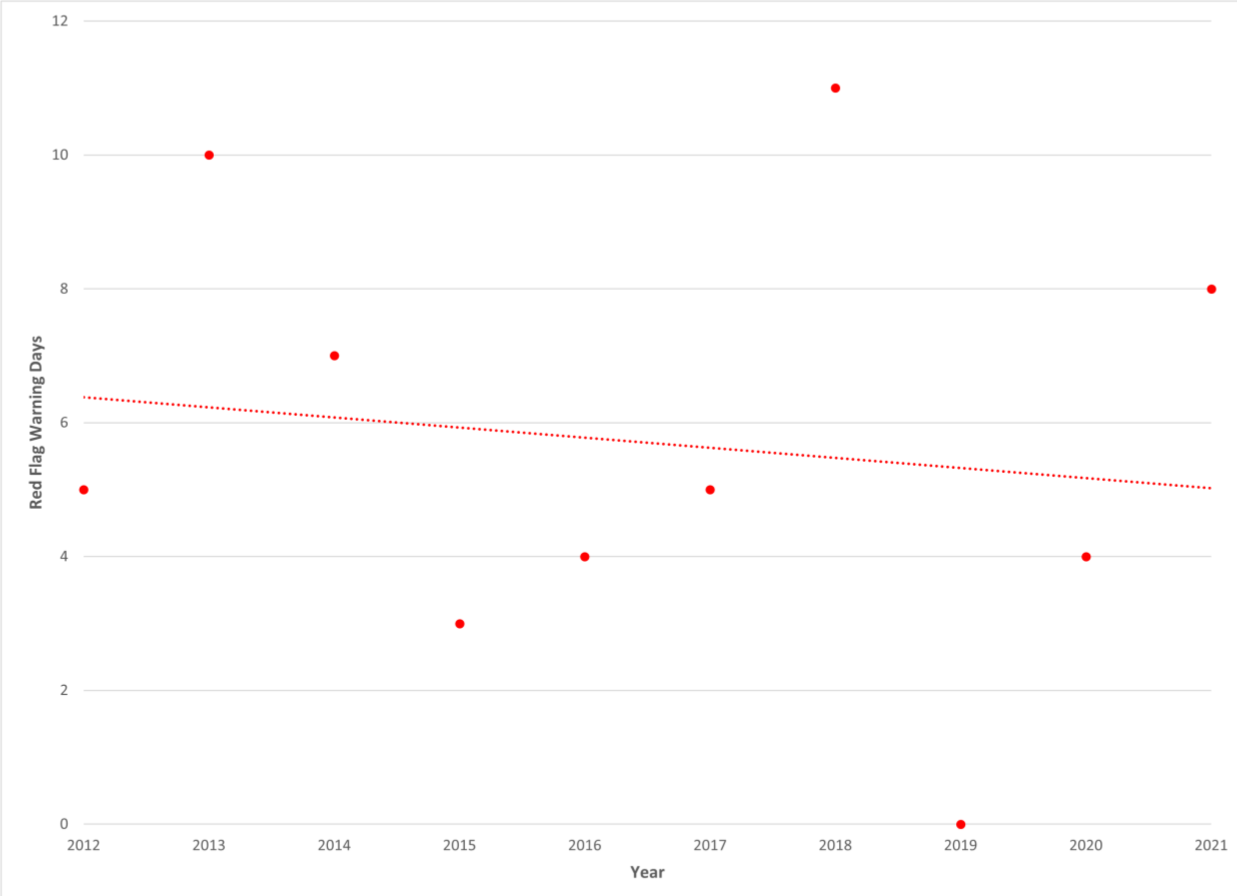

Figure 2-7. Number of National Weather Service Red Flag Warning days for zone 102 (Los Alamos).

Precipitation

We analyzed the annual average precipitation (See Figure 2-8) and the number of days per year with heavy rain events (See Figure 2-9). From 1924 through 2010, the annual average precipitation was 18 inches with a standard deviation of 4.4 inches. A long-term drought began in 1998, with precipitation under 15 inches between 2000 and 2003 and again in 2011 and 2012. Annual precipitation values were as low as 10 inches in 2003 and 2012.

The frequency of heavy rain events (See Figure 2-9), defined as precipitation greater than 0.5 inches in one day, does not demonstrate a significant long-term trend since 1950. Although not shown here, there is also no trend in the heaviest events (precipitation >0.75 inches or >1.0 inch per day) in the past 50 years.

Annual average snowfall (See Figure 2-10) demonstrates a decrease in the long-term trend since 1950. Since the drought began in 1998, there have been only three years with above-average recorded snowfall (1981–2010 average = 57 inches).

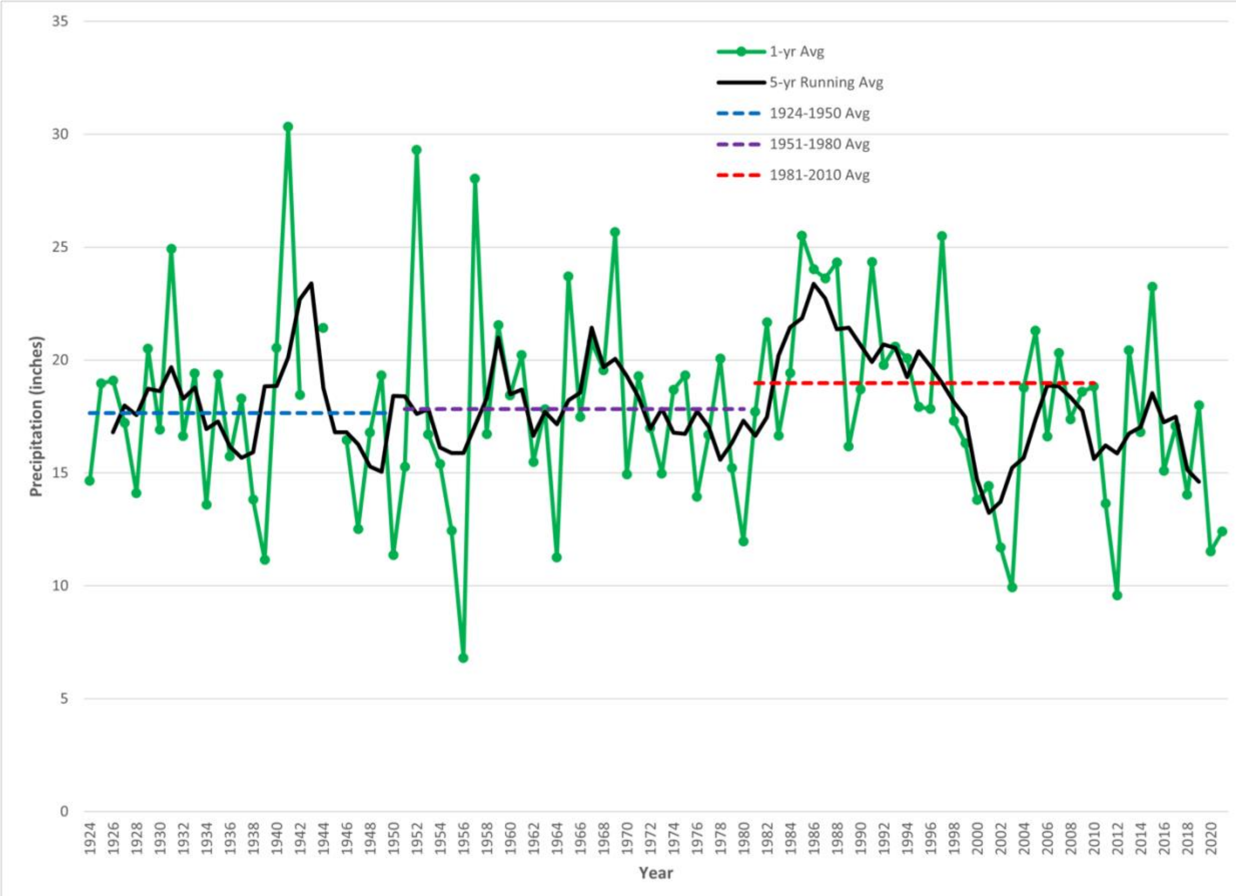

Figure 2-8. Annual precipitation totals for Los Alamos. The dashed lines represent long-term climatological average total precipitation, the black line represents the five-year running average precipitation, and the green line represents the 1-year total precipitation. Significant drought since the 1990s has resulted in below average precipitation in many recent years.

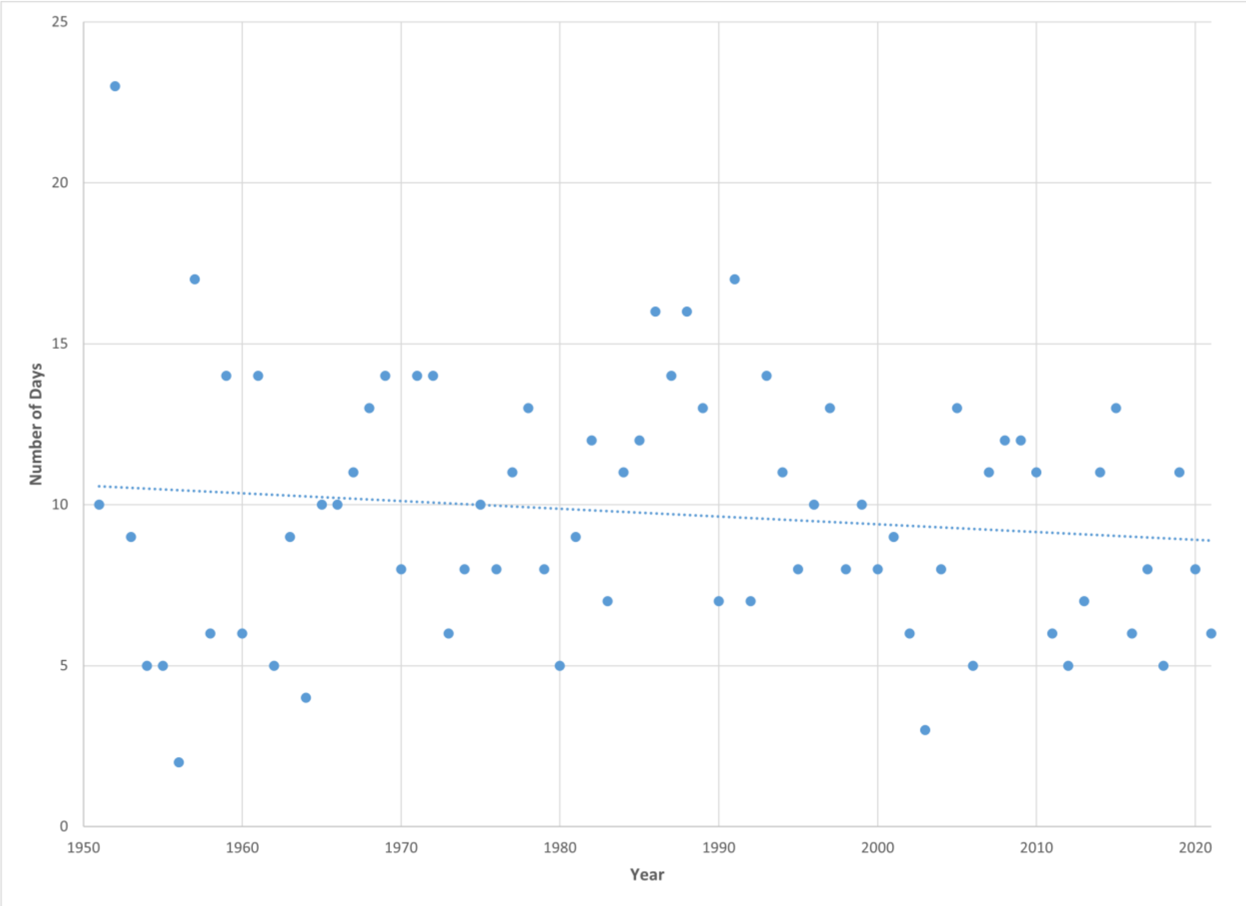

Figure 2-9. Number of days per year with precipitation >0.5 inches. The dashed line represents the trend line for days with precipitation >0.5 inches. The slight decreasing trend since 1950 is not statistically significant.

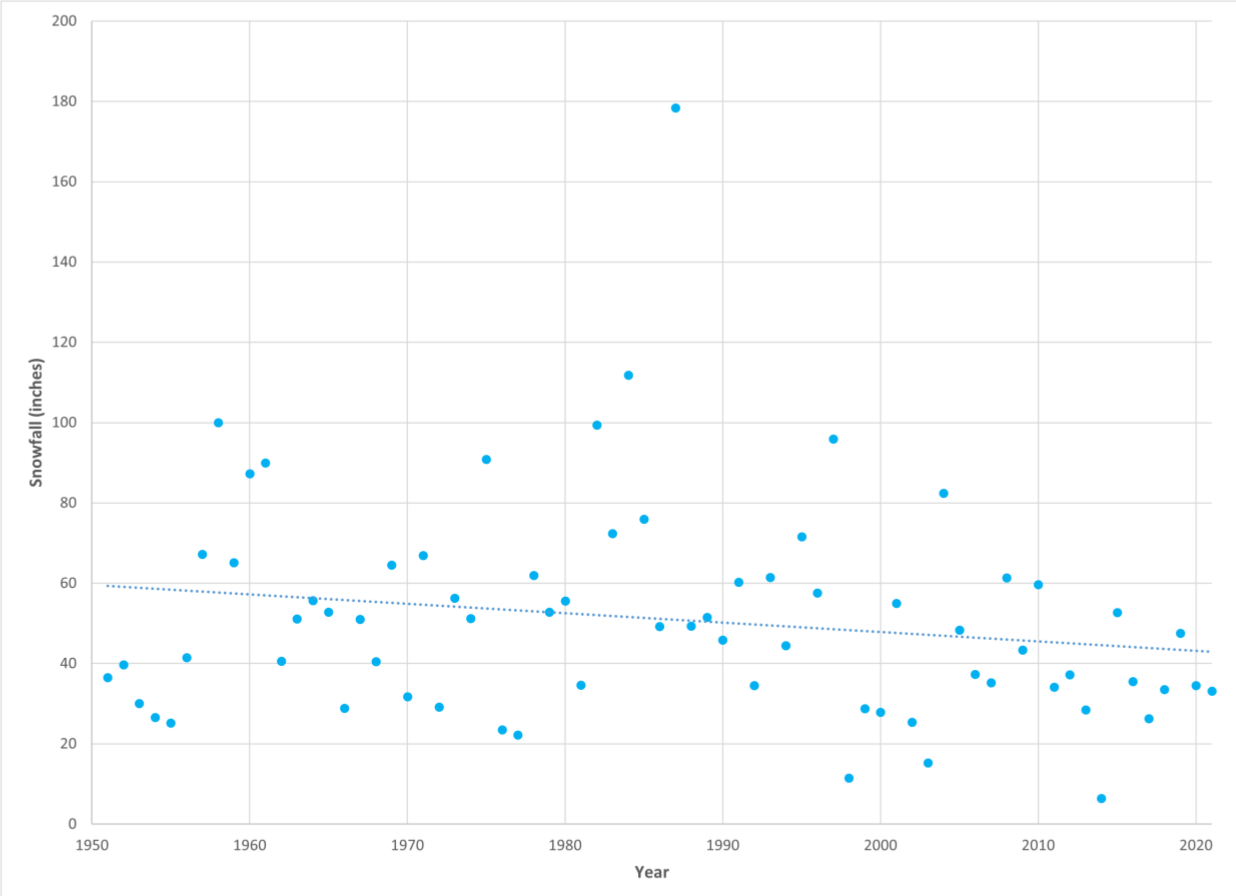

Figure 2-10. Annual average Los Alamos snowfall. The dashed line represents the trend line for snowfall, which shows a decrease in annual snowfall.

Climatic Summary

Average temperatures in Los Alamos have increased over the past 15 to 25 years, consistent with the predictions of the National Climate Assessment for the southwestern U.S. The annual average temperatures for the southwest are predicted to rise by 3.7°F–4.8°F by 2036–2065, and the temperatures measured at Los Alamos are consistent with these predictions. Increases in cooling degree days and reductions in heating degree days will produce increased summer air-conditioning costs and reduced winter heating costs.

Although the predictions of precipitation changes are less certain than temperature predictions, the National Climate Assessment predicts decreasing winter and spring precipitation in the southwest. The Laboratory's data are consistent with these predictions, particularly over the past 22 years, with below-average snowfall in 86 percent of the years. The National Climate Assessment does not make a specific prediction for the southwest for heavy precipitation events. The Laboratory's data does not show a trend in heavy precipitation events in Los Alamos.

The National Climate Assessment predicts increasing wildland fires in the southwest because of warming, drought, and insect outbreaks. Two major wildland fires have impacted the Laboratory in the past 20 years: the 2000 Cerro Grande fire and the 2011 Las Conchas fire. Precursors to these fires included warm, dry years, and local bark beetle infestations (LANL 2012). The Los Alamos data are consistent with the predictions of increasing wildland fires. The annual average wind speed has been increasing, probably related to the reduction in forest cover caused by tree mortality. Increases in average wind speeds affect emergency planning in the event of an aerial release of hazardous substances.

Climate Change Vulnerability Assessment and Resilience Planning

In February 2021 President Joseph Biden issued Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*. In part, the Order emphasizes taking a government-wide approach to the climate crisis and directs federal agencies to develop plans to increase the resilience of their facilities and operations in response to the impacts of climate change. In response to this direction, DOE published its 2021 Climate Adaptation and Resilience Plan. The 2021 Climate Adaptation and Resilience Plan builds on previous DOE actions to increase the resilience of DOE facilities and operations. The plan includes five priority actions, and Priority Action One is to assess vulnerabilities and implement resilience solutions at DOE sites.

As a DOE site, the Laboratory is required to conduct a vulnerability assessment and develop a resilience plan that will be tracked in the DOE Sustainability Dashboard. LANL's Vulnerability Assessment and Resilience Plan project is site-specific and builds on numerous related studies, initiatives, and programs undertaken at the Laboratory.

The Vulnerability Assessment and Resilience Plan project began in summer 2021 by identifying a planning team comprised of experts from across the Laboratory, including stakeholders from every associate directorate. The planning team began the process of identifying critical assets and infrastructure, identifying projected climate change and extreme weather hazards and vulnerabilities, and proposing and assessing climate resilience solutions.

Summary of Permits and Compliance Orders

Table 2-21 presents the environmental permits and administrative compliance orders the Laboratory operated under in 2021.

Table 2-21. Environmental Permits and Legal Orders that the Laboratory Operated under in 2021

Name	Activity	Issuing and Revision Dates	Expiration Date	Administering Agency
Los Alamos National Laboratory Hazardous Waste Facility Permit	A permit regulating management of hazardous wastes at the Laboratory, including storage and treatment. This permit also has standards for closure of indoor and outdoor areas used for hazardous waste storage or treatment. https://www.env.nm.gov/hazardous-waste/lanl-permit/	Renewed November 2010	December 2020 [Administratively Continued until new permit is effective]	New Mexico Environment Department
Administrative Compliance Order No. HWB-14-20 Settlement Agreement and Stipulated Final Order (Supplemental Environmental Projects)	Settlement of Administrative Compliance Order No. HWB-14-20 issued on December 6, 2014, for violations of the Hazardous Waste Act and the Laboratory's Hazardous Waste Facility Permit associated with the Waste Isolation Pilot Plant drum breach. As part of the settlement, DOE is funding a series of Supplemental Environmental Projects, including road improvements on transport routes to the Waste Isolation Pilot Plant. https://www.energy.gov/sites/prod/files/2015/01/f19/LANL%20ACO%20120614.pdf	Settlement Agreement and Stipulated Final Order finalized on January 22, 2016	None	New Mexico Environment Department
Compliance Order on Consent	An order giving requirements for the investigation, corrective actions, and monitoring of Solid Waste Management Units and Areas of Concern. [37925.pdf (nm.gov)]	Issued March 1, 2005 Revised October 29, 2012 Replaced by 2016 Compliance Order on Consent on June 24, 2016 2016 Compliance Order on Consent modified February 2017	December 1, 2021 Transferred to N3B on April 30, 2018	New Mexico Environment Department
Federal Facilities Compliance Order [for Mixed Wastes]	An order requiring the Laboratory to submit an annual update to its Site Treatment Plan for treating all mixed hazardous and radiological wastes (mixed	Issued October 4, 1995 Amended May 20, 1997	None	New Mexico Environment Department

Name	Activity	Issuing and Revision Dates	Expiration Date	Administering Agency
	waste). Los Alamos National Laboratory FFCO (nm.gov)			
Clean Air Act, Title V Operating Permit	A permit regulating air emissions from Laboratory operations (i.e., emissions from the power plant, asphalt batch plant, permanent generators, etc.). These emissions are subject to operating, monitoring, and record-keeping requirements.	Issued August 7, 2009 Reissued October 17, 2018	February 27, 2020 [Administratively continued until new permit is effective]	New Mexico Environment Department
New Mexico Air Quality Control Act Construction Permits	Permits regulating construction or modification of air emissions sources, including the following:			New Mexico Environment Department
	• 3 power plant Permit modification 2 (NSR 2195-B-M3)	Issued September 27, 2000; Reissued November 1, 2011; Major Modification July 26, 2018	None	
	• Asphalt plant at Technical Area 60 Permit revision 1 (GCP3-2195-G)	Issued October 29, 2002 Reissued September 12, 2006	None	
	• 1600-kilowatt generator at Technical Area 33 Permit revision 4 (NSR 2195-F R4)	Issued October 10, 2002 Reissued December 2, 2021	None	
	• Two 20-kilowatt generators and one 225-kilowatt generator at Technical Area 33 (NSR 2195-P)	Issued August 8, 2007	None	
	• Data disintegrator (NSR 2195-H R1)	Issued October 22, 2003 Revised June 14, 2006	None	
	• Chemistry and Metallurgy Research Replacement facility, Radiological Laboratory/Utility/Office Building Permit revision 2 (NSR 2195-N R2)	Issued September 16, 2005 Reissued September 25, 2012	None	
	• LANL exemption notifications - rock crusher removed (NSR 2195)	Issued June 16, 1999	None	
	• Technical Area 35, building 213, beryllium machining (NSR 632)	Issued December 26, 1985	None	
	• Technical Area 3, building 141, beryllium technology facility (NSR 634 M2)	Issued March 19, 1986 Revised October 30, 1998	None	
	• Technical Area 55 beryllium machining (NSR 1081 M1R6)	Issued July 1, 1994 Revised May 12, 2006	None	

Name	Activity	Issuing and Revision Dates	Expiration Date	Administering Agency
Authorization to Discharge [from Outfalls] Under the National Pollutant Discharge Elimination System	A permit authorizing the Laboratory to discharge industrial and sanitary liquid effluents through outfalls under specific conditions, including water quality requirements and monitoring requirements. Los Alamos National Laboratory (LANL) Industrial Wastewater Permit - Final NPDES Permit No. NM0028355 | US EPA	Issued August 12, 2014 Effective October 1, 2014 Modified May 1, 2015 Reissued March 30, 2022 Effective May 1, 2022	April 30, 2027	U.S. Environmental Protection Agency
National Pollutant Discharge Elimination System General Permit for Discharges of Storm Water from Construction Sites	A general permit (not LANL-specific) authorizing the discharge of pollutants during construction activities under specific conditions. Conditions include water quality requirements, inspection requirements, erosion and sediment controls, notices of intent to discharge, preparation of storm water pollution prevention plans, and other conditions. 2017 Construction General Permit (CGP) | US EPA	Effective February 16, 2017	February 16, 2022	
National Pollutant Discharge Elimination System Multi-Sector General Permit for Storm Water Discharges Associated with Industrial Activity	A general permit (not LANL-specific) authorizing facilities with some industrial activities to discharge storm water and some non-storm-water runoff. The permit provides specific conditions for the authorization, including pollutant limits to meet water quality standards, inspection requirements, compliance with biological and cultural resource protection laws, and other conditions. Stormwater Discharges from Industrial Activities-EPA's 2021 MSGP | US EPA	The 2021 Multi-Sector General Permit was issued on February 19, 2021 (Vol. 86 of the Federal Register, Page 10269) and became effective on March 1, 2021.	February 28, 2026	U.S. Environmental Protection Agency
[Individual Permit] Authorization to Discharge [from Solid Waste Management Units and Areas of Concern] Under the National Pollutant Discharge Elimination System	A permit authorizing the Laboratory to discharge storm water from 405 Solid Waste Management Units and Areas of Concern under specific conditions. Conditions include requirements for monitoring and for corrective actions where necessary to minimize pollutants in the storm water discharges. LANL - Storm Water Individual Permit - NPDES Permit No. NM0030759 | US EPA	Issued November 1, 2010	None	U.S. Environmental Protection Agency

Name	Activity	Issuing and Revision Dates	Expiration Date	Administering Agency
Clean Water Act, Section 404/401 Permits	The U.S. Army Corps of Engineers authorizes certain work within water courses at the Laboratory under Clean Water Act Section 404 permits. The projects below were authorized to operate under a Section 404 nationwide permit with Section 401 certification. The following projects had an ongoing annual monitoring requirement:	Effective January 4, 2021 (Four new nationwide permits, 12 nationwide permits reissued, 40 2017 nationwide permits remain effective.)	January 3, 2026 (all current nationwide Section 404 permits)	U.S. Army Corps of Engineers and New Mexico Environment Department (all permits and verifications)
	• Water Canyon Storm Drain Reconstruction Project	Annual monitoring and reporting required through 2023		
	• Mortandad Wetland Enhancement	Annual monitoring and reporting required through 2022		
	• Technical Area 72 Firing Site Storm Water Control	Annual monitoring and reporting required through 2023		
Groundwater Discharge Permit DP-857	A permit authorizing discharges to groundwater from the Laboratory's sanitary wastewater system plant and the Sanitary Effluent Reclamation Facility.	Issued December 16, 2016	February 28, 2026	U.S. Environmental Protection Agency
Groundwater Discharge Permit DP-1589	A permit authorizing discharges to groundwater from the Laboratory's septic tank/disposal systems.	Issued July 22, 2016	October 31, 2015 Application for renewal submitted to the U.S. Environmental Protection Agency in 2019. Administratively extended by the U.S. Environmental Protection Agency pending issuance of new permit.	U.S. Environmental Protection Agency
Groundwater Discharge Permit DP-1793	A permit authorizing discharges to groundwater from the Laboratory's land application of treated groundwater.	Issued July 27, 2015	December 16, 2021 Permit reapplication was submitted to the New Mexico	New Mexico Environment Department

Name	Activity	Issuing and Revision Dates	Expiration Date	Administering Agency
			Environment Department on June 17, 2021. Issuance of the renewed permit is pending.	
Groundwater Discharge Permit DP-1835	A permit authorizing discharges to groundwater from the Laboratory's injection of treated groundwater into six Class V underground injection control wells.	Issued August 31, 2016	July 22, 2021 A permit reapplication was submitted to the New Mexico Environment Department on January 20, 2021. Issuance of the renewed permit is pending.	New Mexico Environment Department
Groundwater Discharge Permit DP-1132	A permit authorizing discharges to groundwater from the Laboratory's Radioactive Liquid Waste Treatment Facility to three discharge locations: Outfall 051, mechanical evaporator system, or solar evaporation tank system.	Pending. Discharges occurring under Temporary Permission authorized by New Mexico Environment Department.	July 27, 2020 Transferred to N3B on April 30, 2018. Permit renewal application submitted to the New Mexico Environment Department Ground Water Quality Bureau on January 29, 2020. The application was determined administratively complete on February 7, 2020. Currently awaiting issuance of Draft Permit.	New Mexico Environment Department

Name	Activity	Issuing and Revision Dates	Expiration Date	Administering Agency
National Pollutant Discharge Elimination System Pesticide General Permit	A general permit authorizing the discharge of pesticides that have potential to enter waters of the U.S. https://www.regulations.gov/document?D=EPA-HQ-OW-2015-0499-0118	Issued October 31, 2011 Reissued October 31, 2016	October 31, 2026	U.S. Environmental Protection Agency

Facilities Included in the Enforcement and Compliance History Online Database

Table 2-22 lists Laboratory facilities in the Enforcement and Compliance History Online database that the U.S. Environmental Protection Agency maintains at https://echo.epa.gov/. This database lists environmental violations in the program areas regulated by the U.S. Environmental Protection Agency, such as water quality under the Clean Water Act or air quality under the Clean Air Act. The facility with compliance monitoring activities recorded within the last five years is listed at the top of the table. We excluded individual Laboratory projects listed as facilities that were only covered under the National Pollutant Discharge Elimination System Construction General Permit.

Table 2-22. Los Alamos National Laboratory Facilities Included in the Enforcement and Compliance History Online Database

Facility Name	Facility Address (all in Los Alamos, NM)	Facility Registry Service ID	Program Area(s) Considered
Los Alamos National Laboratory	1 Mi S Of Los Alamos	110010571880	Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act, Air Emissions Inventory, Toxics Releases Inventory
Los Alamos National Laboratory	P. O. Box 1663	110064871107	Clean Water Act
Los Alamos National Security, LLC, LANL	P. O. Box 1663 Mailstop A104	110038446312	Clean Water Act

Quality Assurance

Waste Management

Triad's programs for waste management, including quality assurance, are described in the institutional procedure P409, LANL Waste Management, and flow-down documents. N3B's programs for waste management, including quality assurance, are described in procedure N3B-P409-0, N3B Waste Management, and flow-down documents.

Air Quality and Protection

Air quality compliance activities are performed in accordance with the procedures and processes described in EPC-CP-QAP-001, *Environmental Compliance Programs Quality Assurance Plan*; EPC-CP-QAP-901, *EPC-CP Quality Procedure to Supplement ADESH-0007, Document Control;* and a series of Program Implementation Plans (PIPs):

- EPC-CP-PIP-0101, Rad-NESHAP Compliance Program
- EPC-CP-PIP-0340, Title V Operating Permit Program
- EPC-CP-PIP-0301, Greenhouse Gas Monitoring and Emissions Reporting

- EPC-CP-PIP-0310, Air Quality Refrigerants
- EPC-CP-PIP-0320, Emergency Planning and Community Right-to Know Act (EPCRA) Section 313 Reporting
- EPC-CP-PIP-0330: Air Quality Regulatory Review and Permitting
- EPC-CP-PIP-0370, Asbestos NESHAP Compliance
- EPC-CP-PIP-0380, Beryllium NESHAP Compliance

These documents ensure that compliance activities are planned, performed, and documented using approved procedures, data quality objectives, and integrated work processes. Over 20 detailed Quality Procedures are in place that flow down from these Program Implementation Plans.

Air Quality Compliance team personnel conduct semi-annual internal inspections of all permitted sources using detailed checklists to ensure all permit requirements are being met. Additionally, the New Mexico Environment Department Air Quality Bureau conducts annual external inspections of LANL's compliance with their Title V Operating Permit.

Analytical data is used to generate various compliance monitoring reports and deliverables that are submitted to regulatory agencies as required by the permit. Each report is subjected to a quality peer review before submittal to ensure that the data is correct, representative, and meets the established data quality objectives. All reports submitted to regulatory agencies are maintained as quality records in accordance with the permit and ADESH-QP-006, *Records Management Plan*.

Refrigerant program personnel also conduct internal semi-annual audits to ensure that refrigerant used in service, maintenance, repair, and disposal activities on refrigeration equipment is accounted for, thereby assuring compliance with the no-venting prohibition under federal regulations.

Members of the Radioactive Air Emissions Management team conduct stack sampling and monitoring activities, sampler inspections, flow measurements, and data analyses to meet regulatory requirements. All activities are conducted in accordance with procedure and with peer review. Representatives of the U.S. Environmental Protection Agency Region 6 periodically visit the site to evaluate operations. Analytical data calculations and compliance reports for the Radioactive Air Emission Team are subject to reviews similar to those described for the Air Quality Control program.

Surface Water Quality and Protection

Triad surface water compliance activities are performed in accordance with the procedures and processes described in EPC-CP-QAP-001, *Environmental Compliance Programs Quality Assurance Plan*; EPC-CP-QAP-901, *EPC-CP Quality Procedure to Supplement*; and EPC-CP-QAPP – *National Pollutant Discharge Elimination System Industrial Point Source Permit, Quality Assurance Project Plan for the National Pollutant Discharge Elimination System Industrial Point Source Permit Self-Monitoring Program*. These documents ensure that compliance activities are planned, performed, and documented using approved procedures, data quality objectives, monthly/quarterly/yearly sampling plans, and integrated work processes. In 2021, the following procedures were used to collect samples, prepare discharge monitoring reports, develop Water Quality Standards, cover the Section 404 permit, and prepare reapplication surveys:

- EPC-CP-PIP-1201, National Pollutant Discharge Elimination System Program Implementation Plan
- EPC-CP-TP-1202, Sampling at National Pollutant Discharge Elimination System Permitted Point-Source Outfalls
- EPC-CP-QP-1204, Performing National Pollutant Discharge Elimination System Reapplication Surveys
- EPC-CP-TP-1205, Calibration/Standardization of Instruments for Field Analysis
- EPC-CP-QP-060, Preparing Discharge Monitoring Reports for the National Pollutant Discharge Elimination System Industrial Point Source Permit Self-Monitoring Program
- EPC-CP-PIP-1301 404/401, Dredge and Fill Permit Program
- EPC-CP-PIP-1001, Water Quality Control Commission Program Implementation Plan.

Surface water compliance samples are collected, and the associated data are analyzed using established data quality objectives that define the appropriate type of data to collect and establish guidelines for the acceptance and use of the analytical data to make decisions regarding compliance at each outfall. These data quality objectives are developed in accordance with U.S. Environmental Protection Agency QA/G-4, *Guidance for the Data Quality Objectives Process*.

In 2021, the following procedures were used to collect samples and prepare reports for the Triad Construction General Permit and the Multi-Sector General Permit programs:

National Pollutant Discharge Elimination System Construction General Permit

- EPC-CP-PIP-2001, NPDES Construction General Permit Program Implementation Plan
- EPC-CP-QP-2002, Performing CGP Stormwater Inspections
- EPC-CP-TP-2003, CGP Rain Gauge Operation and Maintenance.

National Pollutant Discharge Elimination System Multi-Sector General Permit

- EPC-CP-PIP-2101, NPDES Multi-Sector General Permit Program Implementation Plan
- EPC-CP-TP-2102, Installing, Setting Up, and Operating ISCO Samplers
- EPC-CP-TP-2103, Inspecting ISCO Stormwater Runoff Samplers and Retrieving Samples for the MSGP
- EPC-CP-QP-2104, Installing, Inspecting, and Maintaining MSGP Single Stage Samplers
- EPC-CP-QP-2105, MSGP Stormwater Visual Assessments
- EPC-CP-QP-2106, Processing MSGP Stormwater Samples
- EPC-CP-QP-2107, Preparing Discharge Monitoring Reports for the NPDES Multi-Sector General Permit
- EPC-CP-QP-2108, MSGP Routine Facility Inspections
- EPC-CP-QP-2109, MSGP Corrective Actions
- EPC-CP-QP-2110, MSGP Stormwater Pollution Prevention Plan Preparation and Maintenance.

In 2021, N3B used the following procedures to collect samples and prepare reports for the surface water monitoring under the Storm Water Individual Permit, Multi-Sector General Permit and environmental surveillance programs.

- N3B-AP-ER-5008, Verifying and Certifying Individual Permit Corrective Action Measures

- N3B-DI-ER-4010, Desk Instruction for Managing Electronic Precipitation Data for Storm Water Projects
- N3B-DI-ER-4011, Desk Instruction for Managing Electronic Stage and Discharge Data from Stream Gauge Stations
- N3B-SOP-ER-3002, Spring and Surface Water Sampling
- N3B-SOP-ER-4001, Processing Surface Water Samples
- N3B-SOP-ER-4002, Splitting Surface Water Samples with a Dekaport Splitter
- N3B-SOP-ER-4003, Operation and Maintenance of Gauge Stations for Storm Water Projects
- N3B-SOP-ER-4004, Installing, Setting Up, and Operating Automated Storm Water Samplers
- N3B-SOP-ER-5002, Inspection, Installation, and Maintenance of Non-Engineered NPDES Individual Permit Storm Water Control Measures
- N3B-SOP-ER-5004, Inspecting Automated Storm Water Samplers and Retrieving Samples
- N3B-SOP-ER-5006, Determining and Evaluating Drainage Area Boundaries
- N3B-GDE-ER-5013, Inspection Guidance for Environmental Programs Watershed, Retention, and No Exposure Controls
- N3B-GDE-ER-5011, Hydrology for Individual Permit Corrective Actions and Control Measures – Design Guide
- N3B-GDE-ER-5015, Stormwater Best Management Practices Manual
- N3B-SOP-ER-5016, Multi-Sector General Permit Storm Water Corrective Actions
- N3B-QP-RGC-003, Land Application of Drill Cuttings
- N3B-AP-RGC-0002, Minor Spill Response Reporting Procedure
- N3B-PLN-RGC-0001, Sediment Management Decision Tree Guidance
- N3B-PLN-RGC-0003, Un-permitted Discharge Reporting
- N3B-QP-RGC-0002, Land Application of Groundwater
- N3B-EPC-CP-QP-064, MSGP Stormwater Visual Assessments
- N3B-AOP-TRU-3003, Material Release or Spill
- N3B-SOP-RP-0005, Radiological Emergency Response.

Groundwater Quality and Protection

Triad's Ground Water Quality and Protection program operates in accordance with EPC-CP-QAP-001, *Environmental Compliance Programs Quality Assurance Plan*. Discharges to treatment facilities that are part of this program are conducted in accordance with the Laboratory's P409.1 LANL's Waste Acceptance Criteria.

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Chapter 3: Environmental Programs and Analytical Data Quality

This chapter highlights the programs that Los Alamos National Laboratory (LANL or the Laboratory) has in place to (1) comply with environmental laws and regulations and (2) reduce the risk of Laboratory operations adversely affecting the environment. All of the Laboratory's environmental programs contribute to and are part of our Environmental Management System.

We first discuss processes and programs that support Laboratory-wide activities to improve our environmental performance. These processes and programs include the Pollution Prevention Program, the Site Sustainability Program, the Site Cleanup and Workplace Stewardship Program, and Integrated Project Review.

Next, we discuss our dedicated "core" programs that lead our compliance with specific environmental laws. Core programs are generally composed of subject matter experts in the requirements of laws such as the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act.

Finally, we discuss the process the Laboratory uses to ensure that the results from its monitoring and compliance sampling meet Department of Energy (DOE) standards for data quality.

Contents

Introduction

This chapter describes the institutional processes and dedicated “core” programs we use to manage the Laboratory’s environmental performance. These institutional processes and programs combine to form the Laboratory’s Environmental Management System.

This chapter includes information from both the management and operating contractor, Triad National Security, LLC (Triad), and the legacy waste cleanup contractor, Newport News Nuclear BWTX–Los Alamos (N3B). Both organizations have processes and programs to manage and improve the Laboratory’s environmental performance. However, Triad manages an overall, much larger scope of work at the Laboratory than does N3B. Therefore, with the exception of analytical data quality for sampling of environmental media, the bulk of the discussion in this chapter relates to programs managed by Triad.

The final section of this chapter discusses the process the Laboratory uses to ensure that the results from its sampling of environmental media (soil, water, air, foodstuffs, wildlife, and plants) meet DOE standards for data quality. This analytical data quality is crucial for both environmental compliance and legacy waste cleanup and is managed in partnership by N3B and Triad.

Institutional Processes and Programs

Environmental Management System

Certification of the Laboratory’s Environmental Management System to the International Organization for Standardization’s 14001 Standard

The International Organization for Standardization is independent and nongovernmental. It brings together experts to develop voluntary international standards. These standards describe the best practices for conducting a range of activities. The 14001 standard specifies the best practices for an environmental management system to improve an organization’s environmental performance, including reducing environmental impacts such as waste and becoming more environmentally sustainable. The Laboratory has maintained independent, third-party certification for its environmental management system under the 14001 standard since April 2006.

When the legacy waste clean-up contract was separated from the management and operating contract in 2018, each contractor organization took responsibility for its own Environmental Management System. Triad, the Laboratory’s management and operating contractor, currently manages the certified Environmental Management System described above.

N3B is building its Environmental Management System to align with its specific procedures and work controls. For its Environmental Management System, N3B is working toward its 14001 certification with the International Organization for Standardization.

Environmental Management System Program Activities

The Deputy Laboratory Director for Operations chairs Triad’s Environmental Senior Management Steering Committee. The committee sets institutional objectives and annual targets for environmental performance. The three institutional objectives for the Laboratory's environmental performance are (1) clean the past, (2) control the present, and (3) create a sustainable future.

Within these three objectives, Triad's Environmental Senior Management Steering Committee identified the following goals and targets (desired actions) for the 2021 fiscal year.

Clean the Past

GOAL: Clean it out.

Target

Identify and dispose of equipment, materials, and metals no longer in use, including internal and external storage areas.

GOAL: No new backlog.

Targets

Right-purpose existing space; upgrade for ongoing and future use.
Identify, characterize, and process wastes on time.

Control the Present

GOAL: Comply and protect.

Targets

- Create a world-class Waste Management System (planning and turnkey, cradle-to-grave support).
- Create a site-wide maintenance policy and implementation program plus tools to include programmatic, operations, and research and development–owned equipment in addition to facility-owned equipment.
- Identify, characterize, and document all industrial waste streams that discharge to the Sanitary Waste Water System.
- Implement waste-disposal planning for all projects.

GOAL: Optimize resources.

Targets

- Implement an effective chemical management program.
- Reduce the environmental impacts for material acquisition and life cycle management.
- Change the facility and infrastructure institutional siting process so that all siting is approved by the Infrastructure Programs Office and aligns with the comprehensive site plan.

Create a Sustainable Future

GOAL: Advance and apply new technology.

Targets

- Advance characterization technologies and reduce waste life cycle by using research and development to address key science and technology gaps.
- Incorporate best-in-class sustainable design criteria into new construction and campus planning efforts.
- Incorporate institutional resiliency planning (for example, climate change and global pandemics) into the comprehensive site planning process.

GOAL: Communicate and collaborate.

Target

- LANL interacts with a variety of internal and external stakeholders at the community, tribal, local, state, and federal level. In total, all are interested in the Laboratory's environmental mission activities and compliance with applicable state and federal requirements. LANL will continue to work closely with the New Mexico Citizens Advisory Board, the Regional Coalition of LANL Communities, the Buckman Direct Diversion Project, and the Eight Northern Indian Pueblo Council on matters pertaining to our environmental plans and activities. In addition, the Laboratory will continue to work closely with the DOE's Office of Environmental Management and support the office as its leaders brief the above-mentioned entities on legacy waste issues associated with the site.

The Laboratory annually updates a list of the significant environmental aspects that could be associated with its activities. In the language of ISO 14001, "an environmental aspect is an element of an organization's activities, products, or services that has or may have an impact on the environment." Table 3-1 lists and describes the environmental aspects with the potential for significant environmental impacts identified for 2021, along with some example activities.

Managers and teams from each Laboratory directorate develop environmental action plans annually using the institutional goals and targets along with their evaluation of their work activities. In 2021, Triad managed and tracked 228 actions in 12 of these action plans.

Table 3-1. LANL Significant Environmental Aspects

Environmental Aspects	Description	Examples
Air emissions	Activities that release or have the potential to release material into the air.	• Point-source air emissions from stacks, vents, ducts, or pipes • Diffuse air emissions from activities such as remediation and construction activities • Activities producing greenhouse gas contributors such as use of refrigerants and fluorinated gases, travel, and energy consumption.
Interaction with surface water and storm water	Activities that release or have the potential to release pollutants into a watercourse or through direct discharge to or contact with storm water (for example, discharge onto the ground near a waterway).	• Discharges from permitted outfalls • Spills and unintended discharges • Activity within the boundary of a watercourse • Application of pesticides
Discharge to wastewater systems	Activities that release or have the potential to release material to or from a wastewater treatment system (sanitary, chemical, or radiological).	• Laboratory sinks • Kitchens and bathrooms • Wastewater collected and transported to a wastewater facility
Interaction with drinking water supplies/systems or groundwater	Activities that release or have the potential to release material into a drinking water supply system or into groundwater. These activities include planned or unplanned releases onto the ground or into surface water that have the potential to migrate to groundwater. Impacts can be positive or negative.	• Cooling tower water supply use • Work involving groundwater wells or associated systems • Land application of water • Septic systems and sanitary holding tanks • Permitted wastewater storage basins
Work within or near floodplains and wetlands	Building structures or impoundments in a floodplain or wetland, or activities that release or have the potential to release material onto or into a floodplain, wetland, or area of overland flow.	• Monitoring well operations • Structures built in a floodplain or wetland • Activities or emergencies that disrupt the integrity of a floodplain or wetland
Interaction with wildlife and/or habitat	Activities that impact or have the potential to impact federally protected wildlife or their habitats, migratory birds, and other wildlife not managed under any federal law.	• Removal of weeds, trees, brush, or invasive species • Installation and operation of fencing, buildings, power lines, towers, drainage, or other structures • Installation and operation of night lighting • Work operations that generate noise
Biological hazards	Activities that generate, use, or dispose of biological agents. These agents exclude human viral, bacterial, or blood-borne pathogens.	• Management of medical materials and byproducts
Interaction with soil resources	Activities that disturb surface or subsurface soils, or release or have potential to release material onto or into the ground. These activities include planned or unplanned deposition of air-borne particulates and releases of solids or liquids onto	• Ground-disturbing activities, for example, construction, utility line repair, or maintenance of dirt roads • Operations that result in point source air emissions from stacks, vents, ducts, or pipes

Environmental Aspects	Description	Examples
	or into the ground, and activities that may result in migration or deposition of radioactive constituents onto or into the ground. Activities may result from routine work or from emergency or off-normal events.	• Operations that are sources of diffuse air emissions such as open detonation, remediation activities, and decontamination and decommissioning projects • New construction, site selection, and brownfield versus greenfield development
Spark- or flame-producing activities	Activities that cause or have the potential to start a fire or wildfire.	• Off-road vehicle use • Construction or outdoor maintenance work activities • Outdoor spark- or flame-producing operations • Smoking
Cultural/historical resources	Activities that impact or have the potential to impact cultural or historical resources. Resources include, but are not limited to, historical buildings, buildings of special significance, archaeological sites, traditional cultural properties, historic homesteads, and trails. Activities may result from routine work or from emergencies or off-normal events.	• Maintenance or expansion of existing areas (trails, walkways, roads, easements) • Ground-disturbing activities below grade or surface areas • Maintenance, modification, or demolition of structures, including potentially or designated historic structures • Off-road vehicle use • Vegetation removal and weed mitigation activities • Archaeological excavations
Visual resources	Activities that impact or have the potential to impact visual landscapes.	• Construction, management, and maintenance of access roads, fencing, utility corridors, and power transmission systems • Construction, management, and maintenance of staging areas, storage yards, debris piles, litter, and other "eyesores" • Tree thinning • Security or after-hours lighting
Hazardous or radioactive material and waste packaging and transportation	Activities that handle, package, or transport hazardous waste or radioactive materials.	• Transportation of chemicals • Transportation of low-level radiological waste, mixed low-level waste, or transuranic waste
Radioactive waste generation and management	Activities that generate or manage (handle, store, or dispose of) radioactive waste.	• Laboratory or research and development procedures using or generating radioactive material • Cleanup of historical waste disposal areas • Development of alternative processes or controls that reduce radioactive materials utilization and/or cross-contamination
Hazardous or mixed-waste generation and management	Activities that generate or manage (handle, store, treat, or dispose of) hazardous or mixed waste.	• Laboratory or research and development procedures using or generating hazardous materials • Disposal of unused, unspent laboratory chemicals
Solid or sanitary waste generation and management	Activities that generate or manage (handle, store, treat, or dispose of) nonhazardous and	• Laboratory, machining, and process operations wastes (non-hazardous or nonradioactive)

Environmental Aspects	Description	Examples
	nonradioactive waste intended for disposal at a municipal or industrial waste landfill.	• Nonrecyclable waste, for example, some office waste and some construction and demolition debris
Interaction with contaminated sites	Activities that have the potential to increase or spread contamination because they are conducted within the boundary of or in close proximity to contaminated areas. Contaminated areas include solid waste management areas, radiological sites, nuclear facilities, or high-explosive sites.	• Construction • Mitigation • Demolition • Open detonation
Chemical (industrial and laboratory) use and storage	Activities that result in the purchase, use, management, movement, or storage of chemicals. Activities may result from routine work or from emergency or off-normal events.	• Chemical use in research laboratories • Vehicle operation and maintenance (fuels, coolants, lubricants, etc.) • Building cleaning and maintenance (janitorial supplies) • Application of pesticides, fertilizers, and other roads and grounds maintenance chemicals
Radioactive material use and storage	Activities that handle or store radioactive materials.	• Radioactive material machining or processing • Change in location of activities or operations involving work with radioactive materials • Evaluation of processes and operations to increase efficient use of materials
Surplus properties and material management	Activities that manage (handle or store) in-use materials, surplus supplies, real estate, or other property.	• Managing (leasing, renting, selling, or purchasing) active or inactive real estate, includes evaluation of property for contamination • Managing (storing, using, recycling, reusing, disposing of) surplus property • Cleanup and recommissioning of work areas • Decontamination and decommissioning facilities
Resource use and conservation	Activities or practices that affect resource use and conservation, may increase or reduce demand or wastes, or may drive increases in efficiency of resource use (labor, natural material, energy, etc.), use of alternative material, or reuse/recycling opportunities.	• Applying sustainable design principles, for example, cool roofs, natural lighting, insulated glass, and recycled or low-impact building materials • Procuring alternative energy or fuel sources for the Laboratory • Change in the amount of energy or water required for a scope of work • Reusing and repurposing materials, equipment, and supplies • Purchasing “green” or environmentally preferable products
Storage of materials in tanks	Activities that involve handling or storing materials in tanks.	• Operating and/or maintaining aboveground tanks in accordance with the Laboratory’s hazardous waste permit
Engineered nanomaterials	Activities involving intentionally created particles with one or more dimensions between 1 and 100 nanometers.	• Nanotechnology research and development that generates nanoparticles requiring environmental or worker safety controls • Nanoparticle waste characterization, packaging, storage, transport, treatment, or disposal

The online course *Environmental Awareness Training* is required for all employees, including subcontractors, who are onsite for longer than two weeks. Retraining is required every two years. The course is an overview of environmental requirements for the site.

The Laboratory's Environmental Management System has both external audits and internal assessments every year. All findings and corrective actions generated from these audits and assessments are tracked to closure in an issues management system. In 2021, two external certification audits were held, the second of which found one minor nonconformity (a minor deficiency that does not seriously affect the efficiency of the Environmental Management System) related to issues management. Also in 2021, one internal assessment found three minor nonconformities related to training records, storage of waste, and storage of flammables.

DOE sites are annually scored red, yellow, or green on metrics evaluating their Environmental Management Systems. In 2021, the Laboratory scored green on each of the following federal government metrics:

- Activities, products, and services and their associated environmental aspects were evaluated for significance and documented. Any necessary changes were made or are scheduled to be made.
- Measurable environmental objectives were in place.
- Operational controls were established, implemented, controlled, and maintained in accordance with operating criteria.
- An environmental compliance audit program was in place, and audits were completed according to schedule. Audit findings were documented, and corrective actions were implemented.
- As directed by Executive Order 13834, *Efficient Federal Operations*, sustainability goals were addressed.

Site Sustainability

The Laboratory's sustainability efforts and goals align with the following climate-related Executive Orders:

- Executive Order 13990, *Protecting Public Health and the Environment and Restoring Science to Tackle Climate Crisis*, which sets the policy of the federal government to, among other things, reduce greenhouse gas emissions and bolster resilience to the impacts of climate change.
- Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, which announced a goal of net-zero emissions and 100 percent renewable energy by 2050.
- Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, which established government-wide goals for net-zero carbon emissions.

The Laboratory's Site Sustainability Plan focuses on developing more efficient and resilient operations through three key initiatives: (1) replacement of the steam plant with a power plant with new controls, a new gas pipeline, and a more efficient combustion gas turbine generator; (2) construction and operation of an onsite 10-megawatt photovoltaic facility; and (3) implementation of other net-zero carbon emissions or decarbonization measures. The Site

Sustainability Plan has been developed in coordination with other plans for major infrastructure improvements and site upgrades, including a LANL Campus Master Plan.

LANL has made significant improvements in energy and water efficiency over the past 10 years. These include

- Recommissioning heating, ventilation, and air conditioning systems in 40 facilities.
- Replacing and upgrading building automation systems in 15 facilities.
- Continuously monitoring 81 facilities with fault detection and data analytics software SkySpark®.
- Participating in an energy savings performance contract for extensive heating, ventilation, air conditioning, and lighting upgrades, currently in its performance period. About $1.2 million in annual savings is anticipated over 20 years.
- Participating in an energy savings performance contract for the steam plant replacement project, now under construction.
- Developing a photovoltaic facility, including completion of the environmental assessment and biological assessment, now in process.
- Creating the LANL Smart Labs Program.
- Creating the My Green LANL Program for certified sustainable measures.
- Updating the LANL Engineering Standards Manual to incorporate more comprehensive sustainable design criteria, including My Green LANL and Smart Labs.
- Insulating steam pits using infrared technology to save 112,000 British thermal units per year per pit with a payback of just over two years.
- Installing light-emitting diode and motion-sensing lighting in parking garages and solar lighting in outside parking lots.
- Installing 24 personal and nine government electric vehicle charging stations.
- Using a mobile shredding truck to improve paper recycling efficiency with savings in fuel, labor, and operating expenses.

We estimate that over the next 10 years the Laboratory may double its energy use in high performance computing facilities, with accompanying increases in the use of water needed for cooling. To support this mission growth and maintain efficient operations, major investments in water infrastructure are required. In addition to water efficiency initiatives, the Laboratory will continue to operate the Sanitary Effluent Reclamation Facility, implement targeted water use reduction projects, and invest in new water treatment systems that increase the number of concentration cycles in cooling towers.

We are developing a net-zero carbon emissions plan that focuses on four key areas: (1) decarbonization of the electrical supply; (2) research in carbon capture, carbon-neutral hydrogen, bioenergy, and bioproducts; (3) electrification of building heating systems; and (4) reduction of energy use in facilities and vehicles.

Table 3-2. Fiscal year 2021 status and planned strategies for the Laboratory's site sustainability goals

DOE Goal	Fiscal Year 2021 Efforts	Planned Efforts
Reduce energy use intensity (British thermal units per gross square foot) in goal-subject buildings.	We achieved a 7.4% percent% reduction from the fiscal year 2015 baseline and completed efficiency conservation measure designs and scoping for seven facilities.	• Continue to implement building automation standards in facilities • Continue lighting upgrades • Reevaluate facilities that may be entering standby to remove them from the goals • Develop an ongoing commissioning program
Energy Independence and Security Act Section 432 continuous (four-year cycle) energy and water evaluations.	We met the annual target of doing energy and water evaluations in 25% of eligible facilities and assessed software for use in life-cycle cost analysis.	• Complete 21 energy and water evaluations on facilities covered under Section 432 and four evaluations on high-performance sustainable buildings that are not covered
Meter individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate.	We have partially metered 135 LANL-owned facilities and six facilities are fully metered. We added three new gas meters. More than 20 gas meters were purchased to replace broken meters on high-performance sustainable buildings and other facilities.	• Finish communication connections for three new gas meters • Continue meter replacement for 26 high-performance sustainable buildings or future sustainable building candidate facilities
Reduce potable water use intensity (gallons per gross square foot).	We achieved an 18.5% reduction from the fiscal year 2007 baseline in potable water use intensity. Additionally, 32.6 million gallons of wastewater were treated at the Sanitary Effluent Reclamation Facility, reducing the amount of potable water needed for cooling at the Strategic Computing Complex.	• Increase cycles of concentration at the Strategic Computing Complex cooling towers • Continue exploring opportunities for water reclamation at the Sanitary Effluent Reclamation Facility
Reduce nonpotable freshwater consumption (gallons) for industrial, landscaping, and agricultural uses.	All water used at LANL is potable.	N/A
Reduce nonhazardous solid waste sent to treatment and disposal facilities.	LANL diverted 61.5% of nonhazardous solid waste. Some waste was diverted from landfill through the Los Alamos Eco Station; these waste items included concrete, metals, pallets, asphalt, tires, and brush.	• Continue programs such as furniture reuse, reusable moving bins, woody waste composting, clean fill, and others to reduce nonhazardous waste sent to landfill
Reduce construction and demolition materials and debris sent to treatment and disposal facilities.	LANL diverted 50% of construction and demolition waste, including concrete and metals.	• Continue onsite processing and reuse of concrete, including the recycling of the associated rebar

DOE Goal	Fiscal Year 2021 Efforts	Planned Efforts
Reduce petroleum consumption.	Fleet management makes every effort to downsize vehicles during the replacement cycle depending on mission requirements. We are increasing the use of ride-share programs.	• Depending on mission and availability, transition 29 leased vehicles to low greenhouse gas emission types • Downsize 12 large passenger hauling vehicles to smaller, more fuel-efficient types
Increase alternative fuel consumption.	We acquired and used alternative fuels (E85 and biodiesel) through a contract with a local tribal business.	• Continue to contract purchase of E85 and biodiesel • Research alternatives similar to the mobile fueling trucks currently used
Acquire alternative fuel and electric vehicles.	We are increasing use of alternative fuels (E85 and biodiesel) and exploring electric vehicle/plug-in hybrid electric vehicle options.	• Increase and encourage electric vehicle options when replacing fleet vehicles
Increase consumption of clean and renewable electric energy.	Ten percent of LANL's energy comes from clean and renewable sources, while 1.7% of the electrical energy consumed is from renewable sources located on federal land, or "onsite" sources.	• Begin construction of the 10-megawatt onsite photovoltaic system in 2022
Increase consumption of clean and renewable nonelectric thermal energy.	We began planning for net-zero energy, net-zero carbon emissions, and net-zero carbon ready solutions at LANL, which will include thermal energy.	• Identify facility thermal energy solutions to meet zero-emissions interim targets and executive order requirements
Increase the number of owned buildings that are compliant with the Guiding Principles for Sustainable Buildings.	Currently 4.9% of LANL-owned buildings have achieved compliance with the Guiding Principles. We reassessed five existing high-performance sustainable buildings to confirm compliance and assessed energy savings of 24 additional existing buildings to consider for certification.	• Repair meters to keep existing buildings compliant • Prepare for certification of three additional facilities • Continue to focus on new construction projects
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring all sustainability clauses are included as appropriate.	LANL deployed a new procurement system called SAP Ariba with greater capabilities for sustainable acquisition. We evaluated a biobased product piloted by the Department of Defense.	• Develop a sustainable products catalog in Ariba • Expand use of biobased products including one piloted by the Department of Defense
Implement lifecycle, cost-effective efficiency and conservation measures with appropriated funds and/or performance contracts.	We continued installing building automation systems in multiple facilities, improving the Sanitary Effluent Reclamation Facility, and making improvements in building lighting, heating, ventilation, and air conditioning systems.	• Implement $3.5 million of energy- and water-efficiency projects
Electronics stewardship from acquisition, to operations, to end of life.	Currently 96.7% of LANL's eligible electronics procurements are environmentally sustainable, and 100% of electronics were recycled at the end of life. We achieved 100% power management on all eligible personal computers and monitors and ensured excess electronics are available internally and externally for reuse when safe.	• Continue purchase of sustainable electronic office products

DOE Goal	Fiscal Year 2021 Efforts	Planned Efforts
Increase energy and water efficiency in high performance computing and data centers.	We completed a pump replacement project for the Sanitary Effluent Reclamation Facility, which cools supercomputer facilities with reuse water.	• Begin design work on a new, highly efficient high performance computing facility
Implement climate adaptation and resilience measures.	We began work on the Vulnerability Assessment and Resilience Planning document.	• Complete a site-wide Vulnerability Assessment and Resilience Planning document and then update every four years
Reduce Scope 1 & 2 greenhouse gas emissions.	We began work on the LANL Net-Zero Carbon Emission Plan and purchased 12 new plug-in hybrid vehicles.	• Complete a Net-Zero Carbon Emission Plan • Use renewable sources for power procurement • Continue the 10-megawatt photovoltaic project
Reduce Scope 3 greenhouse gas emissions.	We have achieved a 53.8% reduction from the fiscal year 2008 baseline and piloted a telework program that reduces emissions from commuting.	• Implement transportation plan and teleworking options for all employees • Install more electric vehicle chargers

Operating Experience Program

The Laboratory has an operating experience and lessons learned program called “OPEX at LANL.” The purpose of the program is to capture and apply lessons from experiences and to communicate best practices to prevent or reduce the severity of future undesirable events. OPEX at LANL collects and distributes information internal to the Laboratory and from other sources, including the other DOE sites. The program provides an online database of relevant lessons learned, best practices, safety information, security information, and programmatic information for workers to use and share, as well as a quarterly publication that provides event trends, causes, and learning opportunities.

Pollution Prevention

The Laboratory’s Pollution Prevention Program works to reduce waste and pollution resulting from Laboratory operations. The program activities include but are not limited to (1) reducing all types of radioactive waste; (2) funding and supporting projects that reduce or eliminate the use of hazardous chemicals; and (3) identifying and researching emerging contaminants. Program staff prepare an annual Hazardous Waste Minimization Report for the New Mexico Environment Department and support the Laboratory’s Site Sustainability Plan.

The program carries out site-wide initiatives to address potential waste-related risks. For example, the Pollution Prevention Program is currently addressing risk related to per- and polyalkylfluoroalkyl substances (PFAS). Program staff are working alongside compliance specialists to prepare the Laboratory for future state and federal regulation of these substances. Ongoing efforts include identifying legacy and current uses of PFAS at LANL and conducting environmental and operational sampling.

The Pollution Prevention Program recognizes projects across the Laboratory through annual environmental awards and internal and external communications. The program allocates funds to support the work of Laboratory scientists and engineers to minimize use of hazardous substances. We funded work on development of a non-petroleum-based alternative to plastic and research on the use of bacteria as a replacement for strong acid in target component preparation.

The Pollution Prevention Program is collaborating with the LANL Sustainability Office on two initiatives related to the Laboratory’s response to climate change. The first initiative is to reduce use of climate change–causing pollutants. The Sustainability Office and the Pollution Prevention Program are identifying funding opportunities to reduce use of the potent greenhouse gas sulfur hexafluoride. In 2021 Pollution Prevention funded a sulfur hexafluoride gas reclamation unit for the Focused Experiments group. With the device that was purchased, the group can capture and reuse the gas during maintenance activities. The second initiative is a LANL Vulnerability Assessment and Resilience Plan. The plan will enable LANL to identify, prepare for, and meet the challenges posed by climate change.

Site Cleanup and Workplace Stewardship Program

In some locations at the Laboratory, materials and equipment have been abandoned after projects ended or staff retired. The Site Cleanup and Workplace Stewardship Program was established in 2013 to work with organizations on the proper disposition of these items and to prevent similar occurrences. The program staff work with the responsible organization(s) to develop a work plan for removing abandoned items, clearing indoor and outdoor spaces, and implementing sustainable housekeeping practices. Goals of the program are to divert as much material as possible from waste streams and to establish or improve processes to help reduce legacy and abandoned items in the future.

The Site Cleanup and Workplace Stewardship Program works closely with the Property Management Group, Excess Operations, Environmental Protection and Compliance Division, and other organizations to improve processes and policy. In 2020, the program moved into the Infrastructure Programs Office at LANL, allowing better integration with site planning activities. This move has helped integrate cleanup concerns into space management.

In 2021, the Site Cleanup and Workplace Stewardship Program

- Continued improving the management of sheds and transportable storage buildings at LANL by working with organizations to identify points of contacts, installing point-of-contact signage, and updating structure number signage as well as drafting a reuse assessment and reassignment process to better track and manage structures and
- Coordinated over 20 cleanup and metal recycling projects across the Laboratory, including
  - Preparing, downsizing, releasing, and recycling metal at Technical Area 53,
  - Draining and recycling over 35 refrigeration units for Bioscience Division,
  - Working with Physics Division to clean out and remove four storage transportainers,
  - Disconnecting and sending for recycle legacy power supplies and rectifiers,
  - Removing and sending for recycle several large legacy items from a high bay area to allow more room for programmatic growth,
  - Dismantling and sending for recycle several legacy counterweights made of concrete encased in steel,
  - Releasing and recycling three legacy remote handling trailers, and
  - Providing laborer assistance to organizations to help load low-level waste bins, thereby accelerating the project.

Greenhouse Gas Reduction

In fiscal year 2021, the Laboratory achieved a 7.5 percent reduction in Scope 1 and 2 greenhouse gas emissions compared to fiscal year 2008. Scope 1 emissions are direct emissions from Laboratory-owned or leased equipment and vehicles, unplanned releases of gases or vapors onsite, and use of natural gas onsite. Scope 2 emissions are generated by utility companies while producing electricity, heat, or steam purchased by the Laboratory. The Site Sustainability Program’s initiatives to reduce energy use helped reduce the Laboratory’s greenhouse gas emissions.

The Laboratory also has achieved significant reductions in Scope 3 emissions since fiscal year 2008. Scope 3 emissions are generated by offsite activities, including employee commutes, employee ground and air travel, and electricity transmission and distribution losses.

In December 2021, the Biden-Harris administration issued Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, setting numerous goals to reduce overall emissions and capitalize on clean energy production. The Laboratory will work hard to meet these goals in the coming years by installing additional electric vehicle infrastructure, increasing our use of carbon-free electricity, and working with engineers to ensure that cost-effective designs and materials are used for equipment and buildings considering the life cycle of the product or building from construction through disposal.

However, the Laboratory's energy use is expected to steadily increase over the next 10 years as high performance computing and expanded activities at the Los Alamos Neutron Science Center use more electrical power. To help meet the growing electricity demand and reduce greenhouse gas emissions, we are working to finish Phase I of the Steam Plant Replacement project, including adding a more efficient generator and controls, a new high-pressure gas line, and two new efficient natural gas boilers. Once complete, these upgrades will avoid the equivalent emissions of roughly 507 passenger vehicles per year and save the Laboratory roughly $6 million in energy and maintenance costs per year. Additionally, we are in the beginning phases of installing a 10-megawatt photovoltaic onsite.

Integrated Project Review

All new and modified work, activities, operations, and projects at the Laboratory, including changes in scope or location, must be reviewed for environmental and other compliance requirements prior to executing the work.

The Integrated Review Tool is a web-based platform that makes submitting projects for review easier and more consistent. It includes the Permits and Requirements Identification tool, the Excavation/Fill/Soil Disturbance Permit Request system, and the Major and Minor Site-Selection process in a single location. Work owners or planners enter their project information into the application, and subject matter experts review the projects and identify the relevant requirements, actions, and permits needed to perform the work.

The Environmental Protection and Compliance Division's Integrated Project Review Program coordinates environmental subject matter expert reviews and interacts with work owners and planners. The program participants include subject matter experts employed by Triad from the following compliance programs: Air Quality, Biological Resources, Consent Order sites (Solid Waste Management Units and Areas of Concern), Cultural Resources, Environmental Health Physics, National Environmental Policy Act, Resource Conservation and Recovery Act, Waste and Materials Management, and Water Quality.

N3B project managers use the Integrated Review Tool for some projects and internal N3B procedures for the remaining projects. N3B uses procedures N3B-P351, *Project Review Process*, and N3B-P101-17, *Excavation/Fill/Soil Disturbance*, to identify compliance requirements for new or modified activities. The procedures engage subject matter experts from the following N3B compliance programs: Air Quality, Biological Resources, Cultural Resources, Safety and Industrial Hygiene, National Environmental Policy Act, Resource Conservation and Recovery Act, Waste and Materials Management, and Water Quality.

In 2021, Triad subject matter experts reviewed 311 management and operating contractor projects in the Permits Requirements Identification tool and 688 projects in the

Excavation/Fill/Soil Disturbance permitting tool. In addition, 11 legacy waste cleanup projects (performed by N3B) were reviewed in the Permits and Requirements Identification tool.

Over the past several years, the Integrated Project Review Program has supported improvements in the Integrated Review Tool. Several training courses were developed and implemented through the Laboratory's institutional training system in the last several years including: Permits Requirements Identification for the Requestor, Integrated Review Tool – Geographic Information Systems Mapping Training, and Excavation, Fill, and Soil Disturbance Permit Process. Permits Requirements Identification for the Subject Matter Expert training course is being developed for 2022.

Dedicated Core Programs

Air Quality Program

The Laboratory maintains a rigorous air quality program that addresses emissions of radioactive and non-radioactive air pollutants. The program consists of three main parts: compliance and permitting, stack monitoring, and ambient air monitoring.

What are these air quality terms?

Stack – vertical chimney or pipe that releases gases produced by industrial processes into the air.

Ambient air – atmospheric air in its natural state.

Criteria air pollutants – six specific pollutants regulated by the U.S. Environmental Protection Agency under the Clean Air Act because they cause smog, acid rain, or other health hazards.

Hazardous air pollutants – chemicals and radionuclides that at high-enough levels are known or suspected to cause cancer, other serious health effects, or adverse environmental effects.

Compliance and Permitting

LANL operates under several air emission permits issued by the New Mexico Environment Department Air Quality Bureau, as well as approvals issued by the U.S. Environmental Protection Agency for construction of new facilities or operations involving radionuclide emissions. These permits and approvals have federally enforceable emission limits and require specific pollution-control devices, monitoring of emissions from stacks, and detailed recordkeeping and reporting.

LANL is authorized to use materials and operate equipment that produce some air pollutants under the conditions defined in our Title V Operating Permit. Our permitted emission sources include a steam plant, a combustion turbine, boilers and heaters, emergency generators, beryllium operations, chemical use, degreasers, data destruction (paper shredding), evaporative sprayers, and a small asphalt batch plant. Each source type has its own emission limits for criteria air pollutants and hazardous air pollutants. The Title V Operating Permit also includes facility-wide emission limits for criteria and hazardous air pollutants. As part of compliance with the Title V Operating Permit, we report emissions and provide monitoring records from the permitted sources twice a year to the New Mexico Environment Department, which inspects the Laboratory periodically for compliance.

Stack Monitoring

As described in greater detail in Chapters 2 and 4, the Laboratory rigorously controls and monitors emissions of radionuclides from building stacks, as required by the Clean Air Act. We evaluate operations to determine the potential for stack emissions to adversely affect the public or the environment. In 2021, 27 stacks were continuously sampled for the emission of radioactive materials into the air.

Ambient Air Monitoring

The Laboratory operates a network of ambient air quality monitoring stations to detect other possible radioactive air emissions (see Chapter 4). The network includes stations located onsite, in adjacent communities, and in regional locations. In 2021, we operated 44 ambient air quality monitoring stations at distances up to 25 miles from the Laboratory.

Water Quality Programs

The Laboratory has multiple programs dealing with the quality of surface waters and groundwater. We comply with the following National Pollutant Discharge Elimination System permits: the industrial outfall permit, the individual permit for storm water discharges, the construction general permit, the multi-sector general permit, and the pesticide general permit (see Chapter 2). The Laboratory monitors and remediates groundwater (see Chapter 5) and conducts environmental surveillance monitoring on surface water base flow, storm water flow, and deposited sediments (see Chapter 6). We have also implemented low-impact development projects at Technical Areas 3 and 53 that reduce the amount of storm water runoff from developed areas to improve the quality of the storm water flow.

In 2021, we continued the process to renew the Laboratory’s individual permit for storm water discharges. We submitted a renewal application to the U.S. Environmental Protection Agency on June 15, 2019. On November 30, 2020, the New Mexico Environment Department issued the state’s certification of Individual Permit NM0030759. The final permit has not been issued by the U.S. Environmental Protection Agency. The Laboratory’s current individual permit has been administratively continued until a new final permit is issued by the U.S. Environmental Protection Agency.

In 2021, the Laboratory operated under groundwater discharge permits issued by the New Mexico Environment Department. These permits covered discharges from the sanitary wastewater system plant and the sanitary effluent reuse facility, discharges from six septic tank systems, land application of treated groundwater, and injection of treated groundwater into the aquifer through six underground injection control wells.

The New Mexico Environment Department publicly noticed the Laboratory’s draft permit DP-1132 for discharges from the Technical Area 50 Radioactive Liquid Waste Treatment Facility in December 2021 and is planning on finalizing this permit in 2022.

In 2021, we continued operating the Laboratory’s site-wide network of storm water gauge stations to monitor stream flow and collect storm water samples in all major canyons. We also continued operating the early notification system that provides the operators of Santa Fe’s Buckman Direct Diversion (which diverts water from the Rio Grande for Santa Fe’s drinking water supply) early notification of storm water flows through Los Alamos Canyon into the Rio

Grande. Finally, we documented the effectiveness of installed sediment-control measures for the Los Alamos/Pueblo Canyon watershed and the Sandia Canyon wetland to the New Mexico Environment Department.

Hydrology Protocol Study

In the State of New Mexico's *Standards for Interstate and Intrastate Surface Waters* (Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code), Section 128 has uniquely classified some stream reaches on Los Alamos National Laboratory property (Segment 128 Waters) as ephemeral-intermittent reaches. These stream reaches mostly have semi-arid hydrologic characteristics and mostly represent ephemeral waters (having water briefly only in direct response to precipitation). However, intermittent conditions (having water for extended periods at certain times of the year) can occur in some locations.

The New Mexico Environment Department developed a Hydrology Protocol to distinguish between perennial, intermittent, and ephemeral water courses in New Mexico. During the 2015 triennial review of New Mexico's water quality standards, the New Mexico Environment Department, the DOE, the Laboratory, and Amigos Bravos (a nonprofit organization) entered into a legal agreement to share information and data to identify (a) which Segment 128 waters are ephemeral and which are intermittent, (b) the existing uses of Segment 128 waters, (c) the presence of macroinvertebrates or shellfish in these waters, and (d) any significant change to the chemical, physical, or biological integrity of these waters. Between 2015 and 2020, Hydrology Protocol assessments were conducted on Segment 128 stream reaches. The New Mexico Environment Department proposed regulatory changes based on the hydrology protocol studies in the 2020 Triennial Review proceeding.

A public hearing for the 2020 Triennial Review took place over four days beginning on July 13, 2021. Following the hearing, the New Mexico Water Quality Control Commission proposed a new classification at Section 140 of the *Standards for Interstate and Intrastate Surface Waters* for intermittent waters at LANL (140 Waters) based upon hydrology protocol studies. Stream reaches in Twomile Canyon, S Site Canyon and Effluent Canyon have been classified as 140 Waters, and the assigned aquatic life use in these reaches have been changed from limited aquatic life to marginal warmwater aquatic life. The Water Quality Control Commission also adopted the Laboratory's proposal to extend perennial waters as defined in Section 126 (126 Waters). The new 126 waters are located in the Pajarito Watershed and are assigned a coldwater aquatic life use. In total, these changes will result in increased water quality protections for an additional three miles of surface waters within LANL's boundaries. In 2021, the updated portions of the *Standards for Interstate and Intrastate Surface Waters* (Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code) were still proceeding through the triennial review process.

Sanitary Sewage Sludge Management

The Laboratory composts solid wastes produced by its Sanitary Waste Water System to eliminate transporting sewage biosolids offsite for landfill disposal. In 2018 the New Mexico Environment Department Solid Waste Bureau approved the Laboratory's registration renewal of the Sanitary Waste Water System Compost Facility. The compost will be land-applied at the Laboratory for beneficial use. This use includes landscaping, post-construction remediation, and range land restoration. Before compost can be land-applied, it must meet pollutant concentration limits, Class A pathogen requirements, and vector attraction reduction requirements as specified in the U.S. Environmental Protection Agency's *Standards for the Use* *or Disposal of Sewage Sludge* in the Code of Federal Regulations Title 40, Part 503. The final locations and rates for compost application are subject to site selection criteria, best management practices, and administrative controls. For example, compost will not be applied in canyon bottoms, wetlands, or in areas with shallow perched alluvial groundwater. Application rates will not exceed agronomic rates provided by the New Mexico State University Cooperative Extension Service. In 2021, the Sanitary Waste Water System Compost Facility produced 52 tons of composted biosolids. Finished compost has been continually stockpiled at the facility, although some land application of compost occurred at the Sanitary Waste Water System in 2018.

Cultural Resources Management

Approximately 90 percent of DOE land in Los Alamos County has been surveyed by the Laboratory's cultural resources staff for prehistoric and historic cultural resources. Surveys have identified over 1,900 sites, with the oldest occupations dating back 10,000 years. About 79 percent of the Laboratory's cultural resources sites (including structures, trails, agricultural features, and rock art) are associated with Ancestral Pueblo people. However, the sites at the Laboratory also include Archaic Period lithic scatters; late 19th and early 20th century homestead, ranching, and logging sites; and Laboratory buildings used during the Manhattan Project and Cold War eras (~1943–1990).

Current cultural resource management initiatives at the Laboratory include (1) completing cultural resources surveys on all DOE property; (2) determining the eligibility of historic buildings and archeological sites for the National Register of Historic Places; and (3) conducting outreach activities, tours, and educational events for the LANL workforce.

Archaeologists working for the legacy waste cleanup contractor N3B facilitate the cultural resources compliance reviews for legacy waste cleanup projects. N3B archaeologists, the DOE Environmental Management Los Alamos Field Office cultural resources program manager, the DOE National Nuclear Security Administration Los Alamos Field Office cultural resources program manager, and management and operating contractor archaeologists meet every two weeks to discuss legacy waste cleanup activities across the Laboratory on lands managed by the National Nuclear Security Administration Los Alamos Field Office.

To assist in legacy waste cleanup at the Laboratory, N3B archaeologists monitored archeological sites and supported projects in avoiding them, including for land application of water at regional monitoring well R-43 in Technical Area 53, soil sampling done by Triad in Technical Area 54 near Area G, and debris cleanup near site monitoring area LA-SMA-5.2 in Technical Area 41.

Major projects supported by Triad cultural resources staff during 2021 included (1) the Dual-Axis Radiographic Hydrodynamic Test Facility Complex Vessel Repair Facility, (2) the Dual-Axis Radiographic Hydrodynamic Test Facility Complex Vessel Inspection and Staging Facility, (3) the Environmental Test Complex at Technical Area 15, (4) the Energetic Materials Characterization Facility in Technical Areas 6 and 9, and (5) the High Explosives Transfer Station at Technical Area 8.

Other activities of Triad cultural resources staff during 2021 included

- conducting surveys and site recording in Technical Area 68;

- recording sites for the Cultural Landscape Report for the Manhattan Project National Historical Park site at Technical Area 18;
- marking and monitoring sites to be avoided during annual fire road and fire break maintenance;
- assessing the condition and updating photographic records of Nake'muu Pueblo;
- supporting LANL and DOE technical meetings with Santa Clara Pueblo, the Pueblo of Jemez, Pueblo de Cochiti, and Pueblo de San Ildefonso;
- monitoring seasonal recreational use of trails in Technical Areas 70 and 71, and DOE preservation districts in Pueblo Canyon and Rendija Canyon;
- preparing a cultural resources exhibit at Technical Area 53;
- submitting an archaeological site update report for Technical Area 48 to the New Mexico State Historic Preservation Office;
- completing a context and documentation report for a property in Technical Area 16 to support its decontamination and decommissioning;
- completing archival photography of buildings in Technical Areas 3; and
- working with the Bradbury Science Museum to integrate the Laboratory's historical artifacts into the museum's catalog system.

In addition, staff gave numerous presentations and briefings to the Laboratory workforce on LANL cultural resources, conducted outreach activities with local schools, and continued providing learning opportunities for student interns. Other historic building work included supporting a subcontractor that is evaluating buildings on the Laboratory's historic buildings list.

Manhattan Project National Historical Park

The Manhattan Project was the unprecedented effort by the United States to develop an atomic weapon during World War II, and it took place at many sites across the country. In 2014, Congress passed legislation that established the Manhattan Project National Historical Park to interpret and preserve the remaining structures and landscapes associated with the Manhattan Project war effort. The park consists of three units located in Hanford, Washington; Oak Ridge, Tennessee; and Los Alamos, New Mexico. The park unit at Los Alamos features the historic buildings and stories connected with the scientific and engineering aspects of developing an atomic bomb.

In 2021, Cultural Resources staff developed several planning documents related to the park and worked with LANL crafts staff to preserve and maintain several Manhattan Project buildings. Planning documents included a strategy to fully rehabilitate the Slotin Building, a Cultural Landscape Report for Technical Area 18, and a five-year plan for all Manhattan Project buildings at LANL. Both the Slotin Building rehabilitation and the plans outlined in the Cultural Landscape Report will facilitate public tours by providing a safer, more authentic experience. The five-year plan provides a straight-forward path to preserve all of the buildings essential to telling the story of the Manhattan Project.

Preservation work took place at several park sites. The Manhattan Project-era magazine at Technical Area 16 was rehabilitated. A new roof system was installed, and failing retaining walls flanking the entrance were documented, removed, and then replaced with structurally sound replicas crafted by LANL carpenters. In addition, work was completed to replace the asbestos-laden shingles on the façade of the building. Non-asbestos replacement shingles were installed and painted green to restore the building's Manhattan Project-era appearance (see Figure 3-1).

Figure 3-1. The Technical Area 16 Manhattan Project magazine in a state of disrepair before preservation work (left) and after preservation work was completed (right). The Laboratory's preservation work means that the magazine should stand for many more years.

Asbestos shingles were replaced at other Manhattan Project buildings, including Technical Area 16 V-Site, Technical Area 22 Quonset Hut, and Technical Area 14 Q-Site. Also in 2021, a Manhattan Project-era bomb hauler truck used at Los Alamos was donated to the Historical Park (see Figure 3-2).

Biological Resources Management

Our goal is to minimize impacts on sensitive species and their habitats and to ensure all Laboratory activities comply with federal and state requirements for biological resources protection. The Laboratory property contains habitat for three species that are federally listed as either threatened or endangered. Two of these species, the Mexican spotted owl (*Strix occidentalis lucida*) and the Jemez Mountains salamander (*Plethodon neomexicanus*), have been found on the site. Willow flycatchers of unknown subspecies are sometimes detected during migration, but no southwestern willow flycatchers (*Empidonax traillii extimus*) have been documented breeding on Laboratory property.

Figure 3-2. This circa 1942 Chevrolet Bomb Service Truck sits at V-Site awaiting restoration and a return to service—not to transport bombs for the Manhattan Project but to spur park visitors' imaginations and enrich their experience of the past.

Accomplishments

We annually inform and educate the Laboratory workforce about biological resources compliance requirements, including restrictions on the timing and location of work activities to protect federally listed species. The biological resources staff also provide safety briefings on encountering wildlife and information on avoiding impacts to migratory birds from vegetation removal projects and other known hazards to birds, such as open pipes and bollards.

Laboratory biologists conduct annual surveys for the presence of threatened and endangered species that have habitat on LANL property. In 2021, surveys for the Mexican spotted owl confirmed the presence of pairs of owls in two canyons. No evidence was found to suggest that either pair successfully bred in 2021. Southwestern willow flycatchers were not found during surveys in 2021. Surveys for Jemez Mountains salamander were conducted on LANL lands and adjoining land agency lands as part of a regional training workshop. One salamander was found by LANL biologists on non-LANL lands. No salamanders were found on LANL lands.

LANL biologists were authors on five peer-reviewed publications in 2021:

- "Challenging our understanding of western yellow-billed cuckoo habitat needs and accepted management practices" (Wohner et al. 2021a)
- "Sex ratio of Western Bluebirds (*Sialia mexicana*) is mediated by phenology and clutch size" (Bartlow et al. 2021)
- "A field guide for aging passerine nestlings using growth data and predictive modeling" (Sanchez et al. 2021)
- "Early successional riparian vegetation is important for western yellow-billed cuckoo nesting habitat" (Wohner et al. 2021b)
- "Individual nest site preferences do not explain upslope population shifts of a secondary cavity-nesting species" (Abeyta et al. 2021)

Biological Resources Program Reports

LANL biologists supported many projects across the Laboratory with compliance and monitoring activities in 2021. Published reports supporting projects included the following:

- “Biological Evaluation for the Development of a New Transmission Line from the Norton Substation to Los Alamos National Laboratory” (LA-UR-21-21259)
- "A Summary of Biological Resources Compliance for the Rendija Tract at Los Alamos National Laboratory" (LA-UR-21-32151)
- “Pollinator Protection Plan for Los Alamos National Laboratory” (LA-UR-21-21113)
- “Documenting Feral Cattle Activity in White Rock Canyon along the Rio Grande at Los Alamos National Laboratory” (LA-UR-21-27487)
- “2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory” (LA-UR-21-22304)

Wildland Fire Management

The primary objective of the LANL Wildland Fire Program is to provide wildland fire preparedness through fuel mitigation, integration of wildland fire technology, and interagency planning and training. The program staff are located at the Emergency Operations Center and Technical Area 49 Interagency Fire Center along with personnel from the United States Forest Service and National Park Service. The program collaborates with the Los Alamos Fire Department, National Park Service, United States Forest Service, Bureau of Indian Affairs, Northern Pueblo Agencies, and the New Mexico State Forestry Division.

The key functions of the LANL Wildland Fire Program are to

- Conduct or coordinate the site wildland fire hazard analysis.
- Develop wildland fire plans, procedures, and checklists.
- Conduct LANL wildfire mitigation projects, such as thinning trees and establishing and maintaining fire breaks, defensible space, and fire roads.
- Update the LANL website to ensure fire conditions and fire danger ratings are available to the workforce.
- Maintain the LANL Wildland Fire Program database and ensure the program has map-making capabilities for response.
- Conduct training, drills, and exercises with internal and external wildland fire organizations.

Waste Management

The Laboratory produces several types of wastes regulated by either the federal government or the state of New Mexico, including low-level radioactive wastes, hazardous waste, mixed wastes (which are both radioactive and hazardous), transuranic wastes, New Mexico Special Wastes, and others. Transuranic wastes are wastes containing manmade elements heavier than uranium on the periodic table (such as plutonium). Wastes from current and recent operations at the Laboratory are managed by the management and operating contractor, while legacy wastes—defined as wastes generated before 1999—are managed by the legacy waste cleanup contractor, N3B.

The LANL Enduring Mission Waste Management Plan outlines the strategies employed by the Laboratory to compliantly and efficiently dispose of the wastes produced since January 1, 1999. The plan also incorporates pollution prevention strategies to significantly reduce the volume and toxicity of waste generated. Waste minimization efforts have greatly reduced or eliminated many sources of radioactive and hazardous waste across the Laboratory. Offsite shipping to government and commercial treatment, storage, and disposal facilities has minimized onsite waste disposal. The Laboratory is operating a Transuranic Waste Facility that stages transuranic waste for offsite shipment to the Waste Isolation Pilot Plant. Construction continues on replacement low-level radioactive and transuranic liquid waste facilities. As part of the long-term strategy to safely and effectively manage waste at the Laboratory, a budget proposal was submitted to DOE for a new state-of-the-art consolidated waste facility.

Environmental Remediation

In accordance with the 2016 Compliance Order on Consent, the Legacy Waste Cleanup Program investigates and, where necessary, remediates sites to ensure that chemicals and radionuclides associated with releases from past operations do not result in an unacceptable chemical risk or radiological dose to human health or the environment. (For more information about the 2016 Compliance Order on Consent, see Chapter 2.) Sampling is conducted to determine if releases have occurred and, if so, whether the nature and extent of contamination are defined or further sampling is warranted. Using the environmental data obtained for a site, human health and ecological risk assessments are conducted. Sites are remediated if the risk assessments indicate potential adverse impacts to human health, the environment, or both. Corrective actions are complete at a site when we have demonstrated and documented to the regulatory authority's satisfaction that further sampling is not warranted and that the site does not pose an unacceptable risk or dose to humans, plants, or wildlife. Table 3-3 presents a summary of the reports submitted and site investigations conducted in 2021 by N3B in support of the 2016 Compliance Order on Consent.

Table 3-3. Summary of Reports Submitted and Site Investigations Conducted in 2021 under the N3B Environmental Remediation Program

Document/Activity	Technical Area	Number of Sites	Sampling and Remediation
Phase II Investigation Report for Chaquehui Canyon Aggregate Area Investigation Report (Appendix B Consent Order Milestone)	33	16	Forty-three sites were investigated in the Chaquehui Canyon Aggregate Area in 2019–2020. Of these 43 sites, 16 required additional sampling to define the nature and extent of contamination and potential human health and ecological risks, and eight of the 16 sites required soil removal. The Phase II investigation work plan for the 16 sites was implemented in 2021. Based on the results of data evaluations, the U.S. DOE Environmental Management Los Alamos Field Office and N3B recommended the following:

Document/Activity	Technical Area	Number of Sites	Sampling and Remediation
			• Corrective action complete without controls for solid waste management unit 33-010(c), for which extent is defined and which poses no potential unacceptable human health risk under the residential, industrial, and construction worker scenarios, and no unacceptable ecological risk. • Corrective action complete with controls for solid waste management units 33-007(c) and 33-011(d), for which extent is defined and which pose no potential unacceptable human health risk under the industrial and construction worker scenarios, and no unacceptable ecological risk. • Further sampling for solid waste management units 33-001(a), 33-001(b), 33-001(c), 33-001(d), 33-001(e), 33-004(a), 33-004(i), 33-006(a), 33-008(c), 33-011(a), 33-012(a), and 33-017 and AOC C-33-001, for which nature and/or extent are not defined. • Remediation for solid waste management units 33-004(i), 33-008(c), and 33-012(a) and Area of Concern C-33-001 because of potential unacceptable human health risk or dose under two or more scenarios and/or unacceptable ecological risk.
Conclusions/Recommendations: Cleanup objectives were met for three sites. Further corrective actions for the remaining sites will be addressed in 2022.			
Lower Water/Indio Canyon Aggregate Area Investigation Report (Appendix B Consent Order Milestone)	15	6	Six solid waste management units and areas of concern within the Lower Water/Indio Canyon Aggregate Area were investigated to determine the nature and extent of contamination and potential human health and ecological risks. Based on the investigation results, the extent of contamination has been defined at all six sites. Human health risk-screening assessments were performed for all six sites, and ecological risk-screening assessments were performed for five of the sites (an ecological risk-screening assessment was not conducted at one site because there is no source of contamination in the interval 0.0 to 5.0 feet below ground surface and no exposure to ecological receptors). Based on the results of data evaluations presented in the investigation report, the U.S. DOE Environmental Management Los Alamos Field Office and N3B recommended the following: • Corrective action complete without controls for four sites for which extent is defined and which pose no potential unacceptable human health risk or dose under the industrial, construction worker, and residential scenarios, and no unacceptable ecological risk. • Corrective action complete with controls for two sites for which extent is defined and which pose no

Document/Activity	Technical Area	Number of Sites	Sampling and Remediation
			potential unacceptable human health risk or dose under the industrial and construction worker scenarios, and no unacceptable ecological risk.
Conclusions/Recommendations: Cleanup objectives were met for all six sites. Concurrence pending from the New Mexico Environment Department that no further corrective actions are necessary.			
South Ancho Canyon Aggregate Area Investigation Report (Appendix B Consent Order Milestone)	33	11	Eleven solid waste management units and areas of concern within the South Ancho Canyon Aggregate Area were investigated to determine the nature and extent of contamination and potential human health and ecological risks. Based on the evaluation of investigation results, the extent of contamination has been defined at all 11 sites. Human health and ecological risk-screening assessments were performed for all sites. Based on the results of data evaluations presented in the investigation report, the U.S. DOE Environmental Management Los Alamos Field Office and N3B recommended the following: • Corrective action complete without controls for 11 sites for which extent is defined and which pose no potential unacceptable human health risk under the residential scenario, and no unacceptable ecological risk.
Conclusions/Recommendations: Cleanup objectives were met for all 11 sites. Concurrence pending from the New Mexico Environment Department that no further corrective actions are necessary.			

Environmental Health Physics Program

The Environmental Health Physics Program provides technical support to the Laboratory for radiation protection of the public and the environment. We use sampling results and radiological assessment models to calculate dose estimates for the public and for plants and animals. These estimates are communicated to regulatory agencies and the public.

DOE Order 458.1, *Radiation Protection of the Public and the Environment*, also requires us to oversee releases to the public of real estate and portable property (such as surplus equipment and wastes) that could contain residual radioactivity. Examples include land tracts transferred to other owners and debris from demolishing buildings.

What is health physics?

Health physics is the branch of radiation science that deals with effects of ionizing radiation on human health.

Our environmental health physicists support emergency planning and response by providing technical support and dispersion modeling in the case of an accident as well as recommendations for protective actions. We also support environmental remediation projects.

See Chapters 2, 7, and 8 for more information.

Soil, Foodstuffs, and Biota Monitoring

The Soil, Foodstuffs, and Biota Monitoring Program monitors levels of radionuclides, inorganic elements (mostly metals), and organic chemicals (for example, polychlorinated biphenyls [PCBs] and per- and polyfluoroalkyl substances [PFAS]) in local soil, plants, and animals. The program routinely samples surface soil; native vegetation; foodstuffs, including fruits, vegetables, grains, milk, eggs, fish, meat, and honey; small mammals, such as mice; and other animals that have died due to natural causes or accidents, such as roadkill. These samples are collected from Laboratory property, the surrounding communities, and regional background locations. The data are used to (1) determine whether Laboratory operations are affecting levels of chemicals or radionuclides in the environment, (2) monitor for new releases, (3) calculate estimates of radiation dose for the public and for biota, and (4) conduct risk assessments. We compare levels of chemicals in our samples with background levels, screening levels, and effects levels, and we examine wildlife population and community characteristics. The program is described in detail in Chapter 7.

Accomplishments

In 2021, we collected surface soil and native overstory vegetation samples from locations near major operations at the Laboratory, in surrounding communities, and from regional background locations. Samples were analyzed for radionuclides, inorganic elements (mostly metals), and/or organic chemicals.

Annual sampling of soil, native vegetation, and biota took place at several locations. Soil and tree samples were collected around the perimeter of Area G and near the boundary between Technical Area 54 and the Pueblo de San Ildefonso and analyzed for radionuclides. Soil, sediment, small mammals, and nonviable bird eggs were collected around the Dual-Axis Radiographic Hydrodynamic Test Facility and analyzed for radionuclides, inorganic elements, and/or organic chemicals. Small mammals and vegetation were collected upstream of the sediment retention structures located in Los Alamos and Pajarito canyons and analyzed for radionuclides, inorganic elements, and/or organic chemicals.

Small mammals were collected from Los Alamos Canyon on Pueblo de San Ildefonso property as well as from a background location in Española and were analyzed for radionuclides, inorganic elements, and/or organic chemicals. Nonviable bird eggs and nestlings that died of natural causes also were collected near Laboratory firing sites and from Bandelier National Monument and were analyzed for inorganic elements and/or organic chemicals. We opportunistically collected and analyzed tissues from deceased animals (primarily roadkills), including mule deer (*Odocoileus hemionus*), feral cattle (*Bos taurus*), coyote (*Canis latrans*), gopher snake (*Pituophis catenifer*), turkey vulture (*Cathartes aura*), and great horned owl (*Bubo virginianus*). Results from the program's 2021 monitoring efforts are reported in Chapter 7, Ecosystem Health.

Meteorology Program

DOE Order 458.1, *Radiation Protection of the Public and the Environment*, and DOE Order 151.1D, *Comprehensive Emergency Management System*, require DOE sites to measure weather variables. The variables to be measured are determined by any radiation-producing operations taking place at the DOE site, its topography, and the distances to critical receptors. The LANL Meteorology Program maintains a network of five meteorological towers that measure temperature, wind, humidity, pressure, precipitation, and solar radiation across the site. These data are used for emergency planning in the event of a chemical or radiological release, regulatory compliance in the areas of air quality, water quality, and waste management. The data also are used for supporting monitoring programs for surface water and environmental radiation. Weather data can be accessed through the Laboratory's internal (https://weather.lanl.gov) or external network (https://weathermachine.lanl.gov). Three new weather stations were added in 2021, at Technical Areas 16, 54, and 63. Meteorological conditions at LANL for 2021 are reported in Chapter 4, Air Quality.

Natural Phenomena Hazard Assessment

DOE Order 420.1C, *Facility Safety*, requires that nuclear facility structures, systems, and components effectively perform their intended safety functions in the face of natural phenomena hazards (for example, earthquakes, floods, and high winds). As a part of this requirement, natural phenomena hazards are reviewed every 10 years to determine if major modifications to nuclear facilities are required by significant increases in risk from natural phenomena. No meteorological assessments were conducted in 2021.

The LANL Seismic Engineering Team provides seismic hazard analyses of key Laboratory facilities and is focused on improving seismic monitoring, site characterization, and our understanding of the Pajarito Fault system. The Seismic Hazards Geology program conducts field mapping of the Pajarito Fault system in the vicinity of Los Alamos and performs site-specific hazard studies at current and planned facility sites.

Land Conveyance and Transfer

The Laboratory assists DOE with implementing the requirements of U.S Code Title 42, Section 2391 Note (42 USC 2391 Note) which, subject to certain requirements and limitations, directs DOE to transfer specific parcels of land previously owned by DOE in and around the Laboratory to Los Alamos County and to the Secretary of the Interior in trust for the Pueblo de San Ildefonso. These requirements were first established in 1997 by Public Law 105-119, have been amended from time to time, and are codified in federal law at 42 USC 2391 Note. In this document and elsewhere, the terms Public Law 105-119 and 42 USC 2391 Note are sometimes used interchangeably, although the requirements of 42 USC 2391 Note control obligations relating to the Land Conveyance and Transfer project.

The specific DOE land tracts identified for conveyance or transfer were included in "Conveyance and Transfer of Certain Land Tracts Administered by the U.S. Department of Energy and Located at Los Alamos National Laboratory, Los Alamos and Santa Fe Counties, New Mexico" (DOE/EIS 0293), and the original tracts were subsequently subdivided into 32 tracts. To date, 26 of these tracts have been conveyed or transferred in the following ways: 20 tracts have been conveyed to Los Alamos County, three tracts have been conveyed to the Los Alamos County School District, and three tracts have been transferred to the Bureau of Indian Affairs to be held in trust for the Pueblo de San Ildefonso.

Remaining tracts that could be conveyed to Los Alamos County include Tract A-14 in Rendija Canyon, Tracts C-2 and C-4 along New Mexico Route 4, Tract A-18-2 in Bayo Canyon, and additional tracts at Technical Area 21. The Land Conveyance and Transfer project staff continue to work with the DOE National Nuclear Security Administration Los Alamos Field Office to complete the outstanding compliance activities and requirements needed to convey the remaining DOE tracts.

Conveyances to Los Alamos County support local community economic development by providing lands for housing, commercial uses, and recreation. Nearly 460 housing units, including low-income apartments and about 160 market-rate single-family homes, are being developed on tracts previously conveyed to Los Alamos County.

Awards and Recognition

Ali Livesay, an archaeologist with the Laboratory's Environmental Protection and Compliance Division, won second place in the Cordell and Powers Prize Competition at the Pecos Conference for her extemporaneous talk on "A Real Labor of Love: Archaeologies of the Heart at Los Alamos National Laboratory" (see Figure 3-3). Monica Witt, the LANL sustainability manager, received a 2021 DOE Sustainability Award for being a Sustainability Champion (see Figure 3-4).

Figure 3-3. Ali Livesay receives second place in the 2021 Pecos Conference's Cordell/Powers Prize Competition.

Figure 3-4. Members of the sustainability team visit the field that will house the Lab's photovoltaic array. From left: Sustainability Manager Monica Witt, Program Manager Joseph Klose, and Team Leader Genna Waldvogel.

Data Quality Process for Analytical Data

Data management consists of collecting and maintaining sampling data using procedures that ensure that the data comply with established requirements and that data are suitable for their intended use (for example, compliance monitoring or site characterization). Below, we describe the elements of the quality system for sample and data processing and quality assurance for the management and operating contractor (Triad) and the legacy waste cleanup contractor (N3B) at the Laboratory.

Triad and N3B have similar data collection and management programs. Each contractor maintains its own sample management office, but they use the same environmental data management platform (see Environmental Data Management Platform, below). Sample planning and collection is performed by individual programs in coordination with their sample management office (see Figure 3-5). Sample handling, analysis, and data review and evaluation are conducted or overseen by the sample management office. Individual programs are responsible for reporting on data results; the sample management office may assist by providing data sets, but final reports are the responsibility of the program.

In 2021, N3B received and reviewed more than 686,000 analytical results, while Triad received and reviewed more than 294,000 analytical reports. Not all of these results were used in this report. Some results may be related to programs that are not included in the Annual Site Environmental Report.

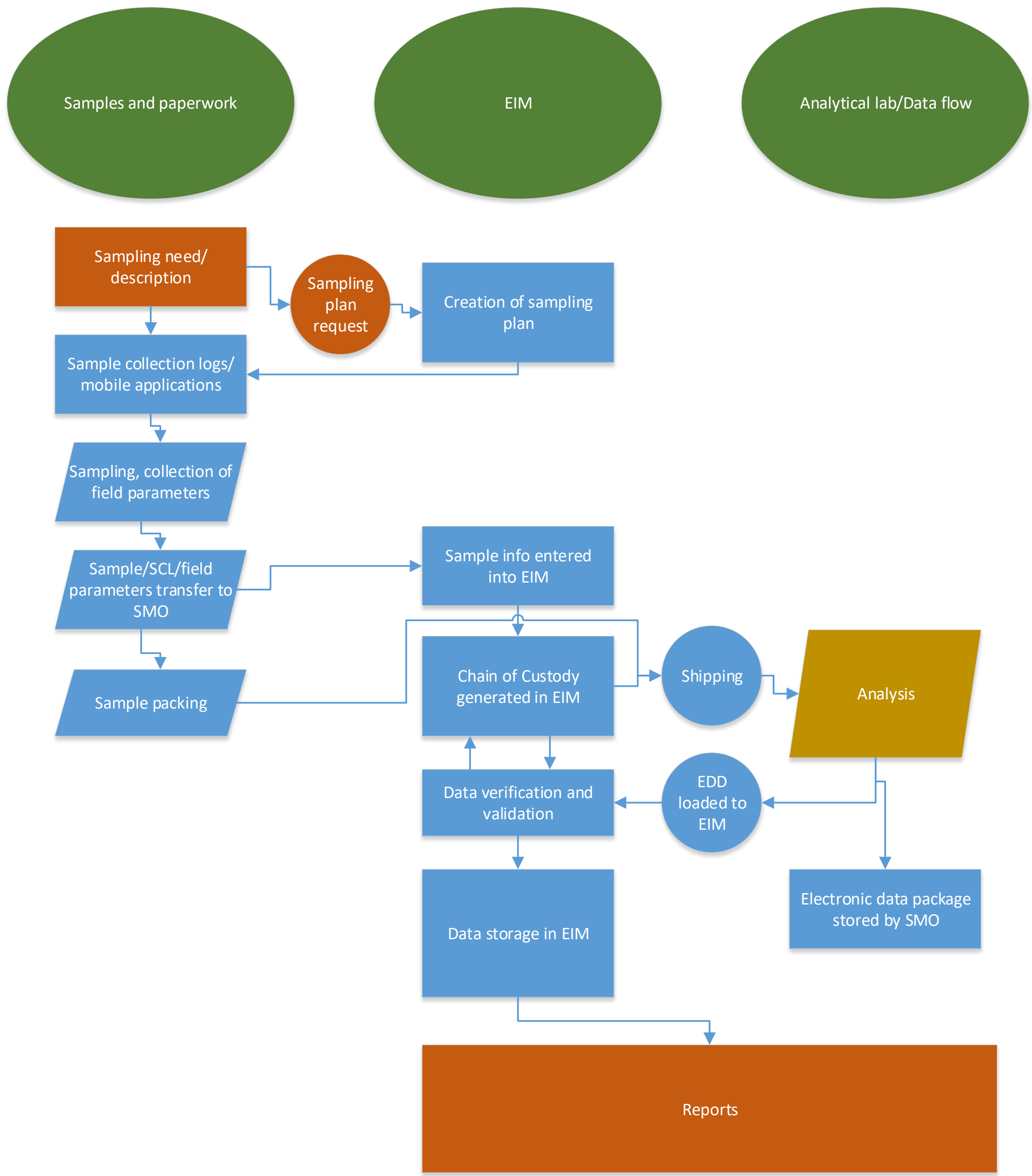

Figure 3-5. Functional diagram of the Sample Management Office work. Green ovals represent the three main Sample Management Office functions. Figures with blue background show data collection steps that directly involve the Sample Management Office. Abbreviations used in this figure: SMO – Sample Management Office; EIM – Environmental Information Management database; SCL – Sample Collection Log, serves as a field chain of custody; EDD – Electronic Data Deliverable text file used to load analytical data into Environmental Information Management database.

Environmental Data Management Platform

The Environmental Information Management database is the core platform used by Triad and N3B and Triad for managing analytical data. This data platform is jointly used by N3B, Triad, and the DOE Oversight Bureau of the New Mexico Environment Department for all LANL environmental analytical data. It interfaces with Intellus, a fully searchable database available to the public through the Intellus website (http://www.intellusnm.com).

Locus Technologies developed and maintains the database structure, which consists of a cloud-based Structured Query Language server database platform with a web-based user interface. It is designed to manage the sample collection and analysis process from planning through data review and reporting. It includes modules for planning sample collection, tracking samples, uploading field data, uploading electronic data deliverables, and conducting automated data review, as well as tools for notifications and reporting. The automated data review module is used in conjunction with manual examinations and full manual validation of selected data.

A Software Change Control Board—consisting of N3B, Triad, and New Mexico Environment Department representatives—oversees modifications made to database functions and user interfaces. This process ensures that changes requested by one organization will not adversely affect the others. Standardized naming conventions are used for sampling locations to create a single list of shared location names.

Data Quality Objective Process

N3B and Triad ensure that the data reported from the analytical laboratories are of sufficient quality to fulfill their intended purpose, and that the data quality is documented so the data can be evaluated for current and future use. The data collected support defensible decision-making, as described in the *Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4)* (EPA 2006).

N3B data quality objectives detail minimum required quality assurance and quality control on a project-specific basis. Examples of projects include the all-sampling events and samples collected to fulfill a set of permit requirements, all-sampling events and samples collected to determine waste disposition, or all samples and sampling events collected to fulfill a memorandum of understanding or regulated agreement.

The project manager determines the project's specific data quality objectives within the boundaries of contracted services and standard operating procedures. If the project's needs exceed contracted services or standard operating procedures, the Sample Data Management Director may initiate revisions to contracts and standard operating procedures.

Sample Collection and Handling

Sample and data management begins with planning the sampling to ensure that the data will meet the data quality objectives for the project. Sample collection and handling follows established methods. Whenever possible, standard U.S. Environmental Protection Agency methods are used. When federal or state approved standard methods are unavailable, LANL-specific procedures are used.

A sampling plan is created in the Environmental Information Management data system. The data system generates sample collection logs and chain-of-custody forms based on the plan. The sample collection log lists the sampling containers and preservatives needed for each analysis requested. Personnel conducting the sampling record information on the sample collection log, including location of sampling (if different from planned), sampling date and time (which are necessary to establish holding time), field parameters if required by the project, and any other comments that may be applicable. Collected samples are placed in coolers and cooled with ice if required. From the time of sampling until delivery to the Sample Management Office, samples are under direct custody of the samplers. At the Sample Management Office, custody is transferred to Sample Management Office staff. Custody transfer is confirmed by signatures. Additionally, before the Sample Management Office accepts samples, tamper-indicating devices, which are also known as custody seals, are placed on every sample container. N3B has implemented an electronic chain of custody that arrives at the Laboratory prior to the official chain of custody. This allows the Laboratory to prepare for the upcoming sample receipt and reduces errors throughout the process.

Before samples are shipped, Sample Management Office staff store samples as required, including in temperature-controlled refrigerators if needed. Glass sample containers are wrapped in bubble bags to prevent breakage. Samples are packed in coolers with blue ice and/or bagged ice to assure proper shipping temperature. The signed chain of custody documents are placed inside the coolers. Coolers are taped shut and protected with tamper-indicating devices. Samples are shipped overnight to the designated analytical laboratory. Upon arrival at the designated lab, the integrity of tamper indicating devices is verified, shipping temperature on arrival is measured, and samples are compared with their respective chain of custody. If both the cooler and sample tamper-indicating devices have been damaged or tampered with, the sample is considered unusable. After the analytical laboratory logs samples into their information management system, the samples are analyzed.

Selection of Analytical Laboratories

Analytical laboratories have been selected through the request for proposal process. N3B and Triad have selected laboratories that meet the DOE Consolidated Audit Program—Accreditation Program requirements (see section on *DOE Consolidated Audit Program—Accreditation Program for Commercial Analytical Laboratories*). For Triad, National Environmental Laboratory Accreditation Program-accredited laboratories are chosen when a given analysis is not available from a contracted DOE Consolidated Audit Program-accredited laboratory. Along with the DOE Consolidated Audit Program accreditation, N3B selects laboratories that meet requirements in their Scope of Work Exhibit “D,” *Scope of Work and Technical Specifications for Off-Site Analytical Laboratory Services*. The Scope of Work Exhibit “D” was developed using the *Department of Defense/Department of Energy Consolidated Quality Systems Manual for Environmental Laboratories*. N3B has contracted with 10 analytical laboratories, eight of which performed certifiable analyses for N3B in 2021. Beyond meeting the minimum requirements of the DOE Consolidated Audit Program and the scope of work, laboratories chosen for a specific analysis are picked for their capacity to maintain a project’s continuity of data, prevent disruptions caused by unforeseen lab closures or instrument failures, and deliver a cost-effective service. This approach allows for split sampling and data quality comparison.

Sample Analysis

Sample preparation and analyses are performed in the laboratories using industry-standard methods such as those from the U.S. Environmental Protection Agency SW-846, the Environmental Measurements Laboratory HASL 300, the Clean Water Act, the American Industrial Hygiene Association, the Occupational Safety and Health Administration, the National Institute of Safety and Health, the American Society for Testing and Materials, and the American Public Health Association. In the absence of an industry standard method, analyses are performed using performance-based methods that meet project-specific data quality objectives.

The choice of a specific method is determined by program or permit requirements or by the desired detection limit. All analyses of laboratory quality control samples are reported back to Triad or N3B. Additionally, LANL sends field quality control samples (blank samples and duplicate samples) periodically for analysis. The frequency of field quality control samples is determined by analytical methods, permits, or LANL procedures.

Data Review and Evaluation

Analytical results are generally returned to LANL in two forms: as an electronic data deliverable and as a data package. An electronic data deliverable is a data file transmitted in a format that can be directly uploaded in database programs. Data packages consist of the combined analytical chain of custody, signed sample collection logs, a validation report if available, and the analytical data report. These documents are usually delivered as a portable document format (pdf) file. Some data users also request a hard copy of the data package. For N3B, laboratory data packages and electronic data deliverables adhere to the requirements specified in Exhibit “D,” *Scope of Work and Technical Specifications for Off-Site Analytical Laboratory Services*.

Electronic data deliverables are loaded into holding tables in the Environmental Information Management database. Automated programs in the database verify the data in these files by checking that

- The data deliverable file is formatted correctly, including in the number and types of fields (text/numeric/date-time);
- The analyses reported agree with those we ordered;
- The data were not already reported (to avoid duplicates);
- The sampling date used by the analytical laboratory agrees with the database sampling date (which is important for holding time evaluation); and
- The dates listed by the lab, such as sampling before preparation date and preparation before analysis date, are consistent.

Upon verification, a Sample Management Office chemist runs an auto-validation routine in the Environmental Information Management database to validate reported data. Auto-validation follows the U.S. Environmental Protection Agency’s National Functional Guidance documents and the *Department of Energy/Department of Defense Consolidated Quality Systems Manual* for validation of the analytical data. The important exclusions from auto-validation are examination of the spectra (mass spectra, ultraviolet spectra, rad alpha spectra), chromatograms (for methods using confirmation column), and filed blank/duplicate samples.

The auto-validation checks and applies proper validation qualifiers and validation reason codes for the following:

- Holding time
- Method blank contamination
- Laboratory control samples and duplicates within limits
- Matrix spike recoveries within limits
- Missing laboratory quality control samples

When verification and auto-validation are completed, data are transferred to production tables in the database.

Data may undergo a manual validation. There are two mechanisms for selecting data for manual validation: data may be randomly selected across different analytical methods and laboratories, or a new detection of a substance or a data quality issue may trigger an elevated, in-depth review. For N3B, a minimum of 10 percent of analytical data is manually validated by a chemist. Project personnel determine if a greater frequency of full validation is required to meet project-specific data-quality objectives and will notify the Sample Management Office accordingly. Triggered validation is performed on specific data at the request of the data owner or the person preparing reports.

During manual validation, selected samples undergo full validation. Data stored in the Environmental Information Management tables and the data packages are reviewed. All aspects of data quality are evaluated, including spectral data. If manual validation results in a change of the data qualification, the changes are entered into the Environmental Information Management database. A description of the changes and a short explanation of reasons for the changes are included. All such changes are tracked in the Environmental Information Management database’s audit tables.

Field quality control samples are evaluated when data sets are prepared for individual programs or data owners. Any detections found in blank samples or large discrepancies in results between duplicated samples are reported back to a Sample Management Office chemist. If the chemist decides that field quality control samples warrant changes in the validation qualifiers or detection status, the changes are entered into Environmental Information Management database.

The primary purpose of data validation is to assess and summarize the quality and defensibility of analytical data for end users. Combined guidelines and requirements ensure the necessary level of confidence in data quality and usability for project activities. The entire data validation process includes a description of the reasons for any failure to meet method, procedural, or contractual requirements, and an evaluation of the failure’s impact on data or a data set.

Environmental Information Management Platform Performance Testing

N3B chemists performed extensive testing of the Automated Data Review Data Validation Module of the Environmental Information Management database, including using electronic data deliverables from actual laboratory analyses. They identified specific issues and opportunities for enhancements. N3B personnel worked with Locus Technology to implement corrections and improvements to ensure that outputs meet requirements prescribed by the Quality Systems Manual and recommendations in the U.S. Environmental Protection Agency's National Functional Guidelines. This work was performed in coordination with Triad and the New Mexico Environment Department. The final Automated Data Review Module was implemented in January 2021. An increased number of full validations were performed to monitor Automated Data Review performance. No major issues were identified. Performance enhancements and improvements are ongoing.

A greater number of full validations increases transparency and ensures a unified treatment of data available to the public on Intellus. Tests by N3B chemists of the system's configuration provide proof of the system's capabilities to accurately perform routine data checks based on analytical methods and regulatory requirements. In addition, the Automated Data Review module was improved for all analytes, particularly radiochemistry data. During this process, N3B chemists manipulated test cases to verify that the actual outcomes matched expected outcomes. The results of this testing were shared with data system architects, and improvements were identified. Additionally, during this process, N3B found that radiochemical capabilities were underutilized and so enhanced the Automated Data Review functionality with respect to radioanalytical assessment.

Record Retention

Original hard copies of chain-of-custody forms and sample collection logs are stored temporarily at the Sample Management Office. Final records are then transmitted to Records Management. The ambient air monitoring program requires that a hard copy Level IV data package remain on site. These records are packaged by the end of each fiscal year and transferred to the LANL Records Center, where they remain on site for five years.

Analytical records are stored in the Environmental Information Management database. The entire N3B and Triad Environmental Information Management database is backed up at least quarterly on N3B or Triad servers. Analytical results are copied daily to the publicly available Intellus database (www.intellusnm.com). Level IV data packages also are uploaded into the LANL Electronic Records Management System to fulfill the long-term record retention requirement. Approximately once a month, the Level IV data packages are copied to Intellus.

Some data and analytical packages are withheld from public view for up to 90 days from the date of receipt. These are usually results from samples collected offsite that LANL shares first with other entities, including nearby counties or Native American tribes.

Quality Assurance

N3B's Sample Data Manager and the Sample Management Office are subject to the N3B Quality Assurance and Transformation Audit and Surveillance program. They are also subject to the following:

- DOE Consolidated Audit Program audits of analytical laboratories used for environmental sampling
- DOE Consolidated Audit Program audits of Treatment, Storage, and Disposal Facilities used for disposal
- Internal audits under the management assessments program

- Quality assurance and transformation in developing project assessment criteria and issues responses in the N3B integrated Contractor Assurance System
- Management observation and verifications
- Performance tracking by personnel who monitor activities conducted under the scope of this sample and data management plan

DOE's Analytical Services Program

The DOE's Analytical Services Program provides environmental management-related services and products to DOE Program Offices and field sites. The various parts of the Analytical Services Program that the Laboratory participates in are described here.

DOE Consolidated Audit Program—Accreditation Program for commercial analytical laboratories

The DOE Consolidated Audit Program provides for assessments of commercial analytical laboratories that analyze environmental samples. Use of third-party auditors replaced the traditional DOE Consolidated Audit Program audits beginning in fiscal year 2018. This has allowed for more in-depth approaches to quality control and oversight of these laboratory facilities in meeting the needs of the DOE. The DOE Consolidated Audit Program has qualified the following three accrediting bodies to perform these audits:

- Perry Johnson Laboratory Accreditation, Inc.
- The American Association for Laboratory Accreditation
- The American National Standards Institute National Accreditation Board

Analytical laboratories are audited against the International Organization of Standardization's Standard 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*; the National Environmental Laboratory Accreditation Conference Standard; and the *Department of Energy/Department of Defense Consolidated Quality Systems Manual*. N3B uses the results from these third-party accreditation assessment reports as part of its oversight for its subcontracted commercial analytical laboratories.

Table 3-4 summarizes the DOE Consolidated Audit Program laboratories currently subcontracted to perform samples analysis for N3B and/or Triad.

Table 3-4. DOE Consolidated Audit Program-Accreditation Program Audits of Laboratories Contracted by N3B and/or Triad in Fiscal Year 2021

Laboratory	Audit Dates	Accrediting Body	Used in FY21
ARS Aleut Analytical, LLC	August 30–31, 2021	ANAB[1]	Y
Brooks Applied Labs, LLC (Bothell, WA)	June 15–19, 2021	ANAB	Y
Southwest Research Institute (San Antonio, TX)	February 1–5, 2021	A2LA[2]	Y
Eurofins TestAmerica (Denver, CO)	August 9–13, 2021	A2LA	N
Eurofins TestAmerica (St. Louis, MO)	December 7–8, 2020	ANAB	N
Eurofins TestAmerica (Knoxville, TN)	December 2–4, 2020	ANAB	N
ALS Environmental (Salt Lake City, UT)	September 9–10, 2021	PJLA[3]	Y
ALS Environmental (Fort Collins, CO)	October 27–30, 2020	PJLA	N

Laboratory	Audit Dates	Accrediting Body	Used in FY21
Materials and Chemistry Laboratory, Inc. (Oak Ridge, TN)	August 23–24, 2021	PJLA	Y
EMSL Analytical, Inc. (Cinnaminson, NJ)	April 26–30, 2021	A2LA	N
GEL Laboratories, LLC (Charleston, SC)	March 29–April 2, 2021	A2LA	Y

[1] *American National Standards Institute National Accreditation Board*
[2] *American Association for Laboratory Accreditation*
[3] *Perry Johnson Laboratory Accreditation, Inc.*

N3B provided support to the DOE Consolidated Audit Program in various ways throughout fiscal year 2021. The team participated in the Analytical Services Program annual training workshop, which consisted of presentations related to the Analytical Services Program activities, the future direction of the program, and technical presentations with regard to data quality and data management. N3B supported four DOE Consolidated Audit Program audits by providing audit observers to EMSL Analytical, Southwest Research Institute, ARS Laboratories, and the Brooks Applied Laboratory audits. Finally, N3B staff played an active role in the DOE Consolidated Audit Program Data Quality Work Group, participating in conference calls and answering questions or requests with regard to issues that emerged during laboratory audits and general laboratory or data quality questions from around the complex. N3B radiochemists actively participated in the development of the Radiochemistry Module 6 of the *Department of Energy/Department of Defense Consolidated Quality System Manual for Environmental Laboratories Version 6.0,* which will replace version 5.3.

Findings from the third-party audits are reported back to the interested DOE sites through the DOE Consolidated Audit Program administrator. N3B tracks all findings from the analytical laboratories it has under contract. The significant findings from fiscal year 2021 are outlined here:

- 12 instances regarded verifying and calibrating support equipment.
- 10 instances regarding missing calibration.
- 6 instances regarding record keeping. Example: A laboratory did not document all procedural deviations from standard test methods or the laboratory did not use appropriate methods and procedures for all laboratory activities.

Before receiving certificates of accreditation, analytical laboratories are required to submit corrective action reports to the accrediting bodies. The accrediting bodies must accept these corrective actions as sufficient before granting accreditation. All N3B subcontracted laboratories received their accreditations in 2021, indicating that the corrective actions were determined to have adequately addressed the identified issues.

DOE Mixed Analyte Performance Evaluation Program

The Mixed Analyte Performance Evaluation Program provides proficiency testing in various environmental matrices, although primarily for radionuclide identification and quantification. Results for proficiency testing help assure field managers of the quality and reliability of environmental data used in decision making. Laboratories are required by the National Laboratory Accreditation Conference Standard and the Quality Systems Manual to participate in proficiency testing in all fields of accreditation, where available.

Although not a mandatory requirement of the Quality Systems Manual, the Mixed Analyte Performance Evaluation Program can be tool to determine a commercial laboratory's analytical radiological capabilities across most environmental matrices. Participation in the Mixed Analyte Performance Program is required for laboratories that perform radiochemical analyses for N3B.

DOE Consolidated Audit Program—Treatment, Storage, and Disposal Facility Audits

Treatment, Storage, and Disposal Facility audit reports generated by the DOE Consolidated Audit Program are one tool DOE Field Office Managers use in performing their DOE O 435.1 annual acceptability reviews for commercial sites. These audits are conducted by volunteers from the DOE and site contractors who use these sites for the disposal of waste. Table 3-5 provides a summary of the most recent audit by the DOE Consolidated Audit Program for the Treatment, Storage, and Disposal Facilities subcontracted to accept radioactive waste from N3B.

Table 3-5. Most Recent Audits of Treatment, Storage, and Disposal Facilities Used by N3B under the DOE Consolidated Audit Program

Treatment, Storage, and Disposal Facility	Most Recent Audit Date
Waste Control Specialists, LLC (Andrews County, TX)	May 4–5, 2021
Perma-Fix Northwest, Inc. (Richland, WA)	May 18–19, 2021
Clean Harbors, LLC (Deer Trail, CO)	December 16–17, 2020
Energy Solutions (Clive, UT)	April 12–13, 2021
Veolia North America (Port Arthur, TX)	January 19–20, 2021
Veolia North America (Henderson, NV)	August 31–September 1, 2020
Veolia North America Trade Waste Incineration (Sauget, IL)	March 4, 2021

Priority I findings identified by the DOE consolidated audit team are reviewed and tracked by the Waste Management Program. Priority II findings are considered significant. The most recent audits identified Priority II findings that were not considered of immediate significance to compliance, policy, or performance. These are outlined below:

- Waste Control Specialist, LLC (Andrews County, Texas)
  - There were three Priority II Findings identified during this audit pertaining to inspection, training, and labeling.
- Perma-Fix Northwest (Richland, Washington)
  - There were two Priority II findings identified during this audit pertaining to documentation.
- Clean Harbors, LLC (Deer Trail, Colorado)
  - There were no significant findings identified during this audit.
- Veolia North America Trade Waste Incineration (Sauget, Illinois)
  - There were no significant findings identified during this audit.
- Energy Solutions (Clive, Utah)
  - There were three Priority II findings identified during this audit pertaining to documentation, signage, and procedure updates.

- Veolia North America (Port Arthur, Texas)
    - There were three priority II findings identified during this audit pertaining to procedures and documentation.
- Veolia North America (Henderson, Nevada)
    - There were no significant findings identified during this audit.

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EPA 2006: 2006. “Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4).” U. S. Environmental Protection Agency report EPA/240/B-06/001, Washington, D.C.

Wohner et al. 2021a: Wohner, Patti J., Stephen A. Laymon, Jenna E. Stanek, Sammy L. King, and Robert J. Cooper. 2021. “Challenging our understanding of western yellow-billed cuckoo habitat needs and accepted management practices.” *Restoration Ecology* 29(3): p.n/a.

Wohner et al. 2021b: Wohner, Patti J., Stephen A. Laymon, Jenna E. Stanek, Sammy L. King, and Robert J. Cooper. 2021. “Early successional riparian vegetation is important for western yellow-billed cuckoo nesting habitat.” *Restoration Ecology* 29(5): p.n/a.

Chapter 4: Air Quality

The purpose of Los Alamos National Laboratory's (LANL's or the Laboratory's) air-quality surveillance is to protect public health and the environment. Air quality is monitored by five programs; each is described in a section of this chapter: (1) ambient air sampling at public locations, (2) exhaust stack sampling at Laboratory facilities, (3) gamma and neutron direct radiation monitoring near radiation sources and in public locations, (4) particulate matter monitoring, and (5) meteorological monitoring of the local climate and weather.

A primary objective of air quality surveillance is to measure levels of airborne radiological materials to calculate radiological doses to humans, plants, and animals. Results are compared with U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency standards. Weather data support many Laboratory activities, including emergency management and response, regulatory compliance, safety analysis, engineering studies, and environmental surveillance programs.

Contents

Introduction

The purpose of the Laboratory's air-quality surveillance is to protect public health and the environment. Air quality is monitored by five programs; each is described in a section of this chapter: (1) ambient air sampling at public locations, (2) exhaust stack sampling at Laboratory facilities, (3) gamma and neutron direct radiation monitoring near radiation sources and in public locations, (4) particulate matter monitoring, and (5) meteorological monitoring of the local climate and weather.

A primary objective of air quality surveillance is to measure levels of airborne radiological materials to calculate radiological doses to humans, plants, and animals. Results are compared with U.S. Department of Energy and U.S. Environmental Protection Agency standards. Radioactivity levels in the air are compared with the limits for members of the public provided in DOE Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, and in *National Emission Standards for Hazardous Air Pollutants*, Title 40 Part 61 of the Code of Federal Regulations. Estimates of public doses prepared using this data are provided in Chapter 8, Public Dose and Risk Assessment.

Ambient Air Sampling for Radionuclides

The Laboratory's air-sampling network measures levels of airborne radionuclides to monitor the releases from Laboratory operations. Radioactivity levels in the air are compared with the U.S. Environmental Protection Agency's concentration levels for environmental compliance, provided in *National Emission Standards for Hazardous Air Pollutants*, Title 40 Part 61 of the Code of Federal Regulations, Appendix E, Table 2.

During 2021, the Laboratory operated 43 environmental air-monitoring stations to monitor radionuclides in the air (see Figure 4-1 and Figure 4-2). Station locations are categorized as regional (away from the Laboratory), perimeter, onsite, or waste site. These stations operate continuously by pulling ambient air through a filter to capture airborne particulate matter. The filters are changed out every two weeks and sent to an offsite analytical laboratory for analysis. The waste site locations monitor radionuclides near the Laboratory's low-level radioactive waste disposal area and radioactive waste storage area, Area G, at Technical Area 54 (see Figure 4-2).

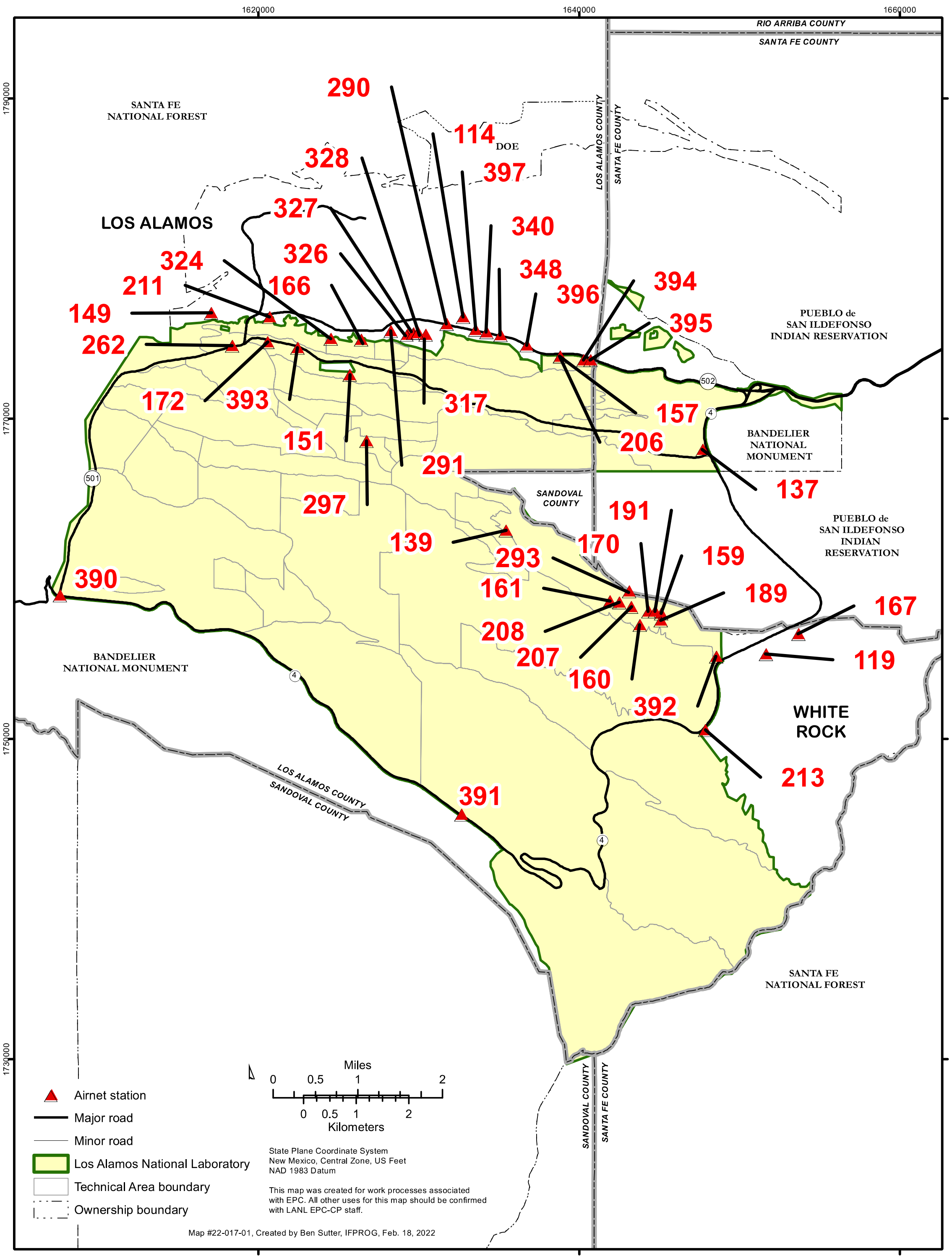
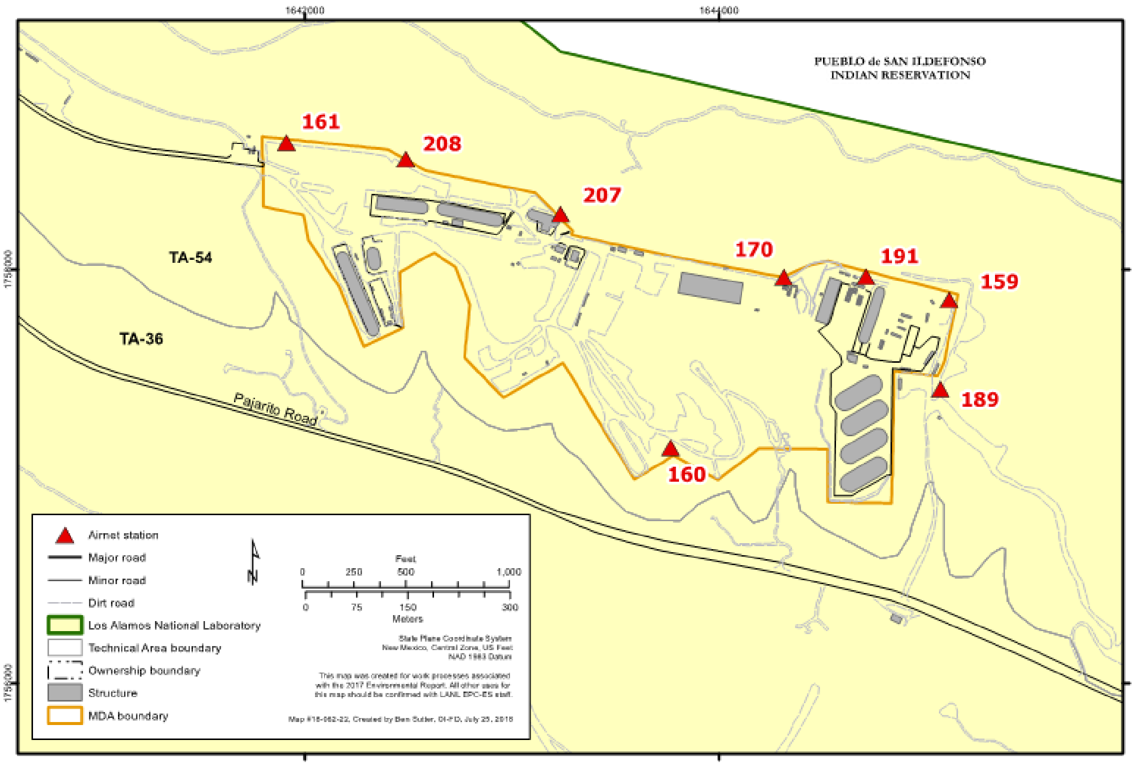


Figure 4-1. Environmental air-monitoring stations at and near the Laboratory



Note: MDA = Material disposal area; TA = Technical area

Figure 4-2. Environmental air-monitoring stations at the Laboratory's Technical Area 54, Area G

Regional Background Levels

The atmosphere contains background levels of radioactivity from naturally occurring radionuclides and airborne radioactive materials resulting from nuclear weapons tests and nuclear accidents. Background levels are measured at regional monitoring stations located in the communities of El Rancho, Española, and Santa Fe. The results are summarized in Table 4-1.

Table 4-1. Average Background Radionuclide Activities in the Regional Atmosphere

Analyte	Units	U.S. Environmental Protection Agency Concentration Level for Environmental Compliance	Average Regional Background Activities
Tritium	pCi/m^3	1500	0 ± 1
Americium-241	aCi/m^3	1900	0 ± 1
Plutonium-238	aCi/m^3	2100	0 ± 1
Plutonium-239/240	aCi/m^3	2000	0 ± 1
Uranium-234	aCi/m^3	7700	13 ± 3
Uranium-235	aCi/m^3	7100	1 ± 1
Uranium-238	aCi/m^3	8300	12 ± 5

Note: pCi/m^3 = picocuries per cubic meter; aCi/m^3 = attocuries per cubic meter.

Perimeter, Onsite, and Waste Site Radionuclides

> **What are cosmic rays?**
>
> Cosmic rays are fragments of atoms that rain down upon the Earth from outside the solar system.

Tritium

Tritium is present in the environment primarily as the result of past nuclear weapons tests and cosmic-ray interactions with the air (Eisenbud and Gesell 1997). Measurements of water vapor in the air and tritium in the water vapor are used to calculate the amount of tritium in the air. During 2021, tritium concentrations were similar to recent years and below the U.S. Environmental Protection Agency's concentration level for environmental compliance of 1,500 picocuries per cubic meter (see Table 4-2). The highest annual tritium activity at any offsite station was less than one percent of the concentration level for environmental compliance.

Table 4-2. Airborne Tritium as Tritiated Water Activities for 2021—Group Summaries

Station Grouping	No. of Stations	Mean ± 2 Standard Deviations (pCi/m^3)		Maximum Annual Station Activity (pCi/m^3)	U.S. Environmental Protection Agency Concentration Level for Environmental Compliance (pCi/m^3)
Regional	3	0	±1	0	1500
Perimeter	30	1	±2	6	1500
Onsite	2	4	N/A	7	1500
Waste site	8	38	N/A	264	1500

Note: pCi/m^3 = picocuries per cubic meter, N/A = not applicable.

For the waste site, the largest tritium concentration was at the southern boundary of Area G (station 160; see Figure 4-2). The annual average concentration is well below 1,500 picocuries per cubic meter, which is the U.S. Environmental Protection Agency concentration level for the public.

The analytical methods comply with U.S. Environmental Protection Agency requirements in *National Emission Standards for Hazardous Air Pollutants*, Title 40 Part 61 of the Code of Federal Regulations, Appendix B, Method 114.

Americium-241

Table 4-3 summarizes the 2021 sampling data for americium-241. The results are similar to recent years and are less than one percent of the americium-241 concentration level for environmental compliance.

Table 4-3. Airborne Americium-241 Activities for 2021—Group Summaries

Station Grouping	No. of Stations	Mean ± 2 Standard Deviations (aCi/m^3)		Maximum Annual Station Activity (aCi/m^3)
Regional	3	0	±1	0
Perimeter	30	0	±2	6
Onsite	2	1	±2	2
Waste site	8	0	±1	1

Note: aCi/m^3 = attocuries per cubic meter

Plutonium

Table 4-4 summarizes the LANL plutonium-238 and plutonium-239/240 data for 2021, which are generally similar to previous years.

Table 4-4. Airborne Plutonium-238 and Plutonium-239/240 Activities for 2021—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 2 Standard Deviations (aCi/m^3)		Maximum Annual Station Activity (aCi/m^3)	
		Plutonium-238	Plutonium-239/240	Plutonium-238	Plutonium-239/240
Regional	3	0 ± 1	0 ± 1	0	0
Perimeter	30	0 ± 2	2 ± 11	3	28
Onsite	2	0 ± 1	1 ± 3	0	2
Waste site	8	0 ± 1	1 ± 1	1	2

Note: aCi/m^3 = attocuries per cubic meter

Every year, dust blown from areas where Manhattan Project–era operations took place results in detectable amounts of plutonium-239 in the air near Technical Areas 01 and 21. The plutonium-239 concentrations at perimeter environmental air-monitoring stations 317 (DP Road), 324 (Hillside 138), and 326 (Middle DP Road) are about one percent of the U.S. Environmental Protection Agency's plutonium-239 concentration level for environmental compliance, which is 2,000 attocuries per cubic meter. This year, the concentration at AIRNET station 326 (Middle DP Road) was 28 aCi/m^3, which might be associated with the Middle DP Road site or with legacy contamination from Material Disposal Area B together with material emitted during the 1940s from the Technical Area 21 stacks. Remediation of Technical Area 21 is continuing.

Uranium

Table 4-5 summarizes the uranium data. The largest concentrations were the result of resuspended soil close to construction projects: roadwork near station 291; new housing near station 326; and a new pedestrian tunnel near station 396. All results are consistent with naturally occurring uranium and are below the applicable concentration levels.

Table 4-5. Airborne Uranium-234, -235, and -238 Activities for 2021—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 2 Standard Deviations (aCi/m^3)		
		Uranium-234	Uranium-235	Uranium-238
Regional	3	13 ± 3	1 ± 1	12 ± 5
Perimeter	30	14 ± 22	1 ± 1	13 ± 23
Onsite	2	8 ± 1	0 ± 1	7 ± 2
Waste site	8	9 ± 5	1 ± 1	10 ± 8

Note: aCi/m^3 = attocuries per cubic meter

Gamma Spectroscopy Measurements

Air samples are analyzed by gamma spectroscopy for the following gamma ray–producing radionuclides: cobalt-60, cesium-134 and -137, iodine-131, sodium-22, and protactinium-234m. These radionuclides were not detected.

Conclusion

All concentrations of airborne radioactive material measured in ambient air samples were below the applicable concentration levels for environmental compliance.

Exhaust Stack Sampling for Radionuclides

Radioactive materials are used in some Laboratory operations. The buildings that house those operations may vent radioactive materials to the environment through an exhaust stack or other release point. The Laboratory's stack monitoring team monitors emission points that could cause a public dose greater than 0.1 millirem during a one-year period. Each of these stacks is sampled in accordance with the *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*, Title 40 Part 61 Subpart H of the Code of Federal Regulations.

Sampling Methodology

Radioactive stack emissions can be one of four types: (1) particulate matter, (2) activated vapors and volatile compounds, (3) tritium, or (4) gaseous mixed activation products. Activated materials are made radioactive by exposure to neutron radiation. This section describes the sampling method for each of these emission types.

Emissions of particulate matter are sampled using a glass-fiber filter. A continuous sample of air from the stack is pulled through a filter that captures small particles. Filters are collected weekly and shipped to an offsite analytical laboratory for analysis.

Charcoal cartridges are used to sample emissions of vapors and volatile compounds generated by operations at the Los Alamos Neutron Science Center at Technical Area 53, the Chemistry and Metallurgy Research Building, and Technical Area 48.

Tritium emissions are measured with collection devices known as bubblers to determine the total amount of tritium released and whether it is in the elemental or oxide form. The bubblers pull a continuous sample of air from the stack, which is then "bubbled" through three sequential vials containing ethylene glycol. The ethylene glycol collects any tritium oxide that may be part of a water molecule. Then, the air is passed through a palladium catalyst that converts the elemental tritium to the oxide form. Following this conversion, the sample is pulled through three additional vials containing ethylene glycol, which collect the newly formed tritium oxide.

The stack monitoring team measures activities of gaseous mixed activation products emitted from the Los Alamos Neutron Science Center using real-time air monitoring data. For this, a sample of air from the stack is pulled through an ionization chamber that measures the total amount of radioactivity in the sample.

Data Analysis

Methods

This section discusses the analysis methods used for each type of the Laboratory's emissions. The sampling methods comply with U.S. Environmental Protection Agency requirements in the

National Emission Standards for Hazardous Air Pollutants, Title 40, Part 61 of the Code of Federal Regulations, Appendix B, Method 114.

Check of the Total Activity

Each week the glass-fiber filters are collected. The total activity is measured before the filters are shipped to an offsite analytical laboratory where they are analyzed using spectroscopy to identify radionuclides. These data are used to quantify emissions of radionuclides; and the results are compared with the total activity measurements to ensure that all radionuclides are identified.

Vaporous Activation Products

Each week the charcoal cartridges are collected and shipped to an offsite analytical laboratory where they are analyzed using spectroscopy. These data are used to identify and quantify the presence of vaporous material.

Tritium

Each week, tritium bubbler samples are collected and transported to the Laboratory's Health Physics Analysis Laboratory, where the amount of tritium in each vial is determined by liquid scintillation counting.

Gaseous Mixed Activation Products

Continuous monitoring is used for gaseous mixed activation products at the Los Alamos Neutron Science Center. There are two reasons for the use of continuous monitoring. First, standard filter paper and charcoal filters will not collect gaseous emissions. Second, the half-lives of these radionuclides are so short that the activity would decay away before any sample could be analyzed offsite. The monitoring system includes a flow-through ionization chamber in series with a gamma spectroscopy system. The real-time current measured by this ionization chamber is recorded. And, the total amount of charge collected in the chamber is integrated daily. The gamma spectroscopy system analyzes the composition of these gaseous mixed activation products.

Results

Table 4-6 provides detailed emissions data for Laboratory buildings with sampled stacks. Table 4-7 lists the stack emissions of the main activation products. Table 4-8 presents the half-lives of the main radionuclides typically emitted by the Laboratory.

Conclusions and Trends

Emission-control systems in Laboratory facilities for particulates such as plutonium and uranium continue to work as designed, and particulate emissions remain very low. Emissions of short-lived gases and vapors were similar to the last ten years. The radioactive emissions from all Laboratory sources amounted to approximately one percent of the regulatory limit.

Table 4-6. Airborne Radioactive Emissions* from LANL Buildings with Sampled Stacks in 2021

Technical Area and Building Number	Tritium (curies)	Americium-241 (curies)	Plutonium (curies)	Uranium (curies)	Thorium (curies)	Particulate or Vapor Activation Products (curies)	Gaseous Mixed Activation Products (curies)
TA-03-029		8.9×10^{-6}	1.8×10^{-5}	4.3×10^{-6}	5.8×10^{-7}		
TA-16-205/450	44.6						
TA-48-001					4.6×10^{-9}	1.8×10^{-5}	
TA-50-001					4.1×10^{-8}		
TA-50-069			6.0×10^{-11}		2.4×10^{-10}		
TA-53-003	8.3					5.1×10^{-5}	24
TA-53-007	4.5					8.6×10^{-1}	185
TA-54-231/375/412			1.6×10^{-10}		4.1×10^{-9}		
TA-55-004	0.3		2.1×10^{-9}	2.0×10^{-8}	1.4×10^{-8}		
TA-55-400			$3.0\text{x}10^{-9}$		$1.8\text{x}10^{-8}$		
Total	57.7	8.9×10^{-6}	1.8×10^{-5}	4.3×10^{-6}	6.7×10^{-7}	8.6×10^{-1}	209

** Values are expressed in scientific notation.*

Table 4-7. Main Activation Products in 2021

Building Number	Nuclide	Emission (curies)*	
TA-53-003	Argon-41	0.97	9.7×10^{-1}
TA-53-003	Carbon-11	23	2.3×10^{1}
TA-53-007	Argon-41	12	1.2×10^{1}
TA-53-007	Carbon-10	0.59	5.9×10^{-1}
TA-53-007	Carbon-11	77	7.7×10^{1}
TA-53-007	Nitrogen-13	32	3.2×10^{1}
TA-53-007	Nitrogen-16	0.70	7.0×10^{-1}
TA-53-007	Sodium-24	0.85	8.5×10^{-1}
TA-53-007	Oxygen-14	1.3	1.3×10^{0}
TA-53-007	Oxygen-15	61	6.1×10^{1}

**The value for emission for each building and nuclide is listed in both standard and scientific notation.*

Table 4-8. Radionuclide Half-Lives

Nuclide	Half-Life
Tritium	12.3 years
Carbon-10	19.3 seconds
Carbon-11	20.4 minutes
Nitrogen-13	10.0 minutes
Nitrogen-16	7.1 seconds
Oxygen-14	70.6 seconds
Oxygen-15	122.2 seconds
Sodium-24	15.0 hours
Argon-41	1.8 hours
Uranium-234	245,500 years
Uranium-235	703,800,000 years
Uranium-238	4,468,000,000 years
Plutonium-238	87.7 years

Nuclide	Half-Life
Plutonium-239	24,100 years
Plutonium-240	6,560 years
Plutonium-241	14.3 years
Americium-241	433 years

Monitoring for Gamma and Neutron Direct-Penetrating Radiation

Gamma and neutron radiation levels are monitored by the Direct-Penetrating Radiation Network (McNaughton 2018) and supplemented by the Neighborhood Environmental Watch Network. The objectives are to monitor gamma and neutron radiation in the environment as required by DOE Order 458.1.

Dosimeters are devices that measure exposure to ionizing radiation. We deployed dosimeters at 85 locations to monitor direct-penetrating radiation in the environment during 2021. Thermoluminescent dosimeters (which monitor gamma and neutron radiation) are deployed at every environmental air-monitoring station (see Figure 4-1 and Figure 4-2). Additional thermoluminescent dosimeters are deployed at Technical Areas 53 and 54, which are potential Laboratory sources of direct-penetrating radiation (see Figure 4-3 and Figure 4-4). Together, all these locations make up the Direct-Penetrating Radiation Network.

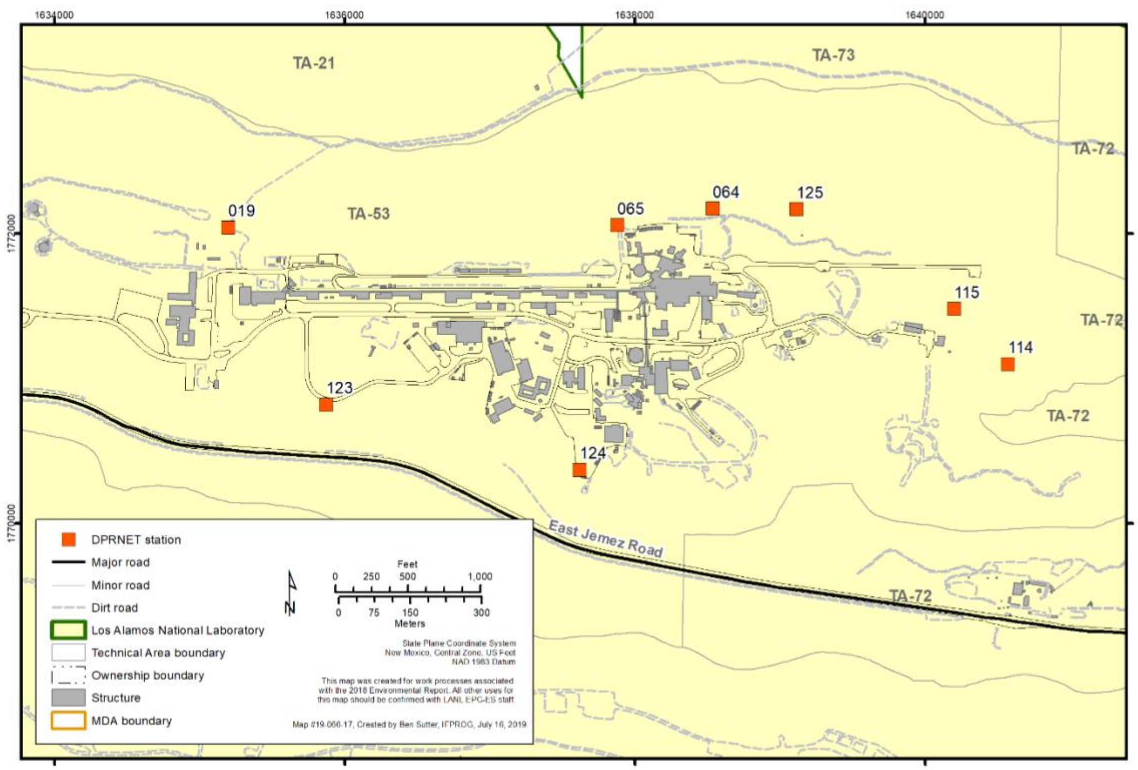


Figure 4-3. Locations of thermoluminescent dosimeters at Technical Area (TA) 53 that are part of the direct-penetrating radiation monitoring network (DPRNET)

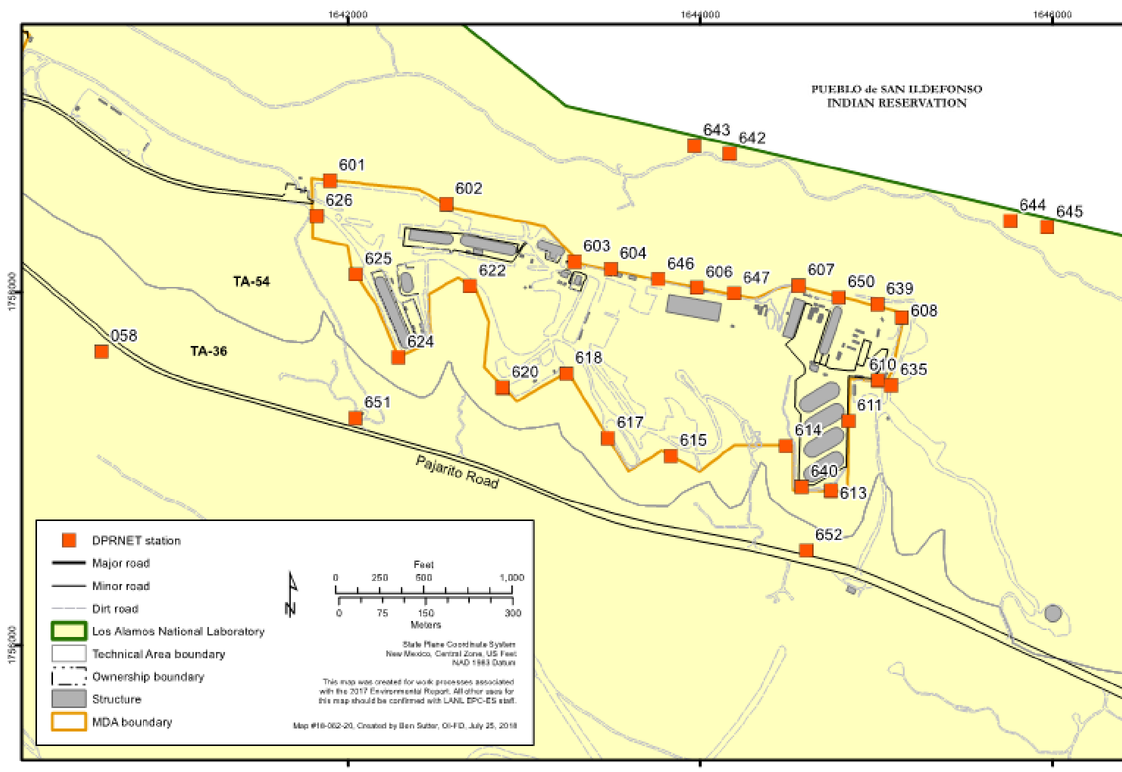


Figure 4-4. Locations of thermoluminescent dosimeters at Area G that are part of the direct-penetrating radiation monitoring network (DPRNET)

Gamma radiation occurs naturally, typically 100 to 200 millirem per year, so it is difficult to distinguish the much smaller levels of radiation contributed by the Laboratory. Radiation from the Laboratory is identified by higher radiation levels near the source and reduced radiation levels at greater distances.

Neutron doses are measured near known or suspected sources of neutrons, including Technical Areas 53 and 54. At 52 locations, the accuracy of the neutron measurements is enhanced by the addition of Lucite blocks that reflect neutrons into the dosimeter. The neutron background is measured at locations far from Laboratory sources.

Quality Assurance

The Radiation Protection Division dosimetry laboratory is accredited by the DOE Laboratory Accreditation Program and provides quality assurance for the dosimeters.

Results

Table 4-9 summarizes the gamma radiation data for 2021. We compared the results to the values recorded in previous years at those stations. At regional locations, the gamma radiation is natural and, as expected, has not changed. At the perimeter stations, the gamma radiation is generally higher than at the regional stations because of increased cosmic radiation at higher altitudes and increased uranium and thorium in the soil. At these stations, the radiation is mostly natural and, as expected, 2021 data are similar to data from previous years. Onsite, the slight decrease likely is not statistically significant. At the Los Alamos Neutron Science Center accelerator facility, there is measurable radiation from the accelerator, which varies from year to year. At the Area G waste site, there is a downward trend as waste is sent to the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

Table 4-9. Gamma Radiation for 2021—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 1 Standard Deviation (millirem)	
		Previous	2021
Regional	11	118 ± 15	121 ± 15
Perimeter	28	125 ± 12	129 ± 11
Onsite	3	130 ± 11	134 ± 9
Los Alamos Neutron Science Center	8	142 ± 23	140 ± 13
Area G Waste Site	33	203 ± 111	144 ± 19

Table 4-10 summarizes the neutron radiation data. At regional stations, the radiation is natural and there is no change. Similar to the gamma radiation data, for waste site locations near Area G, there is a decreasing trend as waste is sent offsite.

Table 4-10. Neutron Radiation for 2021—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 1 Standard Deviation (millirem)	
		Previous	2021
Regional	7	2.6 ± 1.5	1.8 ± 2.2
Perimeter	3	4.4 ± 3.4	3.9 ± 0.6
Onsite	10	2.3 ± 0.5	1.9 ± 0.9
Los Alamos Neutron Science Center	8	3.7 ± 1.1	5.6 ± 2.6
Area G Waste Site	33	136 ± 175	32 ± 26

Locations with a measurable contribution from Laboratory operations are discussed in the following section.

Los Alamos Neutron Science Center at Technical Area 53

Figure 4-3 shows the locations of the dosimeters at Technical Area 53. Previous studies (McNaughton 2013) discuss the possibility that a member of the public on East Jemez Road, south of Technical Area 53, could be exposed to gamma and neutron radiation from the Los Alamos Neutron Science Center in Technical Area 53.

During 2021, dosimeter #115 in Technical Area 53 measured a gamma dose of 163 millirem per year, which is 38 millirem per year above the background of 125 millirem per year. Calculations show that the gamma dose at East Jemez Road is 0.2 percent of the dose measured by dosimeter #115 (McNaughton 2013). Therefore, the gamma dose from Laboratory operations at East Jemez Road was approximately 0.1 millirem per year near this location.

Also, dosimeter #124 at Technical Area 53 measured a neutron dose 6 millirem per year above background. Calculations show that the neutron dose at East Jemez Road is 10 percent of this value (McNaughton 2013). Therefore, the neutron dose from Laboratory operations at East Jemez Road was 0.6 millirem per year near this location.

Technical Area 54, Area G

Figure 4-4 shows the locations of the dosimeters at Technical Area 54, Area G. Area G is a controlled-access area, so Area G data do not represent a potential public dose.

Dosimeters #642 through #645 are in Cañada del Buey. After subtracting background, the 2021 annual neutron dose measured by dosimeter #644 was 4 millirem. This is the dose that would be received by a person who is at the location of the dosimeter 24 hours per day, 365 days per year. As discussed in Chapter 8 (Public Dose and Risk Assessment), an occupancy factor of 1/20 is applied (NCRP 2005). Therefore, the dose in Cañada del Buey at the dosimeter is calculated to be 4 millirem multiplied by 1/20, equaling approximately 0.2 millirem per year, which is similar to previous years.

Neighborhood Environmental Watch Network

During 2021, the Neighborhood Environmental Watch Network did not detect any gamma-ray emissions from airborne radioactive material, which indicates that the annual dose from gamma-emitting material was far below the annual limit of 10 millirem.

Conclusion

Generally, the data are similar to previous years and show that emissions of direct-penetrating radiation from Laboratory facilities were far below the DOE limits.

Total Particulate Matter Air Monitoring

Particulate matter consists of smoke, dust, and other material that can be inhaled. Generally, it is not radioactive. Particulate matter can be harmful in high concentrations.

The total amount of respirable particulate matter is monitored at two locations: near the intersection of New Mexico State Road 4 and Rover Boulevard in White Rock, and at the Los Alamos Medical Center in Los Alamos.

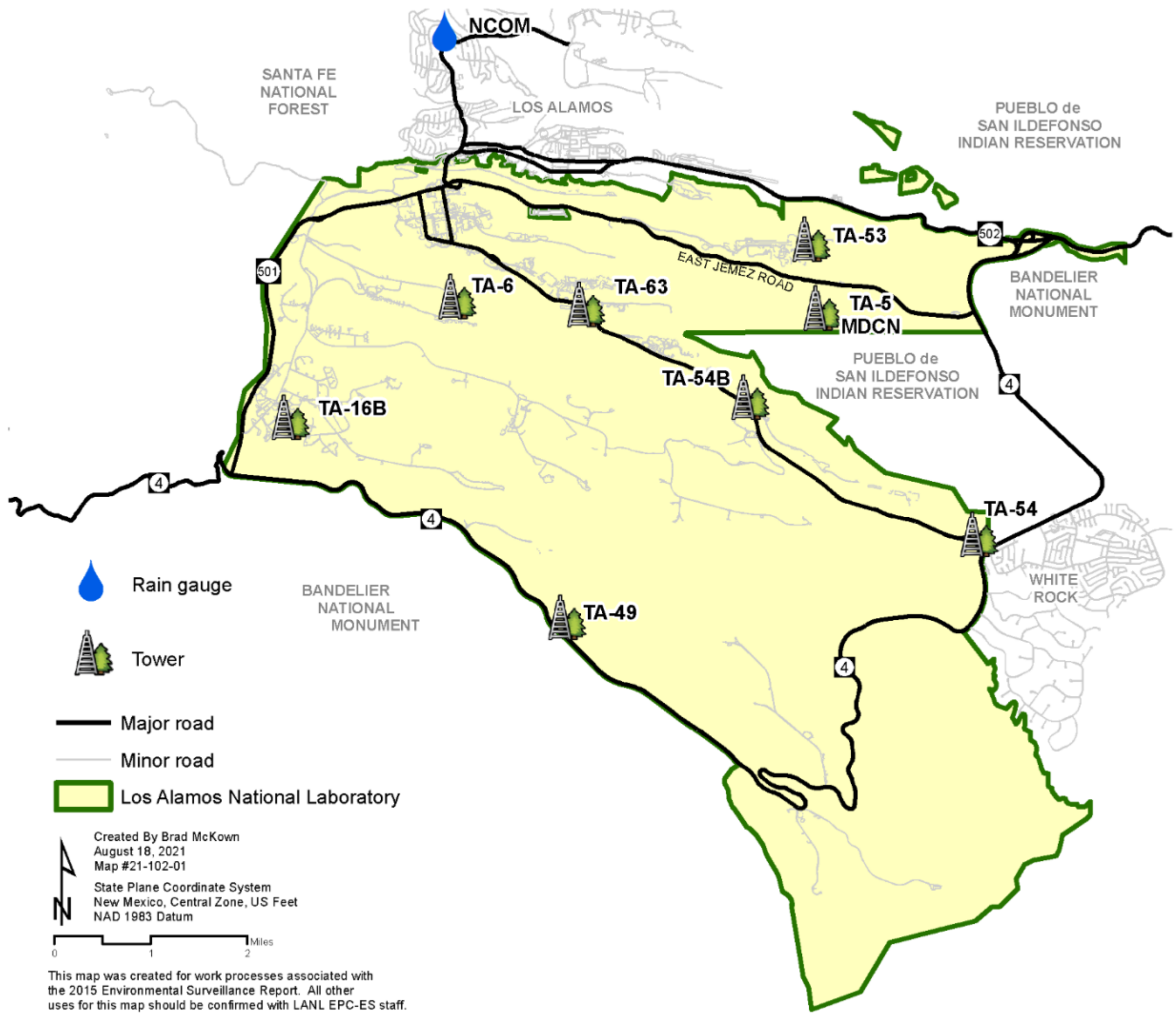
During 2021, the particulate matter concentrations remained well below the U.S. Environmental Protection Agency standard of 35 micrograms per cubic meter for particulate matter smaller than 2.5 micrometers. Typical concentrations (>95 percent of the time) were less than 10 micrograms per cubic meter. The highest concentrations occurred during the spring from windblown dust and during the summer from wildfires.

Meteorological Monitoring

We collect weather data to support many Laboratory activities, including emergency management and response, regulatory compliance, safety analysis, engineering studies, and environmental surveillance programs. The meteorological monitoring program measures wind speed and direction, temperature, atmospheric pressure, relative humidity, dew point, precipitation, and solar and terrestrial radiation, among other atmospheric variables. The meteorological monitoring plan (Dewart and Boggs 2014) provides details of the meteorological monitoring program. A copy of the plan is available at https://weathermachine.lanl.gov.

Monitoring Network

Eight meteorological towers gather weather data at the Laboratory (see Figure 4-5). This includes three new meteorological towers added to the network in 2021 (towers 16B, 54B, and 63). Seven of the towers are on mesa tops (Technical Areas 6, 16, 49, 53, 63, and two towers at Technical Area 54) and one tower is in the bottom of Mortandad Canyon (Technical Area 5). An additional precipitation gauge is at the North Community of the Los Alamos town site. The Technical Area 6 tower is the official meteorological measurement station for the Laboratory.



Note: MDCN = Mortandad Canyon; NCOM = North Community.

Figure 4-5. Locations of eight LANL meteorological monitoring towers and an offsite rain gauge

Sampling Procedures and Data Management

Weather-sensing instruments are located at areas with good exposure, usually in open fields, to avoid impacts on wind and precipitation measurements. Temperature and wind are measured at multiple height levels on open-lattice towers at Technical Areas 6, 49, 53, and 54. The multiple levels provide a vertical profile of these meteorological variables, which is important in assessing wind speed and direction at different heights above ground and in determining atmospheric stability conditions. The multiple levels also provide redundant measurements that enhance data quality checks. Boom-mounted temperature sensors on the towers are shielded from solar radiation and aspirated (provided with constant air circulation) to minimize effects from direct sunlight. Towers 16B, 54B, 63, and Mortandad Canyon are 10-meter tripod towers that measure wind speed, direction, and temperature at the top of the tower. Temperature is measured near ground level (approximately five feet high) at all stations except North Community, and humidity is measured at the same level only at the taller towers at Technical Areas 6, 49, 53, and 54. The North Community station only measures precipitation.

Data recorders at the stations collect most of the instrument results every three seconds, average the results over a 15-minute period, and transmit the averaged data by network connection, telephone modem, or cell phone to a computer workstation. The workstation program automatically edits measurements that fall outside of realistic ranges.

For more than 50 years, these daily weather statistics have been provided to the National Weather Service.

Climate

Los Alamos has a temperate, semiarid mountain climate. The humidity is generally low, and clear skies are present about 75 percent of the time. These conditions lead to high solar heating during the day and strong longwave radiative cooling at night. Winters are generally mild, with occasional winter storms. Spring is the windiest season. Summer is the rainy season, due to the Southwest monsoon, with frequent afternoon thunderstorms. Fall is typically dry and cool, with light wind speeds. Climate statistics are based on analyses of historical meteorological databases maintained by the Laboratory’s meteorology program (Bowen 1990, Bowen 1992, Dewart et al. 2017, Bruggeman and Waight 2021).

December and January are the coldest months, when 90 percent of minimum temperatures are between 4°F and 31°F. Ninety percent of maximum temperatures, which are usually reached in midafternoon, are between 25°F and 55°F. Wintertime arctic air masses that descend into the central United States usually moderate somewhat before they reach the southern latitude of Los Alamos and are sometimes blocked by the Sangre de Cristo Mountains, so subzero temperatures are not common. Winds during the winter are relatively light, so extreme wind chills are not common.

June through August are the warmest months, when 90 percent of maximum temperatures are between 67°F and 89°F. During the summer months, 90 percent of minimum temperatures are between 45°F and 61°F.

Average annual precipitation is calculated using 30 years of data measured at the official Laboratory weather station at Technical Area 6. This is a nationally standardized period updated every decade. (The averaged results are called the climate normals or climatological normal.)

The averaged years for 2021 climatological normals are 1991 to 2020. Other Laboratory stations do not have data going back 30 years.

The average annual precipitation, which includes rain and the water equivalent from frozen precipitation, is 17.36 inches. The average annual snowfall is 43.4 inches. The greatest winter precipitation events in Los Alamos are caused by storms approaching from the west to southwest. Snowfall amounts are occasionally enhanced from orographic lifting as the storms travel up the high terrain.

Table 4-11 presents temperature and precipitation records for Los Alamos from 1924 to 2021.

Table 4-11. Records Set Between 1924 and 2021 for Los Alamos

Measurement	Record	Date or Period
Low temperature	–18°F	January 13, 1963
High temperature	97.5°F	July 11, 2020
Single-day rainfall	3.52 inches	September 13, 2013
Single-day snowfall	39 inches	January 15, 1987
Single-season snowfall	153 inches	1986–1987

The rainy season, when the Southwest monsoon is present, typically begins in early July and ends in mid-September. Afternoon thunderstorms form as moist air from the Gulf of California and the Gulf of Mexico is convectively, orographically, or both convectively and orographically lifted by the Jemez Mountains. The thunderstorms yield short heavy downpours and abundant lightning.

The complex topography of Los Alamos influences local wind patterns, and often a distinct daily cycle of winds occurs. As air close to the ground is heated during the day, it becomes less dense and tends to flow uphill. During the night, as air close to the ground cools, it becomes denser and tends to flow downhill. As the daytime breeze flows up the Rio Grande Valley, it adds a southerly component to the prevailing westerly winds of the Pajarito Plateau. Nighttime airflow enhances the local westerly winds. Flow in the east-west–oriented canyons of the Pajarito Plateau is generally aligned with the canyons. Therefore, canyon winds are usually from the west at night and from the east during the day. Winds on the Pajarito Plateau are usually faster during the day than at night. This is a result of vertical mixing driven by solar heating. During the day, the vertical mixing is strong and brings momentum from higher wind speeds aloft down to the surface, thereby increasing the wind speed.

2021 in Perspective

Figure 4-6 presents a graphical summary of Los Alamos temperatures for 2021, with a comparison of the daily high and low temperatures at Technical Area 6 to the 1991 to 2020 climatological normal values, and to the record values from 1924 to the present. Table 4-12 presents Los Alamos climatological data for 2021. The last line of Table 4-12 shows that the overall average temperature was 1.8°F above the 1991 to 2020 average, total precipitation was 4.95 inches below the 1991 to 2020 average, and snowfall was 10.3 inches below the 1991 to 2020 average. The warmest temperature was 95°F on June 14 and the coolest temperature was –4°F on February 15. Monthly average temperatures in 2021 were above the 1991 to 2020 averages for 10 of the 12 months, with the highest above-average months recorded in September, November, and December. The average wind speed was 0.3 mph above the 1991 to

2020 average. In 2021, the strongest officially recorded wind gust at Technical Area 6 occurred on December 15 at 68 miles per hour. The Technical Area 49 tower measured a wind gust at 80 miles per hour on the same day—the second highest wind gust ever recorded in Los Alamos.

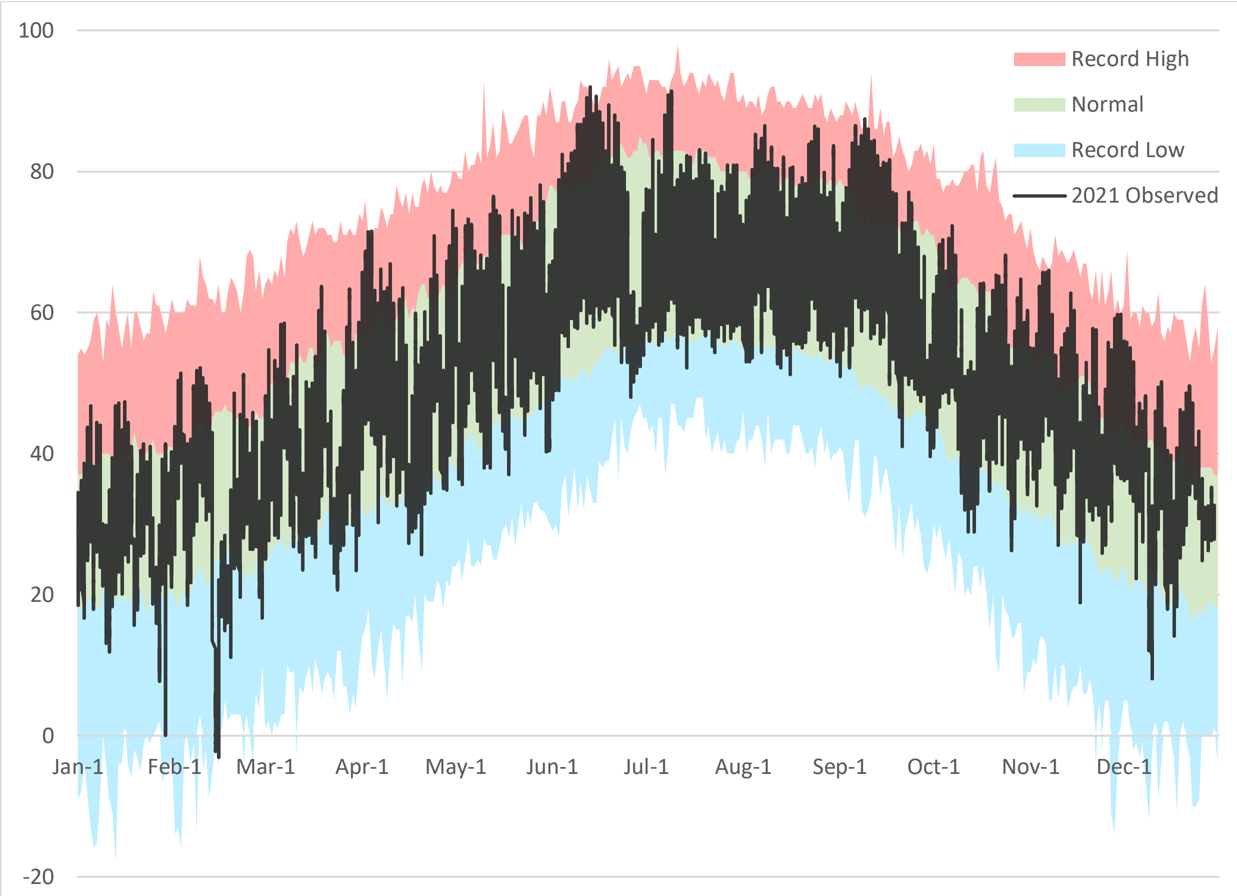


Figure 4-6. Los Alamos daily high and low temperatures in 2021 in degrees Fahrenheit (black) compared with record (red: record highs; blue: record lows) and normal (green) values

Table 4-12. Monthly and Annual Climatological Data for 2021 at Los Alamos

Month	Temperatures (°Fahrenheit)*								Precipitation (inches)*				12-meter† Wind (miles per hour)*				
	Averages				Extremes						Snowfall				Peak Gusts		
	Daily Maximum	Daily Minimum	Overall	Departure‡	Highest	Date	Lowest	Date	Total	Departure‡	Total	Departure‡	Average Speed	Departure§	Speed	From	Date
January	39.6	20.0	29.8	0.1	49	14	7	27	0.75	-0.13	11.6	2	5.3	0.2	44	WNW	30
February	42.2	22.1	32.1	–1.3	54	9	–4	15	0.72	-0.04	10.9	2.6	6.3	0.3	53	WSW	3
March	51.7	28.0	39.9	–1	65	20	16	1	0.77	-0.22	7.2	1.7	7.6	0.7	45	WNW	14
April	62.8	35.3	49.0	1.4	74	5	26	21	0.06	-0.87	0.2	–3	8.6	0.6	52	W	8
May	71.7	44.5	58.1	1.5	80	29	35	4	2.26	1.1	0	–0.2	8.1	0.4	45	S	22
June	81.7	54.8	68.2	1.6	95	14	40	1	2.05	0.89	0	0	6.4	1.1	37	NNE	16
July	82.1	56.9	69.5	0.4	93	10	52	15	1.96	–0.89	0	0	5.7	–0.1	33	NW	1
August	81.8	55.6	68.7	2	89	25	50	17	1.72	–1.48	0	0	6.2	0.7	50	NW	3
September	78.7	52.3	65.5	4.6	90	10	40	22	1.04	–0.98	0	0	6.0	0.1	30	SW	19
October	62.3	38.9	50.6	0.7	73	8	25	27	0.03	–1.51	0	–1.6	6.3	0.5	47	WNW	26
November	57.1	32.6	44.9	6.4	67	8	19	18	0	–0.94	0	–4.5	5.0	–0.5	32	NNW	10
December	45.1	25.8	35.5	5.6	61	1	7	11	1.05	0.13	3.2	–7.3	6.4	1.4	68	W	15
Year	63.1	38.9	51.0	1.8	95	Jun 14	–4	Feb 15	12.41	–4.95	33.1	–10.3	6.5	0.3	68	W	Dec 15

*Data from Technical Area 6, the official Los Alamos weather station
†Wind data measured at 12 meters above the ground
‡Departure column indicates positive or negative departure from 1991 to 2020 (30-year) climatological average
§Departure column indicates positive or negative departure from 1993 to 2020 (28-year) climatological average

Figure 4-7 shows the Los Alamos cumulative precipitation for 2021. Cumulative precipitation was near average through July with a brief time of above-average cumulative precipitation at the end of June and start of July. However, August to November measured significantly below average. The U.S. Drought Monitor (https://droughtmonitor.unl.edu) classified Los Alamos County from the beginning of the year through July as the driest category of "Exceptional Drought." Even though Los Alamos measured below average precipitation in July, there was enough precipitation across New Mexico for the U.S. Drought Monitor to improve the classification for Los Alamos County to "Extreme Drought" in August, and that classification continued through the end of 2021.

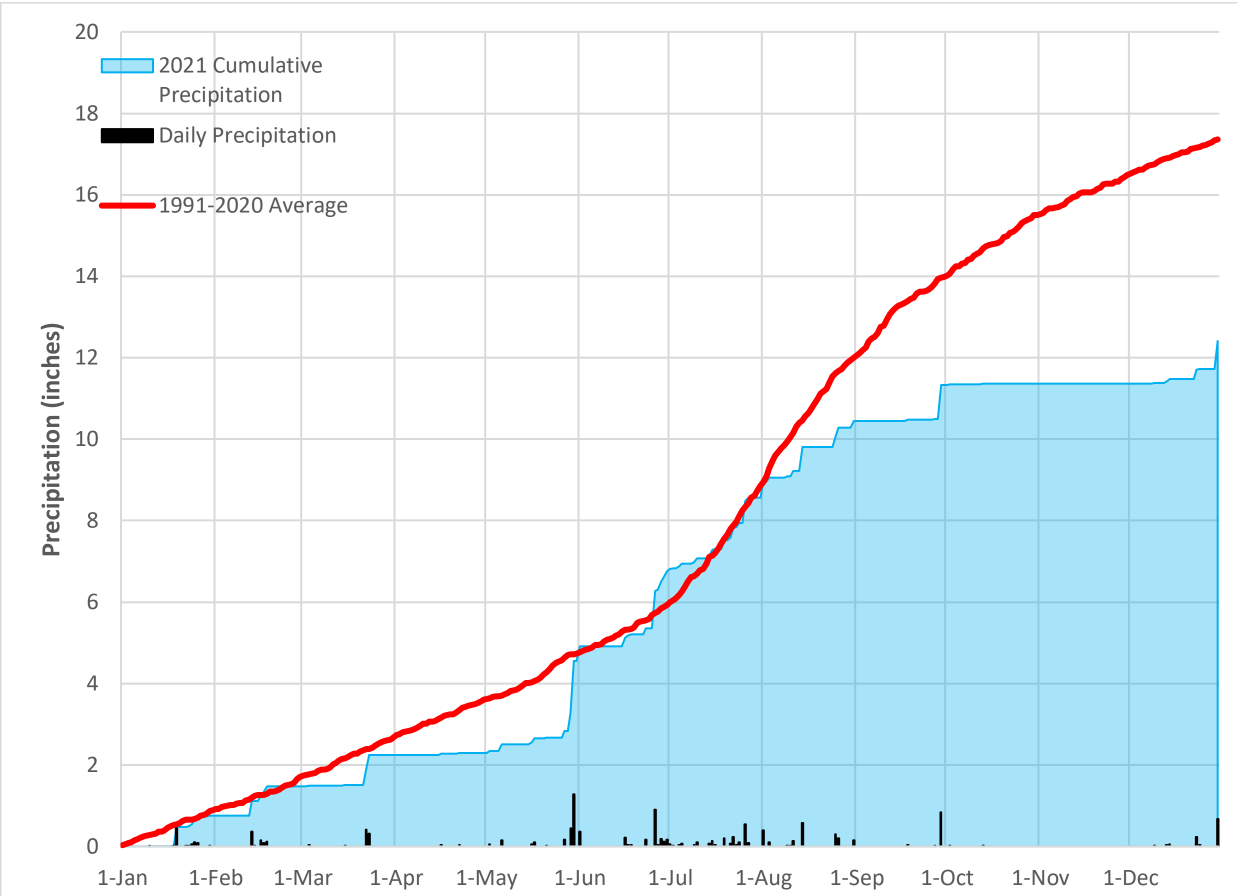


Figure 4-7. Technical Area 6 daily and cumulative precipitation in 2021 versus 30-year average

At the Laboratory's weather stations, approximately 50 percent of the annual precipitation falls during the summer monsoon season, based on the National Weather Service definition of June 15 to September 30. Typically, more precipitation is measured at locations closer to the Jemez Mountains. The Technical Area 54 tower near White Rock tends to measure the least precipitation since it is farthest from the Jemez Mountains. Although not shown here, more precipitation fell during 2021 at Technical Area 6 and North Community compared to Technical Area 54.

Daytime (sunrise to sunset) winds and nighttime (sunset to sunrise) winds are shown in wind roses in Figure 4-8. The wind roses are based on 15-minute average wind observations for 2021 at four mesa-top stations (Technical Areas 06, 49, 53, and 54). Wind roses depict the percentage of time that wind blows from each of 16 cardinal compass point directions and the distribution of wind speed for each direction. During the day, winds are typically from the south and southwest, while at night the winds are usually from the west and northwest. Although not shown in this figure, wind roses from different years are almost identical in terms of the distribution of wind directions, indicating that wind patterns are consistent over time.

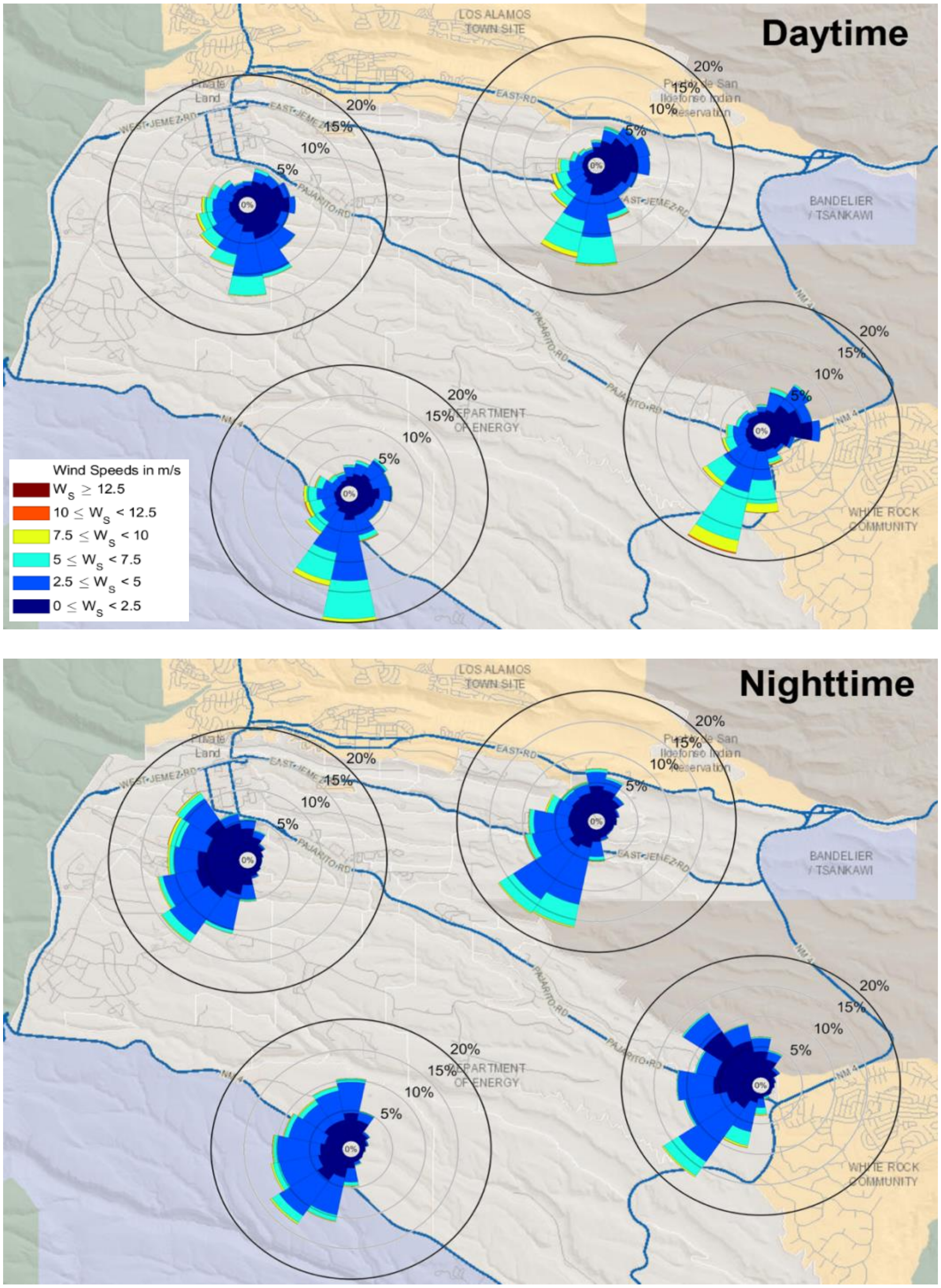


Figure 4-8. Wind roses for 2021 at four mesa-top meteorological towers

Long-Term Climate Trends

Temperature and precipitation data have been collected in the Los Alamos area since 1910. Figure 4-9 shows the historical record of temperatures at Los Alamos from 1924 through 2021. The annual average temperature is the midpoint between daily high and low temperatures, averaged for the year. One-year averages are shown in green in Figure 4-9 and a five-year running average, to show longer-term trends, is shown in black. The five-year average shows that the warm spell during the past 15 years is more extreme than the warm spell during the early-to-mid 1950s and is longer lived. Although not shown in the figure, five of the hottest summers on record have occurred since 2002, and the highest summertime (June, July, and August) average temperature on record was 71.1°F, recorded during 2011.

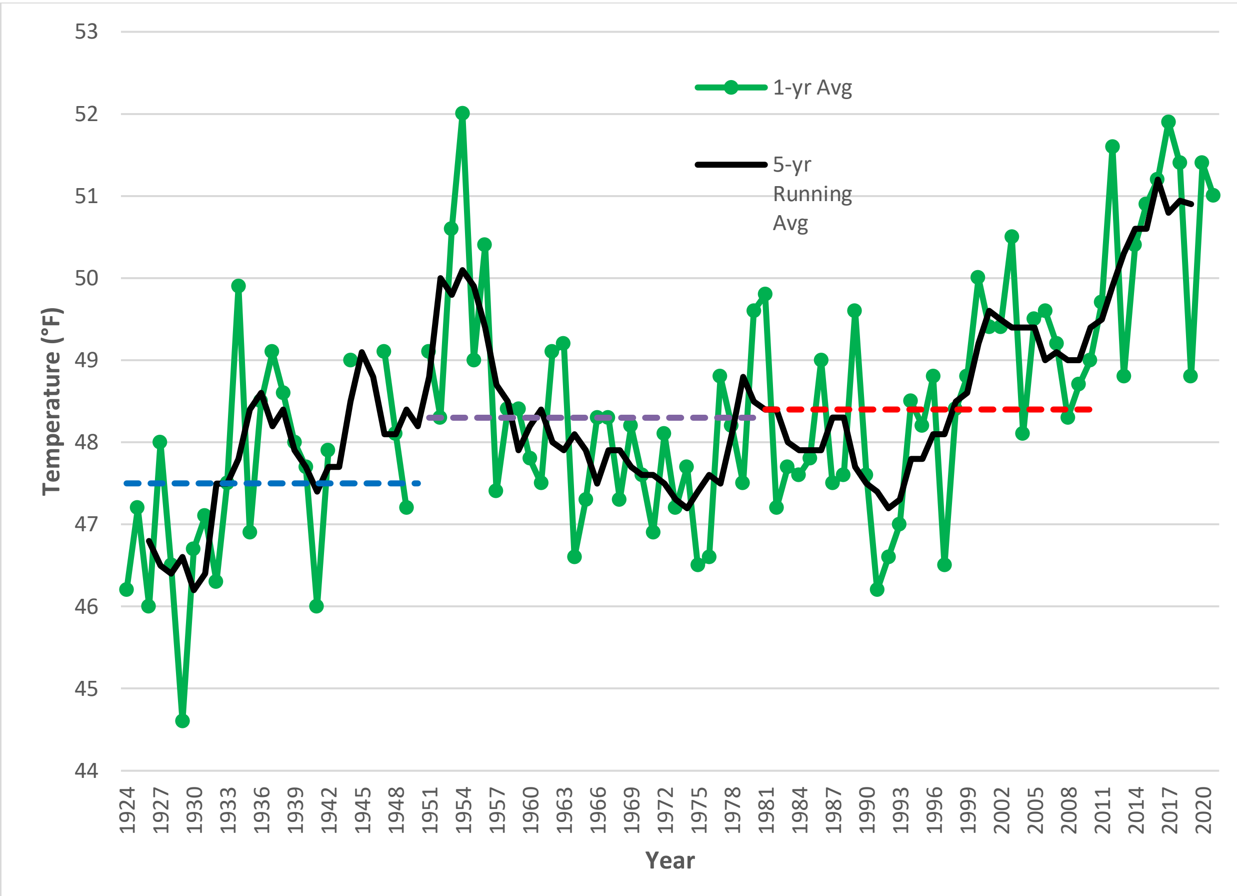


Figure 4-9. Temperature history for Los Alamos with the one-year average in green and five-year running average in black. The dashed lines represent long-term averages (25 and 30 years).

The average temperatures per decade, recorded at Technical Area 06, along with two times the standard deviation, are plotted in Figure 4-10 with the annual average temperature for 2020 and 2021. Ninety-five percent of the annual average temperatures during each decade are within the standard deviation bars. During the decades between 1960 and 2000, the annual average temperatures in Los Alamos varied only slightly from 48°F. However, during the 2001–2010 decade, the annual average temperature increased to above 49°F, and this value is statistically significantly higher than previous decades. During the recent 2011–2020 decade, the average temperature increased even more than the previous decade, with annual average temperatures above 50°F. The annual average temperatures in 2020 and 2021 continue to demonstrate a warming climate for Los Alamos, consistent with predictions for a warming climate in the southwestern United States (Intergovernmental Panel on Climate Change 2014).

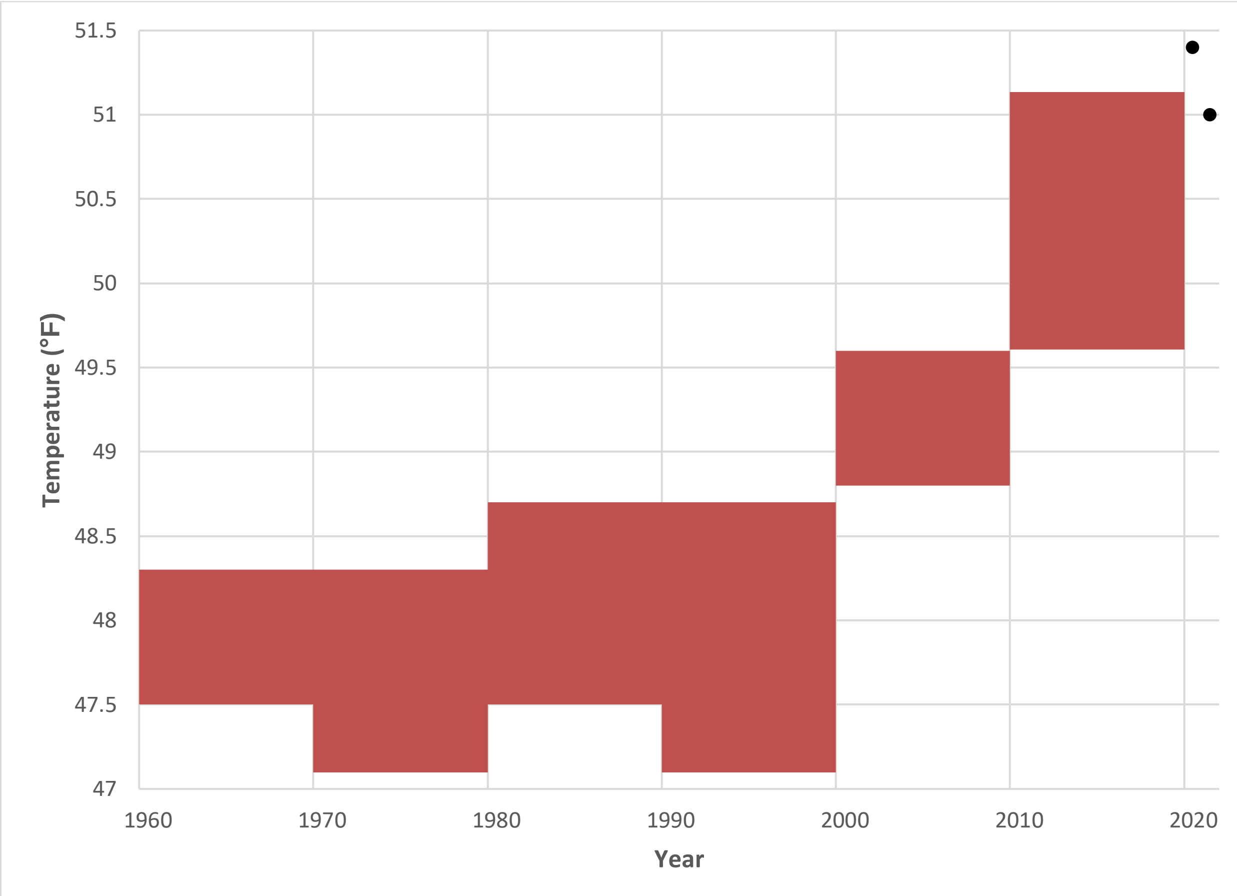


Figure 4-10. Technical Area 06 decadal average temperatures with two times the standard deviation for 1960 through the beginning of 2020, and the annual average temperatures for 2020 and 2021 (black points)

Figure 4-11 presents the historical record of the annual precipitation at Technical Area 06. As with the historical temperature profiles, the five-year running averages and three long-term averages (25- or 30-year periods) are also shown. The 1998 through 2021 period shows the most recent drought, although near-average precipitation from 2004 to 2010 and above-average precipitation in 2015 did occur during this period.

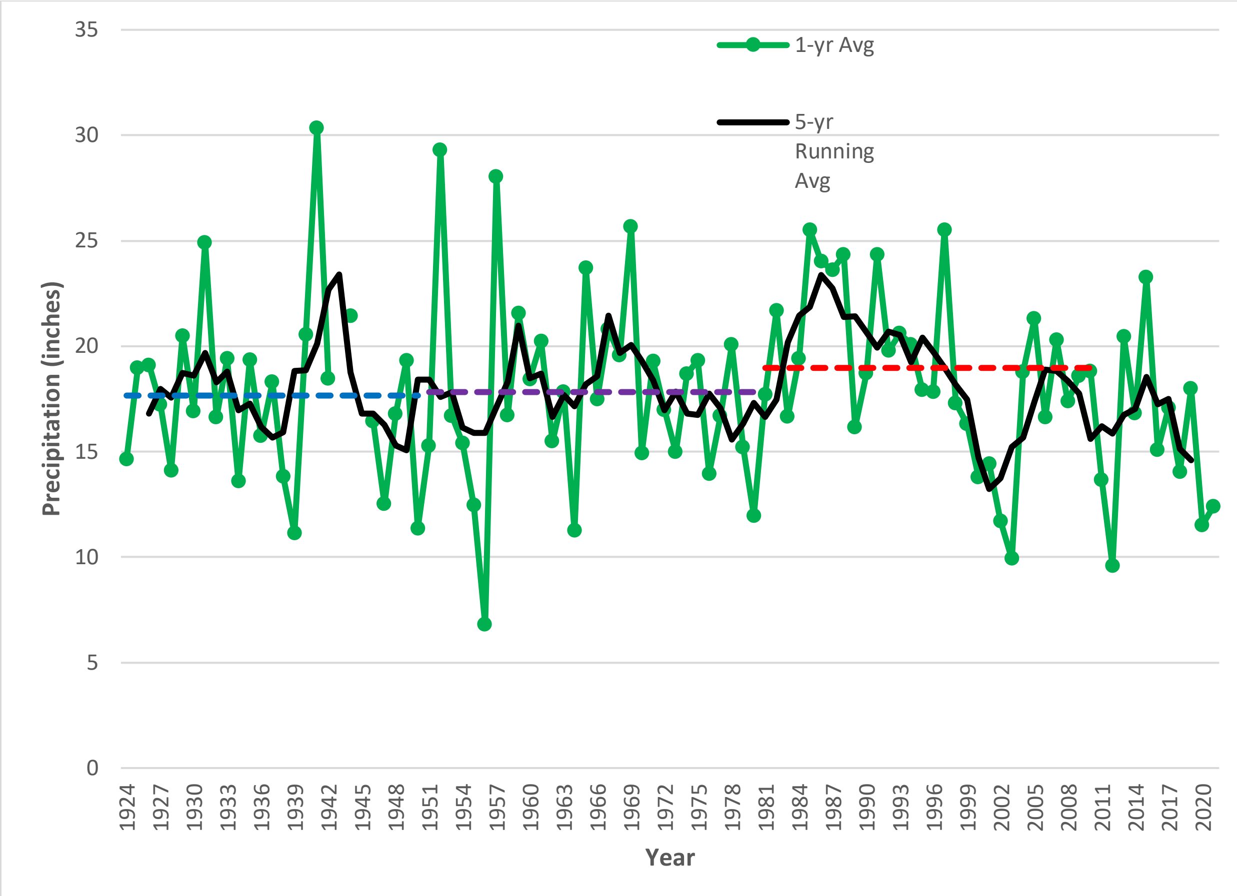


Figure 4-11. Total precipitation history for Los Alamos with the one-year total in green, five-year running average in black, and the dashed lines representing long-term averages (25 and 30 years)

Quality Assurance

Air Quality Sampling

The quality assurance program satisfies requirements in the U.S. Environmental Protection Agency's *National Emission Standards for Hazardous Air Pollutants*, Title 40 Part 61 of the Code of Federal Regulations, Appendix B, Method 114. The quality assurance project plans and implementing procedures specify the requirements and implementation of sample collection, sample management, chemical analysis, and data management. The requirements follow U.S. Environmental Protection Agency methods for sample handling, chain of custody, analytical chemistry, and statistical analyses of data.

The quality assurance plan for ambient air sampling is described in the procedure "Quality Assurance Project Plan for the Radiological Air Sampling Network," SOP-5140, and 25 supporting procedures. The stack sampling quality assurance plan is described in the procedure "Rad-NESHAP Compliance Program, Program Implementation Plan," EPC-CP-PIP-0101, and 42 supporting procedures.

Direct Radiation Monitoring

The quality assurance plan for direct penetrating radiation is described in the procedure “Direct Penetrating Radiation Monitoring Network (DPRNET),” EPC-ES-TPP-007, and the procedure “Obtaining the Environmental Dose from the Model 8823 Dosimeter,” EPC-ES-TP-002. Quality Assurance for the Model 8823 Dosimeter is provided by the Radiation Protection Division dosimetry laboratory, which is accredited by the DOE Laboratory Accreditation Program.

Meteorological Monitoring

Time-series plots of the data are generated for a meteorologist to conduct data quality reviews. Daily statistics such as daily minimum and maximum temperatures, daily total precipitation, and maximum wind gust are also generated and checked for quality and out-of-range values.

Meteorological instrument and data logger manufacturers’ recommendations are followed, and operating conditions determine how often to calibrate the weather sensing instruments. All wind instruments are calibrated every six months, while all other sensors are calibrated annually, except the solar radiation sensors, which are calibrated once every five years.

Internal self-assessments and external audits of the meteorological program (inclusive of the instruments and methods) are performed periodically.

Annually, a qualified subcontractor inspects the tower and the instruments of all meteorological towers, and performs maintenance.

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Chapter 5: Groundwater Protection

Los Alamos National Laboratory (LANL or the Laboratory) monitors and characterizes groundwater for the groundwater protection program and the 2016 Consent Order. We collect hundreds of groundwater samples each year and analyze them for a wide range of organic and inorganic constituents and radionuclides. We also implement measures to control contaminant migration.

LANL's groundwater monitoring network includes 195 sampling locations in four types of water: base flow (persistent surface water), alluvial groundwater, perched-intermediate groundwater, and regional aquifer groundwater. Many locations are grouped to monitor area-specific water quality and other aquifer characteristics. Areas with monitoring groups include Technical Area 16-260 (around the Building 260 former outfall), Technical Area 21, Technical Area 54, the Chromium Investigation area, Material Disposal Area AB, and Material Disposal Area C.

We use sampling results from some groundwater wells to define the nature and extent of known contaminant plumes and to evaluate and model changes in plume location and concentrations over time. This information guides corrective actions where they are needed. We have placed other wells to monitor for new contamination. The results help us comply with the requirements of U.S. Department of Energy orders and New Mexico and federal regulations.

Site-wide groundwater monitoring indicates only two notable areas of groundwater contamination at the Laboratory: an RDX (royal demolition explosive; hexahydro-1,3,5-trinitro-1,3,5-triazine) plume beneath Cañon de Valle in the vicinity of Technical Area 16 and a chromium plume beneath Sandia and Mortandad canyons.

RDX, primarily associated with historical machining of high explosives at Technical Area 16, has infiltrated into groundwater beneath Cañon de Valle. In some areas, RDX concentrations exceed the New Mexico tap water screening level of 9.66 micrograms per liter in perched-intermediate groundwater and the regional aquifer. The RDX plume is completely within the LANL boundary and is approximately three miles from the nearest public water supply wells.

Hexavalent chromium is present in the regional aquifer beneath Sandia and Mortandad canyons at concentrations above the New Mexico groundwater standard of 50 micrograms per liter. The hexavalent chromium releases occurred from 1956 to 1972. An interim measure to address the plume is ongoing.

The groundwater protection program also provides monitoring to support current Laboratory operations. This program includes monitoring required by authorizations issued by the New Mexico Environment Department's Groundwater Quality Bureau, such as groundwater discharge permits, as well as monitoring required to meet facility groundwater monitoring plan requirements under the Laboratory's Hazardous Waste Facility Permit.

Contents

Introduction

The Laboratory routinely monitors the quality of local groundwater. A regional aquifer is present beneath the Laboratory at depths ranging from 600 to 1,200 feet below the ground surface. Our groundwater monitoring and protection efforts focus on the regional aquifer not only because it supplies drinking water but also because it includes groundwater found within canyon-floor sediments and within rocks and sediments at intermediate depths below the canyon bottoms and above the regional aquifer.

What is an aquifer?

The word aquifer literally means "water bearer" and refers to an underground layer of rock or sediment that contains enough accessible water to be of interest to humans (Buddemeier et al. 2000).

U.S. Department of Energy (DOE) Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, requires operators of DOE facilities to ensure that radionuclides from DOE activities do not cause private or public drinking water systems to exceed the drinking water maximum contaminant levels in the *National Primary Drinking Water Regulations*, Title 40 Part 141 of the Code of Federal Regulations. Operators also must document baseline conditions of the groundwater quantity and quality.

In 2016, DOE and the New Mexico Environment Department signed a new Compliance Order on Consent (Consent Order) addressing legacy waste cleanup. The previous consent order was signed in 2005. The Consent Order continues to require the Laboratory to submit an Interim Facility-Wide Groundwater Monitoring Plan to the New Mexico Environment Department for approval each year. The monitoring locations, frequency of monitoring, and substances that LANL must monitor are updated in the plan each year. The legacy waste cleanup contractor, Newport News Nuclear BWXT-Los Alamos, LLC (N3B), is responsible for implementing the groundwater program in accordance with the approved Interim Facility-Wide Groundwater Monitoring Plans (N3B 2020, 2021). LANL's hazardous waste facility permit and groundwater discharge permits (see Chapter 2) require some additional groundwater monitoring activities at the Laboratory.

Hydrogeologic Setting

The following section describes the distribution and movement of groundwater at the Laboratory and includes a summary of groundwater contaminant sources and distribution. Additional details can be found in reports available at the Laboratory's electronic public reading room (https://eprr.lanl.gov) and at the DOE Environmental Management–Los Alamos electronic public reading room (https://ext.em-la.doe.gov/EPRR/).

The Laboratory is in Northern New Mexico on the Pajarito Plateau. The Pajarito Plateau extends from the Sierra de los Valles range of the Jemez Mountains eastward to the Rio Grande. Rocks composed of Bandelier Tuff are the uppermost layer of the plateau (see Figure 5-1). The tuff was formed from ash and other volcanic materials that erupted 1.6 to 1.2 million years ago from the volcanic field of the Jemez Mountains (a volcanic field is an area with a geologic history of volcanic activity). The tuff is more than 1,000 feet thick in the western part of the plateau and thins to about 260 feet above the Rio Grande.

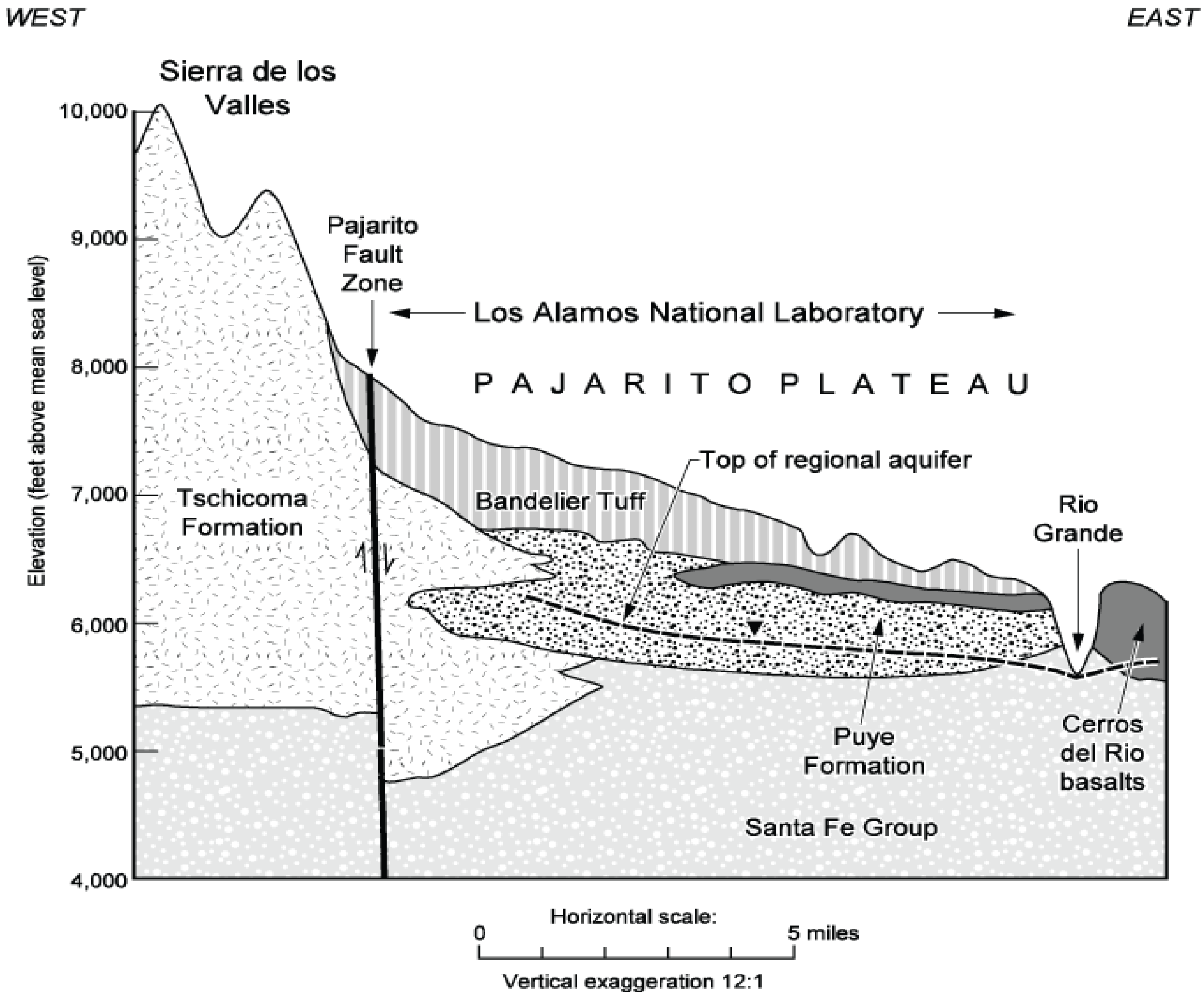


Figure 5-1. Generalized geologic cross-section of the Pajarito Plateau

On the western edge of the Pajarito Plateau, the Bandelier Tuff overlaps the Tschicoma Formation, which consists of older volcanic deposits (see Figure 5-1). The Puye Formation, a largely unconsolidated sedimentary deposit, underlies the tuff beneath the central and eastern portion of the plateau. The Puye Formation consists of sand and gravel that washed off the Sierra de los Valles range prior to the eruptions producing the Bandelier Tuff. The Cerros del Rio basalt flows, which originated mostly from a volcanic center east of the Rio Grande, extend into the Puye Formation beneath the Laboratory. These formations overlie the sediments of the Santa Fe Group, which cross the Rio Grande Valley and are more than 3,300 feet thick.

The Laboratory sits atop a thick zone of mainly unsaturated rock and sediments. Groundwater beneath the Pajarito Plateau occurs in three modes (see Figure 5-2): (1) perched alluvial groundwater in the bottom of some canyons, (2) small areas of intermediate-depth perched groundwater, and (3) the regional aquifer.

Hydrogeologic Terms

Saturated rock or sediment is completely wet.

Unsaturated rock or sediment has air in its pore spaces.

Perched groundwater is a zone of saturation of limited thickness that occurs above the regional aquifer.

Alluvial groundwater is a zone of saturation that exists in sands and gravels in the bottoms of canyons.

Perched alluvial groundwater is a limited area of saturated rocks and sediments directly below canyon bottoms. Surface water moves through the alluvium (clay, sand, silt, or gravel deposited by running water) until less-permeable layers of rock disrupt downward flow, resulting in shallow perched bodies of groundwater. Most of the canyons on the Pajarito Plateau have infrequent surface water flow and, therefore, little or no alluvial groundwater. A few canyons have saturated alluvium in their western ends, supported by runoff from the Jemez Mountains. In some locations, discharges from Laboratory outfalls supplement or maintain surface water. As alluvial groundwater moves down a canyon, it is used and transpired by plants, or it percolates into underlying rock or sediments.

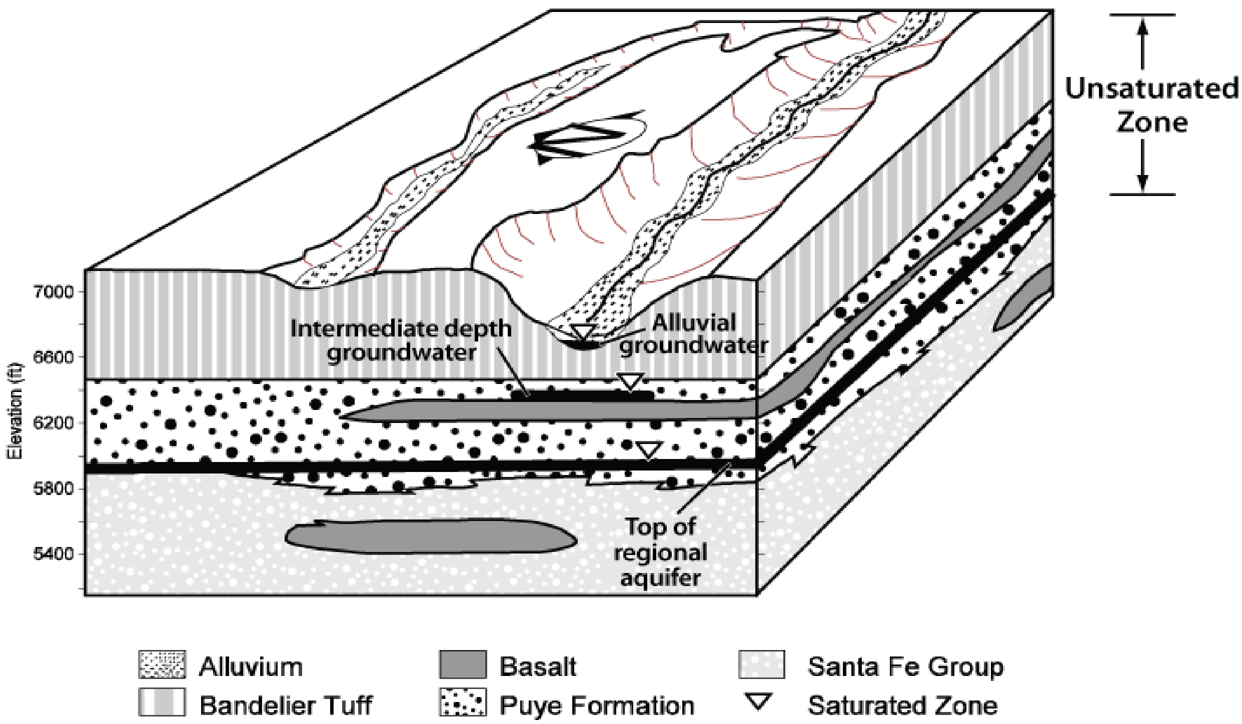


Figure 5-2. Illustration of geologic and hydrologic relationships on the Pajarito Plateau, showing the three modes of groundwater occurrence: perched alluvial groundwater, perched intermediate-depth groundwater, and groundwater within the regional aquifer.

Perched-intermediate groundwater occurs within the lower part of the Bandelier Tuff, within the Puye Formation, and within the Cerros del Rio basalt layer beneath some canyons. These intermediate-depth groundwater bodies are formed in part by water moving downward from beneath the canyons until it reaches a layer of rock that allows little or no water to pass through. Depths of the perched-intermediate groundwater zones vary; for example, the depth to perched-intermediate groundwater is approximately 120 feet beneath Pueblo Canyon, 450 feet beneath Sandia Canyon, and 500 to 750 feet beneath Mortandad Canyon.

The uppermost level of water in the regional aquifer, known as the water table, occurs at a depth of approximately 1,200 feet below ground surface along the western edge of the plateau and 600 feet below ground surface along the eastern edge (see Figure 5-1 and Figure 5-3). Studies indicate that water from the Sierra de los Valles range is the main source of recharge for the regional aquifer (LANL 2005a). Groundwater near the water table generally flows east, with local northeast or southeast flows observed. The speed of groundwater flow varies but is typically around 30 feet per year. The regional aquifer is separated from alluvial and perched-intermediate groundwater by layers of unsaturated tuff, basalt, and sediment. The limited extent of the alluvial and intermediate groundwater bodies, along with unsaturated rock and sediment that underlies them, restricts their contribution to recharging the regional aquifer although, locally, they are important parts of the complete hydrologic pathway to the regional aquifer.

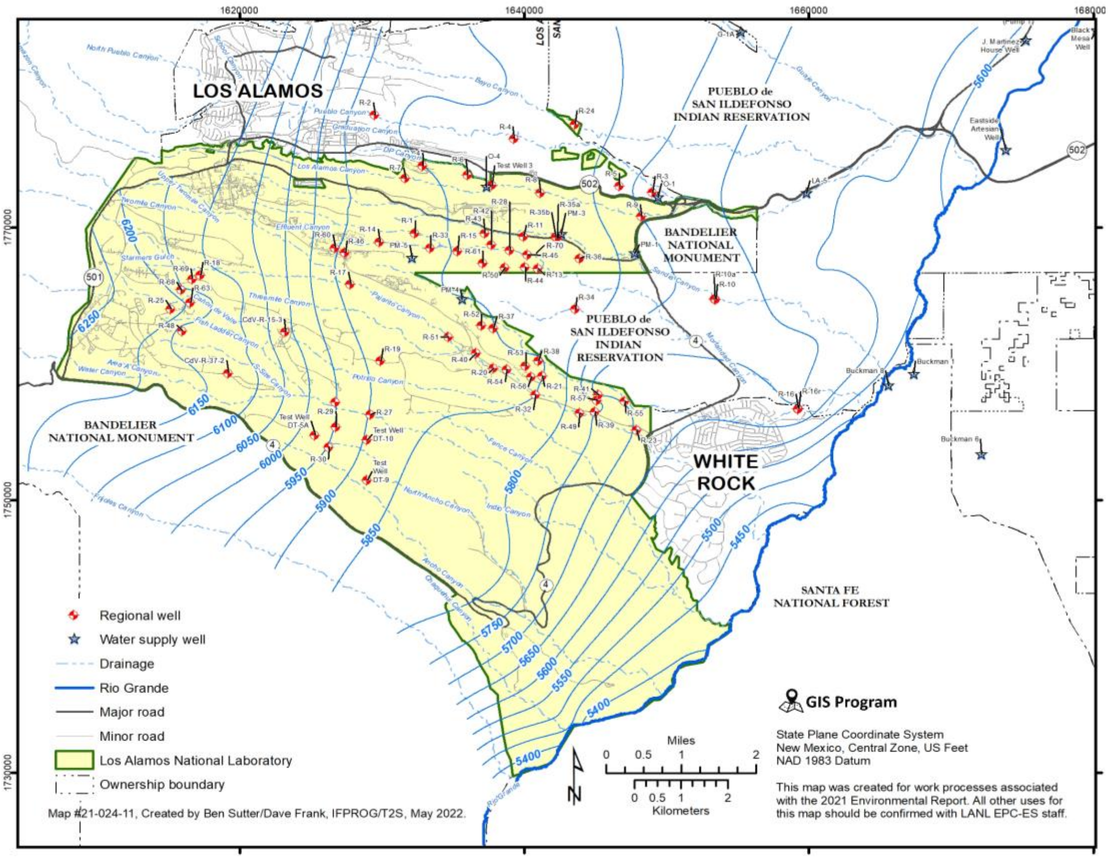


Figure 5-3. Contour map of average water table elevations for the regional aquifer. This map is a generalization of the data.

Regulatory Overview

The screening levels listed in Table 5-1 provide a basis to evaluate results reported in this chapter. Section IX of the Consent Order describes the role of data screening in the corrective action process. Screening values are used to identify the potential for unacceptable risk resulting from the presence of contaminants in groundwater and surface water. Regulatory criteria related to groundwater quality form the basis for the screening values with which groundwater monitoring results are compared in this chapter. Exceedance of a screening level indicates a possible need for further evaluation of risk.

Groundwater standards and screening levels are set by three regulatory agencies. DOE has authority under the Atomic Energy Act of 1954 to set standards for certain nuclear materials. DOE Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, establishes dose limits for radiation exposure and provides derived concentration technical standards for radionuclide levels in air and water based on those dose limits. For drinking water, DOE calculates derived concentration technical standards based on the U.S. Environmental Protection Agency's 4-millirem-per-year drinking water dose limit.

The U.S. Environmental Protection Agency and the New Mexico Water Quality Control Commission set screening levels and standards for other constituents. The U.S. Environmental Protection Agency Safe Drinking Water Act's maximum contaminant levels are the maximum permissible level of a contaminant in water delivered to any user of a public water system. The New Mexico Water Quality Control Commission groundwater standards, found in *Ground and Surface Water Protection*, Title 20, Chapter 6, Part 2 of the New Mexico Administrative Code, apply to all groundwater with a total dissolved solids concentration of 10,000 milligrams per liter or less. The New Mexico standards include numeric criteria for many substances and also contain a separate list of toxic pollutants.

The Consent Order requires screening and reporting of groundwater data and describes the screening criteria. In general, the screening levels are the lower of either the New Mexico groundwater quality standard or the federal maximum contaminant level. If neither of these exist for a given chemical, the New Mexico Environment Department's tap water screening levels, provided in the Risk Assessment Guidance for Site Investigations and Remediation: Volume I, Soil Screening Guidance for Human Health Risk Assessments (New Mexico Environment Department 2019) are used. These values are available in Table A-1 of that document. If no New Mexico Environment Department tap water screening level has been established for the chemical, then the U.S. Environmental Protection Agency's regional human health medium-specific screening level for tap water, adjusted to a 1×10^{-5} excess risk for carcinogenic contaminants, is used. The U.S. Environmental Protection Agency updates the regional screening levels for tap water periodically; 2018 values were used to prepare this chapter. Updated New Mexico Water Quality Control Commission groundwater standards went into effect in December 2018, with revised standards for some additional constituents becoming effective in July 2020.

The New Mexico Water Quality Control Commission numeric criteria for contaminant concentrations apply mostly to filtered water samples, which represent the concentration of a constituent dissolved in groundwater. However, the standards for mercury, organic compounds, and nonaqueous phase liquids apply to unfiltered samples, which represent both the dissolved concentration of the constituent and the concentration associated with suspended sediments in the groundwater sample. The U.S. Environmental Protection Agency applies maximum contaminant levels and regional screening levels for tap water to both filtered and unfiltered sample results, depending on the chemical.

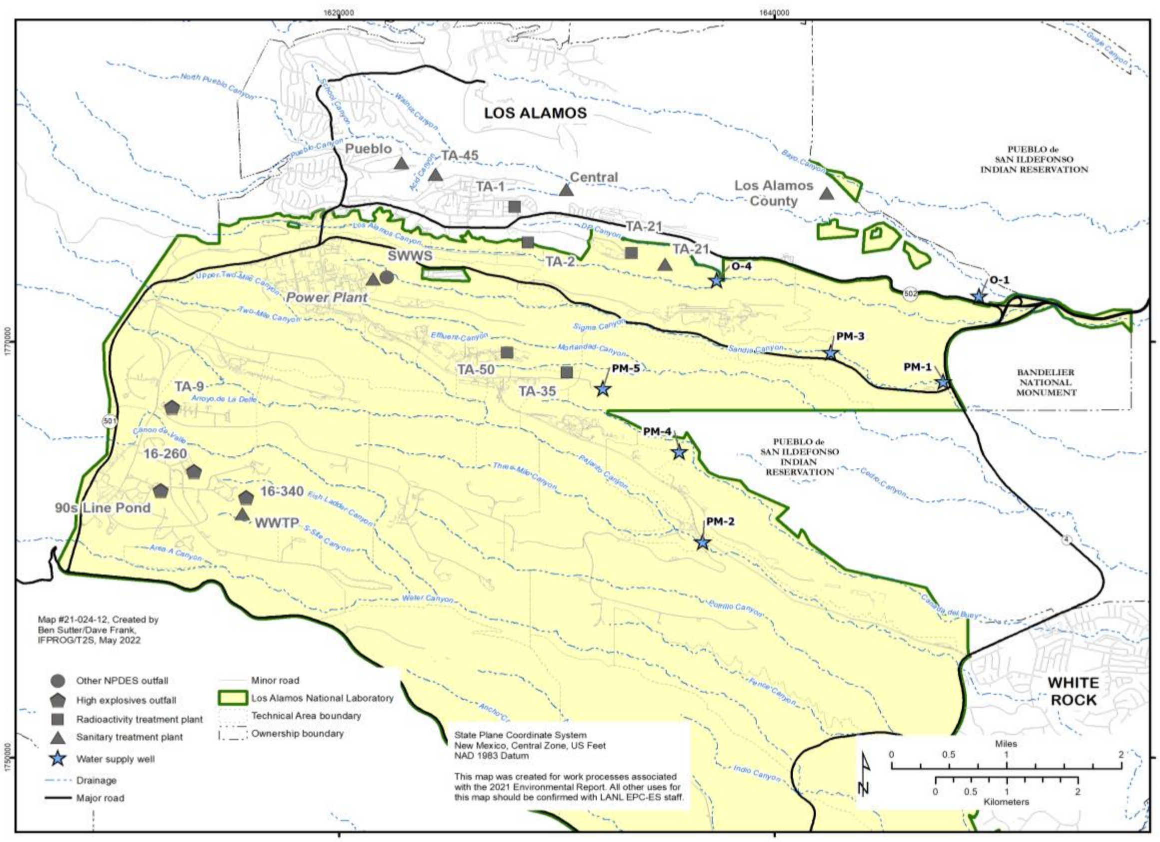
For radioactivity in groundwater, we compare sample results with screening levels, including the New Mexico Water Quality Control Commission groundwater standards for combined radium-226 and radium-228, DOE's drinking water concentration technical standards (derived from DOE's 4-millirem-per-year dose limit), and the U.S. Environmental Protection Agency maximum contaminant level drinking water standards.

Table 5-1. Application of Screening Levels to LANL Groundwater Monitoring Data

Sample Type	Constituent	Screening Levels	References	Notes
Water supply wells	Radionuclides	• New Mexico groundwater standards • Concentration technical standards derived from DOE's 4-millirem-per-year drinking water dose limit • U.S. Environmental Protection Agency maximum contaminant levels	• 20.6.2 New Mexico Administrative Code • DOE Order 458.1 Chg 4 • Code of Federal Regulations Title 40 Parts 141–143	This sampling is conducted in addition to the regulatory compliance sampling conducted by the water supply system operator (see Water Supply Well Monitoring section below).
Water supply wells	Nonradionuclides	• New Mexico groundwater standards • U.S. Environmental Protection Agency maximum contaminant levels	• 20.6.2 New Mexico Administrative Code • Code of Federal Regulations Title 40 Parts 141–143	This sampling is conducted in addition to the regulatory compliance sampling conducted by the water supply system operator (see Water Supply Well Monitoring section below).
Non-water–supply groundwater samples	Radionuclides	• New Mexico groundwater standards • Concentration technical standards derived from DOE's 4-millirem-per-year drinking water dose limit • U.S. Environmental Protection Agency maximum contaminant levels	• 20.6.2 New Mexico Administrative Code • DOE Order 458.1 Chg 4 • Code of Federal Regulations Title 40 Parts 141–143	New Mexico groundwater standards apply to all groundwater. The concentration technical standards (derived from DOE's 4-millirem-per-year drinking water dose limit) and U.S. Environmental Protection Agency maximum contaminant levels are provided for comparison only.
Non-water–supply groundwater samples	Nonradionuclides	• New Mexico groundwater standards • U.S. Environmental Protection Agency maximum contaminant levels • U.S. Environmental Protection Agency regional screening levels for tap water	• 20.6.2 New Mexico Administrative Code • Code of Federal Regulations Title 40 Parts 141–143 • 2016 Compliance Order on Consent	A hierarchy of levels applies as screening levels for groundwater. See the Regulatory Overview section for explanation.

Potential Sources of Contamination

Historical discharges from Laboratory operations have affected all three groundwater zones. Figure 5-4 shows the key locations of historical effluent discharges. Rogers (2001) and Emelity (1996) summarize effluent discharge history at the Laboratory.



Note: NPDES = National Pollutant Discharge Elimination System; SWWS = sanitary wastewater system; TA = technical area; WWTP = wastewater treatment plant

Figure 5-4. Major liquid release outfalls potentially affecting groundwater; most outfalls shown are currently inactive

Drainages that received some Laboratory effluents in the past include Mortandad Canyon, Pueblo Canyon from its tributary Acid Canyon, and Los Alamos Canyon from its tributary DP Canyon. Water Canyon and its tributary Cañon de Valle received effluents produced by high-explosives processing and experimentation. Sandia Canyon received discharges of power plant cooling water, other cooling tower water, and water from the Laboratory's Sanitary Wastewater Systems Plant. Over the years, Los Alamos County has operated several sanitary wastewater treatment plants in the area and currently operates one in Pueblo Canyon.

Since the early 1990s, the Laboratory has significantly reduced both the number of industrial outfalls and the volume of water discharged. The remaining discharge amounts have been reduced through treatment process upgrades so that they meet applicable standards.

A site-wide sampling program for the emerging contaminants known as per- and polyfluoroalkyl substances (PFAS) took place during 2020 and 2021. A handful of locations recorded results above the New Mexico Environment Department tap water screening level of 70 nanograms per liter; none of these locations are in the regional aquifer (which serves as the water supply for the Laboratory and community). Based on consultation with the New Mexico Environment Department, sampling for PFAS may be discontinued after two rounds of sampling unless results exceed 70 nanograms per liter.

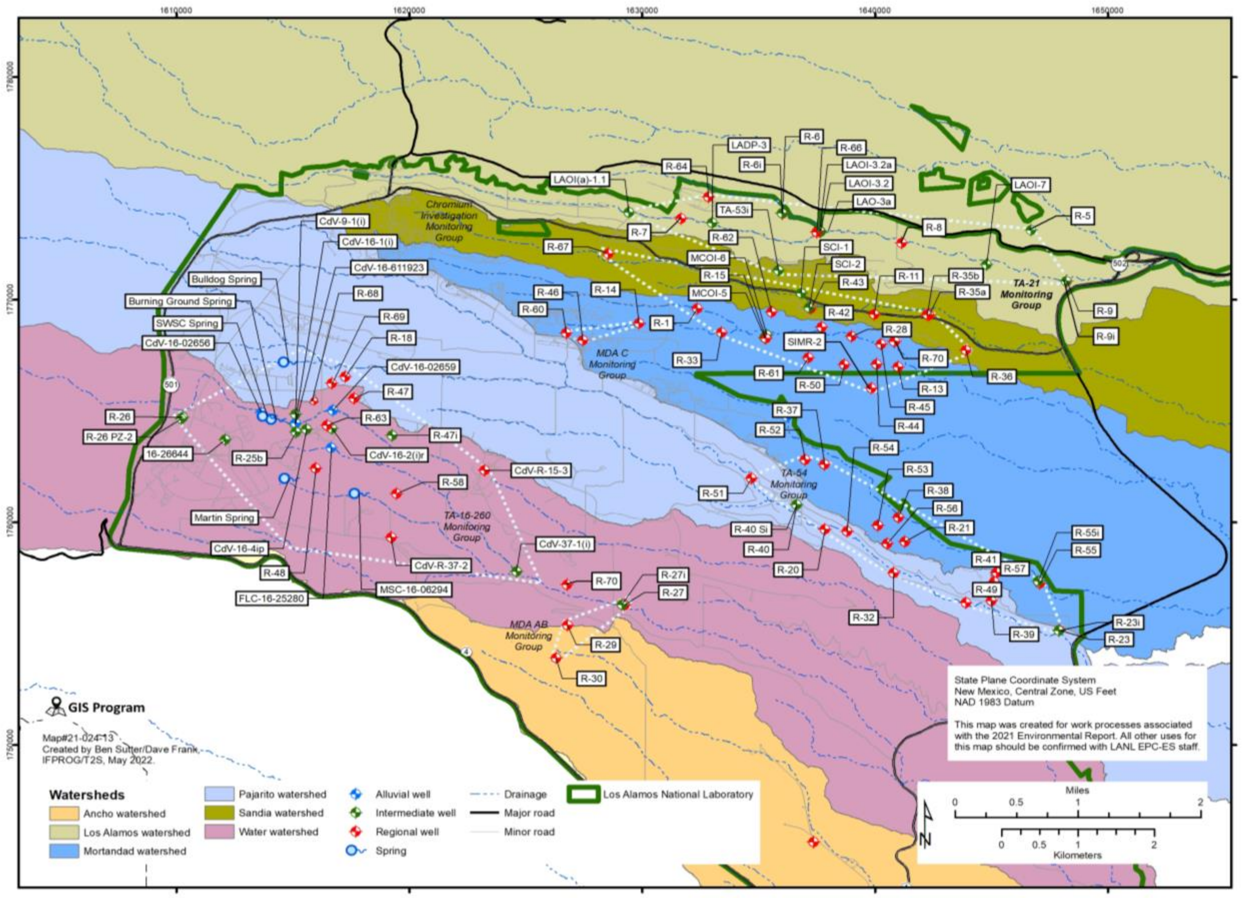
Groundwater Monitoring Network

We monitor water quality and other characteristics by taking samples from wells in alluvial groundwater, perched-intermediate groundwater, and the regional aquifer; springs that discharge shallow perched-intermediate and regional aquifer groundwater; and streams that maintain perennial base flow. Some wells have multiple screens (entry points for water) at different depths.

Some wells and springs are part of six area-specific monitoring groups defined to address monitoring objectives unique to the area. Area-specific monitoring groups include Technical Area 54, Technical Area 21, Material Disposal Area AB, Material Disposal Area C, the Chromium Investigation area, and the Technical Area 16-260 outfall (see Figure 5-5). We assign wells and springs not included within one of these six area-specific monitoring groups to the General Surveillance monitoring group (see Figure 5-6). We also monitor numerous springs along the Rio Grande (see Figure 5-7; Purtymun et al. 1980).

In addition, we monitor groundwater quality at three alluvial, two intermediate, and four regional aquifer wells for compliance with our groundwater discharge permits (see Chapter 2, New Mexico Water Quality Act: Groundwater Discharge Regulations). Alluvial wells SCA-3, MCA-RLW-1, and MCA-RLW-2 are operated for discharge permit purposes only, and results are summarized in the Groundwater Discharge Permit Monitoring section that follows. We have included monitoring required under LANL's Hazardous Waste Facility Permit within the Interim Facility-Wide Groundwater Monitoring Plan and reported results throughout this chapter.

We collected samples from 11 Los Alamos County water supply wells (see Figure 5-7). We also collected samples from wells located on Pueblo de San Ildefonso lands and from the Buckman well field operated by the City of Santa Fe. Figure 5-7 shows groundwater monitoring locations on the Pueblo de San Ildefonso, which mostly represent the regional aquifer; however, Vine Tree Spring and Los Alamos Spring discharge from perched-intermediate groundwater and wells LLAO-1b and LLAO-4 monitor alluvial groundwater.



Note: MDA = Material disposal area

Figure 5-5. Groundwater monitoring wells and springs assigned to area-specific monitoring groups

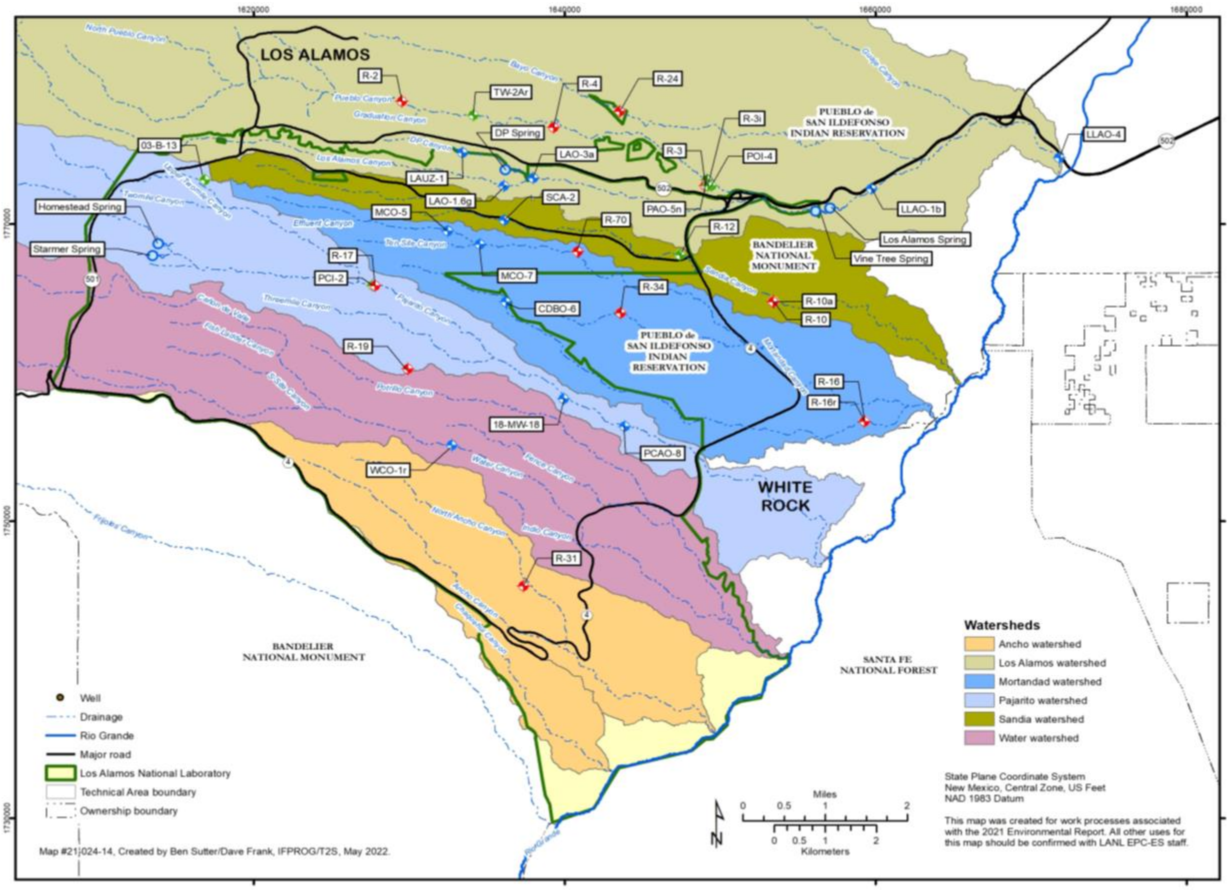


Figure 5-6. Groundwater monitoring wells and springs assigned to watershed-specific portions of the General Surveillance monitoring group.

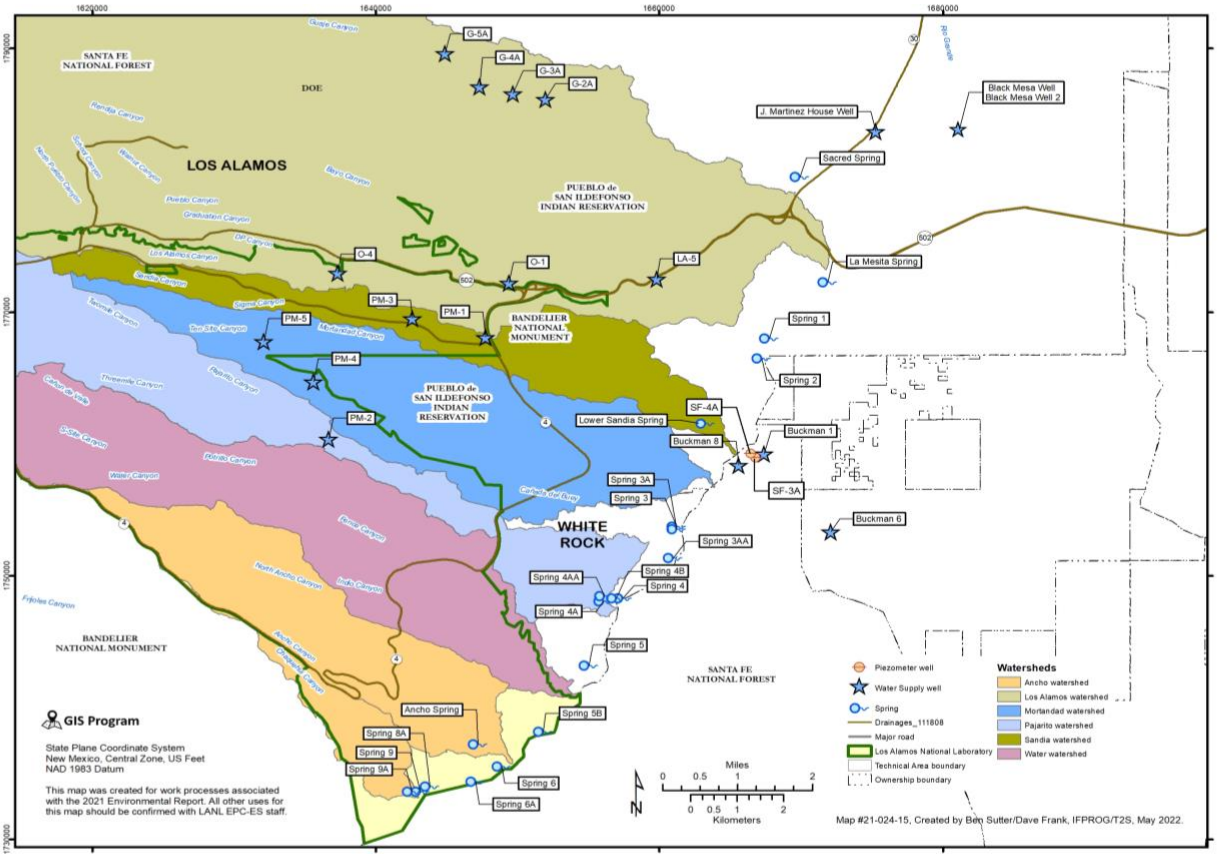


Figure 5-7. Water supply wells and piezometers used for monitoring at Los Alamos County, the City of Santa Fe Buckman well field, and Pueblo de San Ildefonso, and springs used for groundwater monitoring in White Rock Canyon

Groundwater Data Summary and Interpretation

The groundwater monitoring data for 2021 are available from the Intellus New Mexico website at https://www.intellusnm.com.

We report analytical laboratory results reported in relation to several limits. The **method detection limit** is the lowest concentration of a substance that the analytical laboratory can state with 99 percent confidence is greater than zero. It is determined from analysis of a set of standardized samples containing the substance. The **practical quantitation limit** is the lowest concentration of a substance that can be accurately measured. The practical quantitation limit is approximately (but not always) three times the method detection limit. Concentrations between the method detection limit and the practical quantitation limit are identified as estimated concentrations and are marked with a "J" qualifier in the analytical report and in the results from the Intellus website.

A **nondetect** result means that the analytical laboratory did not detect the substance in the sample. These results are marked with a "U" qualifier. In the past, the Laboratory sometimes reported nondetect results at the practical quantitation limit value. Therefore, for older results, the detected but estimated results (results between the method detection limit and the practical quantitation limit) may have a lower reported value than nondetect results for the same substance. Recent groundwater sample nondetect results are reported at the method detection limit.

The method detection limit and practical quantitation limit do not apply to radiological measurements. For radiological measurements, the minimum detectable activity is similar to the method detection limit. To be considered a detected activity, a radiological measurement must be greater than the minimum detectable activity.

Groundwater Sampling Results by Monitoring Group

The following sections discuss groundwater sampling results for the six area-specific monitoring groups, the General Surveillance monitoring group, springs along the Rio Grande, and Los Alamos County and City of Santa Fe water supply wells. We have grouped the tables and discussions according to the groundwater zone, proceeding from deepest (the regional aquifer) to shallowest (the alluvial groundwater). The accompanying tables and text mainly address constituents found at levels above screening levels. In a few cases, we discuss other constituents that are below screening levels, such as tritium, to track trends where we observed potential Laboratory influences. The discussion addresses radionuclides, inorganic compounds, inorganic elements (primarily metals), and organic compounds for each groundwater zone.

Water Supply Well Monitoring

Los Alamos County

We collected samples from 11 Los Alamos County water supply wells that produce water for the community and the Laboratory (see Figure 5-7) in addition to Los Alamos County's regular monitoring, and we specifically address potential Laboratory contaminants. All drinking water produced by the Los Alamos County water supply system meets federal and state drinking water standards as reported in the county's annual drinking water quality report (https://www.losalamosnm.us/common/pages/DisplayFile.aspx?itemId=18583904). In 2021, no water supply wells showed detections of Laboratory-related constituents above applicable drinking water standards.

City of Santa Fe

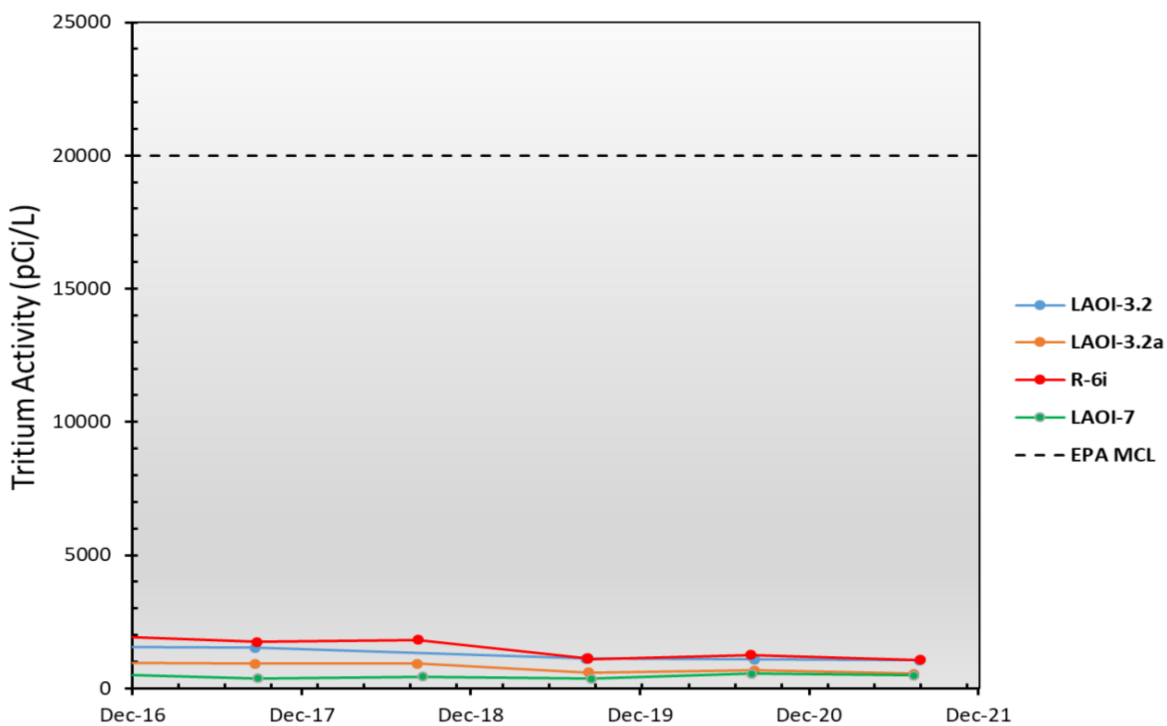
In 2021, we sampled three water supply wells (Buckman-1, Buckman-6, Buckman-8) in the City of Santa Fe's Buckman well field. We also collected samples from two piezometers (wells typically used to measure water levels; SF-3A, SF-4A) in the well field (LANL 2012a). These samples were collected in addition to the City of Santa Fe's regular monitoring and specifically address potential Laboratory contaminants. No Laboratory-related constituents were present above standards for these locations. The City of Santa Fe publishes an annual water quality report that provides additional information (https://www.santafenm.gov/water_quality).

Technical Area 21 Monitoring Group

Technical Area 21 is located on a mesa bordered by Los Alamos Canyon on the north and DP Canyon on the south. It contains two historical operational areas, DP West and DP East, which produced liquid and solid radioactive wastes. The operations at DP West included plutonium processing and, at DP East, operations included weapons initiators production and tritium research. From 1952 to 1986, a liquid waste treatment plant discharged effluent containing radionuclides from the plutonium-processing facility into DP Canyon (see Figure 5-4).

Potential sources of groundwater pollutants in the vicinity of Technical Area 21 include the outfall of the liquid waste treatment plant (Solid Waste Management Unit 21-011[k)], adsorption beds and disposal shafts at Material Disposal Area T, adsorption beds at Material Disposal Area U, the former Omega West reactor cooling tower (Solid Waste Management Unit 02-005), DP West, DP East, waste lines, an underground diesel fuel line, and sumps. The Technical Area 21 monitoring group includes wells in perched-intermediate groundwater and in the regional aquifer.

Samples from several wells that monitor perched-intermediate groundwater in the Technical Area 21 monitoring group contain tritium that likely originated from the former liquid waste treatment plant, the Omega West Reactor, or both. Tritium concentrations in perched-intermediate wells R-6i, LAOI-3.2, LAOI-3.2a, and LAOI-7 in 2021 are generally consistent with concentrations measured in recent years (see Figure 5-8; see Figure 5-5 for well locations) and show long-term declines over time. The highest tritium concentration among these wells in 2021 was 1,070 picocuries per liter in R-6i, down from 1,260 picocuries per liter in 2020. For comparison, the U.S. Environmental Protection Agency maximum contaminant level for tritium in drinking water is 20,000 picocuries per liter.



EPA MCL = The U.S. Environmental Protection Agency maximum contaminant level for tritium in drinking water

Figure 5-8. Tritium concentrations in sampled perched-intermediate groundwater from wells in the Technical Area 21 monitoring group in Los Alamos Canyon

Chromium Investigation Monitoring Group

The Chromium Investigation monitoring group resides in Sandia and Mortandad Canyons. Chromium is present in the regional aquifer below these canyons at levels above the New Mexico Environment Department groundwater standard of 50 micrograms per liter in an area estimated to be approximately one mile in length and about a half-mile wide (see Figure 5-9 and Figure 5-10).

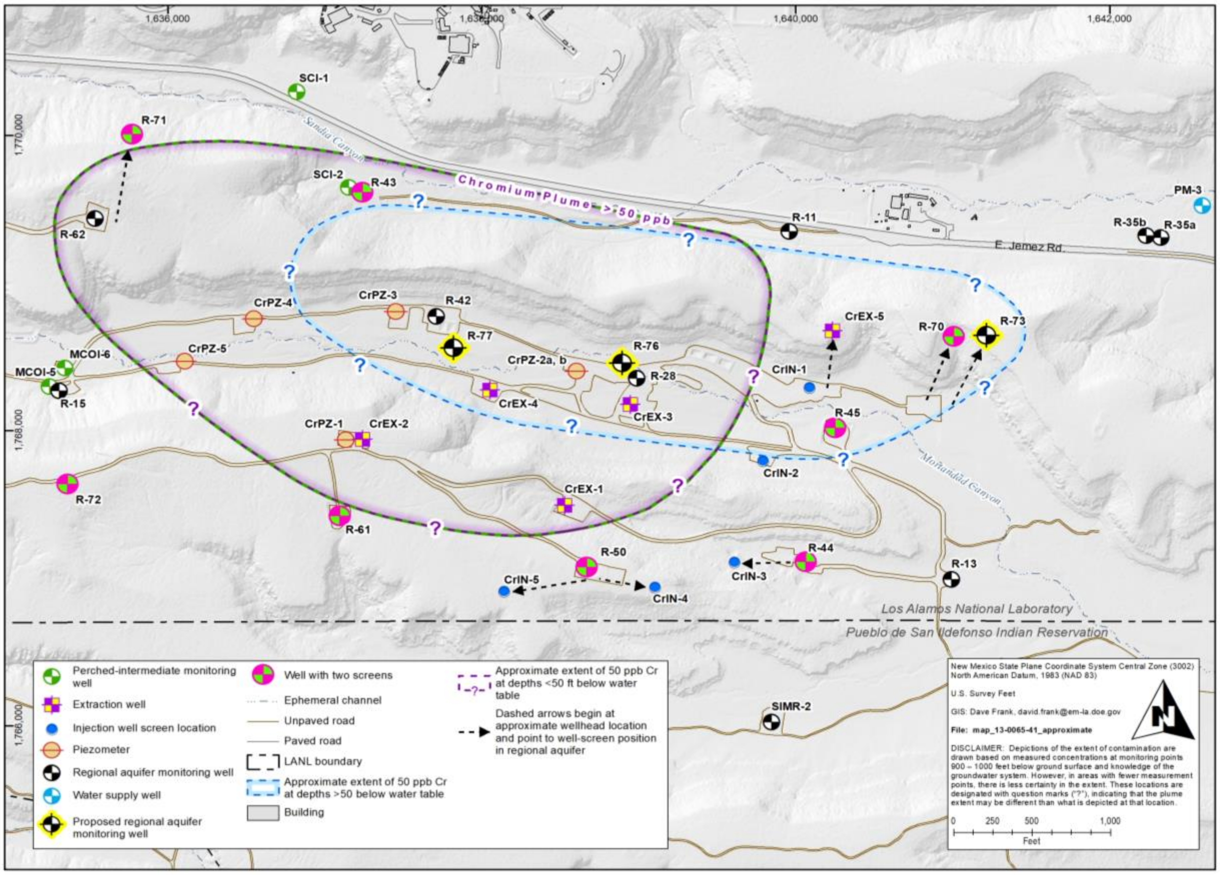


Figure 5-9. Approximation of the chromium plume footprint in the regional aquifer, as defined by the 50 microgram per liter New Mexico Environment Department groundwater standard

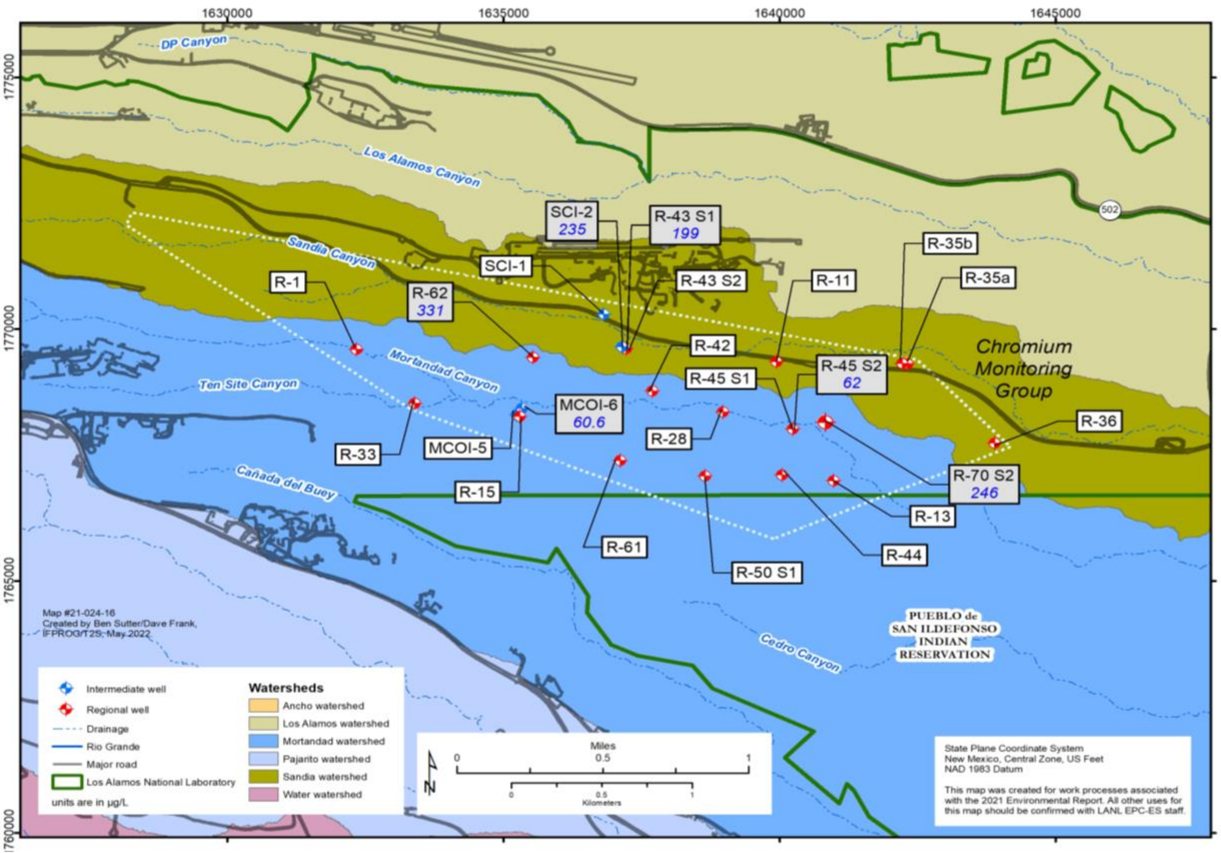


Figure 5-10. The Chromium Investigation monitoring group perched-intermediate and regional aquifer monitoring wells. The white dashed outline encompasses the wells included in the monitoring group. Labels for the wells include maximum chromium concentrations in 2021 at wells with recorded concentrations greater than the New Mexico groundwater standard of 50 micrograms per liter (µg/L).

From 1956 to 1972, LANL used potassium dichromate as a corrosion inhibitor in the cooling system at the Laboratory's power plant (LANL 1973), and it was present in the effluent discharged through an outfall to Sandia Canyon. These past discharges of potassium dichromate are the source of the hexavalent chromium observed in groundwater beneath Sandia and Mortandad Canyons. A conceptual model for the sources and spatial distribution of chemicals and radionuclides in groundwater in this area is presented in the Investigation Report for Sandia Canyon (LANL 2009a), the Phase II Investigation Report for Sandia Canyon (LANL 2012b), and the Compendium of Technical Reports Conducted Under the Work Plan for Chromium Plume Center Characterization (LANL 2018a). The conceptual model indicates that chromium originated from releases into Sandia Canyon and then migrated below ground, along geologic perching horizons to locations in the regional aquifer beneath Sandia and Mortandad Canyons.

Chromium contamination generally occurs within the upper 100 feet of the regional aquifer (LANL 2009a, 2012b, 2017, 2018b). A few locations (e.g., well R-70 area) are known to have chromium deeper than 100 feet. Additional investigations are underway to determine the vertical extent of that contamination. Perchlorate contamination is also present in groundwater beneath Mortandad Canyon. The primary source of perchlorate is effluent discharges from the Radioactive Liquid Waste Treatment Facility from 1963 until March 2002.

Chromium Monitoring Results and the Chromium Plume Interim Measure

The 2021 chromium concentrations exceeded the New Mexico groundwater standard of 50 micrograms per liter in four regional aquifer wells within the monitoring group: R-43 screen 1, R-45 screen 2, R-62, and R-70 screen 2 (see Figure 5-11).

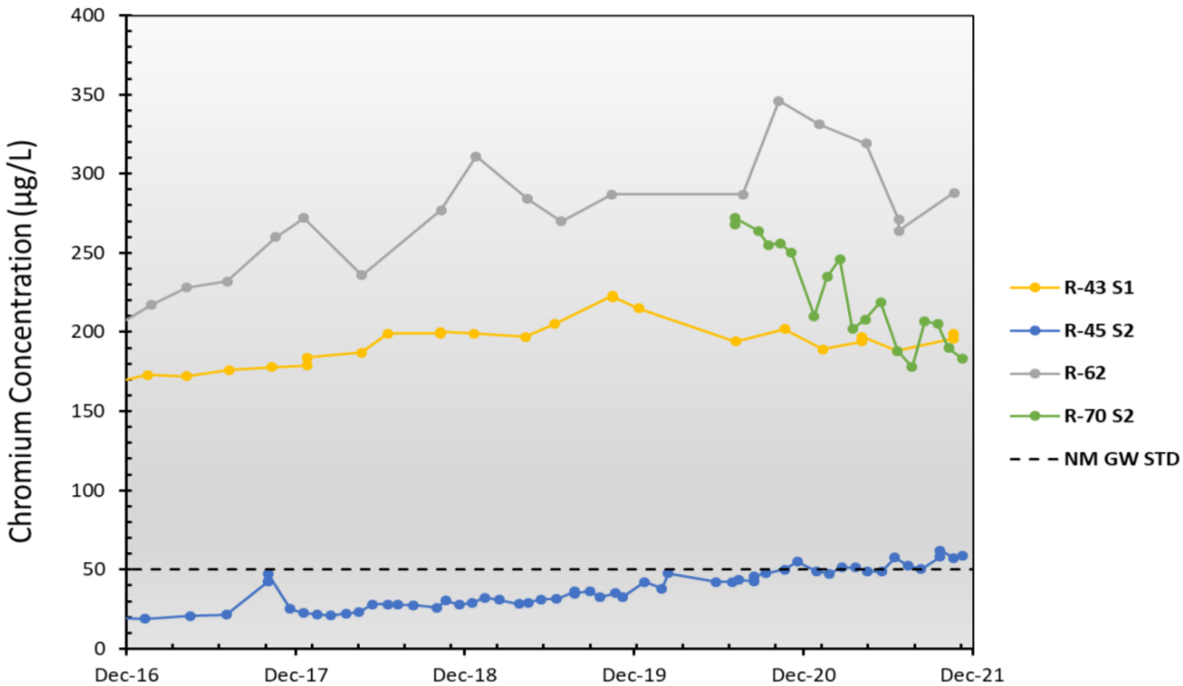


Figure 5-11. Trends in chromium concentrations for four regional aquifer wells that exceeded the New Mexico Groundwater Standard (NM GW STD) for chromium of 50 micrograms per liter (µg/L)

The Laboratory is implementing an interim measure to maintain the portion of the plume that contains 50 micrograms per liter or more of chromium completely within the Laboratory boundary (LANL 2015). To accomplish this task, we are extracting contaminated groundwater from a group of up to five extraction wells, piping the extracted water to an above-ground ion exchange treatment system, and, following treatment, injecting the treated water back into the regional aquifer through up to five injection wells located in the downgradient portion of the plume.

The interim measure targets the area along the boundary between the Laboratory and the Pueblo de San Ildefonso, on the eastern downgradient portion of the plume (see Figure 5-9). Two regional aquifer wells, R-44 and R-50, monitor the effectiveness of the interim measure at the plume edge along the common boundary (see Figure 5-12). Wells R-44 and R-50 each have two screens; R-44 screen 2 is near the water table at 985.3 to 995.2 feet below the ground surface, and R-50 screen 2 is approximately 100 feet below the water table at 1185.0 to 1205.6 feet below the ground surface. The deeper screen has shown consistent chromium concentrations within naturally occurring (background) levels, indicating that the chromium contamination at that location is less than the depth of that screen. The levels of chromium in R-50 screen 1 continue to steadily decrease over time in response to the interim measure but showed a slight increase during the several months when the system was shut down because of the COVID-19 pandemic (see Figure 5-12). Chromium concentrations in R-44 screen 1 and screen 2 have historically been below the New Mexico groundwater standard for chromium and are dropping further in response to the interim measure (see Figure 5-12).

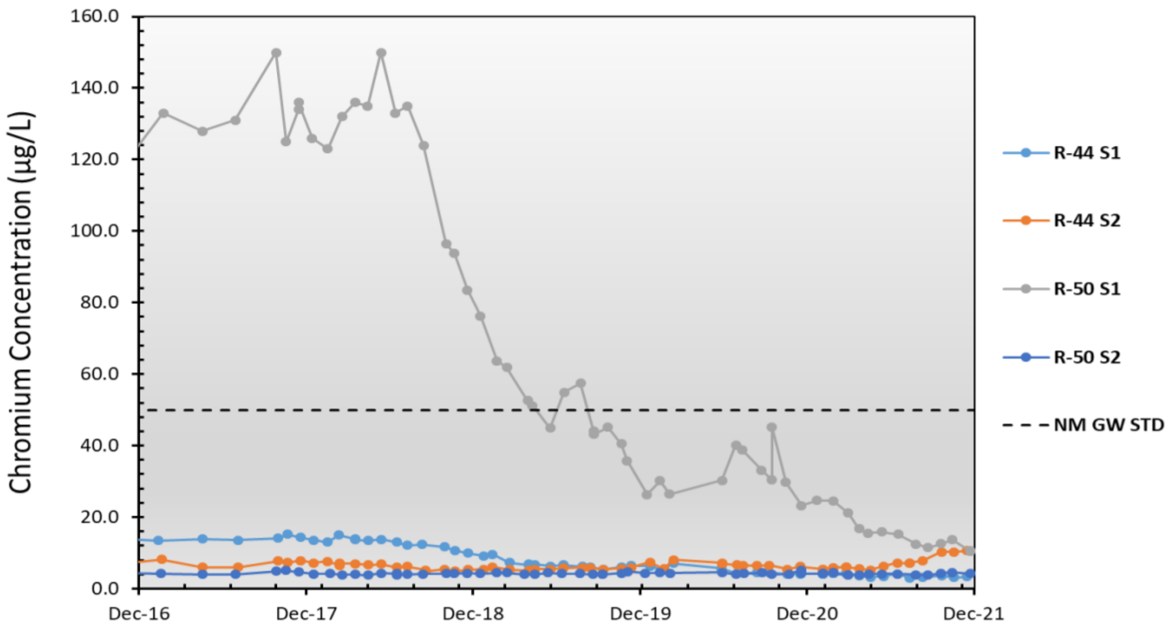


Figure 5-12. Trends in the chromium concentrations for the regional aquifer wells that monitor the effectiveness of the interim measure at the downgradient plume edge. The New Mexico Groundwater Standard (NM GW STD) for chromium is 50 micrograms per liter (µg/L).

Interim measure operations along the northeastern portion of the plume began in late 2019. For 2021, chromium concentration data from monitoring wells in that portion of the plume are not showing significant response to the interim measure. Trends in chromium concentrations in those wells may be influenced by other factors, such as decreasing concentrations of chromium in water recharging the regional aquifer. Both R-11 and R-45 screen 1 showed decreasing concentrations in chromium apparently independent of the interim measure (see Figure 5-13).

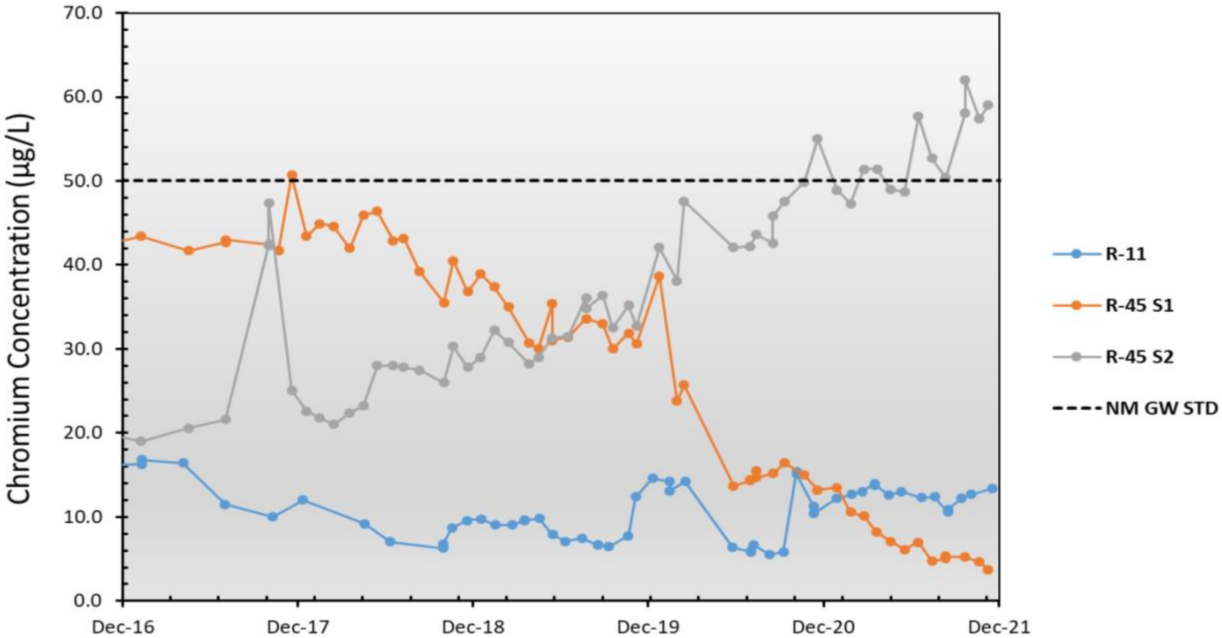


Figure 5-13. Trends in chromium concentrations of two regional wells (R-11 and the two screens of R-45) in the Chromium Investigation monitoring group located along the northeast edge of the plume; these trends are not a reflection of the interim measures, rather a trend in chromium concentrations in water recharging the regional aquifer. The New Mexico Groundwater Standard (NM GW STD) for chromium is 50 micrograms per liter (µg/L).

Two wells located along the northwestern upgradient portion of the chromium plume, R-62 and R-43 (two screens), continued to show a steady increase in the concentration of chromium in 2021 (see Figure 5-14). LANL will install new monitoring wells in this area to further characterize the extent of chromium and perchlorate contamination. We will use data from these wells to evaluate whether mitigation actions are necessary in this area.

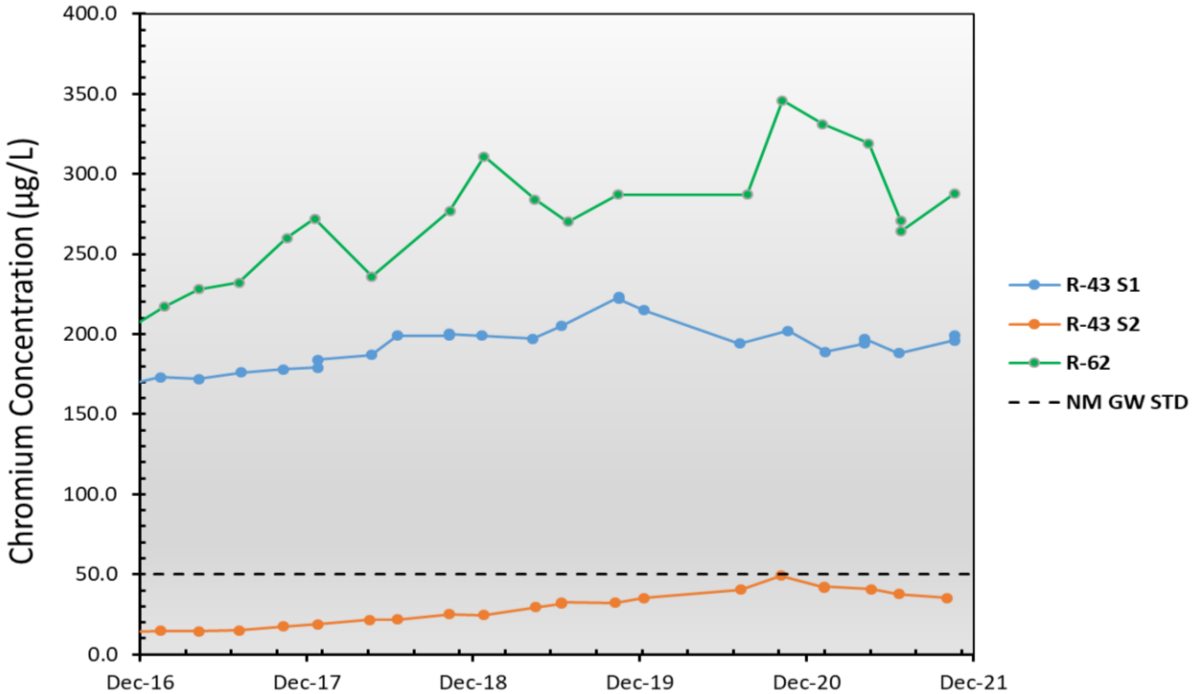


Figure 5-14. Regional monitoring wells R-43 (two screens) and R-62 are located on the northwestern portion of the chromium plume. These two wells show a continued increase in chromium concentrations in 2021.

Two perched-intermediate wells reported chromium concentrations above the standard: SCI-2 and MCOI-6. Chromium concentrations continue to decline in SCI-2 and remain steady in MCOI-6 (see Figure 5-15).

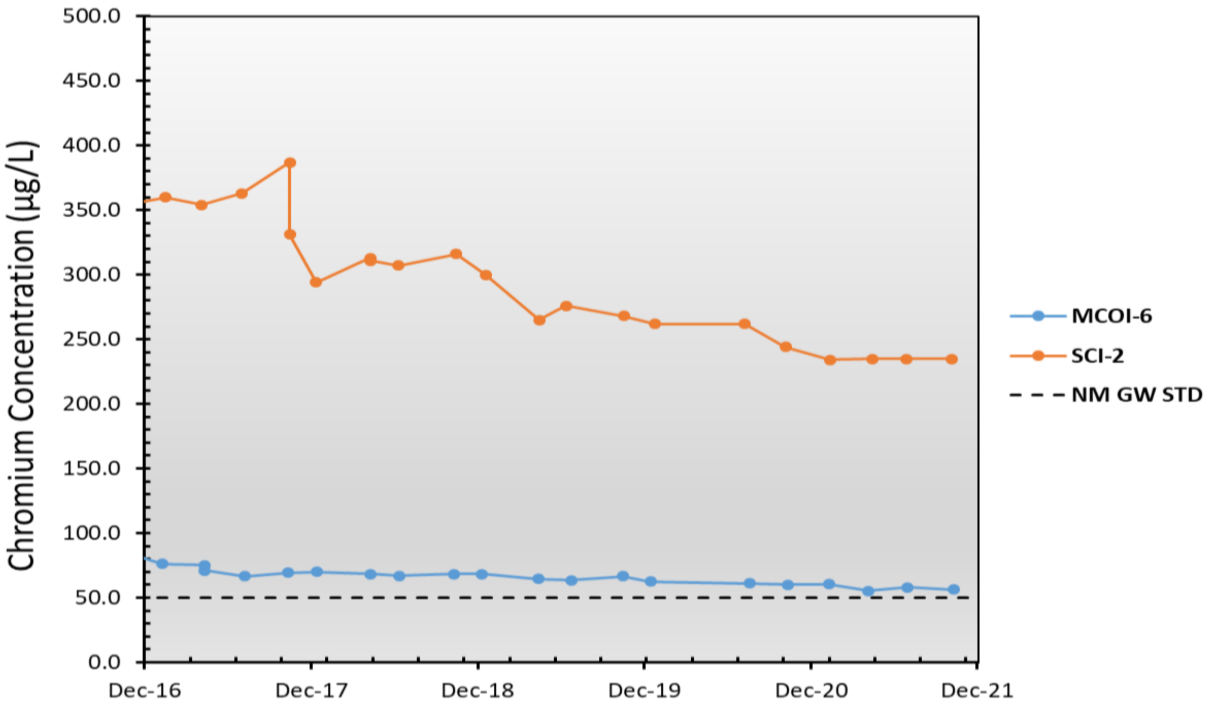
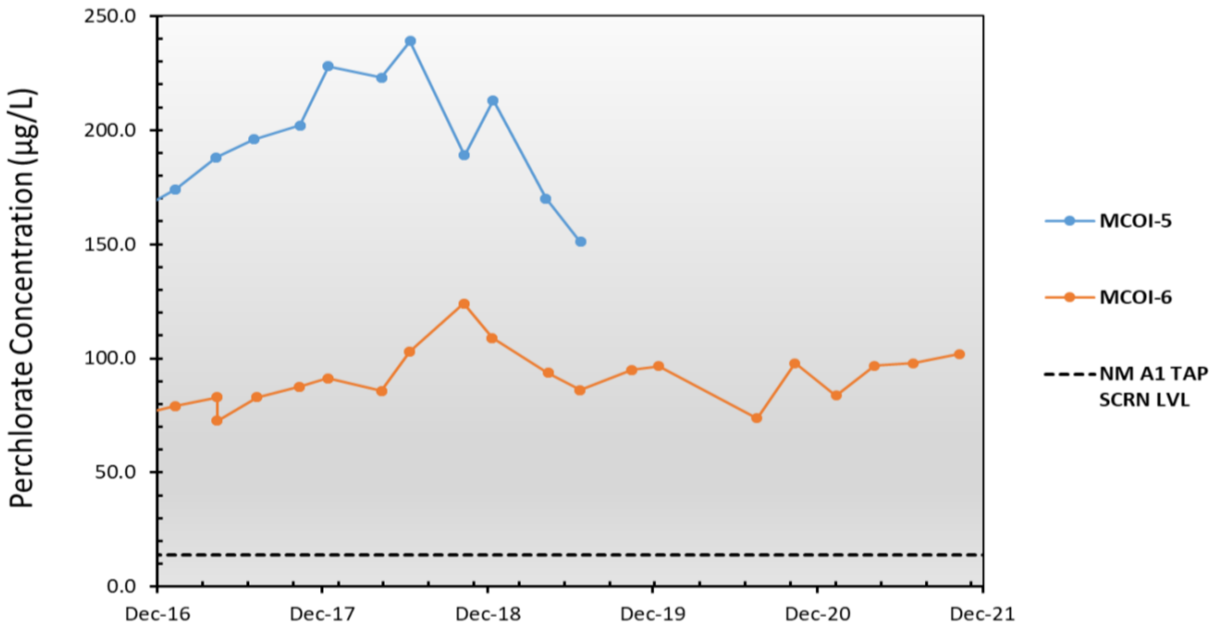


Figure 5-15. Trends in chromium concentrations for perched-intermediate groundwater monitoring wells in the Chromium Investigation monitoring group with chromium concentrations that exceeded the New Mexico Groundwater Standard (NM GW STD) of 50 micrograms per liter (µg/L)

Other Monitoring Results

Perchlorate is present above the New Mexico Environment Department tap water screening level of 13.8 parts per billion in two perched-intermediate wells, MCOI-5 and MCOI-6 (see Figure 5-16). In perched-intermediate well MCOI-6, the perchlorate concentration trends are relatively stable. Perchlorate concentrations at MCOI-5 were showing a decreasing trend, although we have not sampled the well since 2019 due to insufficient saturation in the screened interval. Perchlorate concentrations in regional aquifer well R-15 are below 13.8 parts per billion, and R-61 screen 1 has historically shown concentrations near or slightly above 13.8 parts per billion. We continue to monitor perchlorate and, if necessary, will incorporate remedial actions for perchlorate as part of the chromium remediation efforts.



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

Figure 5-16. Trends in perchlorate concentrations for perched-intermediate groundwater monitoring wells in the Chromium Investigation monitoring group with perchlorate detections above the New Mexico tap water screening level of 13.8 micrograms per liter (µg/L)

Other constituents detected in the Chromium Investigation monitoring group include 1,4-dioxane and tritium in perched-intermediate wells MCOI-5 and MCOI-6 (see Figure 5-17 and Figure 5-18). The trend for 1,4-dioxane had been primarily flat at MCOI-6 but has recently shown an upward trend. Well MCOI-5 has had a continued increasing trend in 1,4-dioxane recently, although between 2018 and 2019, we saw a decrease in concentration from 27.9 micrograms per liter to 22.9 micrograms per liter. However, as noted above, additional sampling of MCOI-5 has not been completed since 2019 due to insufficient water. Concentrations of 1,4-dioxane are not present above the screening level of 4.59 micrograms per liter in the regional aquifer. Perched-intermediate wells MCOI-5 and MCOI-6 have tritium concentrations far below the U.S. Environmental Protection Agency maximum contaminant level for tritium in drinking water of 20,000 picocuries per liter.

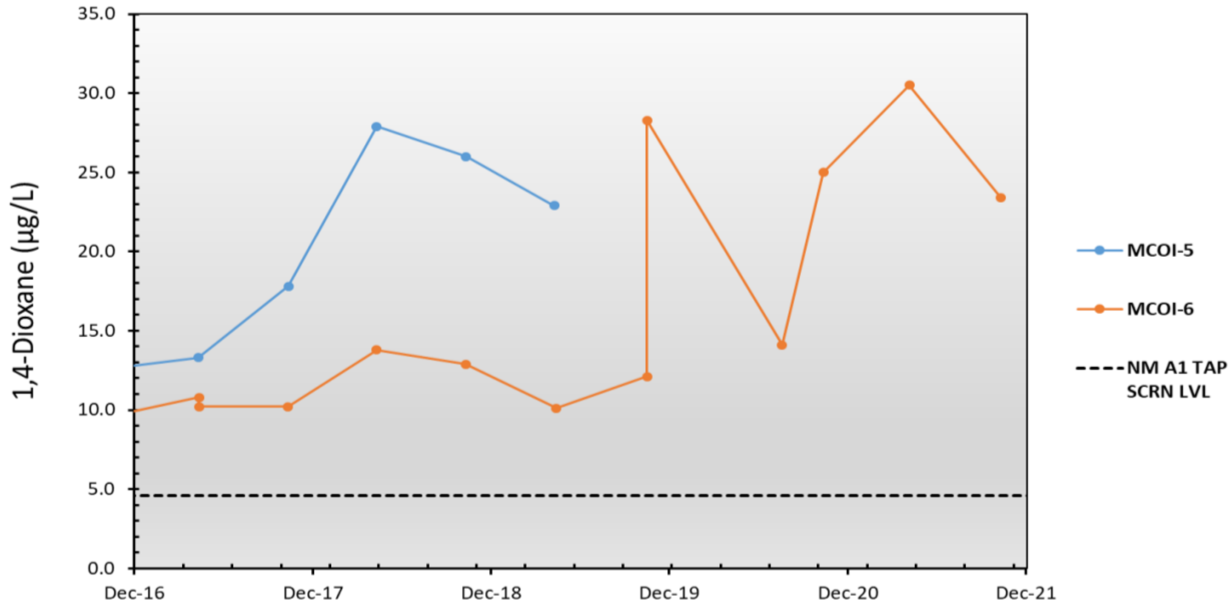


Figure 5-17. Concentrations of 1,4-dioxane in perched-intermediate groundwater monitoring wells with detections of 1,4-dioxane in the Chromium Investigation monitoring group. The New Mexico groundwater standard for 1,4-dioxane is 4.59 micrograms per liter (µg/L). MOI-5 has not been sampled since 2019 due to insufficient water. (NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level).

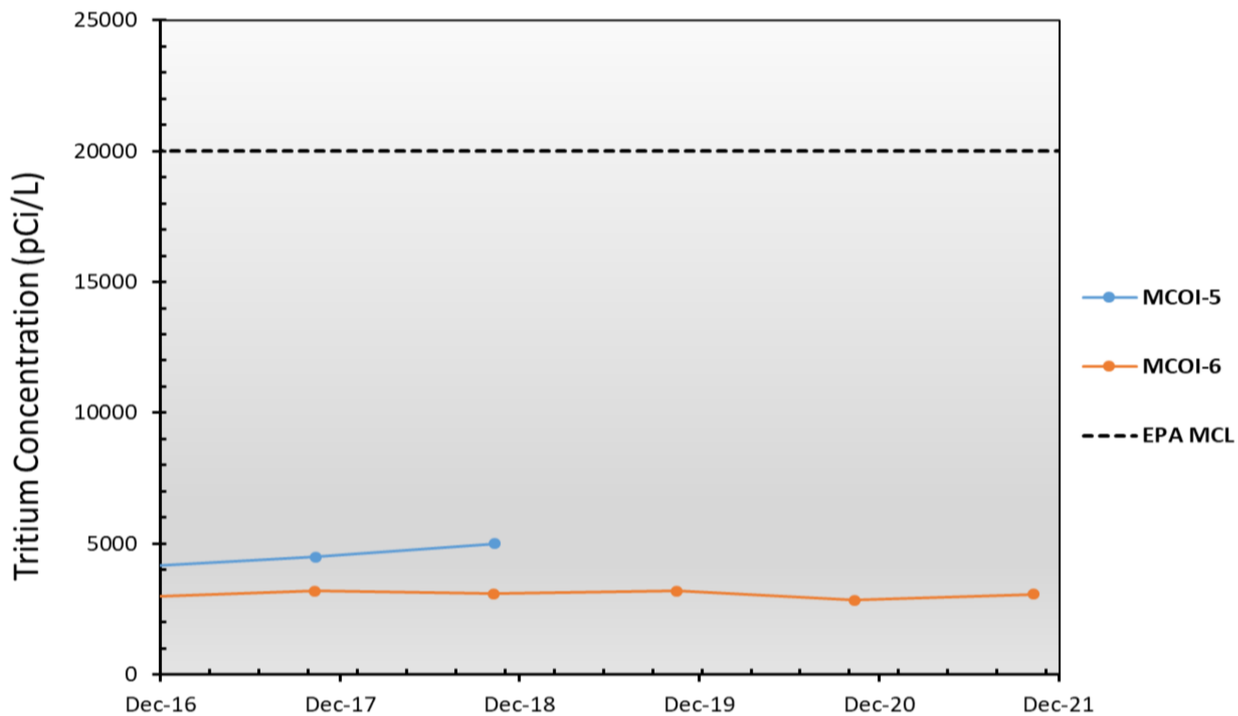


Figure 5-18. Tritium concentrations in perched-intermediate groundwater monitoring wells in the Chromium Investigation monitoring group. MOI-5 has not been sampled since 2019 due to insufficient water. The U.S. Environmental Protection Agency maximum contaminant level for tritium in drinking water is 20,000 picocuries per liter (pCi/L).

Material Disposal Area C Monitoring Group

Material Disposal Area C is located in Technical Area 50, at the head of Ten Site Canyon. It is an inactive landfill where solid low-level radioactive wastes and chemical wastes were disposed of between 1948 and 1974. Vapor-phase volatile organic compounds and tritium are present in the upper 500 feet of the unsaturated soil and rock beneath Material Disposal Area C (LANL 2011a). The primary volatile organic compound is trichloroethylene. The Material Disposal Area C monitoring group includes nearby regional aquifer monitoring wells (see Figure 5-5). Monitoring data indicate no contamination is present in the groundwater in the regional aquifer immediately downgradient of Material Disposal Area C. No perched-intermediate groundwater is present beneath Material Disposal Area C.

Technical Area 54 Monitoring Group

Technical Area 54 is located in the east-central portion of the Laboratory on Mesita del Buey. The technical area includes four material disposal areas designated as Areas G, H, J, and L; a waste characterization, storage, and transfer facility (Technical Area 54 West); active radioactive waste storage operations at Area G; hazardous and mixed-waste storage operations at Area L; and administrative and support areas.

At Technical Area 54, groundwater monitoring is conducted to support both (1) monitoring of solid waste management units and areas of concern (particularly Areas G, H, and L) under the Compliance Order on Consent and (2) the Laboratory's Hazardous Waste Facility Permit. The Technical Area 54 monitoring group includes perched-intermediate and regional wells (see Figure 5-5).

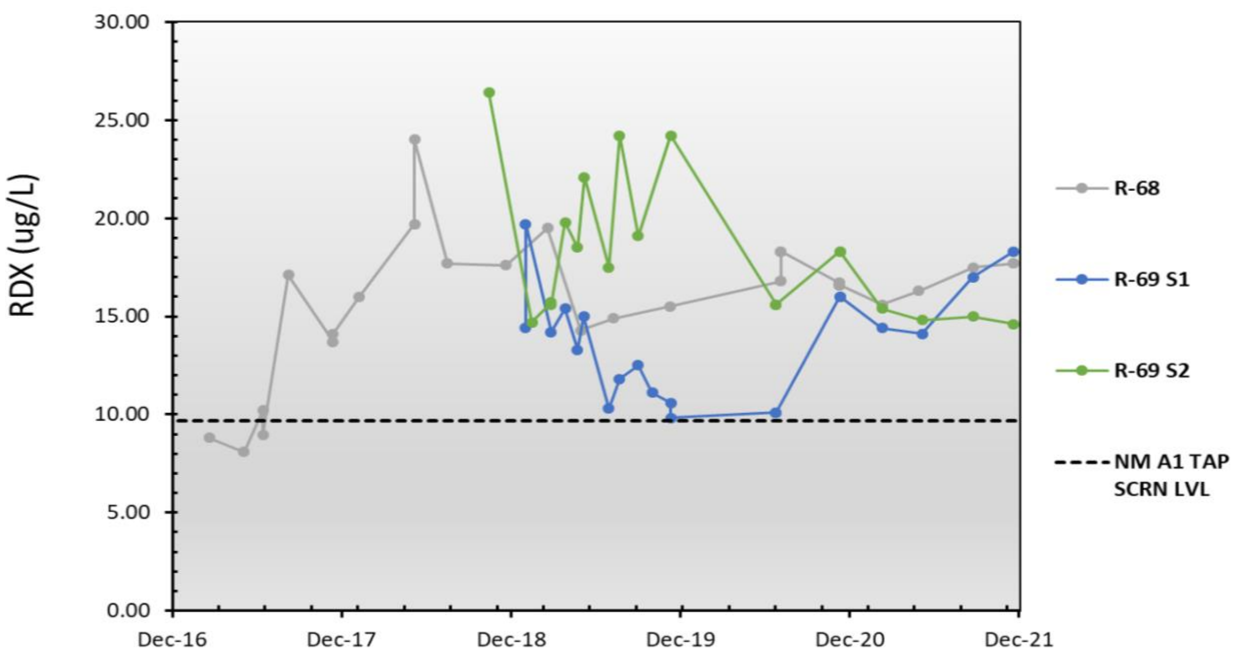
Monitoring data show that vapor-phase volatile organic compounds are present in the upper portion of the unsaturated zone beneath Areas G and L. The primary vapor-phase volatile organic compounds at Technical Area 54 are 1,1,1-trichloroethane; trichloroethylene; and Freon-113. Tritium is also present (LANL 2005b, 2006, 2007).

Periodic detections of a variety of substances, including several volatile organic compounds from the groundwater monitoring network, have occurred around Technical Area 54. In 2021, we detected the chemical 1,4-dioxane above the U.S. Environmental Protection Agency maximum contaminant level of 4.59 micrograms per liter at well R-37 screen 1, with a concentration of 6.22 microgram per liter. This event is the third detection of 1,4-dioxane above the screening level at this well. We will continue to monitor the trend here. The sporadic and limited spatial nature of the volatile organic compound detections and the minimal amount of tritium data suggest that Technical Area 54 may not be the source of the detected compounds (LANL 2009b).

Technical Area 16 260 Monitoring Group

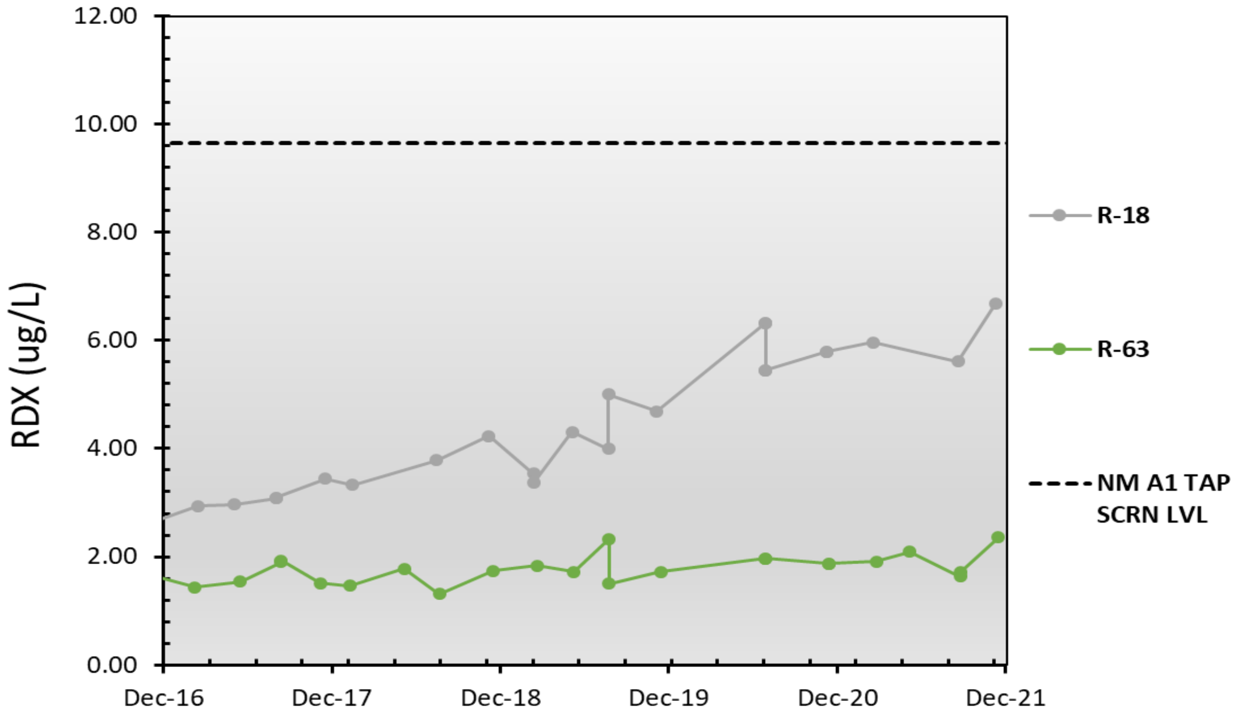
Water Canyon and Cañon de Valle (a tributary of Water Canyon) cross the southwest portion of LANL where the Laboratory develops and tests explosives. In the past, the Laboratory released wastewater into both canyons from several high-explosives-processing facilities in Technical Areas 16 and 09 (see Figure 5-4). The Technical Area 16-260 monitoring group in the upper Water Canyon/Cañon de Valle watershed monitors substances released from Consolidated Unit 16-021(c)-99, which includes the Technical Area 16-260 outfall and associated solid waste management units. The Technical Area 16-260 outfall discharged high-explosives-bearing water from a high-explosives machining facility to Cañon de Valle from 1951 through 1996. These discharges served as a primary source of high-explosives and inorganic element contamination (primarily barium) in the area (LANL 1998, 2003, 2011b). Current evidence indicates that, over time, the effluent from the Technical Area 16-260 outfall, sometimes mixed with naturally occurring surface water and alluvial groundwater in Cañon de Valle, infiltrated from Cañon de Valle and percolated through unsaturated rock layers to perched-intermediate groundwater zones and ultimately into the regional aquifer.

RDX is the primary groundwater contaminant in this area and the only contaminant that exceeds its screening level in the regional aquifer. We have detected RDX in the regional aquifer in wells R-18, R-63, R-68, and R-69 screens 1 and 2 (see Figure 5-19 and Figure 5-20). Wells R-68 and R-69 screens 1 and 2 have recorded RDX concentrations above the tap water screening level of 9.66 micrograms per liter. RDX concentrations in regional monitoring wells R-63 and R-18 were below the screening level but are exhibiting stable to increasing trends (see Figure 5-20). Other substances, including tetrachloroethene, trichloroethylene, boron, and barium, are present in all groundwater zones but are well below applicable standards in the regional aquifer.



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

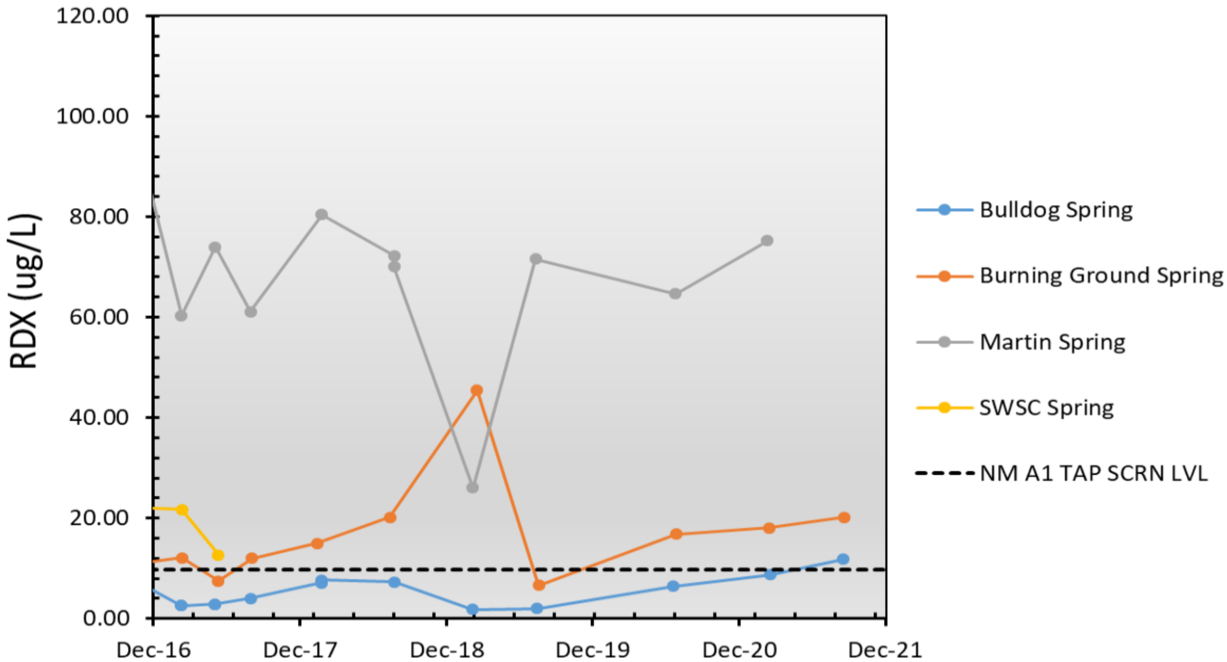
Figure 5-19. RDX concentrations in regional aquifer well R-68 and R-69 screens 1 and 2. The New Mexico groundwater standard for RDX is 9.66 micrograms per liter (µg/L).



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level.

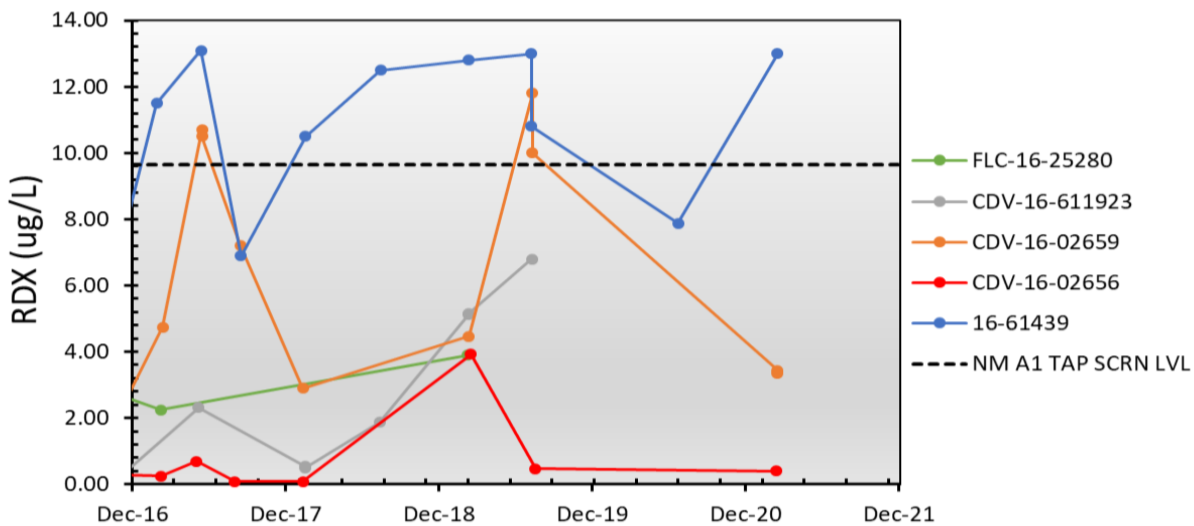
Figure 5-20. RDX concentrations in regional aquifer wells R-18 and R-63. The New Mexico groundwater standard for RDX is 9.66 micrograms per liter (µg/L).

Springs, surface water, alluvial groundwater, and perched-intermediate groundwater in the area contain explosive compounds, including RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), and TNT (2,4,6-trinitrotoluene). We have detected barium, boron, iron, manganese, nitrosodiethylamine[N-] and nitrosodimethylamine[N-] above their respective screening levels in some locations in springs, alluvial groundwater, and perched-intermediate groundwater. Figure 5-21, Figure 5-22, and Figure 5-23 show RDX concentrations in springs, alluvial wells, and perched-intermediate wells. The springs discharge from shallow perched-intermediate groundwater zones. Of the springs sampled, the concentrations of RDX are highest in Martin Spring, but it shows a declining trend over time (see Figure 5-21). RDX concentrations at Burning Ground Spring have been relatively steady over the past five years (see Figure 5-21), except for samples collected in July 2015 and March 2019. SWSC Spring, near the former location of the Technical Area 16-260 outfall, does not have consistent flow; it was not sampled in 2021.



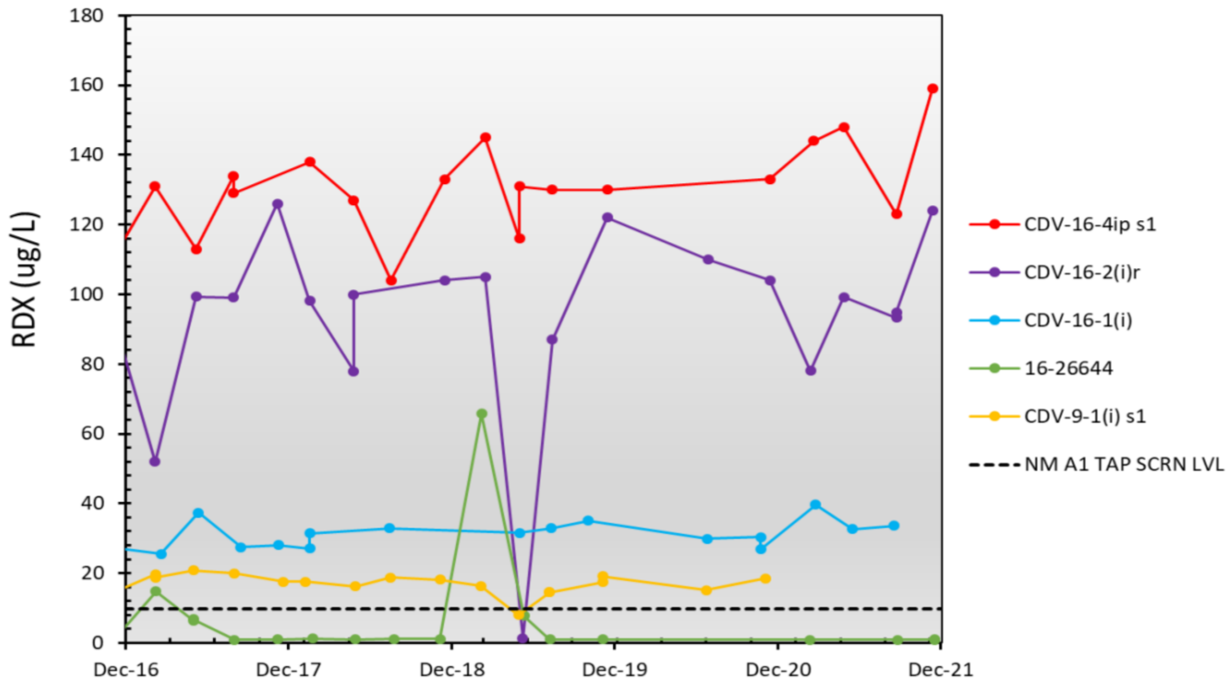
Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

Figure 5-21. RDX concentrations in two springs in Cañon de Valle, one spring in Martin Spring Canyon, and one spring in Bulldog Gulch, in Technical Area 16 (see locations in Figure 5-5). The New Mexico groundwater standard for RDX is 9.66 micrograms per liter (µg/L).



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

Figure 5-22. RDX concentrations in alluvial groundwater wells in Cañon de Valle and Fishladder Canyon. The New Mexico groundwater standard for RDX is 9.66 micrograms per liter (µg/L).



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

Figure 5-23. RDX concentrations in perched-intermediate groundwater wells. The New Mexico groundwater standard for RDX is 9.66 micrograms per liter (µg/L).

RDX concentrations in alluvial monitoring wells show significant variability because of seasonal influences but remain relatively low (see Figure 5-22). RDX concentrations in each of the perched-intermediate wells show some variability (see Figure 5-23). Long-term monitoring of some of these springs and alluvial wells is now included in the annual Interim Facility-Wide Groundwater Monitoring Plan (N3B 2021).

We submitted an investigation report on RDX contamination in perched-intermediate and regional groundwater to the New Mexico Environment Department in August 2019. In May 2020, we submitted a report on fate and transport modeling and risk assessment for RDX in groundwater to the New Mexico Environment Department. The report concluded that there is no risk to human health over the next 50 years. We will evaluate risks to human health beyond 50 years in a revision of this report.

Material Disposal Area AB Monitoring Group

The Material Disposal Area AB monitoring group is located in Technical Area 49. Also known as the Frijoles Mesa Site, Technical Area 49 is located on a mesa near the western end of Ancho Canyon. Part of the area drains into Water Canyon. The canyons in the Ancho Canyon watershed are mainly dry, with no known persistent alluvial groundwater zones and no known perched-intermediate groundwater.

LANL used the site of Material Disposal Area AB to test nuclear weapons components from 1959 to 1961 (Purtymun and Stoker 1987, LANL 1988). The testing involved isotopes of uranium and plutonium; lead and beryllium; explosives such as TNT, RDX, and HMX; and barium nitrate. Some of this material remains in shafts on the mesa top. Further information about activities, solid waste management units, and areas of concern at Technical Area 49 can be found in earlier Laboratory reports (LANL 2010a, 2010b).

In 2021, we found no constituents in Material Disposal Area AB monitoring group wells at concentrations above standards or screening levels.

White Rock Canyon Monitoring Group

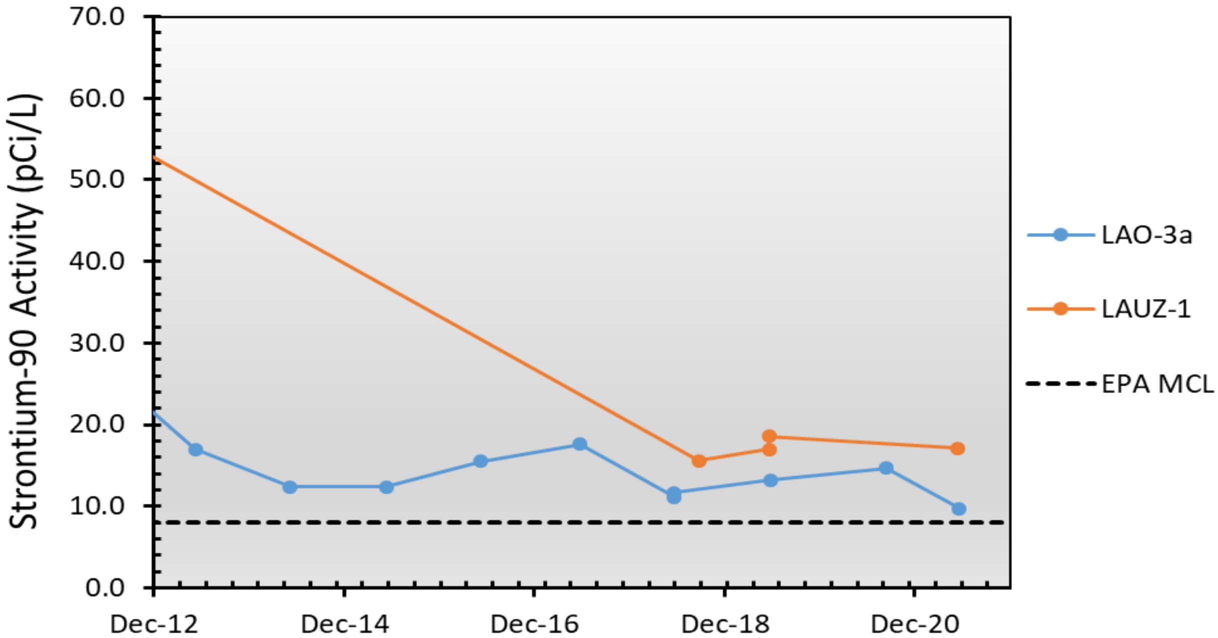
The springs that flow along and near the Rio Grande in White Rock Canyon mostly discharge regional aquifer groundwater (Purtymun et al. 1980). A few springs appear to discharge perched-intermediate groundwater. Some other springs may discharge a mixture of regional aquifer groundwater, perched-intermediate groundwater, and percolation of recent precipitation (Longmire et al. 2007). The White Rock Canyon springs serve as important monitoring points for evaluating the Laboratory’s potential to impact the Rio Grande (see Figure 5-7).

Two constituents, iron and aluminum, were detected above applicable groundwater standards or screening levels in 2021. The New Mexico groundwater standard for iron is 1,000 micrograms per liter. Iron was detected at the Rio Grande at Otowi Bridge and at the Rio Grande at Frijoles at a concentration of 4,890 and 1,290 micrograms per liter, respectively. The New Mexico Environmental Department tap water screening level for aluminum is 5,000 micrograms per liter. Aluminum was detected at the Rio Grande at Otowi Bridge at 7,150 micrograms per liter.

General Surveillance Monitoring

Los Alamos and Pueblo Canyon

Alluvial wells LAO-3a and LAUZ-1 in Los Alamos Canyon (see Figure 5-6) continue to show strontium-90 concentrations above the U.S. Environmental Protection Agency’s 8 picocuries per liter maximum contaminant level (see Figure 5-24). We sampled alluvial well LAUZ-1 only periodically since 2011; it was sampled in 2018, 2019, and 2021. In 2011, the concentration of strontium-90 was 64.5 picocuries per liter. The concentration of strontium-90 in well LAUZ-1 was 18.6 picocuries per liter in 2019 and 17.1 picocuries per liter in 2021. The source of the strontium-90 is Solid Waste Management Unit 21-011(k), which was an outfall from industrial waste treatment at Technical Area 21. Strontium-90 is persistent at this location and in several downgradient alluvial wells near the confluence of DP Canyon with Los Alamos Canyon, but it has not been migrating to alluvial locations farther down Los Alamos Canyon (LANL 2004).



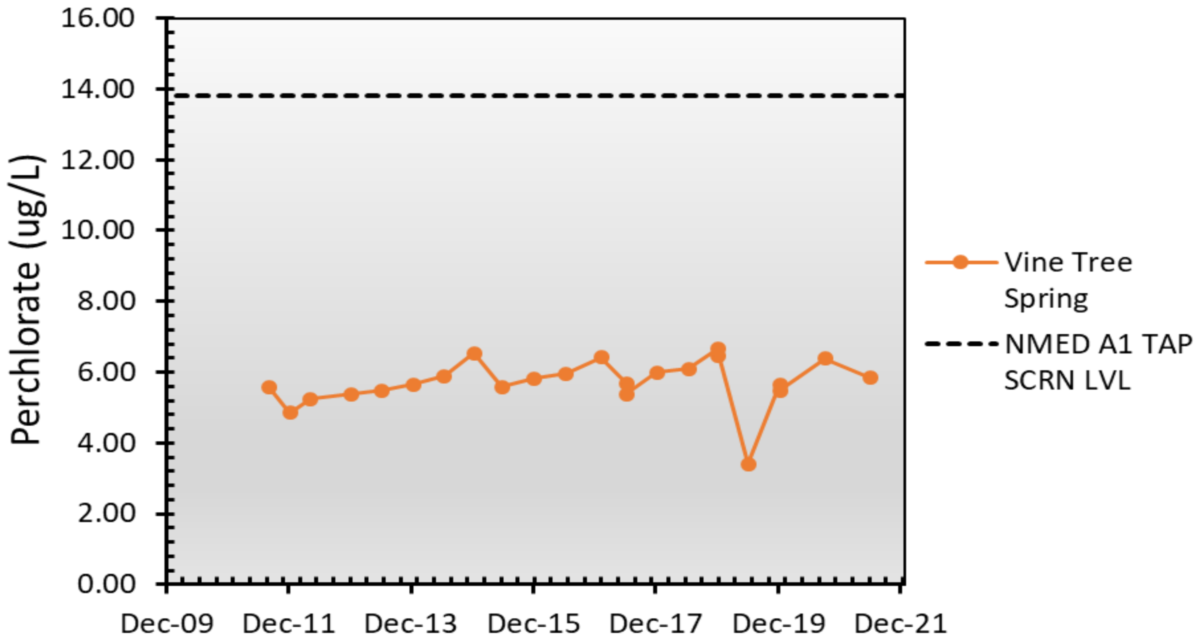
Note: EPA MCL = U.S. Environmental Protection Agency maximum contaminant level for drinking water

Figure 5-24. Strontium-90 levels at alluvial monitoring well LAO-3a and LAUZ-1. The U.S. Environmental Protection Agency maximum contaminant level for strontium-90 in drinking water value is 8 picocuries per liter (pCi/L).

Alluvial well PAO-5n and intermediate wells POI-4 and R-3i in Pueblo Canyon showed results above the New Mexico Environment Department tap water screening level of 70 nanograms per liter for PFAS; respectively, the results were 107.61, 89.7, and 75.8 nanograms per liter. Alluvial well LAUZ-1 in Los Alamos Canyon showed a result of 520 nanograms per liter. As a new emerging contaminant, this was the second sampling event for PFAS. We will continue to monitor for PFAS at these locations.

Lower Los Alamos Canyon

Vine Tree Spring on Pueblo de San Ildefonso land represents discharge of perched-intermediate groundwater. Sampling at Vine Tree Spring began as a replacement for nearby Basalt Spring, which we had sampled since the 1950s until it dried up around 2010. The perchlorate concentration in Vine Tree Spring for 2021 is consistent with prior years' data (see Figure 5-25). The perchlorate contamination may be associated with historical Laboratory operations. For context, the perchlorate values are below the risk-based screening level of 13.8 micrograms per liter. The screening level for perchlorate is determined according to a hierarchical data-screening process required under the 2016 Consent Order.



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

Figure 5-25. Perchlorate concentrations at Vine Tree Spring. The New Mexico risk-based screening level for perchlorate is 13.8 micrograms per liter (µg/L).

Sandia Canyon

The General Surveillance monitoring group wells located in Sandia Canyon that are not part of the Chromium Investigation monitoring group include regional aquifer wells R-10 and R-10a and perched-intermediate well R-12. Wells R-10 and R-10a are located on Pueblo de San Ildefonso land. We measured no constituents near or above standards or screening levels in these wells during 2021.

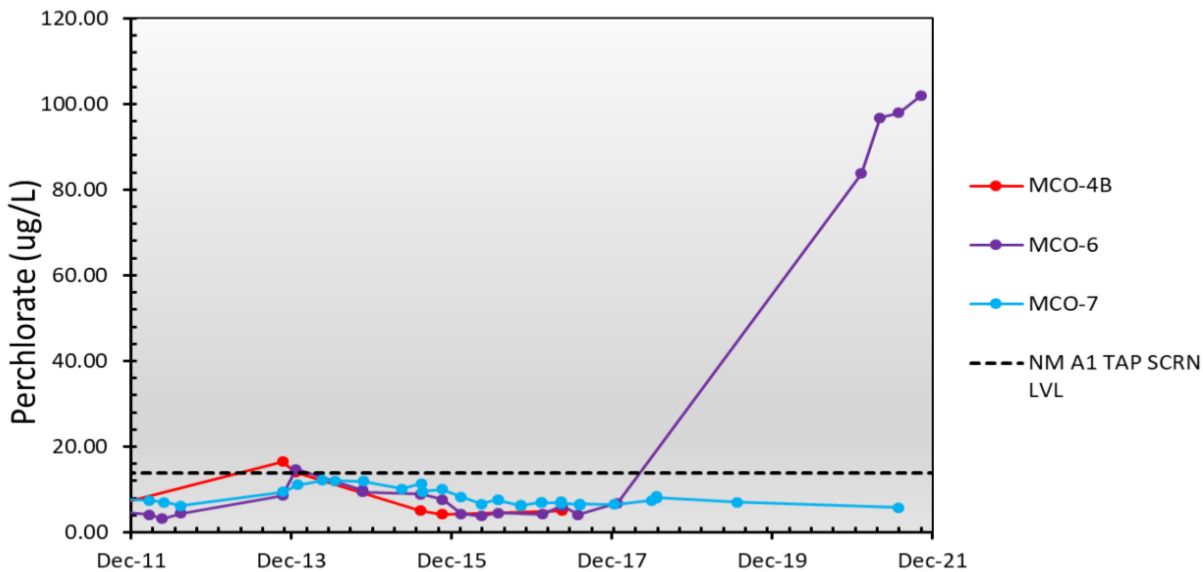
Mortandad Canyon

Several regional aquifer wells in Mortandad Canyon are part of the General Surveillance monitoring group. No constituents in the regional aquifer during 2021 were measured above their respective screening values for these wells.

Under the groundwater discharge plan application for the Technical Area 50 Radioactive Liquid Waste Treatment Facility outfall, we collect quarterly and annual samples from seven alluvial, perched-intermediate, and regional aquifer wells to monitor groundwater impacts from discharges to the outfall in Mortandad Canyon, as discussed in Chapter 2 and later in this chapter. See Chapter 2 for a discussion of results from direct monitoring of the outfall.

Historically, we have detected perchlorate in alluvial monitoring wells MCO-4B, MCO-6, and MCO-7 (see Figure 5-26). Since the 2002 Radioactive Liquid Waste Treatment Facility upgrades, the perchlorate concentrations from these wells are low relative to past perchlorate concentrations in Mortandad Canyon alluvial groundwater. Due to insufficient water, we had not sampled MCO-4B and MCOI-6 since 2017 and 2018, respectively. In 2021, we sampled MCO-6, yielding quarterly results of 83.8, 96.8, 97.9, and 102 micrograms per liter of perchlorate.

Nitrate, fluoride, and total dissolved solids are far below applicable standards in these alluvial wells.



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

Figure 5-26. Perchlorate concentrations at General Surveillance monitoring group and groundwater discharge plan monitoring wells MCO-4B, MCO-6, and MCO-7 in Mortandad Canyon alluvial groundwater. The New Mexico tap water screening level for perchlorate is 13.8 micrograms per liter (µg/L).

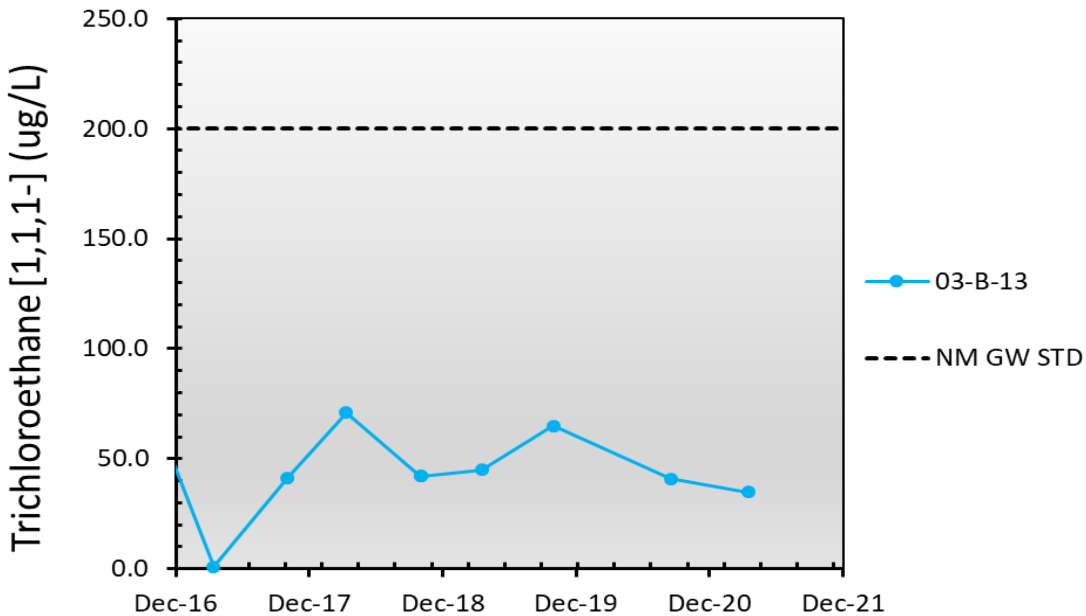
Cañada del Buey

Alluvial well CDBO-6 in Cañada del Buey was dry in 2021 and, thus, not sampled.

Pajarito Canyon

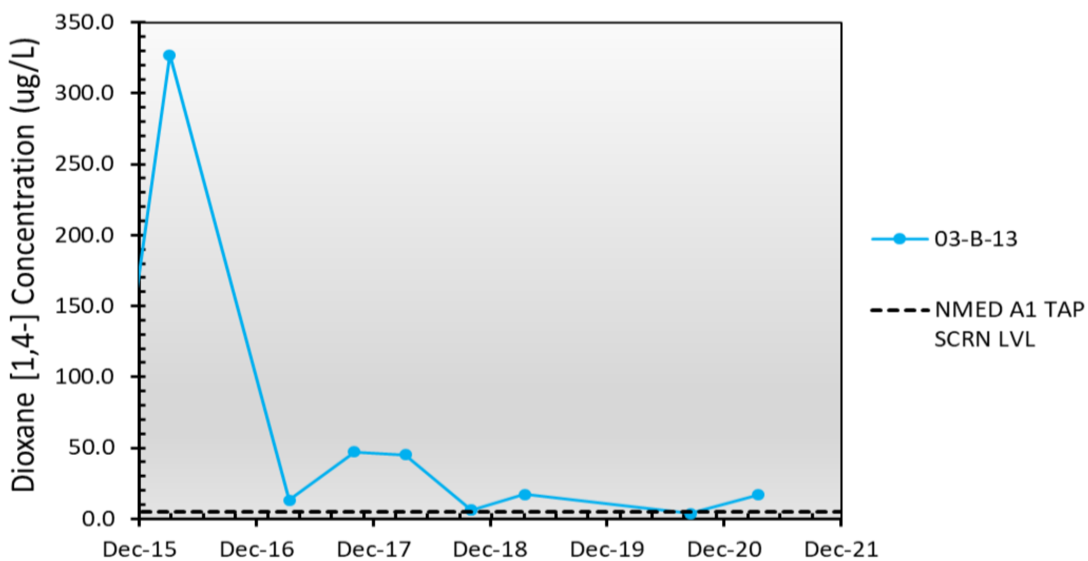
The Pajarito Canyon watershed begins in the Sierra de los Valles, west of the Laboratory. Twomile and Threemile Canyons at the Laboratory are tributaries of Pajarito Canyon. Saturated alluvium is present in portions of Pajarito Canyon, including a reach in lower Pajarito Canyon, but does not extend beyond the Laboratory's eastern boundary. In the past, the Laboratory released small amounts of wastewater into tributaries of Pajarito Canyon from several high-explosives-processing sites at Technical Area 09. A nuclear materials experimental facility occupied the floor of Pajarito Canyon at Technical Area 18. Waste management areas at Technical Area 54 occupy the mesa north of the lower part of the canyon.

Solid Waste Management Unit 03-010(a) is the outfall area from a former vacuum repair shop behind the warehouse at Technical Area 03. The outfall area is located on a small tributary to Twomile Canyon. A small zone of shallow perched-intermediate groundwater is present, apparently recharged by runoff from adjacent parking lots and building roofs. We sample this perched groundwater at a depth of approximately 21 feet via well 03-B-13. In 2021, samples from this well contained 1,1,1-trichloroethane at concentrations below the New Mexico groundwater standard (see Figure 5-27). Additionally, 03-B-13 contained aluminum at 1,130 micrograms per liter, down from 5,430 micrograms per liter in 2020, and iron at 727 micrograms per liter, down from 3,240 micrograms per liter in 2020. The New Mexico groundwater standard for aluminum is 5,000 micrograms per liter and for iron is 1,000 micrograms per liter. We detected 1,4-dioxane at 16.9 micrograms per liter in 03-B-13, above the 4.59 microgram per liter New Mexico groundwater standard (see Figure 5-28).



Note: NM GW STD = New Mexico groundwater standard

Figure 5-27. Concentrations of 1,1,1-trichloroethane in Pajarito Canyon perched-intermediate groundwater at General Surveillance monitoring group well 03-B-13. The New Mexico groundwater standard for 1,1,1-trichloroethane is 200 micrograms per liter (µg/L).



Note: NMED A1 TAP SCRN LVL = New Mexico Environment Department tap water screening level

Figure 5-28. Concentrations of 1,4-dioxane in Pajarito Canyon perched-intermediate groundwater at General Surveillance monitoring group well 03-B-13. The New Mexico groundwater standard for 1,4-dioxane is 4.59 micrograms per liter (µg/L).

Several other alluvial and perched-intermediate groundwater and regional aquifer wells in Pajarito Canyon are part of the General Surveillance monitoring group. At alluvial well 18-MW-18, we measured chloride at 287 milligrams per liter, above the New Mexico groundwater standard of 250 milligrams per liter.

Water Canyon

Water Canyon has only one General Surveillance monitoring group location—alluvial well WCO-1r. We canceled the 2021 sampling event because of insufficient water during the time of sampling. During the previous sampling event in 2019, we detected iron at 1,560 micrograms per liter, which is above the 1,000 micrograms per liter New Mexico groundwater standard.

Groundwater Discharge Permit Monitoring

In samples collected in support of groundwater discharge permits (from wells MCA-RLW-1, MCA-RLW-2, MCOI-6, SCA-3, SCI-1, R-1, R-14 screen 1, R-46, and R-60), no permit-related constituents were measured above applicable standards or screening levels in 2021. Alluvial wells MCA-RLW-1, MCA-RLW-2, and SCA-3 were dry during the monitoring period. Several analytes related to historical operations were detected in perched/intermediate aquifer well MCOI-6; these various analytes measured above applicable standards or screening levels as presented in the Chromium Investigation Monitoring Group portion of this report.

Summary—Emerging Contaminants

PFAS are manufactured compounds used for a variety of purposes in various industrial, commercial, and consumer applications. As of December 2018, three PFAS compounds are identified as toxic pollutants under *Ground and Surface Water Protection*, Title 20, Chapter 6, Part 2 of the New Mexico Administrative Code: perfluorohexane sulfonic acid, perfluorooctanoic acid, and perfluorooctane sulfonate. In 2020 and 2021, we sampled for these three PFAS constituents at all Interim Facility-Wide Groundwater Monitoring locations.

Beginning in 2022, no additional PFAS sampling will be conducted at locations where two rounds of PFAS sampling were performed and no PFAS regulatory standard was exceeded (see Table 5-2). At locations where two rounds of PFAS sampling were not conducted or at locations where a regulatory standard was exceeded, PFAS sampling will continue. In addition, if regulatory standards for PFAS constituents change in the future, we will evaluate the change and determine if we need to conduct additional sampling for PFAS constituents. The current New Mexico screening level for total PFAS in water is 70 nanograms per liter.

Because of the potential for cross-contamination when sampling for these compounds, a task group consisting of the New Mexico Environment Department, N3B, and DOE personnel was established before sampling in 2020 to determine best practices for collecting these samples. A standard operating procedure developed by the California State Water Boards, referenced in the N3B Groundwater Sampling SOP N3B-SOP-ER-3003, R0, is used by sampling personnel when collecting PFAS samples.

Table 5-2. PFAS Results for Years 2020 and 2021

Canyon	Location	Sample Date	Report Result[a] (nanograms per liter)	Sample Purpose
Technical Area 21 Monitoring Group				
Los Alamos	LAOI-7	8/26/2020	30.11	REG[b]
	LAOI-7	8/11/2021	31.93	REG
	R-6	8/25/2020	0.842 J[c]	FD[d]
	R-6	8/26/2021	2.78	REG
	R-9i S1	8/24/2021	31.56	FD
	R-9i S1	8/24/2021	29.4	REG
Sandia	TA-53i	9/11/2020	2.06	REG
	TA-53i	8/20/2021	1.63	REG
Chromium Investigation Monitoring Group				
Mortandad	R-70 S1	8/4/2020	1.45 J	REG
	R-70 S2	8/4/2020	4.88	FD
	MCOI-6	11/9/2020	0.68 J	REG
Material Disposal Area C Monitoring Group				
Mortandad	R-14 S1	11/18/2020	1 J	REG
Technical Area 54 Monitoring Group				
Pajarito	R-52 S1	10/14/2020	0.995 J	REG
Technical Area 16 Monitoring Group				
Pajarito	Bulldog Spring	7/17/2020	6.93 J	REG
	Bulldog Spring	3/16/2021	7.37 J	REG
Water	16-26644	3/11/2021	0.635 J	REG
	16-61439	7/21/2020	7.21 J	REG
	16-61439	3/15/2021	6.71	REG
	Burning Ground Spring	3/13/2021	0.654 J	REG
	CDV-16-02656	7/25/2020	2.18	REG
	CDV-16-02659	3/15/2021	10.2	REG
	CDV-16-02659	3/15/2021	10.2	FD
	CdV-16-2(i)r	3/12/2021	10.9	REG
	CDV-16-4ip S1	3/19/2021	10.4	REG
	CDV-16-611937	7/25/2020	8.5	REG
	CDV-16-611937	3/15/2021	3.84	REG
	Martin Spring	7/23/2020	14.474 J	REG
	Martin Spring	3/10/2021	9.385 J	REG
	R-26 PZ-2	7/20/2020	2.13	REG
	R-26 PZ-2	3/17/2021	3.26	REG
	R-63i	3/25/2021	0.842 J	REG
	R-69 S1	3/9/2021	1.43 J	REG
	R-69 S2	3/9/2021	1.03 J	REG

Canyon	Location	Sample Date	Report Result[a] (nanograms per liter)	Sample Purpose
General Surveillance Monitoring Group				
Los Alamos	LAO-3a	9/10/2020	46.56	REG
	LAO-3a	6/16/2021	9.43 J	REG
	LAUZ-1	6/9/2021	520	REG
	LLAO-4	9/3/2020	10.11	REG
	LLAO-4	6/15/2021	8.5	REG
Pueblo	PAO-5n	9/1/2020	179.4	REG
	PAO-5n	6/18/2021	107.61	REG
	POI-4	9/8/2020	107.6	REG
	POI-4	6/10/2021	89.7	REG
	R-2	8/31/2020	14.762 J	REG
	R-2	8/31/2020	15.422 J	FD
	R-2	6/22/2021	5.56 J	REG
	R-2	6/22/2021	5.03 J	FD
	R-24	6/11/2021	0.883 J	REG
	R-3i	9/8/2020	84.7	REG
	R-3i	9/8/2020	83.1	FD
	R-3i	6/21/2021	75.8	REG
	TW-2Ar	9/4/2020	7.79	REG
	TW-2Ar	6/18/2021	6.92	REG
Lower Los Alamos	Vine Tree Spring	6/8/2021	16.01	REG
Sandia	R-12 S1	8/7/2020	17.04	REG
	R-12 S2	8/7/2020	5.88 J	REG
	R-12 S2	8/7/2020	6.79 J	FD
Mortandad	MCO-7	8/18/2020	82	REG
	MCO-7	7/26/2021	48.09	REG
	MCO-7	7/26/2021	47.19	FD
Pajarito	18-MW-18	4/12/2021	6.72	REG
	03-B-13	4/13/2021	6.3	REG

[a] Combined analytical result for perfluorohexane sulfonic acid, perfluorooctanoic acid, and perfluorooctane sulfate.
[b] Regular investigative sample (REG).
[c] The analyte is classified as detected, but the reported concentration value is expected to be more uncertain than usual.
[d] Field duplicate (FD) sample for quality assurance purposes.

Overall Results

The Laboratory has been monitoring groundwater for many years. As described in this chapter, only two areas are showing groundwater contaminants of sufficient concentration and extent to warrant an action such as interim measures, further characterization, and potential remediation under the 2016 Consent Order: (1) RDX contamination in the vicinity of Technical Area 16 and (2) chromium contamination beneath Sandia and Mortandad Canyons. We will continue to implement interim measures for the chromium plume in 2022 and beyond. Further characterization work and studies to evaluate groundwater risks and potential remediation strategies are ongoing in both areas.

Quality Assurance

The 2021 Interim Facility-Wide Groundwater Monitoring Plan (N3B 2020) documents all methods and procedures used to perform the field activities associated with these data.

Sampling and data validation were conducted using standard operating procedures that are part of a comprehensive quality assurance program. For a comprehensive list of these standard operating procedures, refer to Appendix B of the 2021 Interim Facility-Wide Groundwater Monitoring Plan (N3B 2020).

Analytical results meet the N3B minimum data quality objectives as outlined in N3B-PLN-SDM-1000, "Sample and Data Management Plan." N3B-PLN-SDM-1000 sets the validation frequency criteria at 100% Level 1 examination and Level 2 verification of data and at 10% minimum Level 3 validation of data. A Level 1 examination assesses the completeness of the data as delivered from the analytical laboratory, identifies any reporting errors, and checks the usability of the data based on the analytical laboratory's evaluation of the data. A Level 2 verification evaluates the data to determine the extent to which the laboratory met the analytical method and the contract-specific quality control and reporting requirements. A Level 3 validation includes Levels 1 and 2 criteria and determines the effect of potential anomalies encountered during analysis and possible effects on data quality and usability. A Level 3 validation is performed manually with method-specific data validation procedures. N3B personnel validate laboratory analytical data as outlined in N3B-PLN-SDM-1000; N3B-AP-SDM-3000, "General Guidelines for Data Validation"; N3B-AP-SDM-3014, "Examination and Verification of Analytical Data"; and additional method-specific analytical data validation procedures. All associated validation procedures have been developed, where applicable, from the U.S. Environmental Protection Agency document EPA QA/G-8, "Guidance on Environmental Data Verification and Data Validation," the "Department of Defense/Department of Energy Consolidated Quality Systems Manual for Environmental Laboratories," the U.S. Environmental Protection Agency "National Functional Guidelines for Data Validation," and the American National Standards Institute/American Nuclear Society 41.5-2012 (R2018), "Verification and Validation of Radiological Data for Use in Waste Management and Environmental Remediation."

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Chapter 6: Watershed Quality

Los Alamos National Laboratory (LANL or the Laboratory) collects and analyzes storm water runoff to check for a variety of substances and characteristics, such as chemical and radionuclide levels, the volume and duration of flow, and the total amount of suspended sediment. We compare these sampling results with New Mexico water quality standards, target action levels, and radiological dose guidelines. The State of New Mexico uses our surface water data in updating its determinations of impaired waters on and near the Laboratory every two years.

We also analyze newly deposited sediment samples each year for chemical and radionuclide levels. We compare sediment sampling results with human and ecological health screening criteria. We have found that over time, at any given sampling location, storm water–related transport of sediment generally results in similar or lower levels of Laboratory-released chemicals and radionuclides at that location than previously existed because of the deposition of new sediment. The Laboratory continues to have several impaired stream reaches, as defined by the New Mexico Environment Department. Laboratory industrial outfalls are regulated to help minimize these impairments.

Contents

Introduction

Effluents (liquid discharges from industrial operations) containing radionuclides, inorganic chemicals, and organic chemicals were released into canyons the Laboratory during the early years of its operations. Treatments to reduce contaminants in effluents began in the 1950s. Effluent discharges at the Laboratory have been conducted under permits from regulatory agencies since 1978.

Non-Laboratory but human-related as well as natural sources of chemicals and radionuclides also exist. Such sources include the natural composition of rocks and soils, substances associated with trees burned during forest fires, atmospheric deposition of radionuclides and chemicals such as polychlorinated biphenyls (PCBs), and releases from developed areas on the Pajarito Plateau. These sources contribute to the measured levels of chemicals and radionuclides in surface water and sediment across the Pajarito Plateau.

We monitor chemical and radionuclide levels in surface water and sediment in and around the Laboratory to (1) document the water quality in streams within and downstream of the Laboratory and (2) evaluate risks to human and ecosystem health. Sampling results are compared with New Mexico water quality standards, target action levels from LANL's Individual Permit (Permit No. NM0030759), radiological dose guidelines, and human and ecosystem health screening criteria. The Individual Permit is LANL's authorization to discharge (from solid waste management units and areas of concern) under the National Pollutant Discharge Elimination System.

The data presented in this chapter is compiled from three Laboratory programs:

- Annual environmental surveillance sampling of storm water runoff and sediment (N3B 2021a, N3B 2022a, N3B 2022b)
- Implementation of the annual Interim Facility-Wide Groundwater Monitoring Plans (N3B 2020, N3B 2021b), which includes sampling of persistent surface water in streams
- Storm water runoff monitoring associated with the Individual Permit (N3B 2022c)

The legacy waste cleanup contractor Newport News Nuclear BWXT–Los Alamos (N3B) assumed responsibility for implementing the Laboratory's surface water and sediment surveillance program, groundwater protection program, and the Individual Permit in April 2018. The managing and operating contractor, Triad, manages Clean Water Act compliance for current operations, including complying with outfall permit limits and implementing storm water pollution prevention plans and low-impact development controls. Triad has also installed engineered structures for watershed enhancement.

At the Laboratory, we consider any soil that is either suspended in water or that has been deposited by surface water flows as sediment. Many of our sediment samples are collected from dry stream channels or adjacent floodplains, and not from aquatic habitats.

Hydrologic Setting

Laboratory lands contain all or parts of seven watersheds that drain into the Rio Grande basin (see Figure 6-1). The watersheds are named after the major drainage canyon in the watershed. Listed from north to south, the major canyons for these watersheds are Los Alamos, Sandia, Mortandad, Pajarito, Water, Ancho, and Chaquehui canyons. Los Alamos, Pajarito, and Water Canyon watersheds have their headwaters west of the Laboratory in the eastern Jemez Mountains, mostly within the Santa Fe National Forest. The remainder of the watersheds have their headwaters on the Pajarito Plateau. Only the Ancho Canyon watershed is located entirely on Laboratory land. Pueblo Canyon, which is north of Los Alamos Canyon but not on Laboratory land, is also monitored because of historic Laboratory activities in the area.

In 2021, snowmelt runoff crossed the downstream (eastern) boundary of the Laboratory at gaging stations in Ancho, Chaquehui, Los Alamos, Mortandad, Pajarito, Pueblo, Sandia, and Water canyons, and Cañada del Buey (a subwatershed of Mortandad Canyon). Total snowmelt runoff for 2021 measured at these stations is estimated at 13 acre-feet, with most of the runoff occurring in Pajarito Canyon. Total storm water runoff for June to October 2021 measured at the downstream Laboratory boundary is estimated at 7 acre-feet. Most of this runoff occurred in Ancho, Pajarito, and Water canyons; minimal runoff (less than 1.5 acre-feet) occurred in Potrillo Canyon (a subwatershed of Water Canyon), Pueblo (a subwatershed of Los Alamos Canyon), Sandia, Mortandad, and Chaquehui canyons, and Cañada del Buey. No effluent from the Los Alamos County Waste Water Treatment Facility reached gaging station E060.1 in lower Pueblo Canyon during storm events in 2021. We know this because gaging station records show that flow recorded at gaging station E059.5 (directly below the facility) did not reach the downstream gaging station E060.1. Note: Precipitation data for 2020 have been corrected.

Figure 6-2 shows the precipitation and storm water runoff volume for the Laboratory for the monsoonal period of June through October during the years 1995 to 2021.

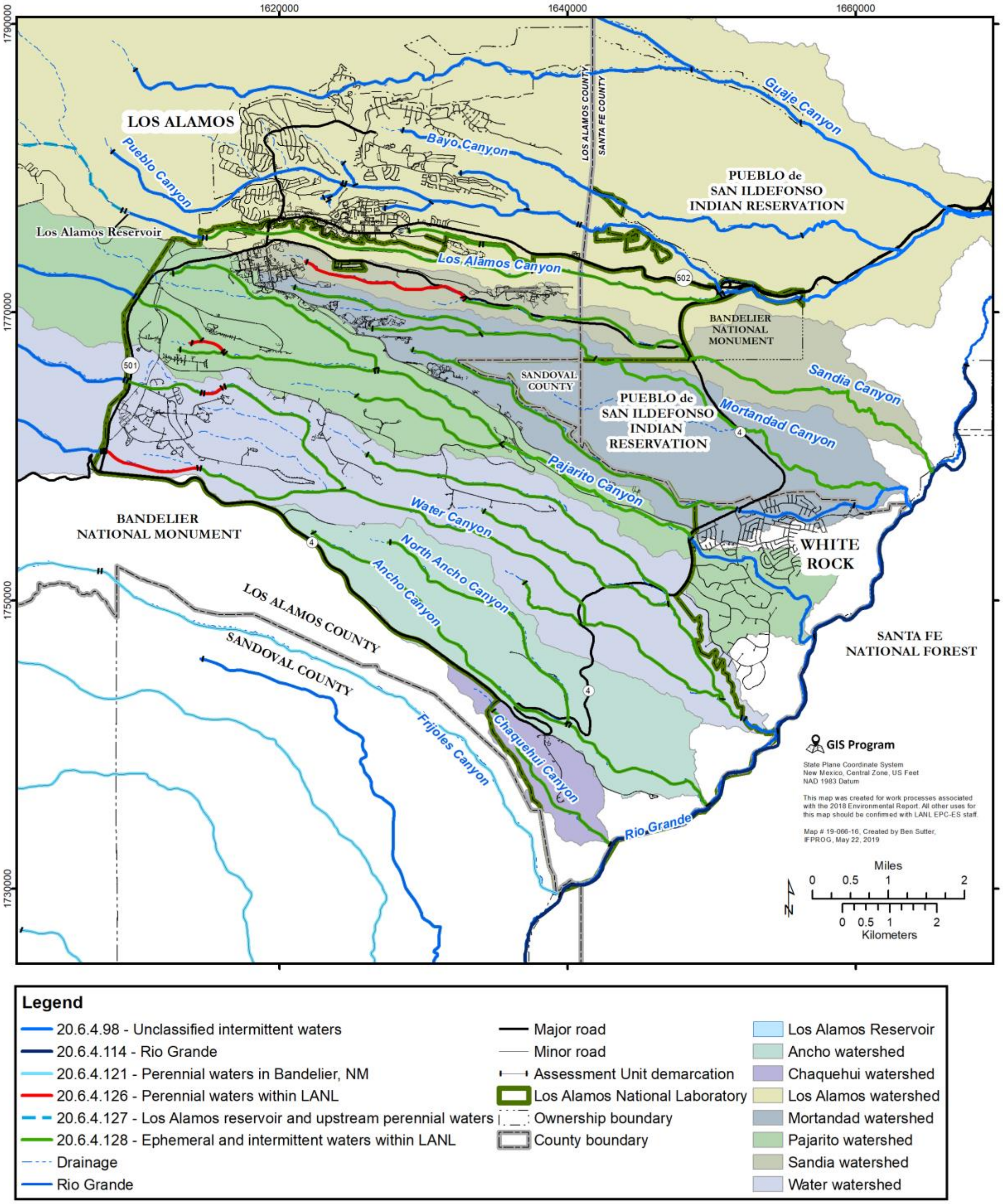
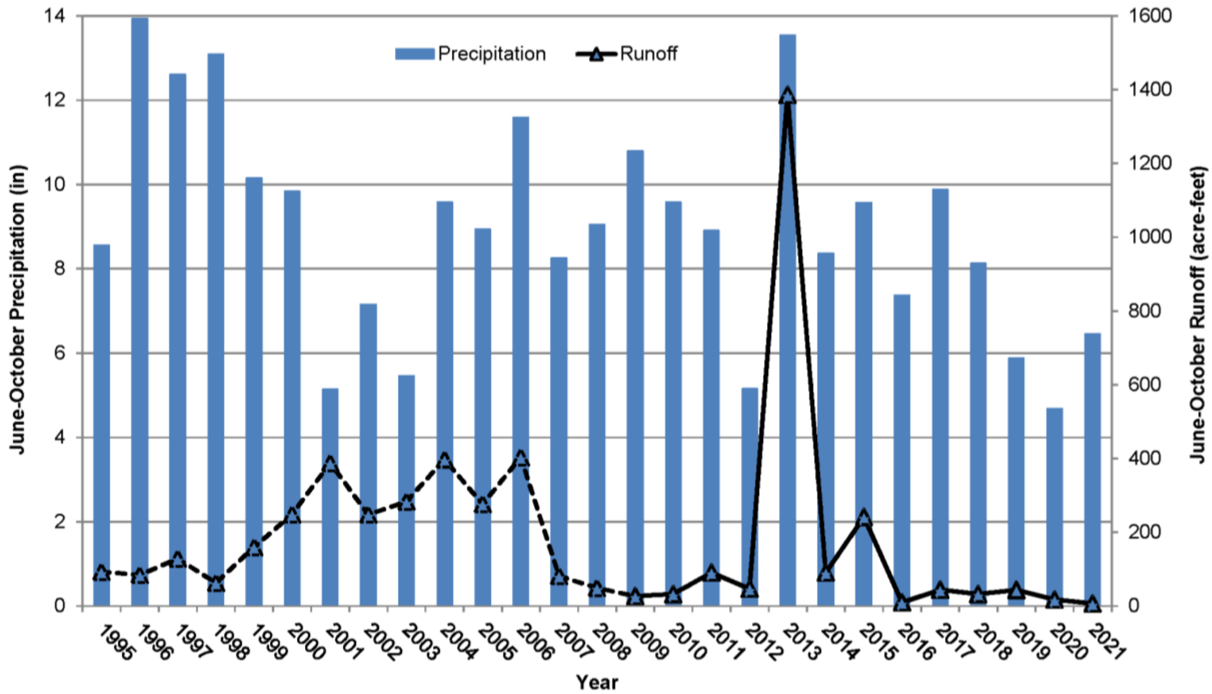


Figure 6-1. Stream reaches and watersheds within and around the Laboratory. Map shows the classifications of streams from Standards for Interstate and Intrastate Surface Waters, Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code.



Note: Precipitation data for 2020 have been corrected.

Figure 6-2. Total June–October precipitation from 1995 to 2021 averaged across the Laboratory's meteorological tower network (Technical Area 06, Technical Area 49, Technical Area 53, Technical Area 54, and northern community), and estimated June–October storm water runoff volume in Laboratory canyons from 1995 to 2021. Dashed line indicates data with potential quality problems.

Standards, Screening Levels, and Designated Uses for Stream Reaches

Surface Water Standards and Screening Levels

The New Mexico Water Quality Control Commission establishes surface water quality standards for New Mexico in *Standards for Interstate and Intrastate Surface Waters*, Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code. The standards used for this chapter were approved by the U.S. Environmental Protection Agency on July 24, 2020, and can be found online at https://www.env.nm.gov/surface-water-quality/wqs/. We use the New Mexico Environment Department's protocol for assessing attainment of surface water quality standards (NMED 2019). Hardness-dependent aquatic life criteria for metals are calculated using water hardness values of concurrent samples (EPA 2006a, WQCC 2020).

U.S. Department of Energy (DOE) Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, sets total dose limits for radioactivity released during Laboratory operations. Limits apply to members of the public, plants, and animals. Therefore, our radiological assessment of surface water evaluates the potential exposures of aquatic organisms as well as animals living on land (collectively called "biota"). We compare radionuclide activities in surface water with the DOE biota concentration guides (DOE 2019) and with site-specific modifications by McNaughton et al. (2013). Biota concentration guides for either aquatic, riparian, or terrestrial animals are used for evaluation, depending on how often surface water is present at the location being evaluated. Both perennial reaches and intermittent reaches are screened using aquatic, terrestrial, and riparian animal biota concentration guides; ephemeral reaches are screened using terrestrial animal biota concentration guides. Biota dose results are provided in Chapter 7.

We compare surface water results for gross alpha radioactivity and isotopes of radium with the New Mexico water quality standards. The gross alpha standard does not apply to source, special nuclear, or byproduct material regulated by DOE under the Atomic Energy Act of 1954. The gross alpha radioactivity data discussed in this chapter were not adjusted to remove these sources of radioactivity.

We compare surface water results from the Individual Permit site monitoring areas with the target action levels specified in the Individual Permit. Individual Permit site monitoring areas are described further in the Chapter 2 section titled "LANL's Individual Permit Authorization to Discharge under the National Pollutant Discharge Elimination System (from Solid Waste Management Units and Areas of Concern)." Additional details for site monitoring area results are provided in the Individual Permit Annual Report (N3B 2022d).

Terms related to surface water

Base flow – the portion of a perennial stream's flow that is sustained between precipitation events.

Effluent – water resulting from industrial processes that is discharged to the environment

Floodplain – an area of land adjacent to a stream that may receive water when the stream floods

Storm water – water that comes as runoff from rain and snowmelt events

Stream reach – a section of a stream or river along which similar hydrologic conditions exist, such as discharge, depth, area, geology, and slope

Surface water – water on the surface of a continent, such as in a river, lake, or wetland

Watershed – the area of land that contributes water flow to a particular stream or river

Sediment Screening Levels

We compare analytical results for chemicals in sediment to the New Mexico Environment Department's risk-based soil screening levels (New Mexico Environment Department 2021a) and radionuclides in sediment to the Laboratory's risk-based screening action levels (LANL 2015). If there are no New Mexico soil screening levels for a particular chemical, the U.S. Environmental Protection Agency's regional screening levels are used (U.S. Environmental Protection Agency 2020). Soil screening levels for inorganic and organic chemicals and screening action levels for radionuclides are levels considered safe for industrial, construction worker, or residential exposure scenarios. If concentrations of substances are below screening action levels or soil screening levels, then adverse human health effects are highly unlikely. In addition, we use sediment background values from Ryti et al. (1998) for reference. (Note: The New Mexico surface water quality standards only address total PCBs but not individual PCB congeners, while the soil screening levels address individual PCB congeners, but not total PCBs).

These various screening levels provide a high level of confidence in determining a low probability of risk to human health. They are not designed or intended to provide definitive estimates of actual risk and are not based on designated land use (U.S. Environmental Protection Agency 2001). For example, onsite data are compared with residential screening levels, although no residences are nearby. We evaluate human health risks from exposure to storm water in Chapter 8, Public Dose and Risk Assessment.

For evaluating risks to biota, we compare radionuclide activities in sediment with the DOE biota concentration guides (DOE 2019) and with site-specific modifications by McNaughton et al. (2013). Biota concentration guides for riparian and terrestrial animals are used for the evaluation.

State of New Mexico Assessments of Stream Reaches

The New Mexico Environment Department Surface Water Quality Bureau uses surface water sampling results to evaluate impairment of the state's stream reaches (delineated as assessment units) under Section 303(d) of the Clean Water Act. They update the list of impaired stream reaches, including those on Laboratory property, every two years (New Mexico Environment Department 2021b).

Under *Standards for Interstate and Intrastate Surface Waters*, Title 20 Chapter 6 Part 4 of the New Mexico Administrative Code, stream reaches within the Laboratory boundary are classified as perennial (having water throughout the year), or ephemeral and intermittent (having water for extended periods only at certain times of the year or having water briefly only in direct response to precipitation) (New Mexico Water Quality Control Commission 2020). A stream reach is assigned one or more of the following designated uses based on its stream flow (perennial or ephemeral/intermittent) and other characteristics: cold water aquatic life, marginal warm water aquatic life, limited aquatic life, livestock watering, wildlife habitat, primary and secondary (human) contact.

Stream reaches within the Laboratory boundary are divided into assessment units. An assessment unit is considered impaired when one or more of the New Mexico surface water quality standards are not being met for one or more pollutants. The standards applied to each assessment unit depend on the designated use(s) of that assessment unit.

The locations of assessment units on and around the Laboratory are shown in Figure 6-1. The current status of each designated use (supported, not supported, or not assessed) for each assessment unit, and the identified cause of impairment, if any, are listed in Table 6-1 (NMED 2021b).

Table 6-1. 2022–2024 LANL Assessment Units, Impairment Cause, and Designated Use(s) Supported, Not Supported, or Not Assessed

Assessment Unit Name	Impairment Cause	Designated Use Supported	Designated Use Not Supported	Designated Use Not Assessed
Acid Canyon (Pueblo Canyon to headwaters)	Gross alpha,[‡] aluminum, PCBs,* copper	None	Wildlife habitat, livestock watering, marginal warm water aquatic life	Primary contact
Ancho Canyon (North Fork to headwaters)	PCBs	Wildlife habitat	Limited aquatic life	Secondary contact, livestock watering
Ancho Canyon (Rio Grande to North Fork Ancho)	PCBs, mercury	Livestock watering	Limited aquatic life, wildlife habitat	Secondary contact
Ancho Canyon (Rio Grande to Ancho Springs	PCBs, mercury	Livestock watering	Limited aquatic life, wildlife habitat	Secondary contact
Arroyo de la Delfe (above Kieling Spring)	Copper, PCBs, aluminum, gross alpha	None	Limited aquatic life, livestock watering, wildlife habitat	Secondary contact
Arroyo de la Delfe (Pajarito Canyon to Kieling Spring)	Copper, PCBs, aluminum, gross alpha	None	Limited aquatic life, livestock watering, wildlife habitat	Secondary contact
Cañada del Buey (within LANL)	PCBs, gross alpha	None	Limited aquatic life, livestock watering	Secondary contact, wildlife habitat
Cañon de Valle (below LANL gage E256)	Gross alpha	Wildlife habitat, limited aquatic life	Livestock watering	Secondary contact
Cañon de Valle (LANL gage E256 to Burning Ground Spring)	PCBs	Livestock watering	Cold water aquatic life, wildlife habitat	Secondary contact
Cañon de Valle (upper LANL boundary to headwaters)	Gross alpha, PCBs	Wildlife habitat	Marginal warm water aquatic life, livestock watering	Primary contact
Cañon de Valle (within LANL above Burning Ground Spring)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Chaquehui Canyon (within LANL)	PCBs	Wildlife habitat, livestock watering	Limited aquatic life	Secondary contact
DP Canyon (400 meters upstream of grade control to upper LANL boundary)	Copper, PCBs, aluminum, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
DP Canyon (100 meters downstream of grade control to 400 meters upstream of grade control)	Copper, PCBs, aluminum, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
DP Canyon (Los Alamos Canyon to 100 meters downstream of grade control)	PCBs, aluminum, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact

Assessment Unit Name	Impairment Cause	Designated Use Supported	Designated Use Not Supported	Designated Use Not Assessed
Fence Canyon (above Potrillo Canyon)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Graduation Canyon (Pueblo Canyon to headwaters)	Copper, PCBs	Livestock watering	Wildlife habitat, marginal warm water aquatic life	Primary contact
Indio Canyon (above Water Canyon)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Kwage Canyon (Pueblo Canyon to headwaters)	Not assessed	Not applicable	Not applicable	Primary contact, wildlife habitat, livestock watering, marginal warm water aquatic life
Los Alamos Canyon (DP Canyon to upper LANL boundary)	PCBs, cyanide, selenium, gross alpha, mercury	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Los Alamos Canyon (New Mexico Route 4 to DP Canyon)	Aluminum, PCBs, cyanide, radium, gross alpha, mercury	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Mortandad Canyon (within LANL)	Copper, PCBs, gross alpha, mercury	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
North Fork Ancho Canyon (Ancho Canyon to headwaters)	Gross alpha, PCBs	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Pajarito Canyon (Arroyo de La Delfe to Starmers Spring)	None	Livestock watering, cold water aquatic life wildlife habitat	None	Secondary contact
Pajarito Canyon (lower LANL boundary to Two-Mile Canyon)	Aluminum, PCBs, copper, gross alpha, cyanide	Wildlife habitat, limited aquatic life, livestock watering	None	Secondary contact
Pajarito Canyon (Two-Mile Canyon to Arroyo de La Delfe)	PCBs, silver, copper, gross alpha	Wildlife habitat	Livestock watering, limited aquatic life	Secondary contact
Pajarito Canyon (upper LANL boundary to headwaters)	Gross alpha, cyanide, PCBs, aluminum, mercury	None	Warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Pajarito Canyon (within LANL above Starmers Gulch)	Aluminum, gross alpha	Wildlife habitat	Livestock watering, limited aquatic life	Secondary contact
Potrillo Canyon (above Water Canyon)	Gross alpha	Limited aquatic life, wildlife habitat	Livestock watering	Secondary contact
Pueblo Canyon (Acid Canyon to headwaters)	Gross alpha, PCBs, copper, aluminum	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact

Assessment Unit Name	Impairment Cause	Designated Use Supported	Designated Use Not Supported	Designated Use Not Assessed
Pueblo Canyon (Los Alamos Canyon to Los Alamos Waste Water Treatment Plant)	Gross alpha, aluminum, PCBs, selenium	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Pueblo Canyon (Los Alamos Waste Water Treatment Plant to Acid Canyon)	Gross alpha, PCBs	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Sandia Canyon (Sigma Canyon to National Pollutant Discharge Elimination System Outfall 001)	PCBs, aluminum,[§] copper,[§] temperature	Livestock watering	Wildlife habitat, cold water aquatic life	Secondary contact
Sandia Canyon (within LANL below Sigma Canyon)	PCBs, aluminum,[§] gross alpha, mercury,[§] copper[§]	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
South Fork Acid Canyon (Acid Canyon to headwaters)	Gross alpha, copper, PCBs	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Ten Site Canyon (Mortandad Canyon to headwaters)	PCBs, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Three-Mile Canyon (Pajarito Canyon to headwaters)	Gross alpha	Limited aquatic life, wildlife habitat	Livestock watering	Secondary contact
Two-Mile Canyon (Pajarito Canyon to headwaters)	PCBs, aluminum, copper, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Walnut Canyon (Pueblo Canyon to headwaters)	PCBs, copper	Livestock watering, wildlife habitat	Marginal warm water aquatic life	Primary contact
Water Canyon (Area A Canyon to New Mexico Route 501)	None	Cold water aquatic life, livestock watering, wildlife habitat	None	Secondary contact
Water Canyon (within LANL above New Mexico Route 501)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Water Canyon (within LANL below Area A Canyon)	PCBs, aluminum, gross alpha, mercury	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact

*PCBs are total PCBs in the water column.

†Levels of these metals are considered an impairment for acute aquatic life standards.

‡Gross alpha levels in surface water samples are currently not adjusted to remove sources of radioactivity from source, special nuclear, or byproduct material regulated by DOE under the Atomic Energy Act of 1954.

§LANL submitted a third-party IR Category 4b demonstration entitled "Sandia Canyon Assessment Unit NM-9000.A_047 and NM-128.A_11 Dissolved Copper, Mercury and Total Recoverable Aluminum 4B Demonstration" (https://www.env.nm.gov/surface-water-quality/303d-305b/). Accordingly, the associated aluminum and copper listings in this assessment unit are noted as IR Category 4B.

Surface Water and Sediment Sampling

Surface Water Sampling Locations and Methods

We sample surface water in all major canyons and tributaries on current or former Laboratory lands. This includes an emphasis on monitoring close to and downstream of potential sources of Laboratory-released substances, including monitoring at the downstream Laboratory boundaries and east of New Mexico State Road 4.

We maintain 37 stream gaging stations on and near the Laboratory, all of which are equipped with automated samplers that activate at the start of storm water runoff events. Storm water samples are also collected at eight additional stream channel locations that do not have active gaging stations. The number of gaging stations and stream channel sampling locations remains fairly constant over time. However, not all gaging stations or channel sampling locations experience storm water flow in any given year, so the number of locations with samples varies from year to year. The sampling locations are chosen to monitor surface water flow onto and off of Laboratory and former Laboratory lands and at the confluence of canyons.

The automated samplers at gaging stations are programmed to start collecting water ten minutes after the peak flow during a runoff event, referred to as "Peak + 10." The year 2021 was the eleventh year that the Peak + 10 sampling method was employed at the gaging stations. This method was implemented based on comments by the New Mexico Environment Department that results from water samples collected before the peak of the storm flow were highly variable and therefore, not ideal for monitoring contaminant and sediment transport. Programming the automated samplers to sample 10 minutes after the peak ensures that samples are not collected on the rising limb of the hydrograph. Previously, from 2004–2010, samples were collected right at the peak of the runoff event. As a result, current storm water sampling results are not directly comparable to data collected before the 2011 monitoring season.

To meet monitoring requirements under the Individual Permit, we have also installed samplers in 250 site monitoring areas to sample storm water runoff directly from 405 solid waste management units and areas of concern. These samplers do not remain in operation during months with freezing temperatures. Because rainstorms on the Pajarito Plateau are frequently very localized and not all rainfall events produce storm water runoff, not all active Individual Permit sampling locations collect samples each year.

Water from springs is regulated by groundwater standards and is discussed in Chapter 5. Water discharged from springs that has infiltrated and resurfaced is base flow that is regulated by surface water standards. We collected grab samples of base flow at locations identified in the "Interim Facility-Wide Groundwater Monitoring Plan for the 2021 Monitoring Year, October 2020–September 2021" and the "Interim Facility-Wide Groundwater Monitoring Plan for the 2022 Monitoring Year, October 2021–September 2022" (N3B 2020, N3B 2021b).

Figure 6-3 shows locations where samples were collected in 2021 for storm water at stream gaging stations, at sediment-detention basins, and for base flow. Figure 6-4 shows Individual Permit site monitoring areas where compliance samples were collected in 2021. Twenty-four samples were collected from 21 Individual Permit site monitoring areas in 2021.

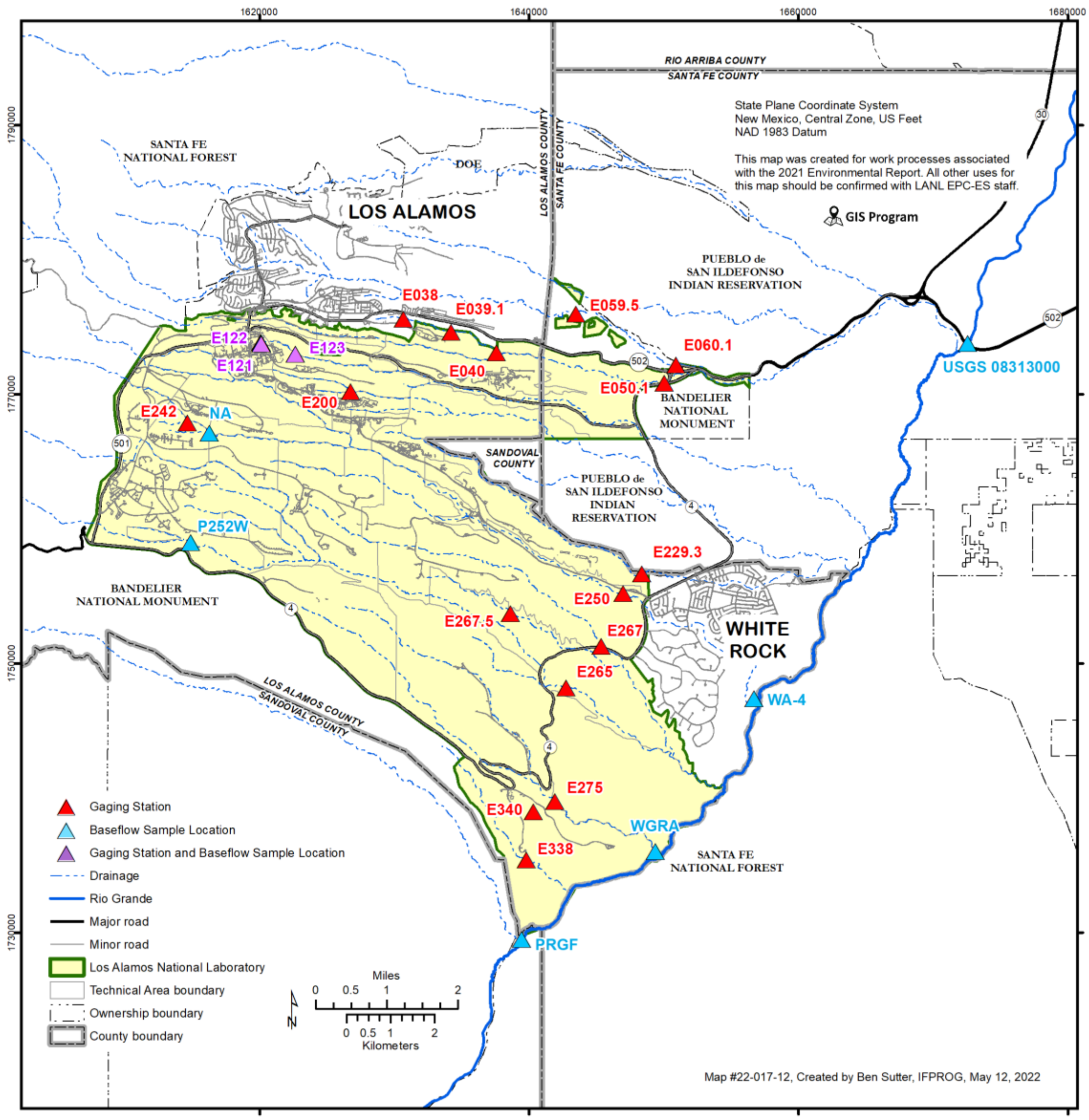


Figure 6-3. Locations sampled for storm water in 2021 at stream gaging stations and for base flow.

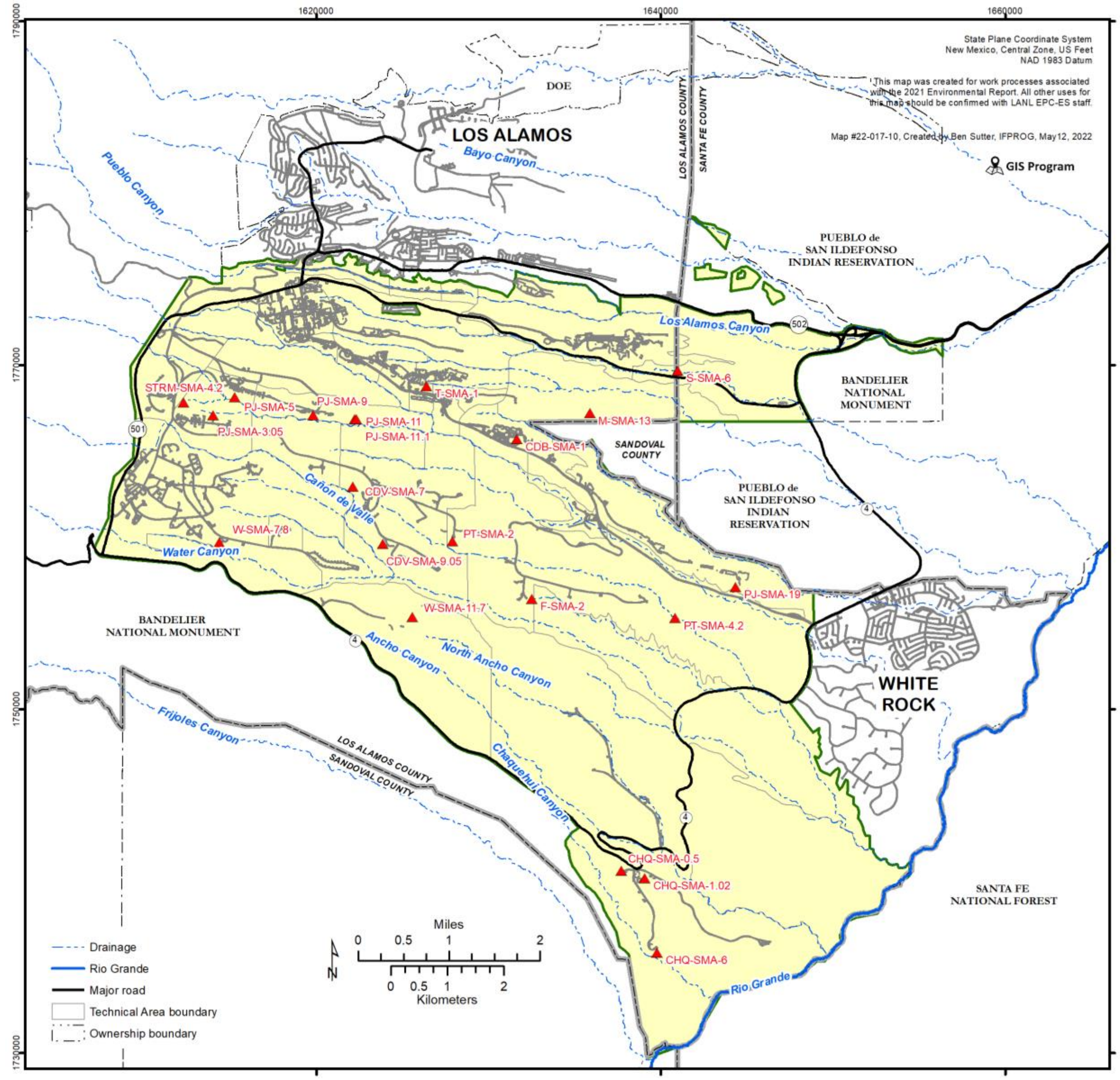
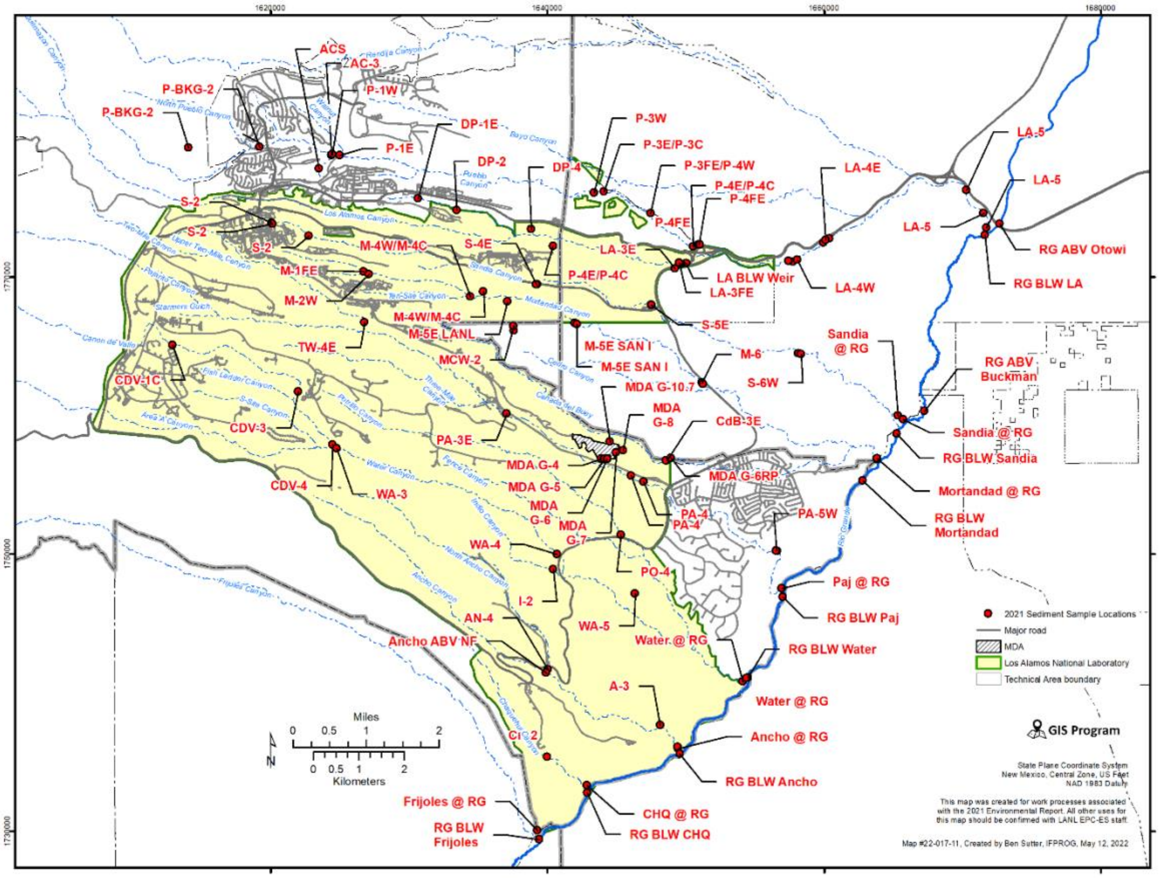


Figure 6-4. Individual Permit (IP) site monitoring areas where automated samplers collected storm water samples in 2021.

Sediment Sampling Locations and Methods

Figure 6-5 shows locations sampled for sediment in 2021 as part of the annual environmental surveillance program. Sediment samples were collected at a depth of between 0 and 6 inches, depending on the thickness of the uppermost sediment layer. We collected samples from stream channels and floodplains where new sediment was deposited during 2021. For streams with flowing water, sediment samples were collected near the edge of the main channel adjacent to, but not in, the water. During 2021, storm water runoff flowed in every canyon on Laboratory property; therefore, sediment samples were collected from all major watersheds.



Note: MDA = Material disposal area; RG = Rio Grande; BLW = below; @ = at; LA = Los Alamos Canyon; P = Pueblo Canyon; A or AN = Ancho Canyon; AC = Acid Canyon; S = Sandia Canyon; WA = Water Canyon; ABV = above; CdB = Cañada del Buey; PA = Pajarito Canyon; M or Mort = Mortandad Canyon; BKG = background; I = Indio Canyon

Figure 6-5. Locations sampled in 2021 for sediment as part of the annual environmental surveillance program.

Results

Table 6-2 summarizes inorganic chemical results for 2021 storm water and base flow samples and Table 6-3 summarizes organic chemical and radionuclide results for 2021 storm water and base flow samples. We collected storm water from 19 locations and base flow samples from 9 locations in 2021. For inorganic chemicals, nine locations had no exceedances, five had one inorganic element exceed an applicable New Mexico water quality standard (typically total aluminum), four had two inorganic elements exceed (total aluminum plus one other inorganic element), and the remainder had more than two inorganic elements exceed an applicable New Mexico water quality standard. For organic chemicals and radionuclides, seven locations had no exceedances, seven had one chemical or radioactivity measure exceed an applicable New Mexico water quality standard (typically either gross alpha or total PCBs), nine had two chemicals or radioactivity measures exceed (typically total PCBs and one other), and the remainder had more than two organic chemicals or radioactivity measures exceed an applicable New Mexico water quality standard. The surface water monitoring data for 2021 and previous years are available through the Intellus New Mexico website (https://intellusnm.com).

Table 6-4 summarizes chemical results for 2021 sediment samples at locations that exceeded screening levels for at least one chemical. There were minimal exceedances of screening levels for sediment samples collected in 2021; out of 99 sediment samples collected, only 7 had exceedances. Plots showing the number of sediment samples taken and the number of samples exceeding screening levels between 2011 and 2021 are provided in Figure 6-6 for the six chemicals with exceedances in 2021. All radionuclide concentrations in sediment samples collected in 2021 were below screening action levels and the DOE biota concentration guides, so there were no exceedances to report.

Results from compliance sampling for the Individual Permit are not presented in the following tables but are discussed in the text and included in the figures in the Discussion and Trends section below. Tables of the Individual Permit sampling results for 2021 are available in the Storm Water Individual Permit Annual Report (N3B 2022d). Analyses are not performed for every substance in every Individual Permit sample; the analyses that are requested in a given year vary depending on the chemicals or radionuclides that have previously been detected in the solid waste management units and areas of concern within a site monitoring area.

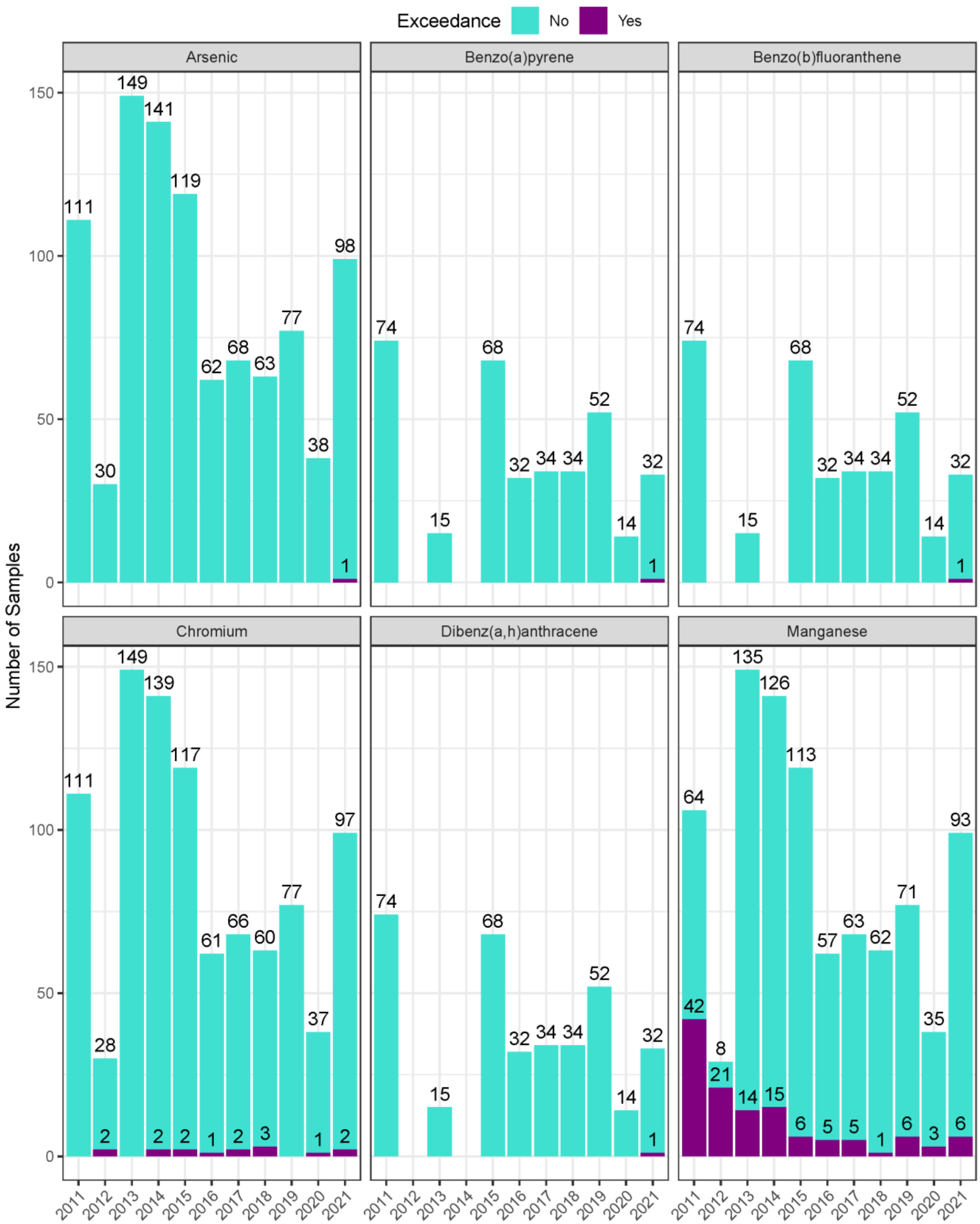


Figure 6-6. Numbers of sediment samples collected and numbers of samples exceeding screening levels each year for 2011 through 2021 for the six chemicals that exceeded screening levels in sediment in 2021.

Table 6-2. 2021 Storm Water and Base Flow Results for Inorganic Chemicals

Location Description	Stream Gage Number	Total Aluminum*			Dissolved Copper			Dissolved Lead			Dissolved Manganese			Total Mercury			Total Selenium			Dissolved Silver			Dissolved Zinc		
		Analyses**	Detects†	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance
Ancho at Rio Grande§	NA	1	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
Ancho below SR-4	E275	2	2	2	2	2	0	2	2	0	2	2	0	2	2	1	2	2	2	2	0	0	2	2	0
Between E252 and Water at Beta§	NA	1	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	1	0
CdB above SR-4	E229.3	3	3	3	3	3	0	3	3	0	3	3	0	3	2	0	3	3	3	3	0	0	3	3	0
Chaquehui at TA-33	E338	2	2	2	2	2	1	2	1	0	2	2	0	2	2	0	2	2	2	2	0	0	2	1	0
Chaquehui tributary at TA-33	E340	2	2	2	2	2	2	2	2	0	2	2	0	2	2	0	2	2	2	2	0	0	2	1	0
DP above Los Alamos Canyon	E040	1	1	1	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1	0	0	1	1	0
DP above TA-21	E038	2	2	2	2	2	0	2	1	0	2	2	0	2	1	0	2	1	0	2	0	0	2	2	0
DP below grade ctrl structure	E039.1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	0	1	0	0	1	0	0	1	1	0
E059.5 Pueblo below LAC WWTF	E059.5	2	2	0	2	2	0	2	0	0	2	2	0	2	0	0	2	0	0	2	0	0	2	2	0
Fence below Meenie	E267.5	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	0
Los Alamos below low-head weir	E050.1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	0	1	0	0	1	0	0	1	1	0
Mortandad below Effluent Canyon	E200	5	5	5	5	5	5	5	2	0	5	5	0	5	1	0	5	1	0	5	0	0	5	5	1
Paj BLW S-N Anch E Basin confluence§	NA	1	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
Pajarito above SR-4	E250	2	2	2	2	2	2	2	2	0	2	2	0	2	1	0	2	2	1	2	0	0	2	2	1
Pajarito at Rio Grande§	NA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
Potrillo above SR-4	E267	2	2	2	2	2	0	2	0	0	2	2	0	2	2	0	2	2	2	2	0	0	2	1	0

Location Description	Stream Gage Number	Total Aluminum*			Dissolved Copper			Dissolved Lead			Dissolved Manganese			Total Mercury			Total Selenium			Dissolved Silver			Dissolved Zinc		
		Analyses**	Detects†	Exceedance‡	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance	Analyses	Detects	Exceedance
Pueblo below GCS	E060.1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	0	1	1	0
Rio Grande at Frijoles§	NA	1	1	1	1	0	0	1	0	0	1	1	0	1	0	0	1	0	0	1	0	0	1	0	0
Rio Grande at Otowi Bridge§	NA	2	2	1	2	0	0	2	0	0	2	2	0	2	0	0	2	0	0	2	0	0	2	0	0
Sandia below Wetlands§	E123	5	2	0	5	0	0	5	0	0	5	5	0	5	0	0	5	0	0	5	0	0	5	4	0
Sandia below Wetlands	E123	4	4	3	4	4	4	4	2	0	4	4	0	4	4	0	4	0	0	4	0	0	4	4	0
Sandia left fork at Asph Plant	E122	5	5	4	5	5	4	5	4	2	5	5	0	5	0	0	5	0	0	5	0	0	5	5	4
Sandia right fork at Pwr Plant§	E121	5	1	0	5	2	0	5	0	0	5	5	0	5	0	0	5	0	0	5	0	0	5	5	0
Sandia right fork at Pwr Plant	E121	5	5	5	5	5	5	5	1	1	5	5	0	5	3	0	5	1	0	5	0	0	5	5	5
South Fork of Sandia at E122§	E122	4	3	0	4	4	0	4	0	0	4	4	0	4	0	0	4	0	0	4	0	0	4	4	0
Starmers above Pajarito	E242	2	2	1	2	2	0	2	1	1	2	2	0	2	0	0	2	1	0	2	1	1	2	2	0
Water below SR-4‖	E265	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Unfiltered aluminum is used for base flow samples and aluminum filtered to 10 µm is used for storm water samples.

**Analyses are the number of samples analyzed for that constituent.

†Detects are the number of samples in which that constituent was detected.

‡Exceedances are the number of results that were detected above the screening level.

§Indicates base flow sampling locations; all other locations are storm flow sampling locations (note some locations have both storm flow and base flow samples).

‖ A sample was collected but was not analyzed for any of the chemicals shown (analysis suites are based on site history).

Gray highlighting indicates that a chemical exceeded its screening level in at least one sample from a given location.

Table 6-3. 2021 Storm Water and Base Flow Results for Organic Chemicals and Radionuclides

Location Description	Stream Gage Number	Benzo(a)anthracene			Benzo(b)fluoranthene			Benzo(k)fluoranthene			Chrysene			Dibenz(a,h)anthracene			Dioxins**			Gross alpha			Radium-226 and Radium-228			Total PCB		
		Analyses*	Detects†	Exceedances‡	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances
Ancho at Rio Grande[§ ǁ]	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ancho below SR-4	E275	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2	2	0	0	0	2	2	2
Between E252 and Water at Beta[§ ǁ]	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CdB above SR-4	E229.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3	3	3	0	0	0	3	1	0
Chaquehui at TA-33	E338	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2	2	0	0	0	2	2	2
Chaquehui tributary at TA-33	E340	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2	2	0	0	0	2	2	2
DP above Los Alamos Canyon	E040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	1	1	1
DP above TA-21	E038	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	0	0	0	0	2	2	2
DP below grade control structure	E039.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1
E059.5 Pueblo below LAC WWTF	E059.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0
Fence below Meenie	E267.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	1	1	1
Los Alamos below low-head weir	E050.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Mortandad below Effluent Canyon	E200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	0	5	5	2	0	0	0	6	6	6
Pajarito below S-N Ancho E Basin conf[§ ǁ]	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pajarito above SR-4	E250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	2	2	2	0	0	0	2	2	2
Pajarito at Rio Grande[§ ǁ]	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potrillo above SR-4	E267	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	2	0	0

Location Description	Stream Gage Number	Benzo(a)anthracene			Benzo(b)fluoranthene			Benzo(k)fluoranthene			Chrysene			Dibenz(a,h)anthracene			Dioxins**			Gross alpha			Radium-226 and Radium-228			Total PCB		
		Analyses*	Detects†	Exceedances‡	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances
Pueblo below GCS	E060.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1
Rio Grande at Frijoles[§ ‖]	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Grande at Otowi Bridge[§]	NA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	1	1	1	0	0	1	0	0	1	0	0
Sandia below Wetlands[§]	E123	4	1	1	4	0	0	4	0	0	4	0	0	4	0	0	4	4	0	1	0	0	1	1	0	5	4	4
Sandia below Wetlands	E123	4	1	1	4	1	1	4	1	1	4	1	1	4	0	0	4	4	4	4	1	0	0	0	0	4	4	4
Sandia left fork at Asph Plant	E122	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	4	4	4	5	2	0	0	0	0	5	5	5
Sandia right fork at Pwr Plant[§]	E121	4	1	0	4	1	0	4	1	0	4	1	0	4	1	0	4	4	0	1	0	0	1	0	0	5	4	4
Sandia right fork at Pwr Plant	E121	4	1	1	4	1	1	4	1	1	4	1	1	4	1	1	4	4	4	5	3	0	0	0	0	4	4	4
South Fork of Sandia at E122[§]	E122	4	1	0	4	1	0	4	1	0	4	1	0	4	1	0	4	4	0	0	0	0	0	0	0	4	4	3
Starmers above Pajarito	E242	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	1	1	0	0	0	2	1	0
Water below SR-4[‖]	E265	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Analyses are the number of samples analyzed for that constituent.

†Detects are the number of samples in which that constituent was detected.

‡Exceedances are the number of results that were detected above the screening level.

§Indicates base flow sampling locations; all other locations are storm flow sampling locations (note some locations have both storm flow and base flow samples).

‖ A sample was collected but was not analyzed for any of the chemicals shown (analysis suites are based on site history).

**The dioxin criteria apply to the sum of the dioxin toxicity equivalents expressed as tetrachlorodibenzo-p-dioxin(2,3,7,8-).

Gray highlighting indicates that a chemical exceeded its screening level in at least one sample from a given location.

Table 6-4. 2021 Sediment Locations Where Sample Result Exceeded at Least One Screening Level

Canyon	Stream Reach	Location ID	Chemical	Result (mg/kg)	Residential Soil Cancer Screening Level (mg/kg)	Residential Soil Non-cancer Screening Level (mg/kg)	Industrial Soil Cancer Screening Level (mg/kg)	Industrial Soil Non-cancer Screening Level (mg/kg)	Construction Worker Soil Cancer Screening Level (mg/kg)	Construction Worker Soil Non-cancer Screening Level (mg/kg)
Los Alamos	LA-3FE	LA-61620	Manganese	508	—*	10548	—	160183	—	464
Pajarito	PA-4	PA-61562	Manganese	875	—	10548	—	160183	—	464
		PA-61563	Arsenic	11.5	7.07	13	36	208	216	41
			Manganese	2290	—	10548	—	160183	—	464
Sandia	S-2	SA-61643	Chromium	232	97	45183	505	313931	468	134
			Benzo(b)fluoranthene	2.58	1.53	—	32	—	240	—
			Benzo(a)pyrene	2.03	1.12	17	24	251	173	15
			Dibenz(a,h)anthracene	0.29	0.15	—	3.23	—	24	—
		SA-61653	Chromium	369	97	45183	505	313931	468	134
			Manganese	654	—	10548	—	160183	—	464
Two-Mile	TW-4E	TW-61511	Manganese	602	—	10548	—	160183	—	464
White Rock	RG BLW LA	WR-61549	Manganese	467	—	10548	—	160183	—	464

*A dash (—) indicates that there is not a screening level for a given chemical.

Gray highlighting indicates a particular soil screening level exceeded by a given chemical. The units mg/kg = milligram per kilogram.

Table 6-5 summarizes surface water exceedances in 2021 by providing the total number of exceedances per chemical or radioactive constituent and the percent of all locations analyzed for that chemical or radioactive constituent with an exceedance. Exceedances are categorized by applicable New Mexico water quality standards.

Table 6-5. Number of Locations (Percent of Locations Analyzed) Where New Mexico Water Quality Standards Were Exceeded for Storm Water and Base Flow Results in 2021 for Chemicals or Radioactive Constituents with at Least One Exceedance

Chemical or Radioactive Constituent	Livestock Watering	Wildlife Habitat	Acute Aquatic Life	Chronic Aquatic Life	Human Health-Organism Only
Total Aluminum	—‡	—	16 (67%)	7 (29%)	—
Dissolved Copper	0	—	9 (38%)	3 (13%)	—
Dissolved Lead	0	—	1 (4%)	3 (13%)	—
Dissolved Manganese	—	—	1 (4%)	0	—
Total Mercury	0	3 (13%)	—	—	—
Total Selenium	—	8 (33%)	4 (17%)	1 (4%)	—
Dissolved Silver	—	—	1 (4%)	—	—
Dissolved Zinc	0	—	4 (17%)	2 (8%)	0
Gross alpha	12 (63%)	—	—	—	—
Radium-226 and Radium-228	1 (20%)	—	—	—	—
Total PCB	—	8 (42%)	1 (5%)	4 (21%)	14 (74%)
Dioxin*	—	—	—	—	8 (47%)
Benzo(a)anthracene	—	—	—	—	2 (50%)
Benzo(b)fluoranthene	—	—	—	—	2 (50%)
Benzo(k)fluoranthene	—	—	—	—	2 (50%)
Chrysene	—	—	—	—	2 (50%)
Dibenzo(a,h)anthracene	—	—	—	—	1 (25%)

‡A dash indicates there is no standard for this chemical or radionuclide in this category.

*The dioxin criteria apply to the sum of the dioxin toxicity equivalents expressed as tetrachlorodibenzo-p-dioxin(2,3,7,8-).

Note: The percentage in parentheses represents the percentage of locations that have an exceedance for that analyte.

Discussion and Trends

Storm water and base flow results from 2021 fall within the ranges observed between 2011 and 2020. Sediment data are compared with soil screening levels to determine if the following conceptual model is still accurate: the process of sediment transport by storm water runoff observed in Laboratory canyons generally results in the same or lower levels of LANL-released substances in new sediment deposits than previously existed in a given reach. Through the monitoring program, the Laboratory is able to track the movement and concentration of contaminants over time and take appropriate action to mitigate or slow transport where needed. The comparison of 2021 and historic data with soil screening levels verify this conceptual model and support the idea that the risk assessments presented in the canyons' investigation reports (LANL 2004, 2005, 2006, 2009a, 2009b, 2009c, 2009d, 2011a, 2011b, 2011c) represent an upper bound of potential human health risks in the canyons.

The following sections discuss the chemical and radionuclide results, broken out by whether they are related to background sources (either natural or human-derived) or specifically related to Laboratory operations. Figure 6-7 through Figure 6-18 show the results for chemicals from background or Laboratory sources that exceeded screening levels more than once at a particular location in 2021. In figures showing data from water samples, the colored circles in the top panel show the locations of surface water samples collected at stream gaging stations, sediment detention basins, base flow sampling locations, and Individual Permit site monitoring areas. The color of a circle corresponds to the percentile in which the maximum concentration of samples collected at that location fall relative to the maximum concentrations at other sample locations in the same watershed. The maximum concentrations and the percentiles were calculated from data collected from 2011 through 2021. The percentiles were calculated from a dataset of maximum concentrations of the constituent at each sampled location in the watershed. The range in concentrations represented by each percentile is provided at the top of the figure. The plots in the bottom panel(s) show all results in the watershed for the constituent of interest for each year, with different colors for Individual Permit samples and stream gaging station samples.

Constituents Related to Background Sources

Some chemicals and radionuclides may come from both naturally occurring sources and human-derived sources. Chemicals that are mainly or completely naturally occurring are discussed below.

Aluminum: Storm water samples collected on the Pajarito Plateau in 2021 commonly contained aluminum concentrations above New Mexico water quality standards. However, most or all of this aluminum is likely naturally occurring (Reneau et al. 2010, Ryan et al. 2019). Aluminum is a natural component of soil and Bandelier Tuff, and it is not known to be derived from Laboratory operations in any significant quantity. In 2021, total aluminum concentrations in storm water exceeded the acute aquatic life standard at 16 sampling locations (67% of locations) and the chronic aquatic life standard at 7 sampling locations (29% of locations). There were five exceedances of the target action level for dissolved aluminum concentrations in 17 Individual Permit–related runoff samples collected in 2021 that were analyzed for aluminum. Fourteen of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for aluminum in Table 6-1. However, the New Mexico Environment Department Surface Water Quality Bureau has stated that “the large number of exceedances” for aluminum in surface water on the Pajarito Plateau “may reflect natural sources associated with the geology of the region,” and that aluminum also exceeds 658 micrograms per liter (the acute aquatic life standard for a hardness of 30 mg $CaCO_3$/L) in other parts of the Jemez Mountains area (New Mexico Environment Department 2009).

In 2021, no sediment samples exceeded soil screening levels for aluminum.

Arsenic: Arsenic has both natural and human-derived sources. Coal-fired power plants emit gaseous arsenic. While the Four Corners Generating Station coal-fired power plant has contributed to arsenic contamination, the Laboratory also operated coal-fired power plants historically. Arsenic is also found naturally in the local volcanic rocks. In 2021, none of the filtered gaging station storm water or base flow results exceeded the surface water quality standards for arsenic. The 12 Individual Permit–related samples from 2021 that were analyzed for arsenic did not exceed the target action level. None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for arsenic, as listed in Table 6-1.

In 2021, one sediment sample from Pajarito Canyon exceeded soil screening levels for arsenic.

Copper: Copper is naturally occurring, and it is also associated with explosives firing sites, forest fires, and developed areas, such as buildings and parking lots. Copper sources in developed landscapes include brake pad abrasion and building materials, such as flashing, plumbing pipes, and electrical components (TDC Environmental 2004, Göbel et al. 2007). In 2021, copper concentrations in filtered storm water and base flow samples were detected above the acute aquatic life standard at nine sampling locations (38% of locations) and above the chronic aquatic life standard at three sampling locations (13% of locations).

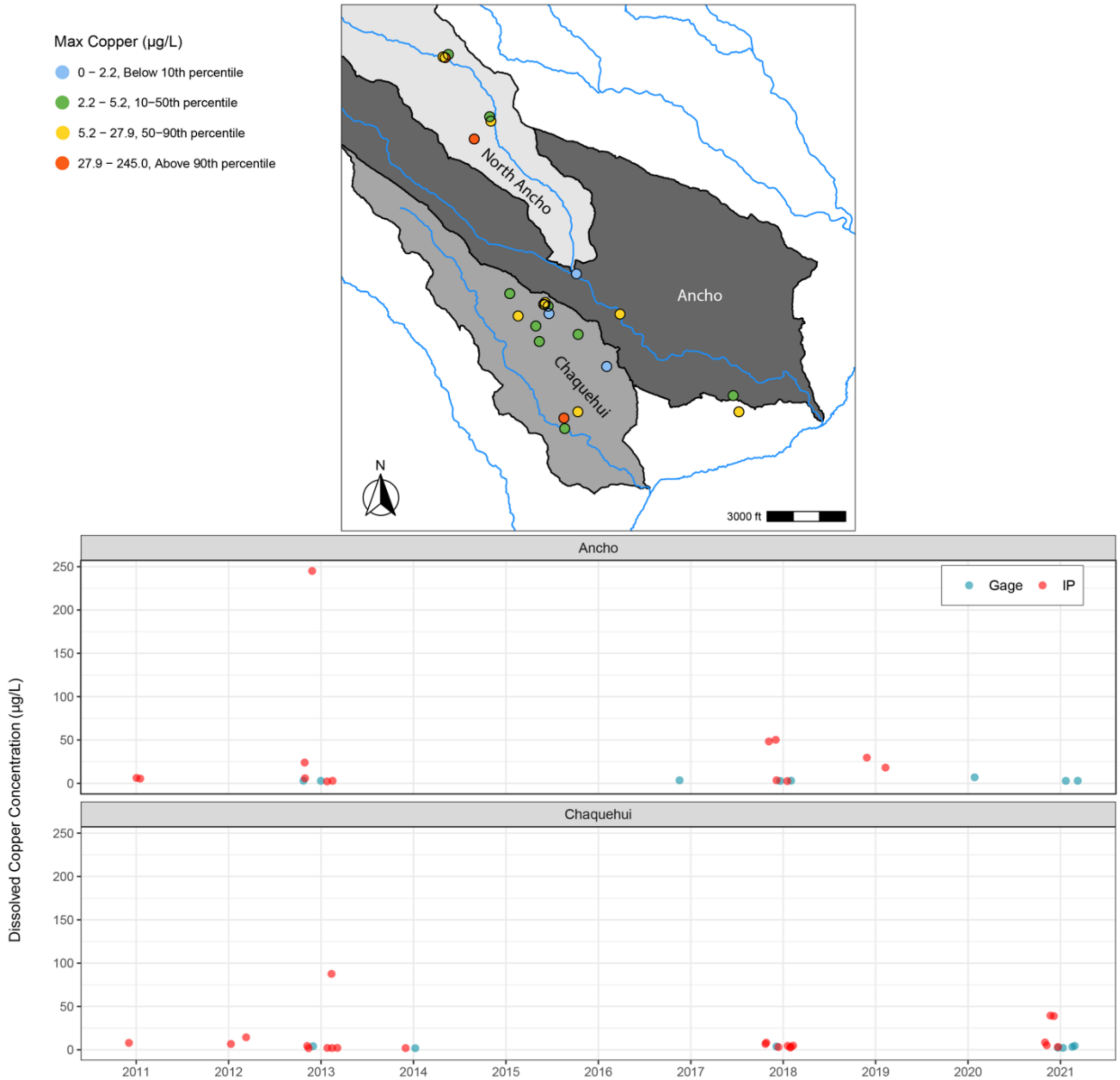
Historically, every watershed across the Laboratory has recorded elevated copper concentrations in storm water at some time, including all of the Laboratory's upstream boundary gaging stations. Thirteen of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for copper (see Table 6-1). In 2021, 17 out of 20 Individual Permit–related runoff samples that were analyzed for copper exceeded the target action level. Figure 6-7, Figure 6-8, and Figure 6-9 show copper concentrations in filtered storm water and base flow for the Ancho and Chaquehui canyons watershed, the Pajarito canyon watershed, and the Sandia and Mortandad canyons watershed, respectively. Concentrations measured in 2021 were similar to those measured in previous years.

In 2021, no sediment samples exceeded soil screening levels for copper.

Lead: Lead is associated with developed areas, such as buildings and parking lots (Göbel et al. 2007). The major lead sources in developed landscapes are lead-based paints, building sidings, and the operation of automobiles (Davis and Burns 1999). Lead concentrations in filtered storm water and base flow in 2021 were detected above the acute aquatic life standard at one sampling location (4% of locations) and above the chronic aquatic life standard at three sampling locations (13% of locations). None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for lead, as shown in Table 6-1. In 2021, 1 out of 13 Individual Permit–related runoff samples that were analyzed for lead exceeded the target action level. Figure 6-10 shows lead concentrations in filtered storm water and base flow for the Sandia and Mortandad canyons watershed, which was the only area with more than one lead exceedance at a single sampling location.

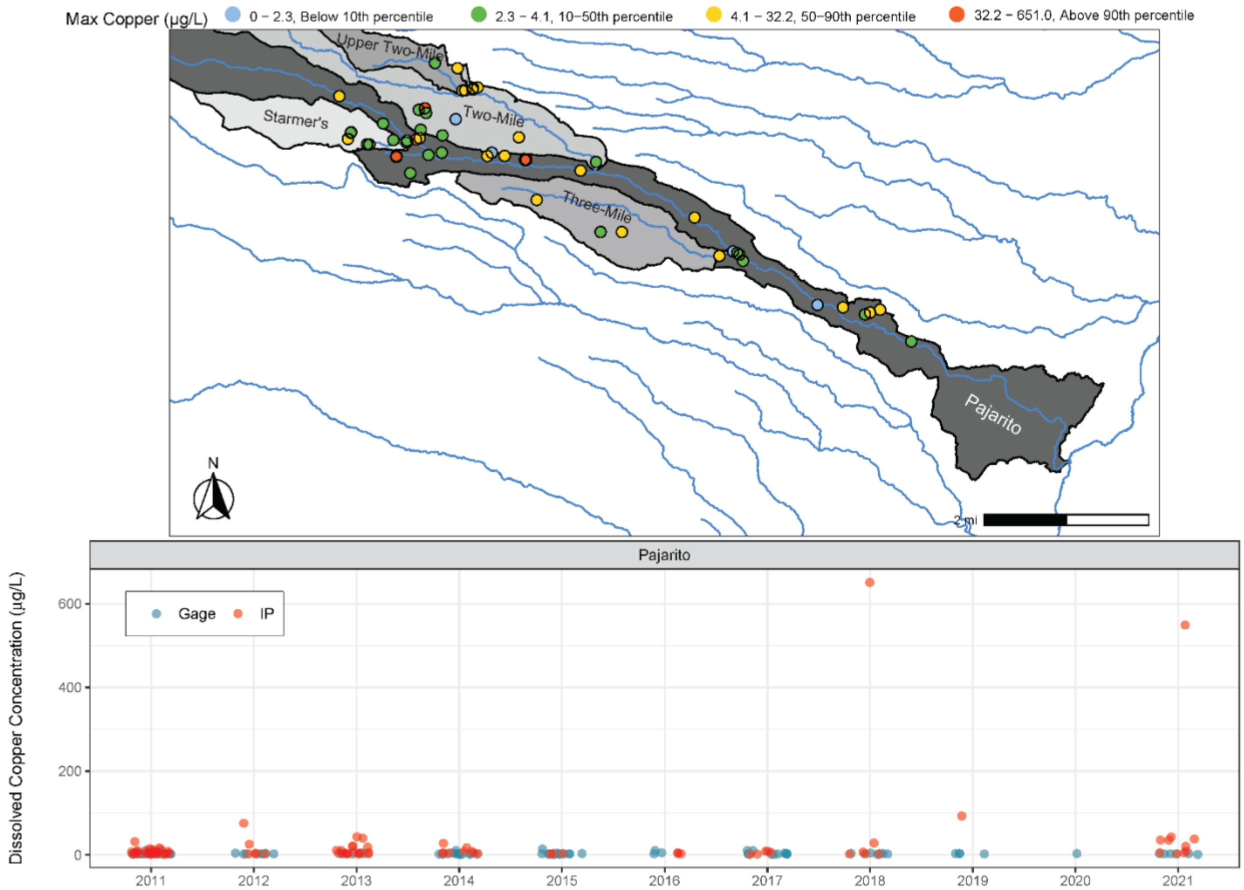
In 2021, no sediment samples exceeded soil screening levels for lead.

Manganese: Manganese is naturally occurring on the Pajarito Plateau. Laboratory operations have not generated or released significant quantities of manganese. Dissolved manganese concentrations were elevated following the Cerro Grande fire and then decreased quickly in subsequent years (Gallaher and Koch 2004, 2005). Manganese concentrations in filtered storm water and base flow in 2021 were detected above the acute aquatic life standard at one sampling location (4% of locations). None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for manganese, as shown in Table 6-1.



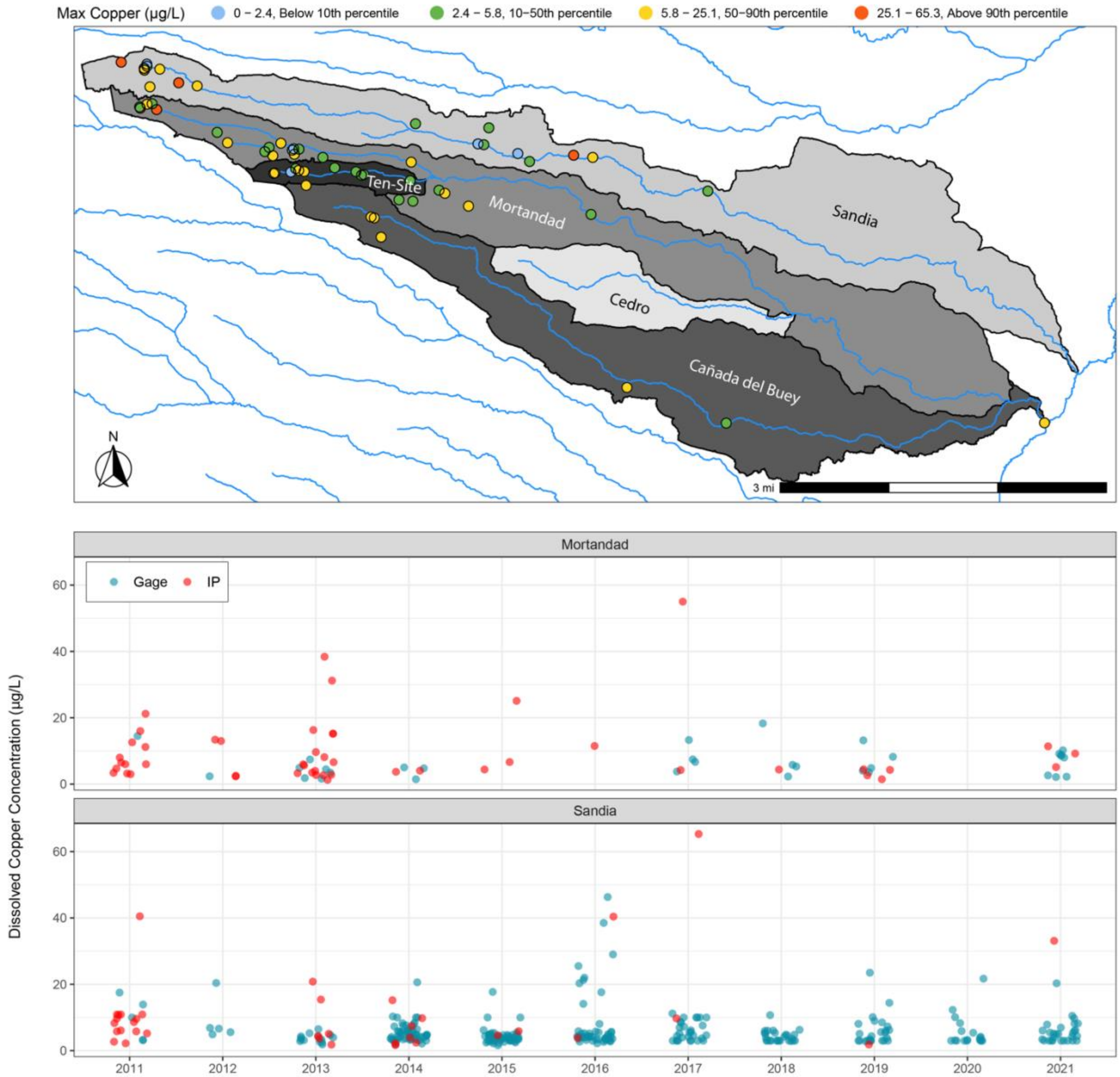
Note: µg/L = microgram per liter.

Figure 6-7. Ancho and Chaquehui canyons watershed copper concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water copper values for each sampling location from 2011 to 2021. Bottom panels: dissolved copper concentrations from Individual Permit and gage station samples from 2011 to 2021.



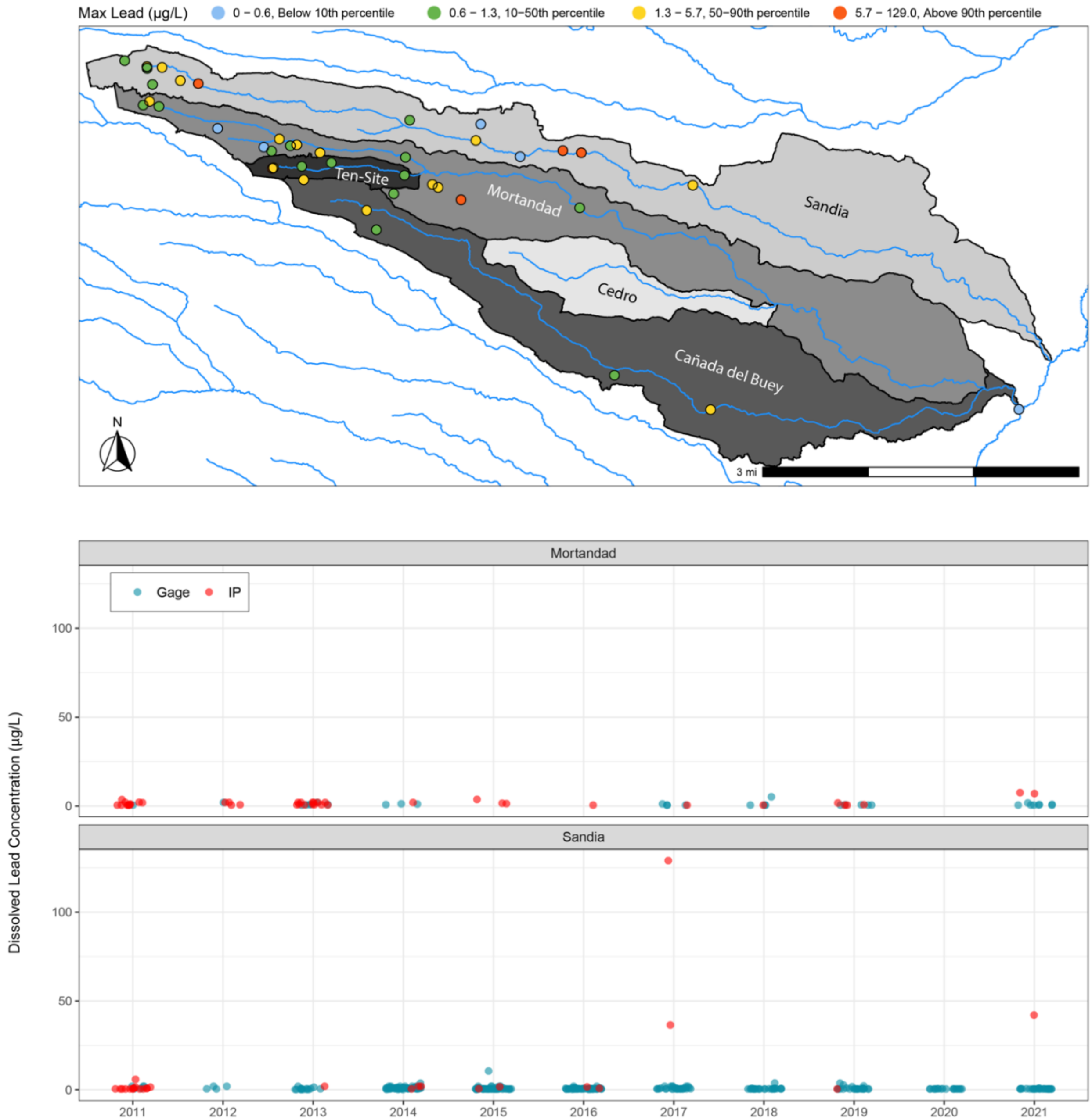
Note: µg/L = microgram per liter.

Figure 6-8. Pajarito canyon watershed copper concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water copper values for each sampling location from 2011 to 2021. Bottom panels: dissolved copper concentrations from Individual Permit and gage station samples from 2011 to 2021.



Note: µg/L = microgram per liter.

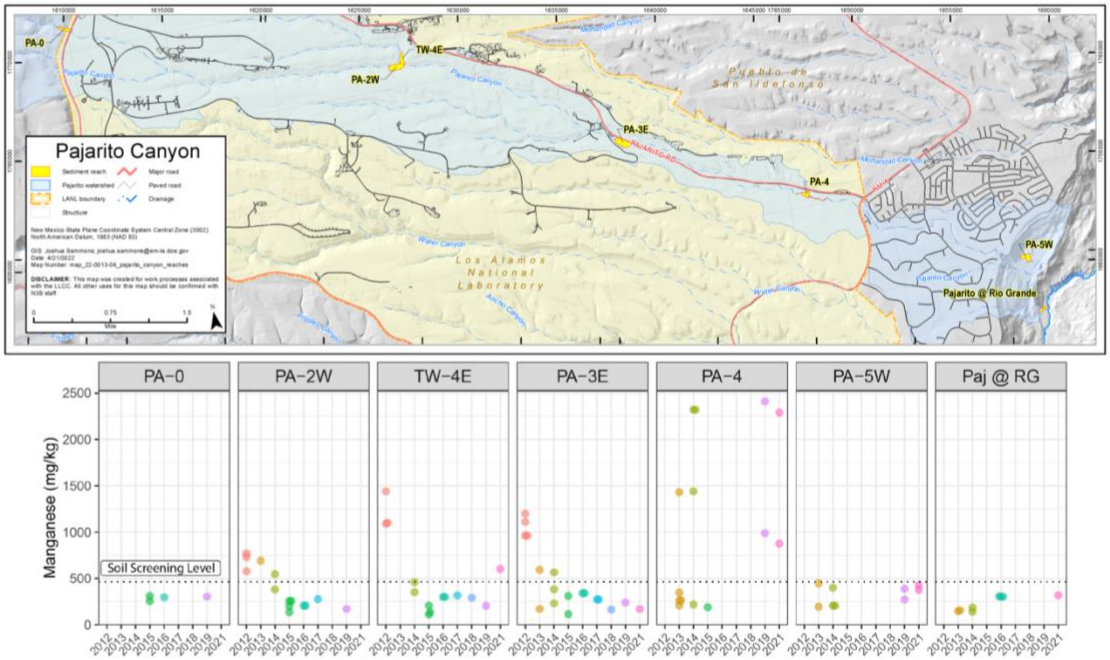
Figure 6-9. Sandia and Mortandad canyons watershed copper concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water copper values for each sampling location from 2011 to 2021. Bottom panels: dissolved copper concentrations from Individual Permit and gage station samples from 2011 to 2021.



Note: µg/L = microgram per liter.

Figure 6-10. Sandia and Mortandad canyons watershed lead concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water lead values for each sampling location from 2011 to 2021. Bottom panels: dissolved lead concentrations from Individual Permit and gage station samples from 2011 to 2021.

In 2021, manganese concentrations in sediment exceeded the construction worker non-cancer soil screening level in six samples. Two or more of these exceedances occurred in sediment samples from Pajarito Canyon and are shown in Figure 6-11.



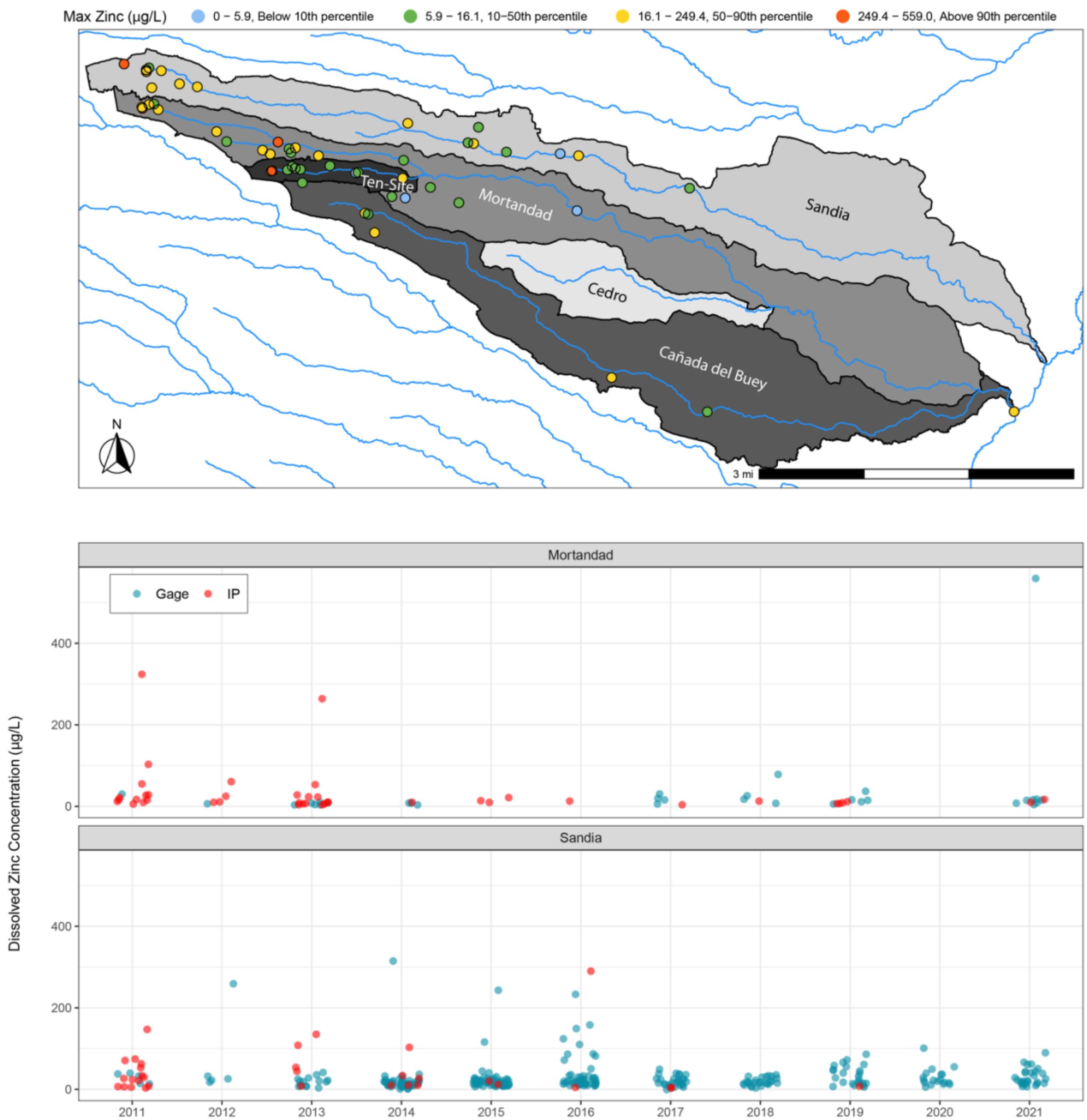
Note: mg/kg = milligram per kilogram.

Figure 6-11. Manganese concentrations in sediment samples in Pajarito Canyon from 2012 to 2021. The Construction Worker Non-Cancer Soil Screening Level for manganese is 464 mg/kg. The locations of reaches are shown in the top panel. Two-Mile Canyon (reach TW-4E) flows into Pajarito Canyon.

Selenium: Selenium is naturally occurring on the Pajarito Plateau. Laboratory operations have not generated or released significant quantities of selenium. Total selenium concentrations were elevated following the Cerro Grande fire and then decreased quickly in subsequent years (Gallaher and Koch 2004, 2005). In 2021, total selenium concentrations in storm water and base flow were detected above the wildlife habitat standard at eight sampling locations (33% of locations), above the acute aquatic life standard at four sampling locations (17% of locations), and above the chronic aquatic life standard at one sampling location (4% of locations). Two of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for selenium in Table 6-1. In 2021, 2 out of 12 Individual Permit–related runoff samples that were analyzed for selenium exceeded the target action level.

In 2021, no sediment samples exceeded soil screening levels for selenium.

Zinc: While naturally occurring, zinc can also be associated with developed areas. Zinc sources include automobile tires, galvanized materials, motor oil, and hydraulic fluid (Rose et al. 2001, Councell et al. 2004, Washington State Department of Ecology 2006). In 2021, filtered zinc concentrations in storm water and base flow samples were detected above the acute aquatic life standard at four sampling locations (17% of locations) and above the chronic aquatic life standard at two sampling locations (8%). None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for zinc as shown in Table 6-1. Filtered zinc concentrations did not exceed the Individual Permit target action level in the 12 Individual Permit–related storm water samples collected in 2021 that were analyzed for zinc. Figure 6-12 shows zinc concentrations in filtered storm water and base flow for Sandia and Mortandad canyons. Zinc concentrations in 2021 were similar to those measured in 2020.



Note: µg/L = microgram per liter.

Figure 6-12. Sandia and Mortandad canyons watershed zinc concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water zinc values for each sampling location from 2011 to 2021. Bottom panels: dissolved zinc concentrations from Individual Permit and gage station samples from 2011 to 2021.

In 2021, no sediment samples exceeded soil screening levels for zinc.

Gross Alpha: The gross alpha activity is the sum of the radioactivity from alpha particle emissions from radioactive materials. Alpha particles are released by many naturally occurring radionuclides, such as isotopes of radium, thorium, and uranium, and their decay products. In 2021, 12 sampling locations (63% of locations) had gross alpha activities above the livestock watering standard. In 2011, 2012, and 2013, the highest gross alpha activities in storm water were measured in samples containing ash and sediment from the 2011 Las Conchas fire. Gross alpha activities were also particularly high in runoff samples from the large September 2013 flood event. For sampling under the Individual Permit in 2021, gross alpha activity was above the target action level in 20 out of 22 samples collected that were analyzed for gross alpha. Twenty-five of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for gross alpha radioactivity, as shown in Table 6-1. However, the analytical results from 2021 support earlier conclusions that the majority of the alpha radioactivity in storm water on the Pajarito Plateau is from the decay of naturally occurring isotopes in sediment and soil and that Laboratory impacts are relatively small (for example, see Gallaher 2007).

Sediment is not analyzed for gross alpha levels because sediment analysis is targeted to specific radionuclides of concern at a particular location.

Radium-226 and radium-228: In 2021, one sampling location (20% of locations) had radium-226 and radium-228 activity above the livestock watering standard. The 13 Individual Permit–related samples from 2021 that were analyzed for radium-226 and radium-228 did not exceed the target action level. One of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for radium, as shown in Table 6-1. The analytical results from 2021 support earlier conclusions that the majority of the radium-226 and radium-228 found in storm water on the Pajarito Plateau is from the decay of naturally occurring isotopes in sediment and soil (Gallaher 2007).

Constituents Related to Los Alamos National Laboratory Operations

Several constituents were measured in water and sediment that were known to be released during historical Laboratory operations. The nature and extent of the constituents in sediment are described in detail in the canyons' investigation reports referenced in the beginning of the Discussion and Trends section.

The following text describes the occurrences of key constituents in 2021 storm water, base flow, and sediment samples. Results for constituents that exceeded screening levels or standards more than once in 2021 at a particular sample location for storm water and base flow are shown in the figures associated with each chemical below.

Cadmium: Cadmium is associated with combustion of fossil fuel; industrial use such as refinement for nickel-cadmium batteries, metal plating, pigments, and plastics; and activities such as sewage sludge disposal and application of phosphate fertilizers (Agency for Toxic Substances and Disease Registry 2012). In 2021, there were no exceedances observed for filtered storm water samples or base flow samples. There were no exceedances of the target action level for filtered cadmium concentrations in the 12 Individual Permit–related runoff samples in 2021 that were analyzed for cadmium. None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for cadmium, see Table 6-1.

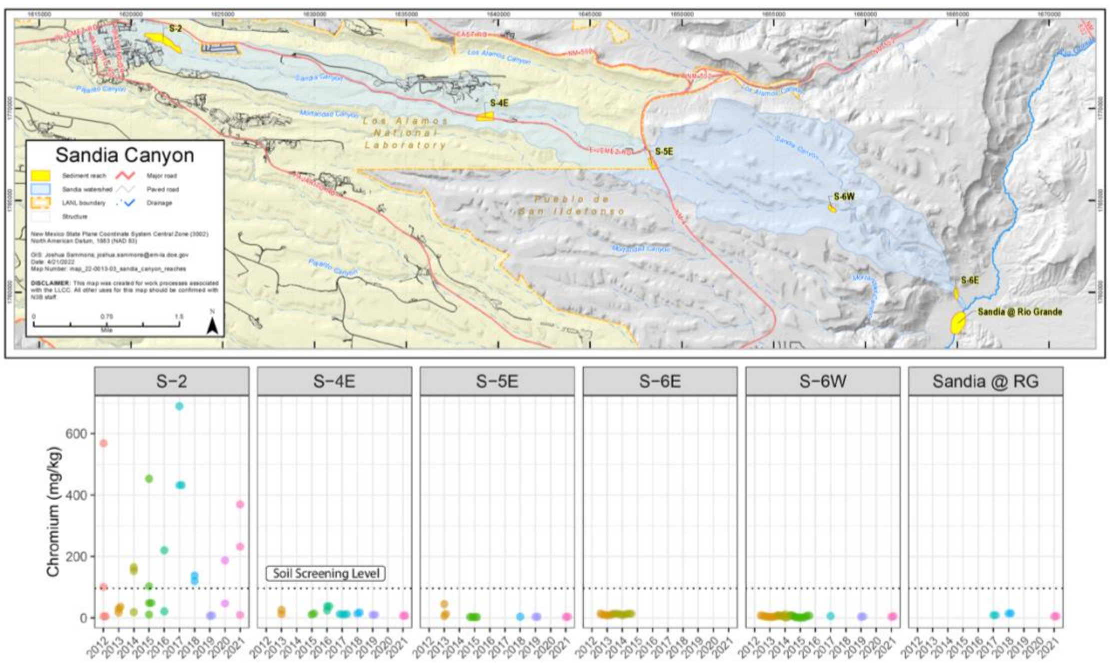
In 2021, no sediment results exceeded soil screening levels for cadmium.

Cesium-137*:* Cesium-137 is a radionuclide that is a byproduct of nuclear fission processes in nuclear reactors and nuclear weapons testing. In 2021, cesium-137 was detected in three gaging station storm water samples but did not exceed the DOE biota concentration guide concentration. Individual Permit–related storm water samples are not analyzed for radionuclides.

In 2021, cesium-137 activity in sediment samples did not exceed the screening action level.

Chromium*:* Chromium is associated with potassium dichromate that was used as a corrosion inhibitor in the cooling system at the Technical Area 3 power plant (LANL 1973) and was discharged through outfall 001 from 1956 to 1972. Filtered storm water and base flow results did not exceed surface water quality standards in 2021 for total chromium or chromium (VI). There were no exceedances of the target action levels for filtered chromium concentrations in the 12 Individual Permit–related runoff samples in 2021 that were analyzed for chromium. None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for chromium, see Table 6-1.

In 2021, two sediment samples exceeded both the residential cancer and the construction worker non-cancer soil screening levels for chromium. These samples were from Sandia Canyon, where chromium was known to have been released, and are shown in Figure 6-13.



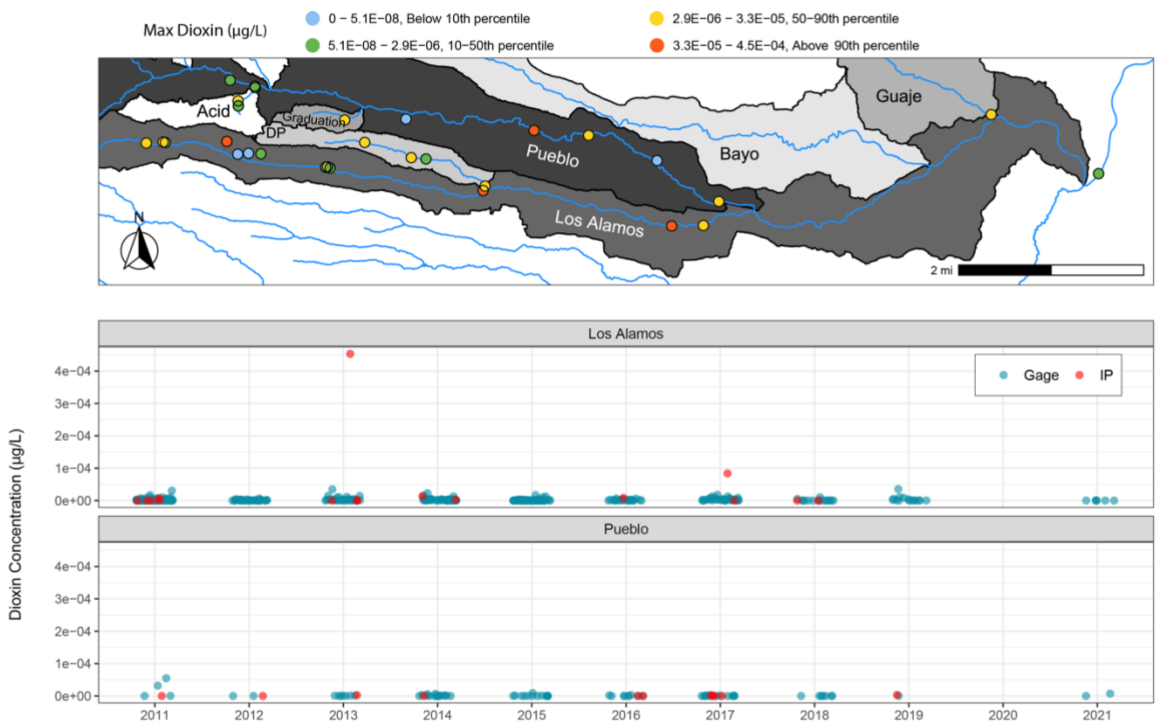
Note: mg/kg = milligram per kilogram.

Figure 6-13. Chromium concentrations in sediment samples in Sandia Canyon from 2012 to 2021. The Residential Cancer Soil Screening Level for chromium is 97 mg/kg. The locations of reaches are shown in the top panel.

Dioxins and Furans*:* Dioxins and furans are associated with the incineration of medical, industrial, municipal, and private wastes; municipal wastewater treatment sludge; coal-fired boilers; and diesel fuel emissions (U.S. Environmental Protection Agency 2006b). Forest fires are also a major, natural source of dioxins (Gullett and Touati 2003). Toxic equivalents are used to report the toxicity-weighted masses of mixtures of dioxins and furans. This is more meaningful than reporting the number of grams of dioxins or furans because toxic equivalents provide information on toxicity (U.S. Environmental Protection Agency 2010). In addition, there are surface water quality standards for a total dioxin toxic equivalent; whereas, there are no standards for individual dioxins or furans. In 2021, dioxin concentrations in storm water and base flow samples exceeded the human health–organism only standard at eight sampling locations (47% of locations). There were no Individual Permit–related samples analyzed for 2,3,7,8-tetrachlorodibenzodioxin (one of the more toxic compounds) in 2021. None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for dioxins or furans, see Table 6-1. Figure 6-14 shows dioxin concentrations in storm water and base flow for the Los Alamos and Pueblo canyons watershed, which was the only area with more than one dioxin exceedance at a single location.

What is the Human Health–Organism Only Surface Water Quality Standard?

This is one of the surface water quality standards used by the state of New Mexico to identify whether a water body or stream reach has adequate water quality for its designated use(s). The intent of this standard is to protect the health of humans who eat fish or other aquatic wildlife (such as crayfish) that live in a lake, river, or stream.



Note: µg/L = microgram per liter.

Figure 6-14. Los Alamos and Pueblo canyons watershed dioxin concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water dioxin values for each sampling location from 2011 to 2021. Bottom panels: dioxin concentrations from Individual Permit and gage station samples from 2011 to 2021.

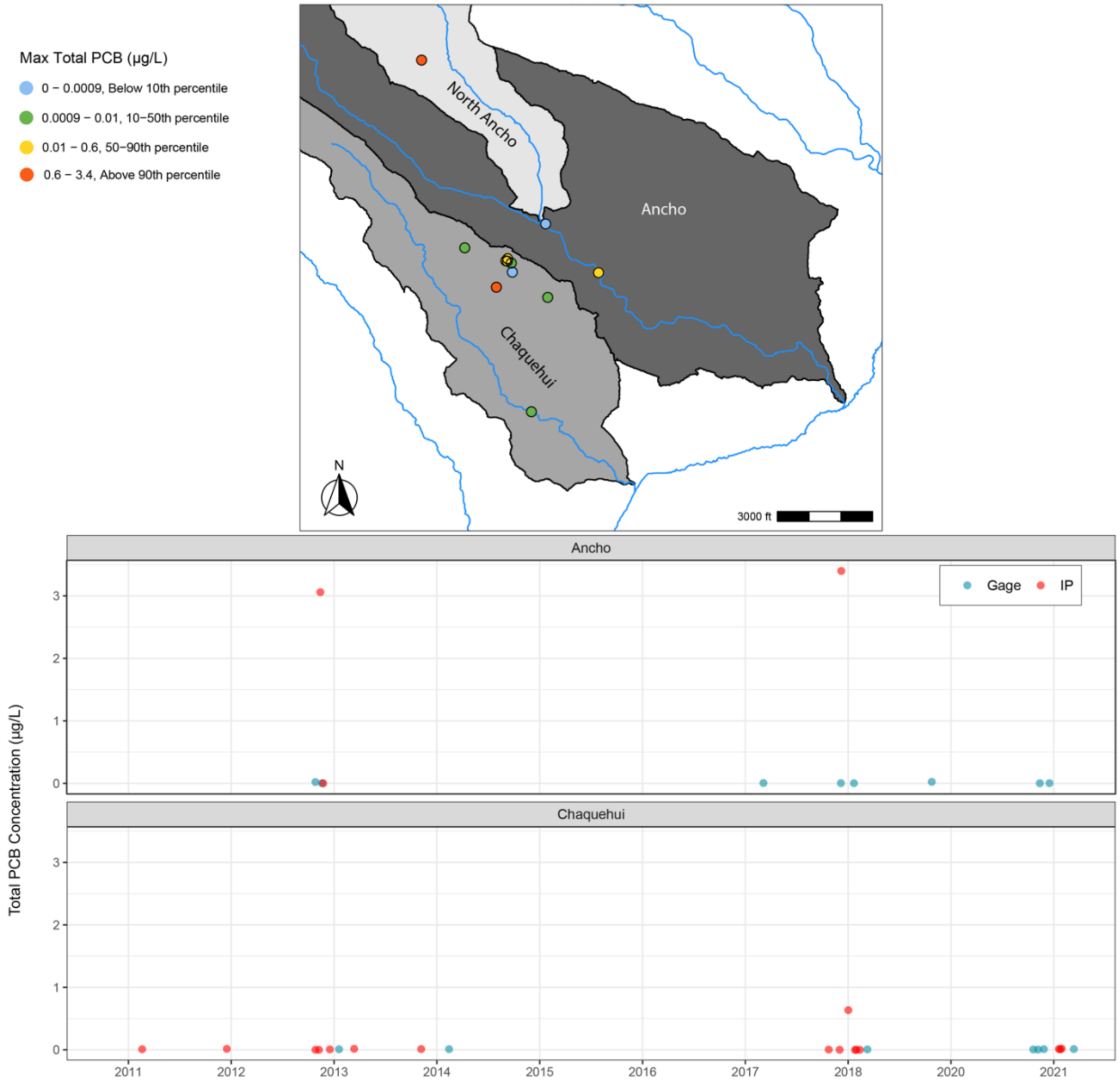
In 2021, no sediment samples exceeded soil screening levels for dioxins or furans.

Mercury: Natural sources of mercury include forest fires and fossil fuels such as coal and petroleum. Human activities such as mining and fossil fuel combustion have led to widespread global mercury pollution. While the Four Corners Generating Station coal-fired power plant has contributed to mercury contamination in the surrounding areas, the Laboratory also operated coal-fired power plants historically. In 2021, total mercury concentrations in storm water and base flow were detected above the wildlife habitat standard at three sampling locations (13% of locations). There were no exceedances of the target action levels for total mercury concentrations in the 12 Individual Permit–related runoff samples in 2021 that were analyzed for mercury. Seven of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for mercury, see Table 6-1.

In 2021, no sediment samples exceeded soil screening levels for mercury.

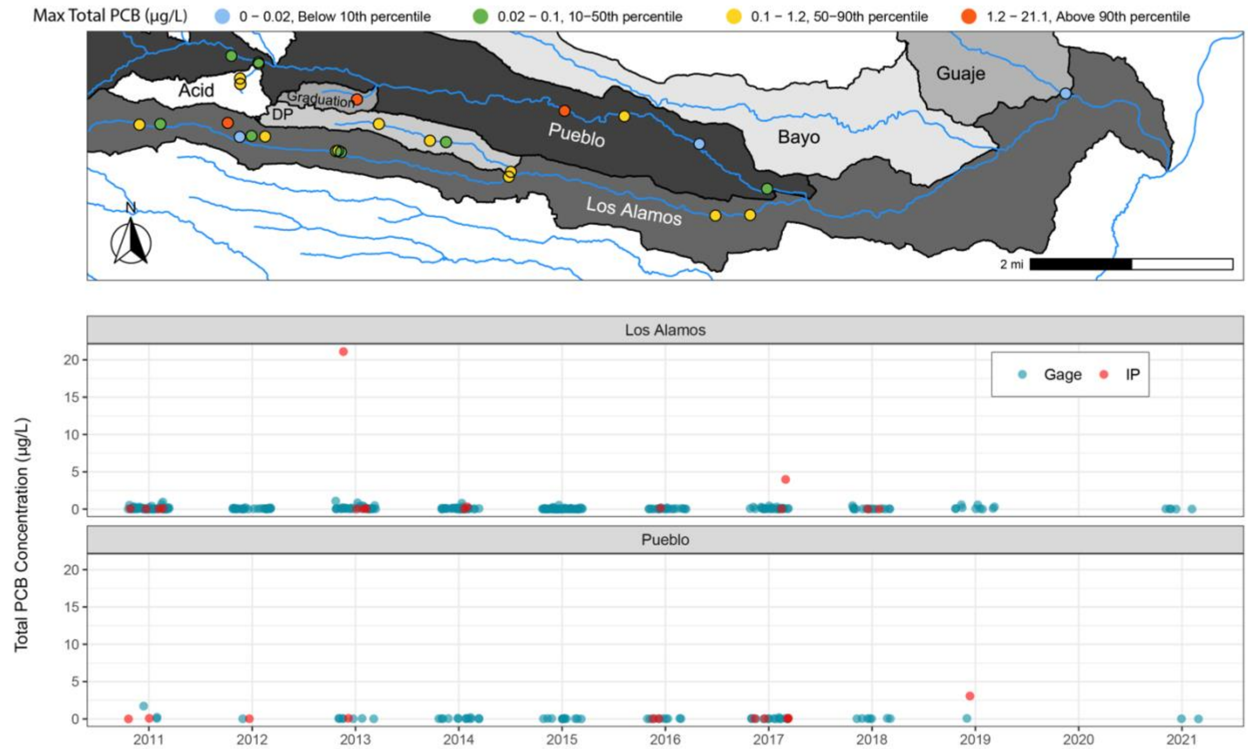
Polychlorinated biphenyls (PCBs): PCBs are stable, persistent organic compounds that break down slowly in the environment. They were commonly used as plastic and paint stabilizers and coolants in electrical appliances before they were banned in the United States in 1979. Many older construction materials used PCBs, including caulking, paints, window putty, and electrical components (Durell and Lizotte 1998, Kakareka and Kukharchyk 2006). As these building components weather and deteriorate, PCBs accumulate on the landscape and are redistributed. PCBs are remobilized and distributed throughout the globe, including through atmospheric deposition (Chevreuil et al. 1996, Duinker and Bouchertail 1989, Grainer et al. 1990, LANL 2012). PCBs are associated with materials used historically by the Laboratory, including transformers; oils, solvents, and paints used in industrial activities, and a former asphalt batch plant in Sandia Canyon.

In 2021, 14 sampling locations (74% of locations) had PCB concentrations above the human health–organism only standard, one sampling location (5% of locations) had concentrations above the acute aquatic life standard, four sampling locations (21% of locations) had concentrations above the chronic aquatic life standard, and eight sampling locations (42% of locations) had concentrations above the wildlife standard. For sampling under the Individual Permit in 2021, PCB concentrations were above the target action level in six out of seven samples collected that were analyzed for PCBs. Twenty-eight of the 39 assessment units on Laboratory or former Laboratory lands are listed as impaired for PCBs, see Table 6-1. Figure 6-15 through Figure 6-18 show total PCB concentrations in unfiltered storm water and base flow for the Ancho and Chaquehui canyons watershed, Los Alamos and Pueblo canyons watershed, Pajarito canyon watershed, and Sandia and Mortandad canyons watershed, respectively.



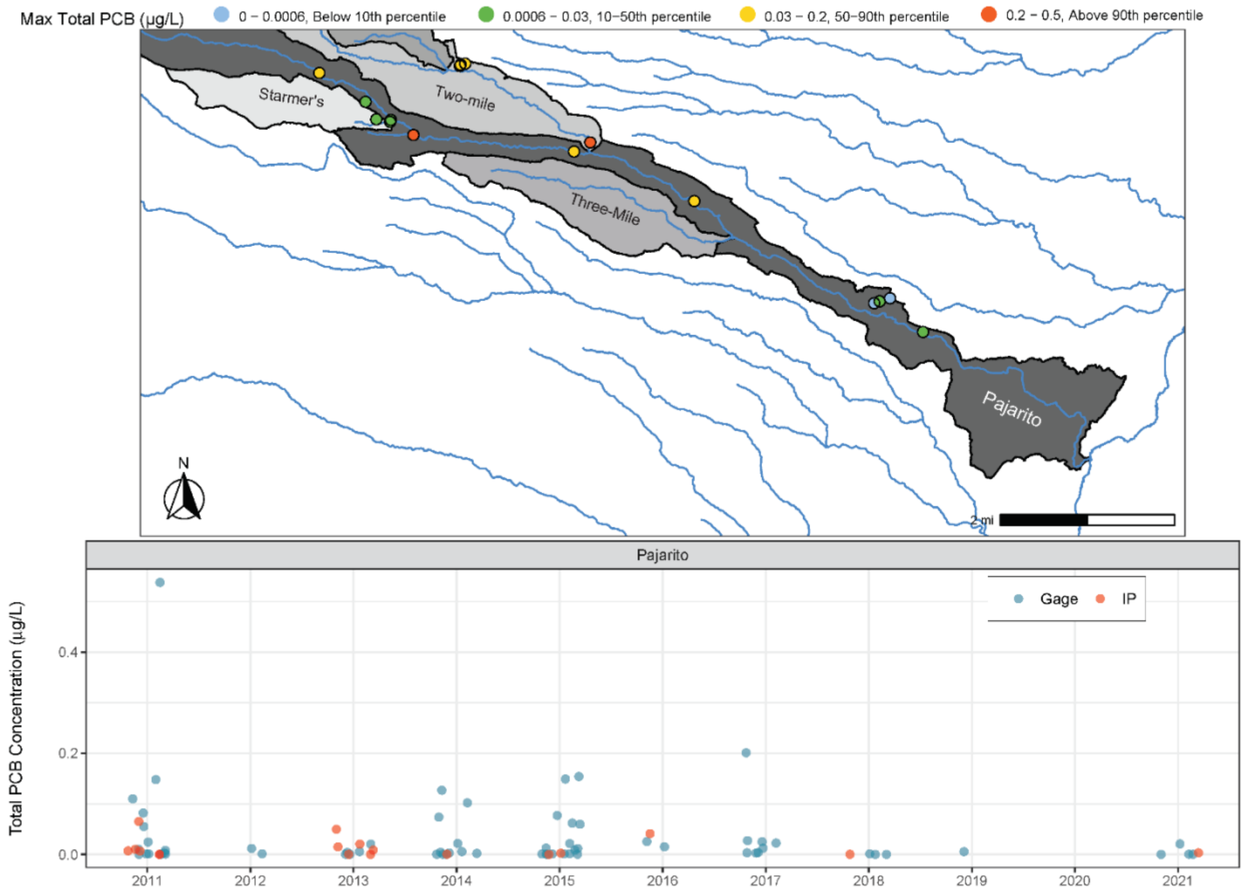
Note: µg/L = microgram per liter.

Figure 6-15. Ancho and Chaquehui canyons watershed total PCB concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2021. Bottom panels: total PCB concentrations from Individual Permit and gage station samples from 2011 to 2021.



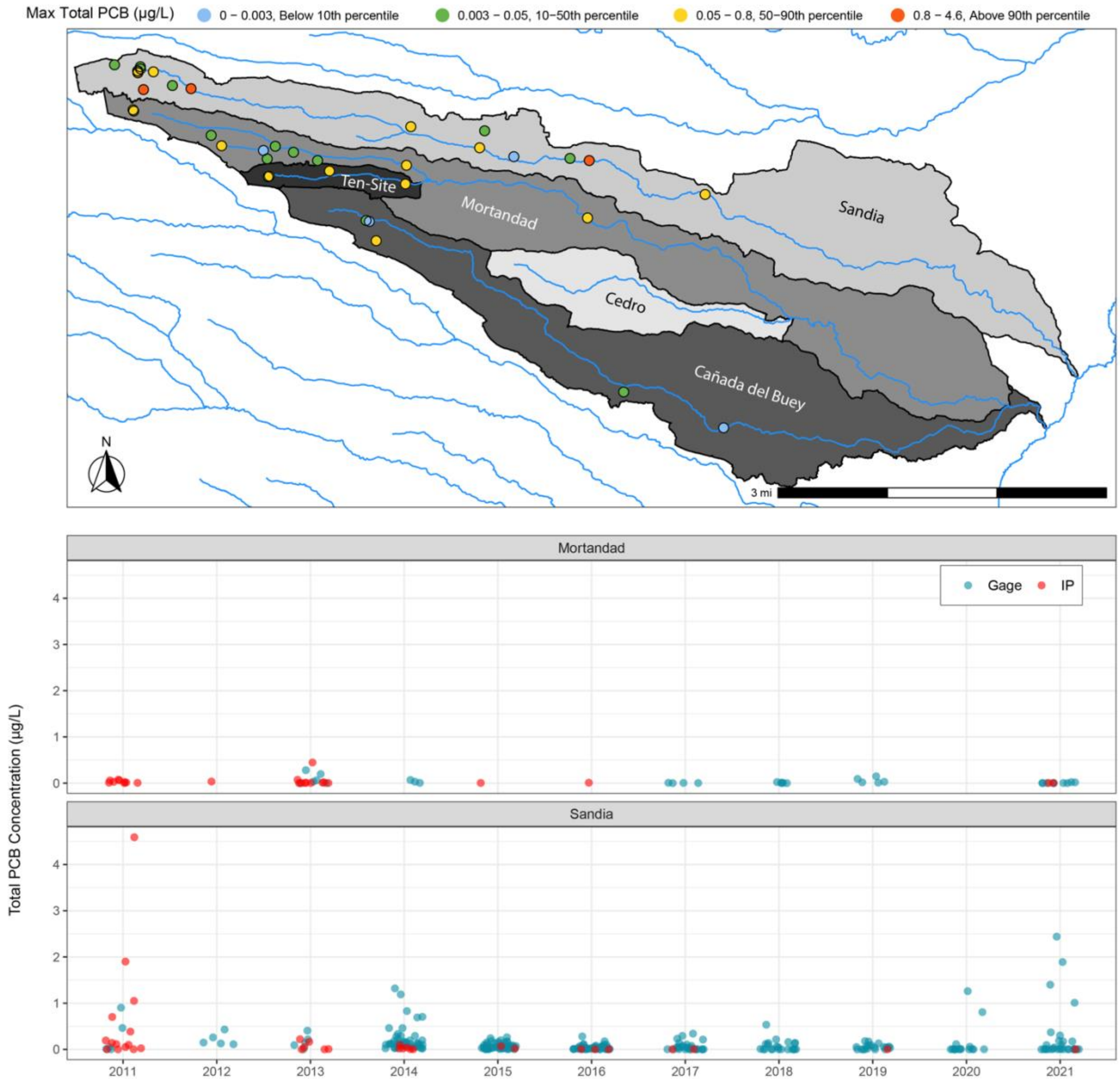
Note: µg/L = microgram per liter.

Figure 6-16. Los Alamos and Pueblo canyons watershed total PCB concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2021. Bottom panels: total PCB concentrations from Individual Permit and gage station samples from 2011 to 2021.



Note: µg/L = microgram per liter.

Figure 6-17. Pajarito canyon watershed total PCB concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2021. Bottom panels: total PCB concentrations from Individual Permit and gage station samples from 2011 to 2021.



Note: µg/L = microgram per liter.

Figure 6-18. Sandia and Mortandad canyons watershed total PCB concentrations in filtered storm water from Individual Permit samplers and gaging stations and base flow from 2011 to 2021. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2021. Bottom panels: total PCB concentrations from Individual Permit and gage station samples from 2011 to 2021.

In 2021, no sediment samples exceeded soil screening levels for PCBs.

Polycyclic Aromatic Hydrocarbons: Asphalt is prepared using petroleum products that contain polycyclic aromatic hydrocarbons, and operations at the former asphalt batch plant in Sandia Canyon released effluent from operations to the canyon. In 2021, two sampling locations (50% of locations) exceeded the human–health organism only standard for 4 of the 19 polycyclic aromatic hydrocarbons with water quality standards (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene). One of these two locations also exceeded the human–health organism only standard for dibenzo(a,h)anthracene. There were no Individual Permit–related exceedances of polycyclic aromatic hydrocarbons in 2021. None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for polycyclic aromatic hydrocarbons (see Table 6-1).

In 2021, one sediment sample from Sandia Canyon exceeded screening levels for three polycyclic aromatic hydrocarbons: benzo(b)fluoranthene, benzo(a)pyrene, and dibenz(a,h)anthracene.

Silver: Silver is associated with Laboratory activities in Pajarito Canyon and Cañon de Valle (LANL 2009a, LANL 2011c). In 2021, dissolved silver concentrations in storm water and base flow were detected above the acute aquatic life standard at one sampling location (4% of locations). For sampling under the Individual Permit in 2021, silver concentrations were above the target action level in 1 out of 13 samples collected that were analyzed for silver. One of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands is listed as impaired for silver (see Table 6-1).

In 2021, no sediment results exceeded soil screening levels for silver.

Thallium: Gaseous emissions from cement factories and coal-fired power plants have led to thallium pollution. While the Four Corners Generating Station coal-fired power plant has contributed to thallium contamination in the surrounding areas, the Laboratory also operated coal-fired power plants historically. In 2021, none of the filtered gaging station storm water or base flow results exceeded the surface water quality standards for thallium. There were no Individual Permit–related exceedances for thallium in 2021. None of the 39 assessment units, or stream reaches, on Laboratory or former Laboratory lands are listed as impaired for thallium (see Table 6-1).

In 2021, no sediment samples exceeded soil screening levels for thallium.

Watershed Protection Measures

In addition to monitoring surface water and sediment, the Laboratory has constructed engineered controls to prevent or minimize the migration of sediment and contaminants. Throughout the Laboratory surface water controls have been designed and installed by various programs in response to regulatory requirements, site conditions, post-fire flooding threats, and general best management practices. These institutional controls are an integral component of storm water management at LANL.

Please refer to the 2020 Annual Site Environmental Report Watershed Quality chapter for details on current controls managed by N3B. No new controls were installed by N3B in 2021.

In 2020 Triad initiated a project to locate and document historical institutional storm water controls. In 2021, Triad continued conducting field assessments by watershed. Information being collected for each storm water control includes photographs, location coordinates, type of control, functionality, preventive or corrective maintenance needs, and determination of continued need for the control. The results will assist Triad in the development of a tracking database and assessment and maintenance schedule. New storm water controls installed in association with construction, environmental remediation, decontamination and demolition, and other activities will be reviewed and incorporated into the database and schedule.

Summary: PFAS Monitoring Results

Investigative monitoring of per- and polyfluoroalkyl substances (PFAS) in storm water and sediment did not occur in 2021.

Conclusion

Overall Results

The results of the storm water, base flow, and sediment data comparisons from samples collected in 2021 verify the conceptual model that storm water–related sediment transport observed in Laboratory canyons generally results in lower concentrations of Laboratory-released chemicals in the new sediment deposits than previously existed in deposits in a given reach. The results also support the idea that the risk assessments presented in the canyons investigation reports represent an upper bound of potential human and ecological health risks in the canyons for the foreseeable future. Although some chemical concentrations in storm water, base flow, and sediment were above screening levels in 2021, these transient events do not significantly affect human or biota health.

The scatter plots in Figure 6-7 through Figure 6-18 show that the concentrations of chemicals exceeding screening levels in storm flow and base flow samples in 2021 fall within or below the ranges recorded in previous years. Total PCB concentrations in Sandia Canyon tended to be higher than in recent years, although still within range of what has been observed. This area will continue to be monitored closely to detect any upward trends.

We continue to observe very few sediment exceedances in 2021. These exceedances included arsenic, chromium, manganese, and polycyclic aromatic hydrocarbons. Sediment results will be tracked over multiple years and compared with nearby surface water results to detect spatial patterns or trends.

Through the human health risk assessments in the canyons' investigation reports, the biota dose assessment (Chapter 7), and human health risk assessment (Chapter 8) in this report, we have concluded that levels of chemicals and radionuclides present in storm water, base flow, and sediment are below levels that would impact human or biota health.

Additionally, the Laboratory's continued maintenance and construction of watershed-scale engineered controls has been effective in minimizing the migration of contaminated sediment downstream to the Rio Grande.

Quality Assurance

Sampling of storm flow, base flow, and sediment, as well as measuring stream flow, is performed according to written quality assurance and quality control procedures and protocols. Current versions of all procedures and guides are listed at https://ext.em-la.doe.gov/EPRR/ReadingRoom.aspx?room=2. These procedures ensure that the collection, processing, and chemical analysis of samples and the validation and verification of analytical data are consistent from year to year.

Analytical results meet the N3B minimum data quality objectives as outlined in N3B-PLN-SDM-1000: "Sample and Data Management Plan." N3B-PLN-SDM-1000 sets the validation frequency criteria at 100% Level 1 examination and Level 2 verification of data, and at 10% minimum Level 3 validation of data. A Level 1 examination assesses the completeness of the data as delivered from the analytical laboratory, identifies any reporting errors, and checks the usability of the data based on the analytical laboratory's evaluation of the data. A Level 2 verification evaluates the data to determine the extent to which the laboratory met the analytical method and the contract-specific quality control and reporting requirements. A Level 3 validation includes Levels 1 and 2 criteria and determines the effect of potential anomalies encountered during analysis and possible effects on data quality and usability. A Level 3 validation is performed manually with method-specific data validation procedures. Laboratory analytical data are validated by N3B personnel as outlined in N3B-PLN-SDM-1000; N3B-AP-SDM-3000: "General Guidelines for Data Validation"; N3B-AP-SDM-3014: "Examination and Verification of Analytical Data"; and additional method-specific analytical data validation procedures. All associated validation procedures have been developed, where applicable, from the U.S. Environmental Protection Agency QA/G-8 Guidance on Environmental Data Verification and Data Validation, the Department of Defense/Department of Energy Consolidated Quality Systems Manual for Environmental Laboratories, the U.S. Environmental Protection Agency National Functional Guidelines for Data Validation, and the American National Standards Institute/American Nuclear Society 41.5: Verification and Validation of Radiological Data.

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Chapter 7: Ecosystem Health

We monitor ecosystem health to determine whether operations at Los Alamos National Laboratory (LANL or the Laboratory) affect plant or animal populations (collectively called "biota"). We collect samples of soil, sediment, plants, and animals on Laboratory property, around the perimeter of the Laboratory, and from more distant locations that provide background comparisons. We also monitor abundance and reproduction in local wildlife populations, including threatened and endangered species.

We test samples for radionuclides, inorganic elements (such as metals), and organic chemicals (such as polychlorinated biphenyls [PCBs], per- and polyfluoroalkyl substances [PFAS], dioxins, furans, and high explosives). We also assess radiation dose for plants and animals living around Laboratory facilities and around sediment retention structures in canyon bottoms. The calculated doses are compared with background levels of radiation, screening levels, and federal standards for plants and animals.

We collected the following samples during 2021:

- *soil and vegetation samples around the perimeter of Material Disposal Area G at Technical Area 54*
- *soil, sediment, small mammal, and bird egg samples around the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15*
- *bird egg and nestling samples at two open detonation sites and at the open burn grounds*
- *small mammal and vegetation samples in Los Alamos and Pajarito canyons on Laboratory property*
- *deceased animals (primarily from animal-vehicle collisions) from various sites on and off the Laboratory*
- *soil and overstory vegetation samples from 16 onsite, 14 perimeter, and six regional background locations*
- *small mammals from Los Alamos Canyon on Pueblo de San Ildefonso property and from background locations.*

In most soil, sediment, plant, and animal samples from onsite and perimeter locations, radionuclides and chemicals were either not detected, had levels similar to background, or had levels below the screening levels that may be harmful to biota. Biota dose assessments indicate that the radiation doses are far below the levels that have adverse effects on plants and animals. Endangered species surveys in 2021 confirmed that two Mexican spotted owl habitats on Laboratory property were again inhabited by adult owls.

Contents

Introduction

An ecosystem includes living organisms, such as plants, animals, and bacteria; nonliving elements, such as soil, air, and water; and the interactions among these components (Smith and Smith 2012). The relative health and function of an ecosystem can be affected by disturbances including wildfire, flooding, drought, invasive species, climate shifts, chemical spills, construction projects, vegetation removal, and other events (Rapport 1998). Los Alamos National Laboratory (LANL or the Laboratory) encompasses habitat for many species of plants and animals (collectively called "biota"). The Laboratory also monitors ecosystem health to determine if past or current releases of radionuclides and chemicals from Laboratory operations are affecting local plants and animals.

We conduct two types of monitoring: facility-specific and institutional. Facility-specific monitoring measures radionuclide and chemical levels associated with specific facilities and operations at the Laboratory. Institutional monitoring occurs on Laboratory property, around the perimeter of the Laboratory, and at regional background locations. The institutional monitoring measures the general levels of radionuclides and chemicals in the areas outside of designated solid waste management units. Institutional monitoring also includes biological surveys for various wildlife species across space and through time.

Some of the samples collected for institutional monitoring rotate on a three-year cycle: (1) soil and vegetation, (2) foodstuffs (results are reported in Chapter 8), and (3) samples from the Rio Grande and nearby reservoirs. In 2021, we collected soil and vegetation samples.

Both institutional and facility-specific results are used to assess the effects of Laboratory-released chemicals and radionuclides on ecosystem health. This is accomplished by the following:

- Measuring levels of radionuclides and other chemicals in soil, plants, and animals from areas on Laboratory property and near the perimeter of the Laboratory, and then comparing these levels with
- levels measured from background locations not affected by Laboratory operations,
    - levels that scientists have determined should trigger further investigation, such as screening levels, and
    - levels that may cause adverse health effects.
- Evaluating trends in radionuclide and chemical levels in soil, plants, and animals over time
- Assessing population parameters and species diversity of animals in areas potentially affected by Laboratory operations
- Estimating radiation dose and chemical risk to biota using the monitoring results
- Biological surveys of threatened and endangered species, migratory birds, small mammals, and plant communities.

Ecosystem Health Assessment Methods

One direct way we assess ecosystem health is by collecting a variety of environmental samples including soil, sediments, native vegetation, honey, small mammals, bird eggs, crayfish, fish, and other animals, analyzing them for substances such as radionuclides, inorganic elements such as metals, and organic chemicals such as polychlorinated biphenyls (PCBs), high explosives, dioxins, furans, volatile organic compounds, semi-volatile organic compounds, and per- and polyfluoroalkyl substances (PFAS).

Soil and Sediment

Soil receives chemicals that are released into the air and particles that are transported by wind and water. Monitoring soil over time directly measures long-term trends of radionuclide and other chemical concentrations around nuclear facilities (DOE 2015).

Levels of constituents in soil and sediment samples collected at and near the Laboratory are compared with regional statistical reference levels. The regional statistical reference level for a chemical or radionuclide in soil is calculated using results from all the soil samples collected at regional background locations during the previous 10 years. The regional statistical reference level is the level below which precisely 99 percent of the results from regional background soil samples fall. As required by the U.S. Department of Energy (DOE), all background locations are at a similar elevation to the Laboratory, more than 9.3 miles away from the Laboratory, and beyond the range of potential influence from normal Laboratory operations (DOE 2015). Radionuclides and other chemicals in soil collected from regional background locations come from naturally occurring sources and from manmade sources other than the Laboratory, including past testing of atomic weapons, power plant emissions, and automobile emissions.

Levels of constituents in soil and sediment are also compared with ecological screening levels for soil. One type of ecological screening level is the highest level of a radionuclide or chemical in the soil that is known to not affect selected animals or plants (the no-effect ecological screening level). Another type is the lowest level in the soil known to be associated with an adverse effect on selected animals or plants (the low-effect ecological screening level). Soil concentrations of chemicals and radionuclides below these ecological screening levels are unlikely to harm plants or animals.

Based on published literature, the Laboratory has estimated no-effect and low-effect ecological screening levels in soil for a series of plants and animals that could occur at the Laboratory and that represent different trophic levels and feeding habits (LANL 2020). We compare our soil results to ecological screening levels in soil for the following terrestrial plants or animals: generic plant; earthworm—representing soil-dwelling invertebrates; desert cottontail (*Sylvilagus audubonii*)—representing mammalian herbivores; deer mouse (*Peromyscus maniculatus*)—representing mammalian omnivores; montane shrew (*Sorex monticolus*)—representing mammalian terrestrial insectivores; Botta’s pocket gopher (*Thomomys bottae*)—representing burrowing mammals; gray fox (*Urocyon cinereoargenteus*)—representing mammalian carnivores; occult little brown bat (*Myotis lucifugus occultus*)—representing mammalian aerial insectivores; American robin (*Turdus migratorius*)—representing avian omnivores, herbivores, and insectivores; violet-green swallow (*Tachycineta thalassina*)—representing avian aerial insectivores; and American kestrel (*Falco sparverius*)—representing avian carnivores (LANL 2020). Ecological screening levels in sediment have also been developed for the following aquatic plants and animals: algae—representing aquatic autotrophs; aquatic snails—representing aquatic herbivore/grazer; daphnids—representing aquatic omnivore/herbivore; fish—representing aquatic intermediate carnivore; and aquatic community organisms (LANL 2020).

Plants and Animal Tissues

Small mammals, such as wild mice, are well suited for monitoring chemical and radionuclide exposures and uptake in biological systems because of their close contact with soil, burrowing behavior, and omnivorous diets (Smith et al. 2002, Talmage and Walton 1991).

Bird eggs and nestlings are useful for monitoring chemical and radionuclide exposures and uptake in biological systems because different bird species occupy different trophic levels. Additionally, the collection of nonviable eggs and/or nestlings that die of natural causes is noninvasive and nondestructive to wild populations. Wild bird eggs have been shown to reflect chemical exposures from the location where a female bird feeds during egg formation (Dauwe et al. 2005). However, chemicals from the female's previous exposures, such as on migration routes or wintering grounds, can also be deposited into eggs (Bustnes et al. 2010). Nestlings tend to solely reflect local chemical exposures due to their limited mobility. Inorganic elements and organic chemicals can adversely affect birds if exposed at high enough concentrations (Jones and de Voogt 1999). Sources of inorganic elements include both releases from human activities and natural geological sources. Birds can be exposed through several routes including food items, ingestion of soil, drinking water, and inhalation.

Levels of chemicals in plant and animal tissues are compared with lowest observable adverse effect levels, when available. A lowest observable adverse effect level is the lowest concentration measured in a plant or animal's tissues that has been associated with an adverse effect (EPA 2014). Levels of radionuclides in tissues are compared with biota dose screening levels, which are set at 10 percent of the DOE limit for radiation doses to biota (DOE 2019, McNaughton 2021).

Estimated Doses to Plants and Animals

The dose to biota is calculated using RESRAD-BIOTA software (version 1.8) (http://resrad.evs.anl.gov/codes/resrad-biota/). This is DOE's methodology for evaluating radiation doses to aquatic and terrestrial biota. This calculated dose is compared with DOE limits: 1 rad per day for terrestrial plants and aquatic animals, and 0.1 rad per day for terrestrial animals (DOE 2019).

Comparisons Among Sites and Over Time

We perform statistical tests to evaluate differences in constituents among sites and to examine trends in constituent levels over time. Examples of these tests include *t*-tests, analysis of variance, Kruskal-Wallis tests, Kendall's Tau tests, linear regressions, and generalized linear models. Statistical analyses are not conducted on datasets where 80 percent or more of the results for a specific chemical or radionuclide are "not detected" (Helsel 2012). Samples collected within approximately the past 10 years are used to study trends over time. These samples are directly comparable because they were analyzed with similar analytical methods and instruments, and have similar detection limits. We test a null hypothesis of no effect for each set of data, and typically there are no differences among locations or no increasing trends over time. For each test, we select a probability level, or p-value, of the null hypothesis being correct at which we accept or reject the null hypothesis. A p-value of less than 5 percent

($p < 0.05$) is used as our threshold to reject the null hypothesis of no difference between locations or no trend over time. If the p-value is greater than 5 percent ($p > 0.05$), we accept the null hypothesis of no difference or no trend.

Facility-Specific Monitoring

Area G at Technical Area 54

Area G was established in 1957 and is the Laboratory's primary low-level radioactive solid waste burial and storage site (DOE 1979, Martinez 2006; see Figure 7-1). Tritium, plutonium, americium, and uranium are the main radionuclides in waste materials at Area G (Mayfield and Hansen 1983). The Laboratory has conducted soil, vegetation, and small mammal monitoring at Area G since 1980 to determine whether radionuclides are migrating beyond the waste burial area (LANL 1981, Mayfield and Hansen 1983).

We collect surface soil and vegetation at Area G each year for testing. Surface soil grab samples (0 to 6 inches deep) and composite tree samples, primarily of one-seed juniper (*Juniperus monosperma*), were collected in May 2021 at 13 designated locations around the perimeter of Area G. Four soil and one composite tree sample were collected at the bottom of Cañada del Buey near the boundary between the Laboratory and the Pueblo de San Ildefonso (see Figure 7-1). All samples were analyzed for tritium, americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, uranium-234, uranium-235/236, and uranium-238.

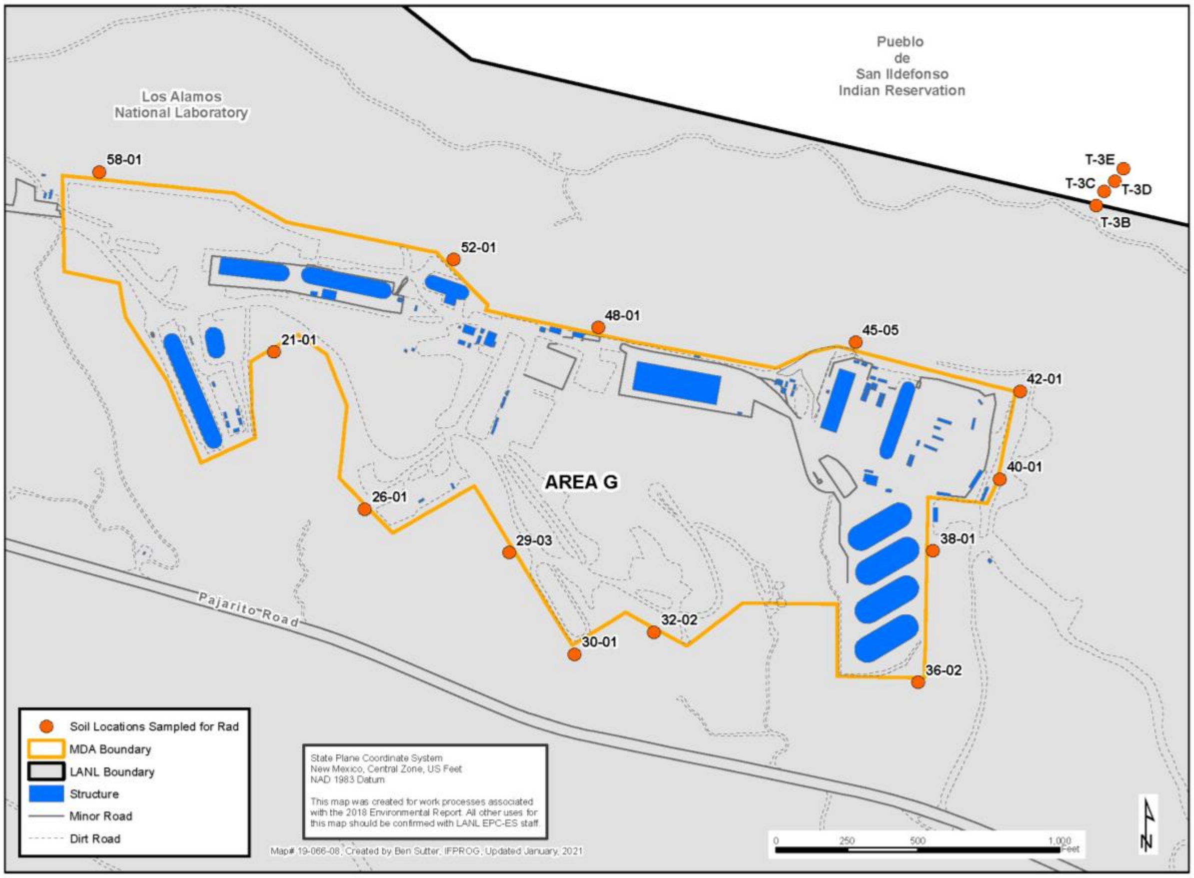


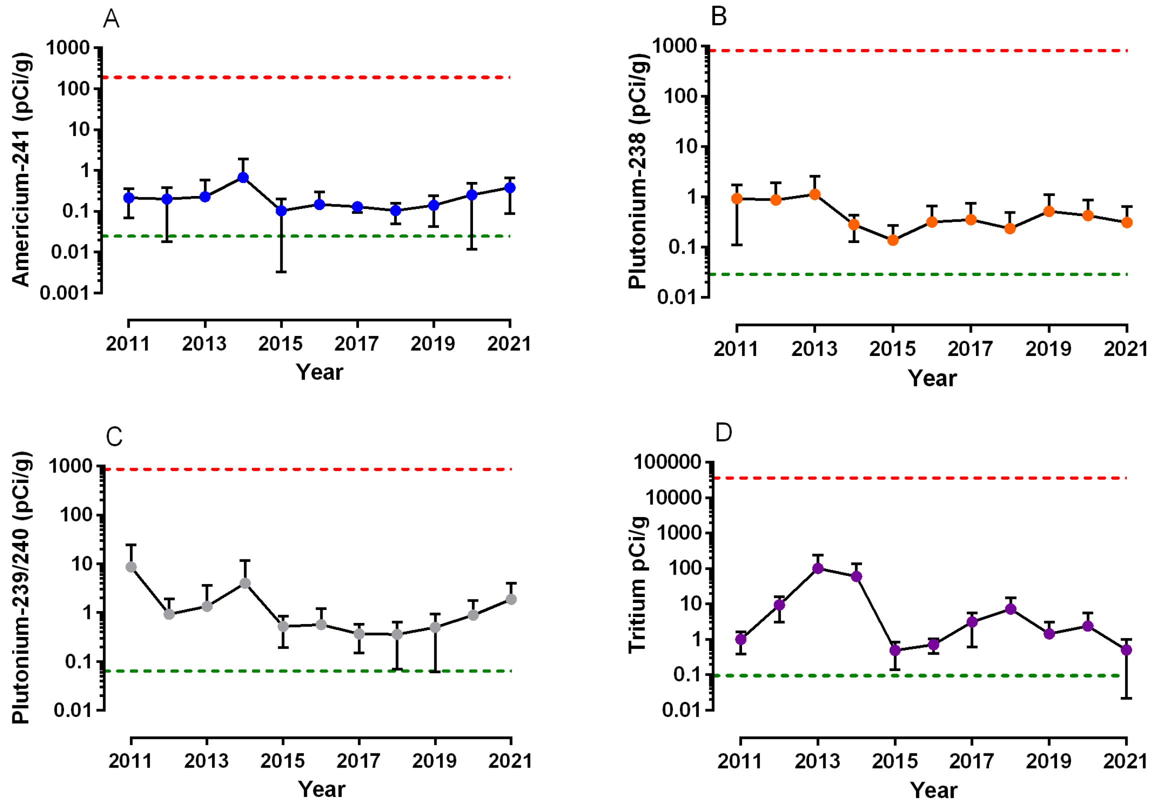
Figure 7-1. Locations of soil and vegetation samples collected around Area G and near the Laboratory and Pueblo de San Ildefonso boundary in 2021. Note: MDA is Material Disposal Area.

Soil Results

The 2021 soil results at Area G are summarized as follows (see Supplemental Table S7-1 for individual results):

- Cesium-137 and strontium-90 activities were below the regional statistical reference levels.
- Uranium-234, uranium-235/236, and uranium-238 activity were similar to or below the regional statistical reference levels.
- Americium-241, plutonium-238, plutonium-239/240, and tritium activities were above the regional statistical reference levels in several locations.
- All radionuclide levels are far below their ecological screening levels in soil.

Americium-241, plutonium-238, and plutonium-239/240 in soil samples collected on the north, northeastern, and eastern side of Area G were above the regional statistical reference level. These concentrations are similar to previous years and most radionuclide levels are not increasing over time (Kendall's Tau, $p > 0.05$; see Figure 7-2). However, americium-241 is increasing at location 48-01 and plutonium-238 is increasing at location 21-01. Although still below the regional statistical reference level, these locations will continue to be monitored. Levels of tritium in soil samples collected on the southern side of Area G were above the regional statistical reference level, which are consistent with data from previous years. Tritium levels are not increasing over time (Kendall's Tau, $p > 0.05$; see Figure 7-2).



Note: pCi/g = picocuries per gram.

Figure 7-2. (A) Americium-241, (B) plutonium-238, (C) plutonium-239/240 activities in surface soil samples collected from five locations on the northern, northeastern, and eastern side (locations 38-01, 40-01, 42-01, 45-05 and 48-01), and (D) tritium activities in surface soil samples collected from two locations on the southern side (locations 29-03 and 30-01) of Area G at Technical Area 54 from 2011 to 2021. Data are compared with the regional statistical reference level (green dashed line) and the lowest no-effect ecological screening level (red dashed line). Note the logarithmic scale on the vertical axis. Points represent mean and error bars represent standard deviation. Bottom error bars are absent on some points, as the error would have been a negative value; however, negative values cannot be shown on a logarithmic axis.

Vegetation Results

Tree samples were collected at the same general locations as the soil samples (see Figure 7-1). However, because of a firebreak along the fence line, some of the trees were located more than 30 feet away from the fence around Area G, particularly on the northern and eastern sides. Levels of radionuclides in native tree samples (primarily one-seed juniper) can be caused by root uptake and by deposition of radionuclides on the surfaces of leaves and branches.

The 2021 native tree results at Area G are summarized as follows (see Supplemental Table S7-2 for individual results):

- Most radionuclides in overstory vegetation samples were either not detected or were below the regional statistical reference levels.
- All activities were below the biota dose screening level for terrestrial plants.
- Radionuclides in vegetation are not increasing over time (Kendall's Tau, $p > 0.05$).

Americium-241 levels in overstory vegetation samples continue to decrease over time at two locations at the northeastern corner of Area G, 45-05 and 48-01 (Kendall's Tau, $p < 0.05$; see Figure 7-3). There was no longer a significant decreasing trend in americium-241 values at location 40-01 and 42-01 after including the 2021 results. The percent of nondetects for americium-241 in these vegetation samples ranges from 36 to 72 percent and could be influencing the results of trend analyses.

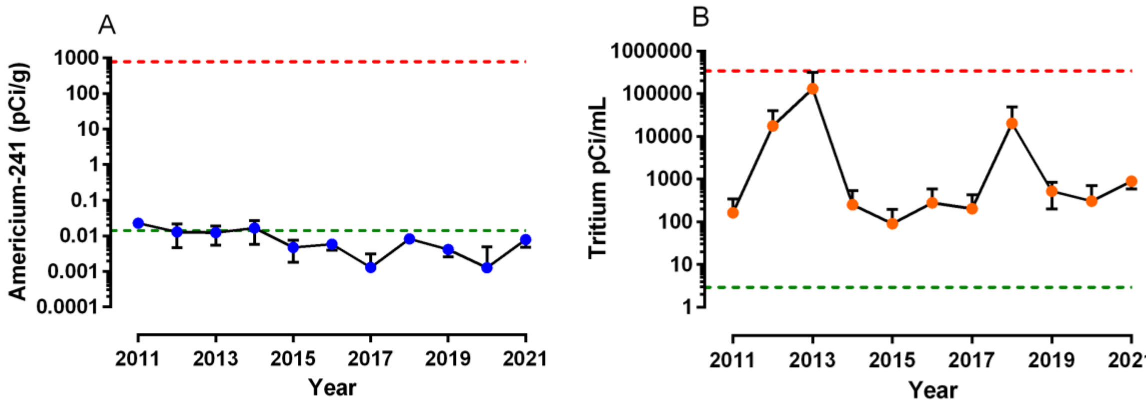


Figure 7-3. (A) Americium-241 activities in overstory vegetation samples collected from five locations on the northeastern corner of Area G (locations 38-01, 40-01, 42-01, 45-05, and 48-01), and (B) tritium activities in overstory vegetation samples collected from two southern locations (locations 29-03 and 30-01) around Area G at Technical Area 54 from 2011 to 2021. Data are compared with the regional statistical reference level (green dashed line) and biota dose screening level for overstory vegetation (red dashed line). Note the logarithmic scale on the vertical axis. Points represent mean and error bars represent standard deviation. Bottom error bars are absent on some points as the error would have been a negative value; however, negative values cannot be shown on a logarithmic axis. Note: pCi/g = picocuries per gram and pCi/mL = picocuries per milliliter.

Similar to previous years, tritium in overstory vegetation was highest (up to 1,120 picocuries per milliliter) in trees growing in the southern sections near the tritium disposal shafts. The levels of plant tritium are highly variable from year to year but have not been increasing over time (Kendall's Tau, $p > 0.05$; see Figure 7-3). Variability in plant tritium levels may be a result of any, or a combination, of the following: soil moisture, depth of roots, time of sampling, distance from the perimeter fence, temperature, or barometric pressure.

Strontium-90 was detected above the regional statistical reference level of 2.34 picocuries per gram in 11 of the overstory vegetation samples collected around Area G (range 2.36–4.93 picocuries per gram; supplemental table S7-2). These levels are far below the biota dose screening level of 53,750 picocuries per gram. Strontium-90 is not a primary waste material at Area G and the levels in the overstory vegetation are likely due to global fallout. Global fallout is brought to the ground by precipitation (Chawla et al. 2010). In New Mexico, precipitation increases with elevation. Our onsite locations are more mountainous than our background locations, and this may explain why strontium-90 was higher in vegetation samples onsite than at the background locations used to calculate regional statistical reference levels.

Laboratory/Pueblo de San Ildefonso Boundary in Cañada del Buey

In 2021, a duplicate-split soil sample (where soil is thoroughly mixed in a bag and then split into two sample containers) was collected at location T-3B on Laboratory property near the Technical Area 54 and Pueblo de San Ildefonso boundary (see Figure 7-1). This location has been sampled from 2016 through 2021. An additional three soil samples were collected on Pueblo de San Ildefonso property at locations T-3C, T-3D, and T-3E near the Laboratory and Pueblo de San Ildefonso boundary (see Figure 7-1).

The 2021 results at the Laboratory/Pueblo de San Ildefonso Boundary in Cañada del Buey are summarized as follows (see Supplemental Table S7-1 for individual results):

- Most radionuclide activities in soil were not detected or were below the regional statistical reference level.
- Soil activity of plutonium-239/240 was above the regional screening levels at location T-3D.
- Soil activities of uranium isotopes were above the regional screening levels at locations T-3D and T-3E.
- All soil radionuclide activities were below all ecological screening levels for soil.
- Americium-241 and strontium-90 activities exceeded their respective regional statistical reference levels in overstory vegetation at T-3D.

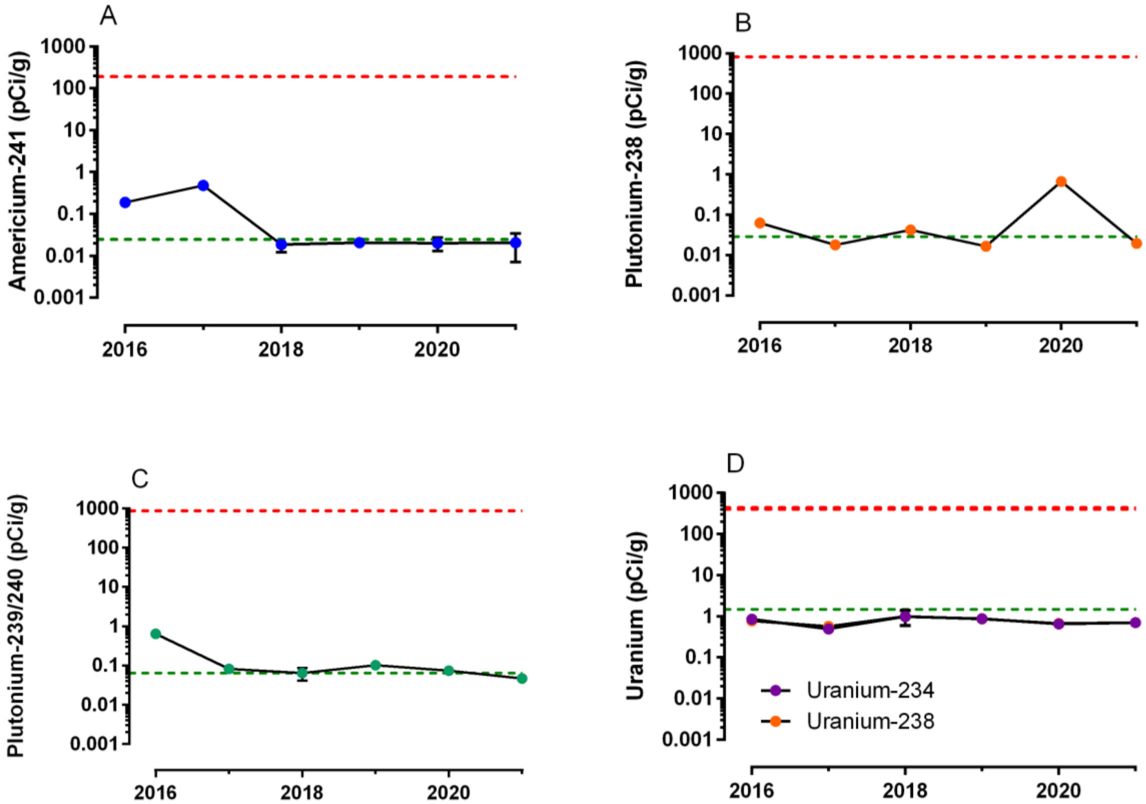
Soil Results

Americium-241 was not detected in any of the soil samples collected near the boundary of Technical Area 54 and Pueblo de San Ildefonso.

Plutonium-238 was detected in one of the duplicate soil samples at T-3B with an activity of 0.0211 picocuries per gram, below the regional statistical reference level of 0.0287 picocuries per gram. Plutonium-238 activities were detected in soil collected from T-3C and T-3E and were 0.0303 and 0.0210 picocuries per gram, respectively. T-3C soil plutonium-238 activity slightly exceeded the regional statistical reference level of 0.0287 picocuries per gram. Plutonium-238 was not detected in the soil sample collected at T-3D (see Table S7-1).

Plutonium-239/240 was detected in both duplicate soil samples at T-3B with activities of 0.0446 and 0.0448 picocuries per gram, below the regional statistical reference level of 0.0643 picocuries per gram. Plutonium-239/240 activities were detected at T-3C and T-3E with activities of 0.0392 and 0.0446 picocuries per gram, respectively, and were below the regional statistical reference level. Plutonium-239/240 soil activity at T-3D was 0.0700 picocuries per gram and slightly exceeded the regional statistical reference level of 0.0643 picocuries per gram (see Table S7-1).

All these observations are well below the no-effect ecological screening levels for americium-241, plutonium-238, and plutonium-239/240 of 190, 820, and 870 picocuries per gram, respectively. Between 2016 and 2021, concentrations of plutonium-239/240 in soil at the T-3B location decreased over time (Kendall's Tau, $p < 0.05$); no other trends are observed in soil radionuclide activity near the TA-54 and Pueblo de San Ildefonso boundary (Kendall's Tau, $p > 0.05$; see Figure 7-4).



Note: pCi/g = picocuries per gram.

Figure 7-4. (A) Americium-241, (B) plutonium-238, (C) plutonium-239/240, and (D) uranium-234 and uranium-238 activities in soil collected near the Technical Area 54 and Pueblo de San Ildefonso border from 2016 through 2021 at the T-3B location on Laboratory property. Results from 2018 through 2021 are the average of duplicated samples. Data are compared with the regional statistical reference level (green dashed line) and the lowest no-effect ecological screening level (red dashed line). Note the logarithmic scale on the vertical axis. Points represent true values (between 2016 and 2017, n = 1 each) or represent mean values (between 2018 and 2020, n = 2 each), and error bars represent standard deviation. Error bars may appear absent on some points, as standard deviations are too small to plot.

All three uranium isotopes were detected in all soil samples collected near Technical Area 54 and the Pueblo San Ildefonso boundary. Most observations were below the regional statistical reference level (Table S7-1). However, at T3-D and T-3E, uranium-234, uranium-235/236, and uranium-238 were detected and were slightly above the regional statistical reference level (Table S7-1). The near 1:1 ratio of uranium-234 to uranium-238 activities indicate that these uranium activities are from naturally occurring sources (U.S. Nuclear Regulatory Commission 2019), and the concentrations observed here are similar to Laboratory background concentrations (Ryti et al. 1998).

Vegetation Results

Americium-241 was not detected in the overstory vegetation sample collected from T-3B. However, americium-241 was detected in the overstory vegetation sample collected from the T-3D location with an activity of 0.0210 picocuries per gram, which exceeded the regional statistical reference level of 0.0139 picocuries per gram.

Strontium-90 was detected in both overstory vegetation samples collected from T-3B and T-3D. Strontium-90 activity in vegetation collected from T-3D (3.10 picocuries per gram) exceeded the regional statistical reference level of 2.34 picocuries per gram. As strontium-90 is not a primary waste material at Area G, the observed levels are likely due to global fallout. All remaining radionuclide activities in overstory vegetation collected near the Technical Area 54 and Pueblo de San Ildefonso boundary were below the regional statistical reference levels. All radionuclides are far below the biota dose screening level, and no radionuclide levels are increasing over time in vegetation (Kendall's Tau, $p > 0.05$; Table S7-2).

Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15

The Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15 is a principal laboratory explosives firing site. Soil, sediment from local drainages, plants, and animals are monitored at the facility to determine whether constituents released from operations may be affecting plants or animals and if the levels are consistent with our expectations of radionuclide and chemical uptake. Environmental monitoring has occurred annually since 1996. The firing site began operations in 2000, with the following timeline for methods of mitigating releases from detonations:

- 2000–2002, open-air detonations
- 2003–2006, detonations using foam mitigation
- 2007–2020, detonations within closed steel containment vessels
- 2021, detonations within closed steel containment vessels inside of a weather enclosure.

We monitor radionuclides, inorganic elements, and organic chemicals such as high explosives, dioxins and furans, and PFAS chemicals in soil and sediment. Routine biota samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility have included overstory vegetation, small mammals, honeybees, honey, bird eggs, and nestlings. Samples of soil, sediment, and one type of biota are collected annually. Typically, the collection of vegetation, honey, and small mammals sampling is rotated, so that each is sampled once in a three-year period. Bird samples are collected opportunistically when abandoned or infertile eggs or deceased nestlings are found in local nest boxes. In 2021, we collected soil, sediment, small mammals, and bird egg samples at the facility. All sample locations are shown in Figure 7-5.

For soil samples, we collect five surface soil subsamples at a depth from zero to two inches and mix them to prepare a composite soil sample at each location. The soil samples were collected in May 2021 on the north, east, south, and west sides of the Dual-Axis Radiographic Hydrodynamic Test Facility perimeter along the fence line. An additional composite soil sample was collected about 75 feet north of the firing point along the side of the protective berm. We collected sediment grab samples at depths from zero to six inches on the north, east, south, and southwest sides within drainages around the facility. All soil and sediment samples were analyzed for the following: (1) the radionuclides americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, tritium, uranium-234, uranium-235/236, and uranium-238; (2) inorganic elements including aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc; and (3) PFAS chemicals and high explosives. In addition, a duplicate sample nearest to the firing point was also analyzed for dioxins and furans.

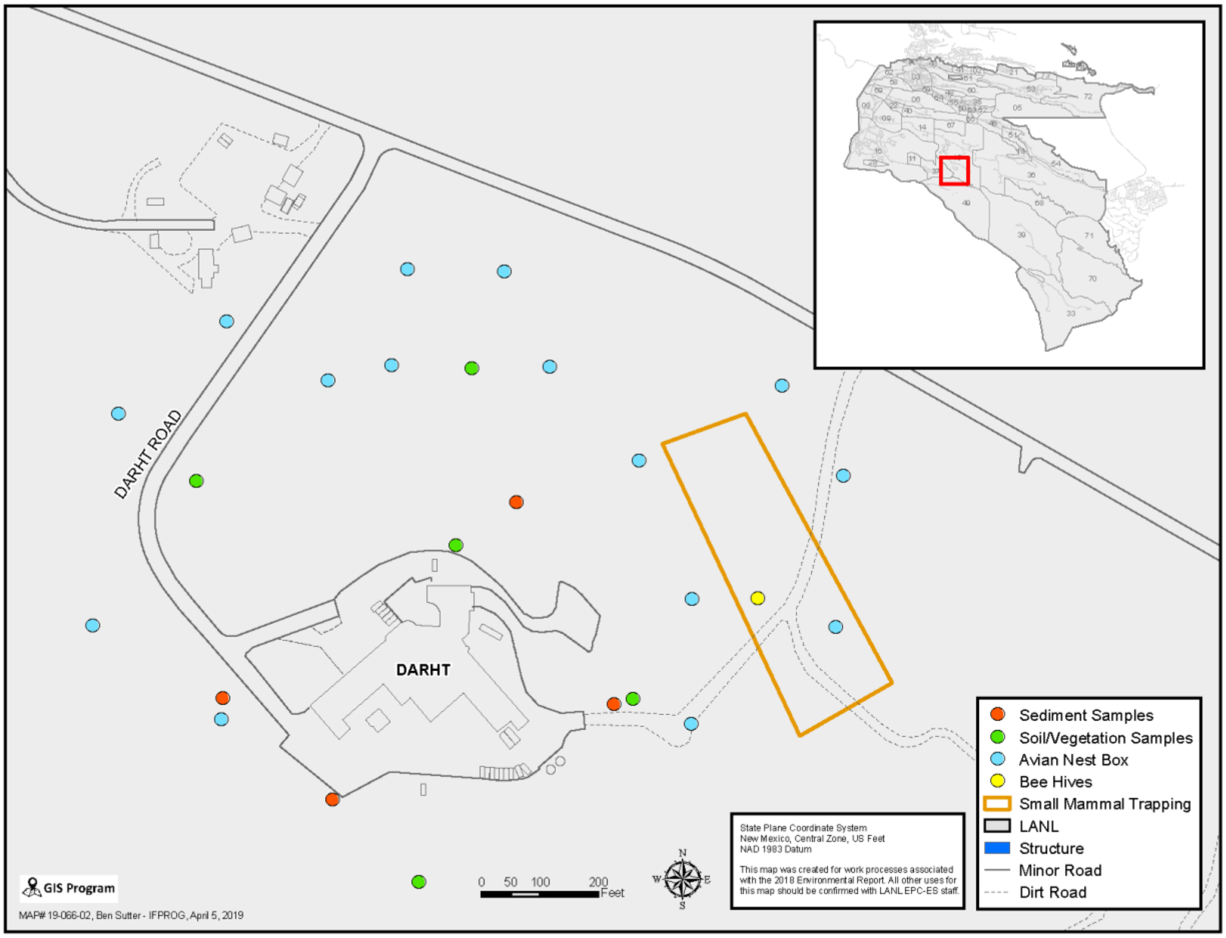


Figure 7-5. Soil, sediment, and biota sample locations at the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) at Technical Area 15.

Small mammals were collected north of the Dual-Axis Radiographic Hydrodynamic Test Facility in May and August 2021 using Sherman® live traps. All animal handling procedures were approved by LANL's Institutional Animal Care and Use Committee. We captured four individual pinyon mice (*Peromyscus truei*) to form a composite sample for radionuclide analyses, one individual pinyon mouse and two brush mice (*Peromyscus boylii*) for inorganic element analyses, two individual pinyon mice and one brush mouse for dioxin and furan congener analyses, and two individual brush mice and one pinyon mouse for PFAS analyses. Eggs that did not hatch were collected from nest boxes surrounding the Dual-Axis Radiographic Hydrodynamic Test Facility. One composite sample of four ash-throated flycatcher (*Myiarchus cinerascens*) eggs was collected in July 2021 and analyzed for inorganic elements.

Constituent results in soil and sediment samples are compared with the baseline statistical reference levels. The baseline statistical reference levels for the Dual-Axis Radiographic Hydrodynamic Test Facility were calculated from samples collected at the facility during 1996 to 1999, before the beginning of firing site operations. The baseline level for each constituent is the precise level below which 99 percent of samples from this time occurred (Nyhan et al. 2001). In cases where there are no baseline statistical reference levels (mostly inorganic elements like aluminum, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, vanadium, and zinc), the soil and biota chemical results are compared with regional statistical reference levels.

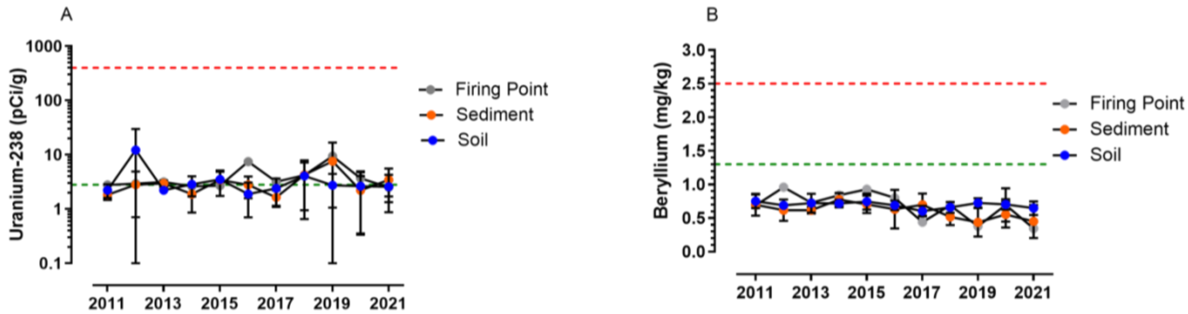
Soil and Sediment Radionuclide Results

The 2021 soil and sediment results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows (see Table S7-3 for individual results):

- Soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility did not contain detectable levels of americium-241 or plutonium-238.
- Most samples did not contain detectable levels of cesium-137 or strontium-90.
- Most of the detectable activities of plutonium-239/240, and all activities of cesium-137 and strontium-90 were below the baseline statistical reference level and/or regional statistical reference level.
- All activities were far below all ecological screening levels in soil.

In 2021, soil and sediment samples contained all three isotopes of uranium. This observation is consistent with previous years. Several samples contained activities of uranium that were higher than the regional statistical reference level and the baseline statistical reference level. The relative isotopic abundance of uranium-234, uranium-235, and uranium-238 activities indicate that the uranium in these samples are depleted uranium from testing activities rather than natural uranium (U.S. Nuclear Regulatory Commission 2019). The levels of uranium are far below all ecological screening levels. Soil and sediment tritium analyses failed in 2021, owing to analytical laboratory cross-contamination, so we do not have tritium data to report.

Operations at the Dual-Axis Radiographic Hydrodynamic Test Facility have changed since 2007 to include the use of closed-containment vessels. Since 2008, uranium-238 activity near the firing point has mostly been similar to the baseline statistical reference level (see Figure 7-6). Levels of radionuclides in soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility are not increasing over time (Kendall’s Tau, $p > 0.05$).



Note: pCi/g = picocuries per gram and mg/kg = milligrams per kilogram.

Figure 7-6. (A) Uranium-238 activities and (B) beryllium concentrations in surface soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility and in the firing point soil sample from 2011–2021 compared with the baseline statistical reference level (mean plus three standard deviations of soil uranium-238 pre-operations, green dashed line) and the lowest no-effect ecological screening level (red dashed line). Note the logarithmic scale on the vertical axis for uranium-238 and the linear scale for beryllium. Points represent true values (firing point 2011–2019) or represent means (sediment, and soil samples and the firing point in 2020 and 2021) and error bars represent standard deviation. Bottom error bars are absent on some uranium-238 points as the error would have been a negative value; however, negative values cannot be shown on a logarithmic axis.

Soil and Sediment Inorganic Element Results

The 2021 soil and sediment inorganic element results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows (see Table S7-4 for individual results):

- Nearly all inorganic elements were found at detectable concentrations in all soil and sediment samples collected in 2021.
- Concentrations of most inorganic elements (aluminum, antimony, arsenic, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, nickel, and potassium) were below all reference and screening levels.
- Concentrations of eight inorganic elements (barium, lead, manganese, mercury, selenium, thallium, vanadium, and zinc) exceeded the no-effect ecological screening level for the plant, montane shrew, or American robin and/or the low-effect ecological screening level for the American robin in some samples.
- The number of locations with concentrations potentially associated with adverse effects at an individual level are minimal, and no impacts to populations or communities of plants and animals are expected.

Consistent with observations in previous years, some soil and sediment samples contained concentrations of barium, lead, manganese, mercury, selenium, thallium, vanadium, and zinc that exceeded the no-effect ecological screening level for the plant, montane shrew, or American robin (see Table 7-1; Table S7-4). All concentrations of barium, manganese, mercury, thallium, and vanadium were below the regional statistical reference levels and the baseline statistical reference levels (when available). As a note, the regional statistical reference level of these elements is also above the no-effect ecological screening level.

Table 7-1. Percent of soil and sediment samples from the Dual-Axis Radiographic Hydrodynamic Facility in 2021 (n = 10) that exceeded an inorganic element screening level or reference level, or that had an increasing trend over time, and the location(s) of the sample(s)

Inorganic Element	Exceedance				Percent of locations with increasing trend over time	Location(s) of exceedance and/or increasing trend
	No-effect ecological screening level (plant, montane shrew, or American robin)	Low-effect ecological screening level (American robin)	Baseline statistical reference level	Regional statistical reference level		
Barium	20%	0%	0%	0%	0%	Soil – N and W sides
Lead	20%	0%	10%	0%	0%	Soil – N side and firing point
Manganese	60%	0%	-	0%	0%	Sediment – S side; Soil – N, E, S, and W sides and firing point
Mercury	40%	0%	0%	0%	0%	Sediment – E side; Soil – N, E, and W sides
Selenium	50%	0%	20%	0%	0%	Sediment – SW and E sides; Soil – W, S, and E sides
Silver	0%	0%	0%	20%	10%	Soil – both firing point sites
Sodium	-	-	-	30%	30%	Sediment – E and S sides; Soil – firing point
Thallium	90%	0%	0%	0%	0%	Sediment – SW, E and N sides; Soil – N, E, S, and W sides and firing point
Vanadium	100%	80%	-	0%	0%	All
Zinc	20%	0%	-	10%	10%	Sediment – S and SW sides

- Indicates no ecological screening level or baseline statistical reference level is available;
N = north, W = west, E = east, S = south, and SW = southwest

Of the inorganic elements that exceeded a screening level or reference level, sodium concentrations are increasing over time in sediment samples collected from the east side and south side, and the soil sample collected at the firing point; silver concentrations are also increasing over time at the firing point of the Dual-Axis Radiographic Hydrodynamic Test Facility (Kendall's Tau, $p < 0.05$). Zinc continues to increase over time in sediment collected from the south and southwest side of the Dual-Axis Radiographic Hydrodynamic Test Facility (Kendall's Tau, $p < 0.05$). Sodium is not due to firing site operations. These results are consistent with observations in previous years and these trends will be monitored closely in future sampling.

Beryllium, listed as a chemical of potential concern before the start-up of operations at the facility (DOE 1995), was not detected above the baseline statistical reference level (1.3 milligrams per kilogram) in any of the soil or sediment samples during 2021. Beryllium concentrations in all soil and sediment samples from 2011 to 2021 have been below the baseline statistical reference level and are not increasing over time (Kendall's Tau, $p > 0.05$; see Figure 7-6). All beryllium concentrations observed in soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility are well below the lowest no-effect ecological screening level of 2.5 milligrams per gram (Table S7-4).

Soil and Sediment Organic Compound Results

The 2021 soil and sediment organic compound results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows (see Table S7-5 for individual results):

- Only one high-explosive chemical (triaminotrinitrobenzene) was detected in one soil sample.
- Dioxin and furan congeners that were detected at the firing point were at concentrations with toxic equivalency values orders of magnitude less than the montane shrew no-effect ecological screening level for 2,3,7,8-tetrachlorodibenzodioxin (TCDD).
- PFAS chemicals were detected at concentrations below ecological screening levels.

Consistent with previous years, the majority of high-explosive chemicals were not detected in the soil or sediment samples collected within or around the perimeter of the Dual-Axis Radiographic Hydrodynamic Test Facility in 2021. Triaminotrinitrobenzene was the only high-explosive chemical detected. It was found in the soil sample collected east of the facility at 0.807 milligrams per kilograms and was below the regional statistical reference level of 1.72 milligrams per kilograms.

Dioxins and furans were evaluated in the duplicate soil samples collected at the firing point; most furans and dioxins, including TCDD, were not detected. The only detected dioxin congeners were 1,2,3,4,6,7,8-heptachlorodibenzodioxin at concentrations of 0.00072 and 0.00113 nanograms per gram and 1,2,3,4,6,7,8,9-octachlorodibenzodioxin at concentrations of 0.00423 and 0.00911 nanograms per gram. 1,2,3,4,6,7,8-heptachlorodibenzofuran and 1,2,3,4,6,7,8,9-octachlorodibenzofuran were detected in one of the duplicate soil samples collected at the firing point at 0.00073 and 0.00101 nanograms per gram, respectively. There are no ecological screening levels for these dioxin congeners; however, toxic equivalent factors for TCDD-like compounds can be used to calculate the TCDD toxic equivalent for dioxin-like compounds. The toxic equivalent factor is 0.01 for 1,2,3,4,6,7,8-heptachlorodibenzodioxin, 0.0003 for 1,2,3,4,6,7,8,9-octachlorodibenzodioxin, 0.01 for 1,2,3,4,6,7,8-heptachlorodibenzofuran and 0.0003 1,2,3,4,6,7,8,9-octachlorodibenzofuran (Van den Berg et al. 2006). Multiplying the detectable concentrations of these congeners by their respective toxic equivalent factors yields a value that is orders of magnitude less than the montane shrew no-effect ecological screening level for TCDD (0.00029 nanograms per gram).

Many soil and sediment samples collected at the Dual-Axis Radiographic Hydrodynamic Test Facility in 2021, including the sample collected near the firing point, did not contain any PFAS chemicals. Detectable concentrations of PFAS chemicals were mostly observed on the east and south sides of the facility. Soil samples contained detectable concentrations of five PFAS chemicals on the east side and six PFAS chemicals on the south side. The sediment samples collected on the east and south sides had the highest concentrations and the greatest number of PFAS chemicals detected (11 of the 14 types of PFAS chemicals tested).

Perfluorooctanesulfonic acid was the only PFAS chemical detected in soil from the west side of the facility and was the most frequently detected PFAS chemical overall, with a range of 0.329 to 32.3 nanograms per gram (n = 5). The perfluorooctanesulfonic acid concentration in the sample collected from the west side was below the regional statistical reference level of 0.697

nanograms per gram, while the concentrations in the four soil and sediment samples on the east and south sides were above that level. However, all concentrations were far below the lowest ecological screening level for perfluorooctanesulfonic acid of 1,800 nanograms per gram.

Some concentrations of PFAS chemicals near the Dual-Axis Radiographic Hydrodynamic Test Facility in 2021 exceeded their regional statistical reference levels; however, they all were below available ecological screening levels. Concentrations of PFAS chemicals observed here are within the range of global observations of concentrations in soil collected from non-polluted sites (Brusseau et al. 2020).

Small Mammal Results

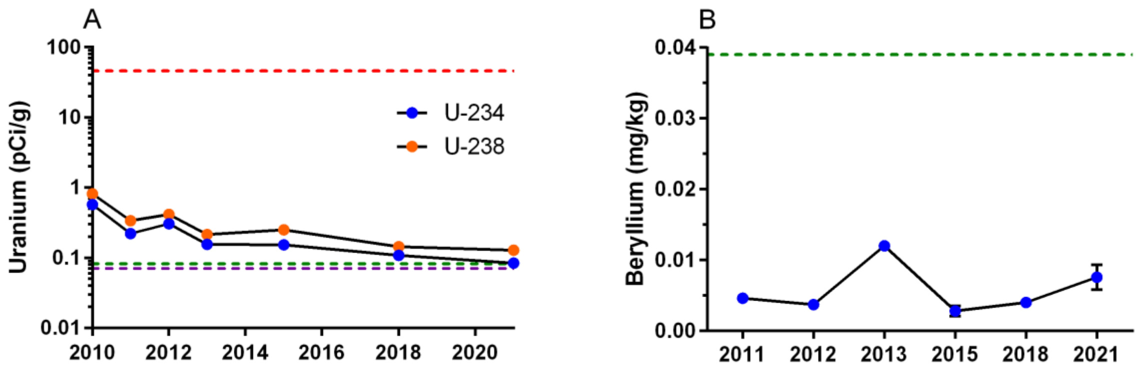
The 2021 small mammal results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows (see Tables S7-6 and S7-7 for individual results):

- Uranium isotopes and strontium-90 were detected in small mammals that were above the regional statistical reference level but were far below biota dose screening levels.
- The majority of inorganic elements in small mammals were below the regional statistical reference levels and were not increasing over time.
- The majority of PFAS chemicals were not detected in small mammal samples collected north of the Dual-Axis Radiographic Hydrodynamic Test Facility.

The composite small mammal samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility did not contain detectable levels of americium-241, cesium-137, plutonium-238, plutonium-239/240, or tritium. Similar to previous years, the composite small mammal sample contained strontium-90 and all three uranium isotopes, which exceeded their respective regional statistical reference levels, but were below biota dose screening levels (Table S7-6). The relative isotopic abundance of uranium-234, uranium-235, and uranium-238 activities indicate that the uranium in the composite small mammal sample is depleted uranium from testing activities rather than natural uranium (U.S. Nuclear Regulatory Commission 2019). Both uranium-234 and uranium-238 activities in small mammals are decreasing over time between 2010 and 2021 (Kendall’s Tau, $p < 0.05$; see Figure 7-7). The amount of uranium-238 in small mammals increased until the year 2007, and then decreased thereafter; the decrease is concurrent with the change from open-air and/or foam-mitigated detonations during the 2000–2006 period to closed vessel containment, starting in 2007.

Most inorganic elements were detected, except for beryllium, silver, and thallium, in one or more samples. The majority of inorganic elements were below the regional statistical reference level, including beryllium (Table S7-7). No inorganic elements are increasing over time (Kendall’s Tau, $p > 0.05$; see Figure 7-7).

Similar to previous years, and consistent with soil and sediment observations, 1,2,3,4,6,7,8,9-octachlorodibenzodioxin was the only dioxin congener detected. It was detected in two of the three small mammal samples collected north of the Dual-Axis Radiographic Hydrodynamic Test Facility in 2021 at concentrations of 1.34 and 7.36 picograms per gram. These concentrations are well below the regional statistical reference level of 101.9 picograms per gram. No other dioxins or furans were detected.



Note: mg/kg = milligrams per gram and pCi/g = picocuries per gram.

Figure 7-7. (A) Uranium-234 and uranium-238 activities and B) beryllium concentrations in whole body mice collected near the Dual-Axis Radiographic Hydrodynamic Test Facility perimeter at Technical Area 15 from 2010–2021 and 2011–2021, respectively; compared with the regional statistical reference level (mean plus three standard deviations of small mammals collected from background locations; beryllium and uranium-234: green dashed line, uranium-238: purple dashed line) and the biota dose screening level (red dashed line). Note vertical axis is a logarithmic scale for uranium and a linear scale for beryllium. Points represent true values, or the mean when multiple results were available; error bars represent standard deviation.

A total of 37 PFAS chemicals each were evaluated in three individual mouse samples collected north of the Dual-Axis Radiographic Hydrodynamic Test Facility in 2021.

- One brush mouse did not contain any detectable PFAS chemical concentrations.
- One brush mouse contained 1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (0.914 nanograms per gram).
- The pinyon mouse contained four PFAS chemicals, including 1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (1.53 nanograms per gram), 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (0.781 nanograms per gram), perfluorononanoic acid (0.217 nanograms per gram), and perfluoroundecanoic acid (0.248 nanograms per gram).

Concentrations of perfluorononanoic acid and perfluoroundecanoic acid slightly exceeded their regional statistical reference levels of 0.155 nanograms per gram (for each of the PFAS chemicals). Our observations are within the ranges of PFAS concentration observed in animal tissues from published studies, including studies that occurred away from point-source pollution and in the Antarctic where global fallout is the primary source of PFAS in the environment (Aas et al. 2014, Bossi et al. 2015). Although PFAS chemicals are increasingly recognized as chemicals of concern, little is known about adverse effects of wildlife tissue concentrations.

Bird Egg Results

Levels of chemicals in bird egg samples were consistent with previous years. Several inorganic elements were not detected, including aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, nickel, silver, thallium, and vanadium. All detectable concentrations of elements were below their regional statistical reference levels and below the lowest observable adverse effect levels, when available (Table S7-8).

Open Detonation and Open Burn Firing Sites

Avian nest boxes have been placed at two open detonation firing sites, Minie (located at Technical Area 36) and Technical Area 39 Point 6, and at the open burn grounds located at Technical Area 16. Inorganic elements (mostly metals), dioxins, and furans are substances of interest at these locations (Fresquez 2011). Nonviable eggs and nestlings that died from natural causes are collected and submitted for chemical analyses.

We collected 8 nonviable eggs on Laboratory property and 10 nonviable eggs in background areas located at Bandelier National Monument. One deceased western bluebird (*Sialia mexicana*) nestling was obtained at the Laboratory in 2021 from a nest box.

Results from eggs collected from the Laboratory were compared with regional statistical reference levels calculated from the nonviable eggs of western bluebirds and ash-throated flycatchers collected from the background locations in 2021 (n = 10 samples). Owing to limited sample mass, nonviable eggs were evaluated for inorganic elements only. In previous years, egg samples have been analyzed on a dry weight basis. However, in 2021, they were all on a wet weight basis.

Results from one nestling were compared to the regional statistical reference levels calculated from deceased nestlings of western bluebirds and ash-throated flycatchers from background locations between 2018 and 2020 (n = 8 samples). Nonviable egg and nestling results were also compared with the lowest observable adverse effect levels from peer-reviewed literature when available.

Bird Egg Results

Inorganic elements in bird eggs collected from Technical Area 36 (two samples) and the open burn grounds (one sample) were either not detected or were only slightly above the regional statistical reference levels (Table S7-9). No nonviable eggs were collected from Technical Area 39 Point 6 in 2021. The two samples from Technical Area 36 included one mountain bluebird and one ash-throated flycatcher egg. The mountain bluebird egg sample contained antimony concentrations of 0.024 milligrams per kilogram, which slightly exceeded the regional statistical reference level of 0.019 milligrams per kilogram (Table S7-9). The ash-throated flycatcher egg sample contained mercury concentrations of 0.019 milligrams per kilogram, which slightly exceeded the regional statistical reference level of 0.011 milligrams per kilogram (Table S7-9) but was far below the lowest observable adverse effect level of 1.9 milligrams per kilogram (Shore et al. 2011). The remaining detectable elements were below the regional statistical reference levels (Table S7-9). The overall results indicate that the levels of inorganic elements in western bluebird and ash-throated flycatcher eggs at the open detonation firing site and at the open burn grounds are not likely to cause adverse effects in breeding bird populations; however, more data are needed, including additional egg samples from background locations and firing sites, to make robust assessments and to evaluate trends over time.

Bird Nestling Results

One deceased western bluebird nestling was obtained at the Laboratory in 2021 from Technical Area 36. This nestling was analyzed for dioxins and furans. Similar to previous years, no dioxins and furans were detected in the nestling sample collected from Technical Area 36.

These findings suggest that the concentrations of inorganic elements and dioxin-like compounds are not of ecological concern at these sites. More data are needed, including additional nestling samples from firing sites, to make robust assessments and to evaluate trends over time.

Sediment and Flood-Retention Structures

The Laboratory has constructed flood- and sediment-retention structures to reduce flood risks and to stop or slow the movement of sediments and associated chemicals and radionuclides off Laboratory property. Many chemicals and radionuclides released into the environment adhere to soil and sediment particles. Storm water flows can transport these soil and sediment particles downstream in canyon bottoms.

The Los Alamos Canyon weir and the Pajarito Canyon flood-retention structure were built following the Cerro Grande fire in 2000. As part of an environmental analysis of actions taken in response to the Cerro Grande fire, DOE identified various measures to minimize impacts resulting from the fire (DOE 2000). One of the measures is monitoring soil, surface water, groundwater, and biota upstream of flood-control structures, within sediment-retention basins, and within sediment traps to determine if constituent concentrations in these areas adversely affect plants or animals.

To this end, we collect native grasses, forbs, and wild mice in the retention basins of the Los Alamos Canyon weir and the Pajarito Canyon flood-retention structure on an annual basis for environmental monitoring purposes.

We attempt to collect the following samples from each location annually: (1) a composite understory vegetation sample for radionuclide, inorganic element, and PFAS analyses; (2) a composite sample of approximately 100 grams of whole-body mice for radionuclide analyses; (3) three individual mice for inorganic elements analyses; (4) three individual mice for PCB analysis; and (5) three individual mice for PFAS analysis. The following two sections report the 2021 results of this monitoring.

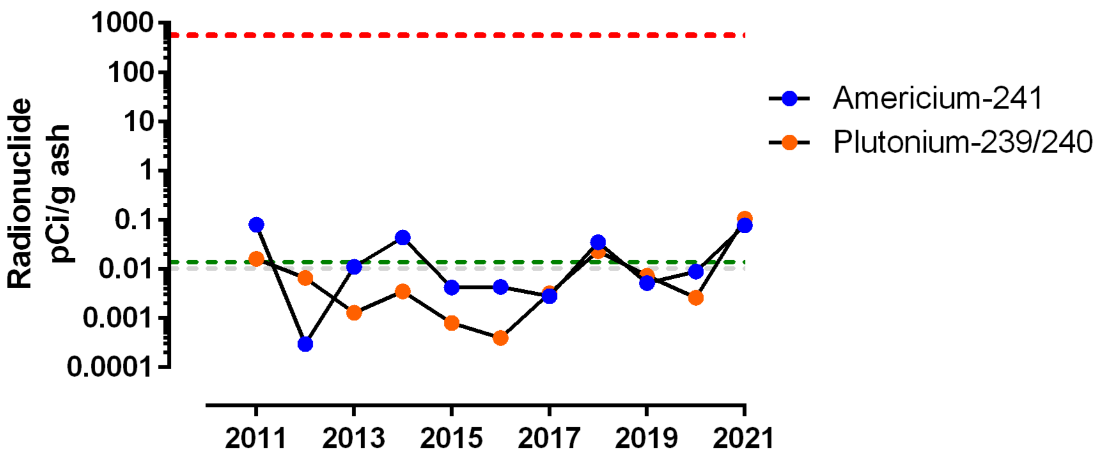
Los Alamos Canyon Weir

The Los Alamos Canyon weir is a water-control structure made of rock-filled wire cages called gabions. The weir was built in Los Alamos Canyon near the northeastern boundary of the Laboratory. The retention basin upstream of the weir covers more than one acre. Accumulated sediment was excavated from the retention basin in 2009, 2011, 2013, and 2014. Sediment excavated in 2009 was placed on the west side of the basin and stabilized, whereas sediment excavated in 2011, 2013, and 2014 was analyzed, placed on a plastic liner, contained within a berm, compacted, and seeded approximately 0.5 miles west of the weir in Los Alamos Canyon.

Vegetation Results

A composite understory vegetation sample was collected within the retention basin and submitted for radionuclide and inorganic element analyses in June 2021. Plants we collected include curly dock (*Rumex crispus*), kochia (*Bassia scoparia*), common mullein (*Verbascum thapsus*), rubber rabbitbrush (*Ericameria nauseosa*), and tarragon (*Artemisia dracunculus*).

In understory vegetation, americium-241, cesium-137, plutonium-239/240, and strontium-90 were detected and were above the regional statistical reference levels but were far below the biota dose screening levels (Table S7-10). The remaining radionuclides were either not detected or were below the regional statistical reference levels (Table S7-10). Americium-241 and plutonium-239/240 activities vary from year to year but are not significantly changing over time (Kendall's Tau, $p > 0.05$; see Figure 7-8). The high variability may be a result of disturbances from soil excavation at the weir or from sampling variability. Plants are collected at different locations within the basin each year. In addition, because of runoff events and water ponding, the stems and leaves of the plants may retain different amounts of sediment each year; sediment on plant material can influence radionuclide results.



Note: pCi/g = picocuries per gram

Figure 7-8. Americium-241 and plutonium-239/240 in understory vegetation collected on the upstream side (retention basin) of the Los Alamos Canyon weir from 2011–2021 compared with the biota dose screening level (red dashed line), and with the regional statistical reference level (green dashed line for americium-241 and gray dashed line for plutonium-239/240). Note the logarithmic scale on the vertical axis. Points represent true values; error bars are not available, as only one sample is collected annually.

Most inorganic elements were detected in understory vegetation and all concentrations of elements were below the regional statistical reference levels (Table S7-11). Similar to previous years, selenium was increasing over time (Kendall's Tau, $p < 0.05$). This trend will continue to be monitored; however, as the concentrations of selenium in the vegetation are below the regional statistical reference levels, it is not of ecological concern. All other levels of inorganic elements in vegetation are not changing over time (Kendall's Tau, $p > 0.05$).

Four PFAS chemicals were detected in the composite understory vegetation sample collected upstream of the Los Alamos Canyon weir in 2021. Perfluorobutanoic acid was detected at 1.30

nanograms per gram, perfluorohexanoic acid was detected at 0.406 nanograms per gram, 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid was detected at 9.33 nanograms per gram, and perfluoropentanoic acid was detected at 5.02 nanograms per gram. Perfluorobutanoic acid (used in synthetic chemistry), perfluorohexanoic acid, and perfluoropentanoic acid (used in many consumer products) are common PFAS chemicals observed in the environment (Ghisi et al. 2019). 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid is a more recently developed PFAS chemical that was manufactured to replace perfluorooctanesulfonic acid and is less toxic than perfluorooctanesulfonic acid (National Association for Surface Finishing 2019). Most detectable concentrations of PFAS in the understory vegetation sample were above their respective regional statistical reference levels. The literature lacks reports of PFAS levels and effects in native vegetation (i.e., non-agricultural plants).

Small Mammal Results

Small mammals were collected from the retention basin in June 2021 using Sherman® live traps. All animal handling procedures were approved by LANL's Institutional Animal Care and Use Committee. We captured three individual plains harvest mice (*Reithrodontomys montanus*) for inorganic element analyses, one deer mouse (*Peromyscus maniculatis*), one brush mouse (*Peromyscus boylii*), and one pinyon mouse (*Peromyscus truei*) for PCB congener analyses. We captured one brush mouse, one plains harvest mouse, and one pinyon mouse for PFAS analyses. Owing to low capture success, no animals were analyzed for radionuclides in 2021.

The 2021 small mammal results at the Los Alamos Canyon Weir are summarized as follows (see Tables S7-12 and S7-13 for individual results):

- Most inorganic elements were detected and were below the regional statistical reference levels.
- Most inorganic elements are not increasing over time.
- Zinc is increasing over time, but the overall concentration is similar to or below the regional statistical reference level.
- PCBs were detected but were below the regional statistical reference levels and the lowest observable adverse effect level.
- PCBs are increasing over time.
- Perfluoroundecanoic acid was detected in two small mammals, which exceeded the regional statistical reference level.
- Perfluoroundecanoic acid observations were within the range of observations in mammals collected from non-polluted sites in published literature.

Many inorganic elements were detected in small mammals (Table S7-12). Thallium concentrations in one mouse were detected at 0.011 milligrams per kilogram and exceeded the regional statistical reference level of 0.004 milligrams per kilogram. All remaining concentrations of elements were below their regional statistical reference levels. Most inorganic elements were not changing over time; however, zinc was increasing; this finding could be driven by the results from 2011–2017 (Kendall's Tau, $p < 0.05$, see Figure 7-9). Although zinc is increasing over time, the overall concentration is similar to or below the regional statistical reference level; thus, this level is not of ecological concern. This trend will continue to be monitored in the future.

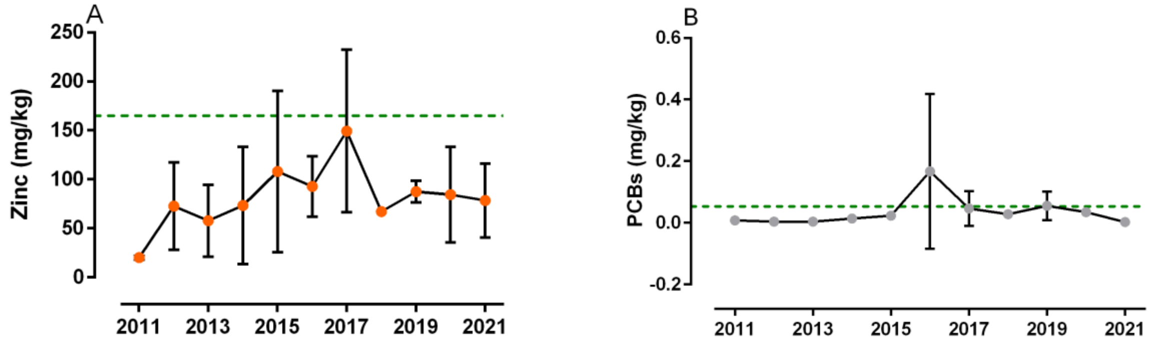


Figure 7-9. (A) Zinc and (B) PCB concentrations in individual whole-body mice samples collected upstream (in the retention basin) of the Los Alamos Canyon weir from 2011–2021 compared with the regional statistical reference level (mean plus three standard deviations of small mammals collected from background locations: green dashed line). Note the linear scale on the vertical axis. Points represent true values or the mean when multiple results were available; error bars represent standard deviation. Error bars may appear absent on some points, as standard deviations are too small to plot. Note: mg/kg = milligrams per kilogram.

PCBs were detected in all three mice collected upstream from the Los Alamos Canyon weir at concentrations of 0.0046, 0.0015, and 0.0004 milligrams per kilogram. These values were all below the regional statistical reference level of 0.0532 milligrams per kilogram (Table S7-13). All observed concentrations are two orders of magnitude below the lowest observable adverse effect level observed in mice (2.5 milligrams per kilogram) reported from PCB-contaminated sites where wild mouse populations were negatively affected (Batty et al. 1990). Thus, these levels are not expected to negatively affect the wild mouse population near the retention basin. The levels of PCBs in small mammals collected from the upstream side of the retention basin are increasing over time (Kendall’s Tau, $p < 0.05$; see Figure 7-9). The variability in PCB concentrations may be related to the removals of sediment from the basin between 2009 and 2014 and accumulation of sediment since that time.

A total of 37 PFAS chemicals were evaluated in small mammals and the majority were not detected. Similar to 2020, perfluoroundecanoic acid was detected in the brush mouse at 0.318 nanograms per gram and in the plains harvest mouse at 0.435 nanograms per gram, which exceeded the regional statistical reference level of 0.154 nanograms per gram. Perfluoroundecanoic acid is a longer chain PFAS molecule and has a greater propensity to bioaccumulate in animal tissues, as these molecules are difficult to metabolize. Perfluorodecane sulfonate was also detected in the plains harvest mouse at 0.166 nanograms per gram below the regional statistical reference level. Concentrations of PFAS chemicals observed here are within the range of observations reported in the published literature for mammals collected from non-polluted sites (Aas et al. 2014, Bossi et al. 2015).

Pajarito Canyon Flood-Retention Structure

The Pajarito Canyon flood-retention structure is located upstream of Technical Area 18. The structure extends 390 feet across the canyon and is about 70 feet high. The bottom of the retention structure is equipped with one 42-inch-diameter drainage culvert, which allows storm water to drain. Accumulated water is retained no longer than 96 hours behind the retention structure; water drains naturally into the existing streambed.

Vegetation Results

In June 2021, a composite understory vegetation sample was collected on the upstream side of the Pajarito Canyon flood-retention structure and analyzed for radionuclides, inorganic elements, and PFAS chemicals. Plants collected included curly dock, lamb's quarter (*Chenopodium album*), lamb's ear (*Stachys byzantine*), stinging nettle (*Urtica dioica*), tamarisk (*Tamarix* sp.), and tarragon.

In the composite vegetation sample, most radionuclides were either not detected or were below the regional statistical reference levels, and all radionuclide activities were below the biota dose screening level (Table S7-14). No trends over time in radionuclide activities in vegetation collected upstream of the Pajarito Canyon flood-retention structure were observed from 2010 to 2021 (Kendall's Tau, $p > 0.05$).

Several inorganic elements were not detected in the composite vegetation sample, and all elements were below the regional statistical reference level (Table S7-15). Selenium and antimony were found to be increasing in vegetation over time (Kendall's Tau, $p < 0.05$). However, the percentage of nondetects for selenium (70 percent) in the vegetation sample is high; therefore, the test for selenium trends has low reliability. Additionally, the concentration of selenium and antimony in the vegetation are below the regional statistical reference levels and are therefore not of ecological concern. All other levels of inorganic elements in vegetation are not changing over time (Kendall's Tau, $p > 0.05$).

No PFAS chemicals were detected in the composite understory vegetation sample.

Small Mammal Results

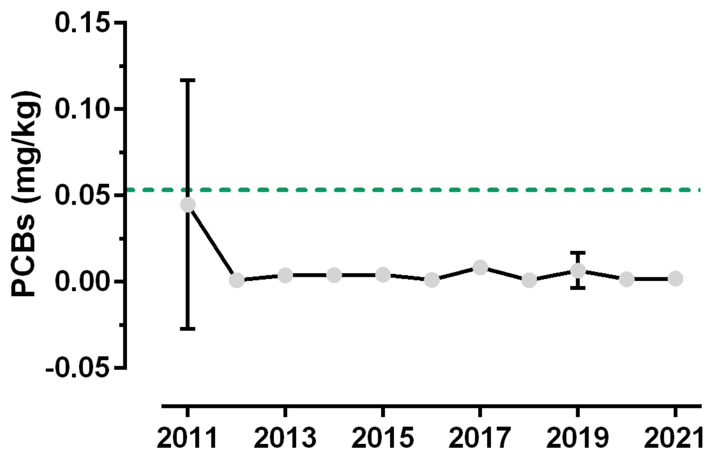
Small mammals were captured from the Pajarito Canyon flood-retention structure in June 2021 using Sherman® live traps. All animal handling procedures were approved by LANL's Institutional Animal Care and Use Committee. We captured three pinyon mice, two brush mice, two deer mice, and one silky pocket mouse (*Peromyscus flavus*). The silky pocket mouse and one pinyon mouse were analyzed for inorganic elements, one brush mouse and two individual pinyon mice were analyzed for PCB congeners, and one brush mouse and two individual deer mice were analyzed for PFAS chemicals. We did not capture enough animals for radionuclide analyses.

The 2021 small mammal chemical analyses results at the Pajarito Canyon flood-retention structure are summarized as follows (see Tables S7-16 and S7-17 for individual results):

- Most inorganic element concentrations in whole-body mouse samples were detected and were below the regional statistical reference levels.
- PCBs were detected at levels below the regional statistical reference level.
- Inorganic elements and PCBs are not increasing over time.
- Concentrations of detected PFAS chemicals were within the range of observations in published literature for mammals collected from non-polluted sites.

Most inorganic element concentrations in whole-body mouse samples were detected and were below their regional statistical reference levels. Only thallium slightly exceeded the regional statistical reference level in one of the mouse samples; thallium was detected at 0.006 milligrams per kilogram and exceeded the regional statistical reference level of 0.004 milligrams per kilogram. Inorganic elements in mice were not increasing over time (Kendall's Tau, $p > 0.05$).

PCBs were detected in the three mice collected upstream from the Pajarito Canyon flood-retention structure at concentrations of 0.0003, 0.00009, and 0.0051 milligrams per kilogram. These values are all below the regional statistical reference level of 0.05318 milligrams per kilogram (Table S7-17). All PCB concentrations are at least three orders of magnitude below the lowest observable adverse effect level observed in mice (2.5 milligrams per kilogram) reported from PCB-contaminated sites where wild mouse populations were negatively affected (Batty et al. 1990). Thus, the current PCB levels are not expected to negatively affect the wild mouse population near the retention basin. PCB concentrations in whole-body wild mice collected upstream of the Pajarito Canyon flood-retention structure are not changing over time (Kendall's Tau, $p > 0.05$; see Figure 7-10).



Note: mg/kg = milligrams per kilogram

Figure 7-10. PCB concentrations in individual whole-body mouse samples collected upstream (in the retention basin) of the Pajarito Canyon flood-retention structure from 2011–2021 compared with the regional statistical reference level (mean plus three standard deviations of small mammals collected from background locations: green dashed line). Note the linear scale on the vertical axis. Points represent the mean and error bars represent standard deviation. Error bars may appear absent on some points, as standard deviations are too small to plot.

A total of 37 PFAS chemicals each were evaluated in three individual mouse samples collected in Pajarito Canyon and the majority of PFAS chemicals were not detected. Each mouse contained detectable concentrations of one PFAS chemical. Perfluoroundecanoic acid, perfluorooctanesulfonic acid, and 1H, 1H, 2H, 2H-perfluorooactane sulfonic acid were detected at 0.140, 7.84, and 0.775 nanograms per kilogram, respectively. Perfluorooctanesulfonic acid exceeded regional statistical reference levels of 1.80 nanograms per gram. Perfluoroundecanoic acid is a longer chain PFAS molecule and has a greater propensity to bioaccumulate in animal tissues, as these molecules are difficult to metabolize. Concentrations of PFAS chemicals observed here are within the range of observations reported in published literature for mammals collected from non-polluted sites (Aas et al. 2014, Bossi et al. 2015).

Small Mammal Monitoring at Pueblo de San Ildefonso

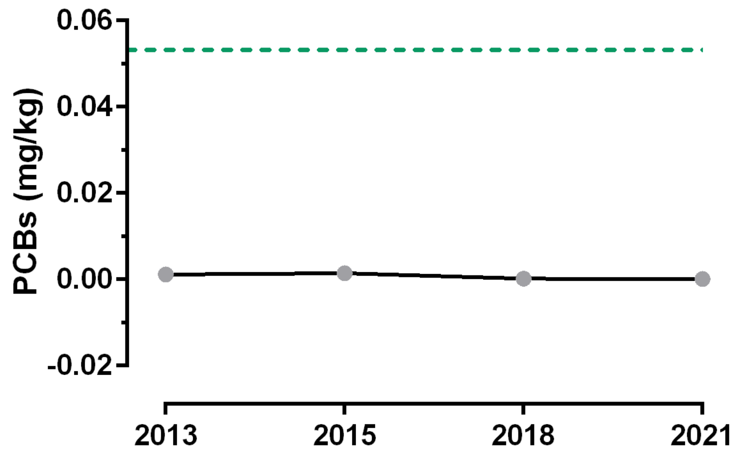
Small mammals are collected on a triennial basis in Los Alamos Canyon downstream of the weir on Pueblo de San Ildefonso property. The goal of the monitoring is to determine whether constituents are migrating downstream of the Laboratory, past the Los Alamos Canyon weir. Small mammals were collected in June 2021 using Sherman® live traps. All animal handling procedures were approved by LANL's Institutional Animal Care and Use committee. We captured eight brush mice and three pinyon mice. Three brush mice and one pinyon mouse were analyzed for radionuclides, two brush mice were analyzed for inorganic elements, one brush mouse and one pinyon mouse were analyzed for PCB congeners, and two brush mice and one pinyon mouse were analyzed for PFAS chemicals.

Most radionuclides were not detected. Strontium-90, uranium-234, and uranium-238 were detected but all were below the regional statistical reference level and far below the biota dose screening level (Table S7-18). A trend analyses could not be performed as a result of low sample size.

Most inorganic element concentrations in whole-body mice were detected and all concentrations were below the regional statistical reference levels (Table S7-19). Trends over time were not analyzed, as inorganic element concentrations in small mammals from this location were only available in 2015, 2018, and 2021.

PCBs were detected in one of the two whole-body mice. The total PCB concentration (0.0002 milligrams per kilograms) was well below the regional statistical reference level of 0.0532 milligrams per kilogram (Table S7-20). Furthermore, the observed concentration is well below the lowest observable adverse effect level observed in mice (2.5 milligrams per kilogram) reported from PCB-contaminated sites where wild mouse populations were negatively affected (Batty et al. 1990). Thus, the current PCB levels are not expected to negatively affect the wild mouse population. Additionally, PCB concentrations in whole-body wild mice collected downstream of the Los Alamos Canyon weir on Pueblo de San Ildefonso property continue to decrease over time (Kendall's' Tau, $p < 0.05$; Figure 7-11). These data suggest that the Los Alamos Canyon weir is retaining Laboratory-derived constituents onsite.

In 2021, PFAS chemicals were evaluated in small mammals from Pueblo de San Ildefonso for the first time; each mouse was evaluated for 37 PFAS chemicals. Two small mammals did not contain any detectable levels of PFAS chemicals. 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid was detected in one brush mouse at 2.03 nanograms per gram, which slightly exceeded the regional statistical reference level of 1.81 nanograms per gram. 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid is a more recently developed PFAS chemical that was manufactured to replace perfluorooctanesulfonic acid and is less toxic than perfluorooctanesulfonic acid (National Association for Surface Finishing 2019). Concentrations of PFAS chemicals observed here are within the range of observations reported in the published literature for mammals collected from non-polluted sites (Aas, et al. 2014, Bossi, et al. 2015).



Note: mg/kg = milligrams per kilogram

Figure 7-11. PCB concentrations in individual whole-body mouse samples collected downstream of the Los Alamos Canyon weir (retention basin) from 2013 to 2021 compared with the regional statistical reference level (mean plus three standard deviations of small mammals collected from background locations: green dashed line). Note the linear scale on the vertical axis. Points represent the mean and error bars represent standard deviation. Error bars may appear absent on some points, as standard deviations are too small to plot.

Institutional Monitoring

Large Animal Monitoring

Monitoring Network

The environmental monitoring and surveillance program has opportunistically collected road-killed mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*) from onsite, perimeter, and background locations since the 1970s (Los Alamos Scientific Laboratory 1973). To date, the program has collected and analyzed approximately 63 deer and 61 elk.

In 2015, the program expanded and began collecting other species including mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), black bear (*Ursus americanus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), great horned owl (*Bubo virginianus*), western screech-owl (*Megascops kennicottii*), red-tailed hawk (*Buteo jamaiciensis*), gopher snake (*Pituophis catenifer*), and additional species killed by vehicles or by other accidents.

In 2021, we collected four mule deer, one feral cow (*Bos taurus*), one gopher snake, two great horned owls, and two turkey vultures (*Cathartes aura*) from onsite and perimeter locations (see Figure 7-12). Duplicate samples were collected from one deer that was collected at Area G. Based on reports from personnel working at Area G, the deer was commonly seen for approximately 6 years; the cause of death is unknown. The feral cow that was struck by a vehicle on the Truck Route was verified as one of seven cattle residing in the Los Alamos and Sandia canyon area since February 2021. The gopher snake was collected at the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15. The majority of animals collected were casualties of vehicle strikes, though others came from different sources. Animal tissue samples were analyzed for radionuclides, inorganic elements, PCBs, and/or PFAS chemicals. Leg bone and muscle were harvested from the deer and cattle, and bone was analyzed for radionuclides while muscle was analyzed for radionuclides, inorganic elements, PCBs, and PFAS. A muscle sample was harvested from the gopher snake and one great horned owl, which were analyzed for PCBs and PFAS, while the remaining body (feathers included and unwashed) were analyzed for radionuclides and inorganic elements. Owing to low sample quality, the two turkey vultures and one great horned owl were submitted as whole body and only analyzed for radionuclides and inorganic elements. A liver sample from the gopher snake was also harvested and analyzed for PFAS.

We statistically tested the results from deer analyses from 2009 through 2021. Generalized linear models were used to assess the effects of year, location (onsite or perimeter), and the interaction of year by location on levels of chemicals and radionuclides. The models did not include deer from background because of small sample size. Models were not run when 80 percent or more of the results for a specific chemical or radionuclide were nondetects (Helsel 2012).

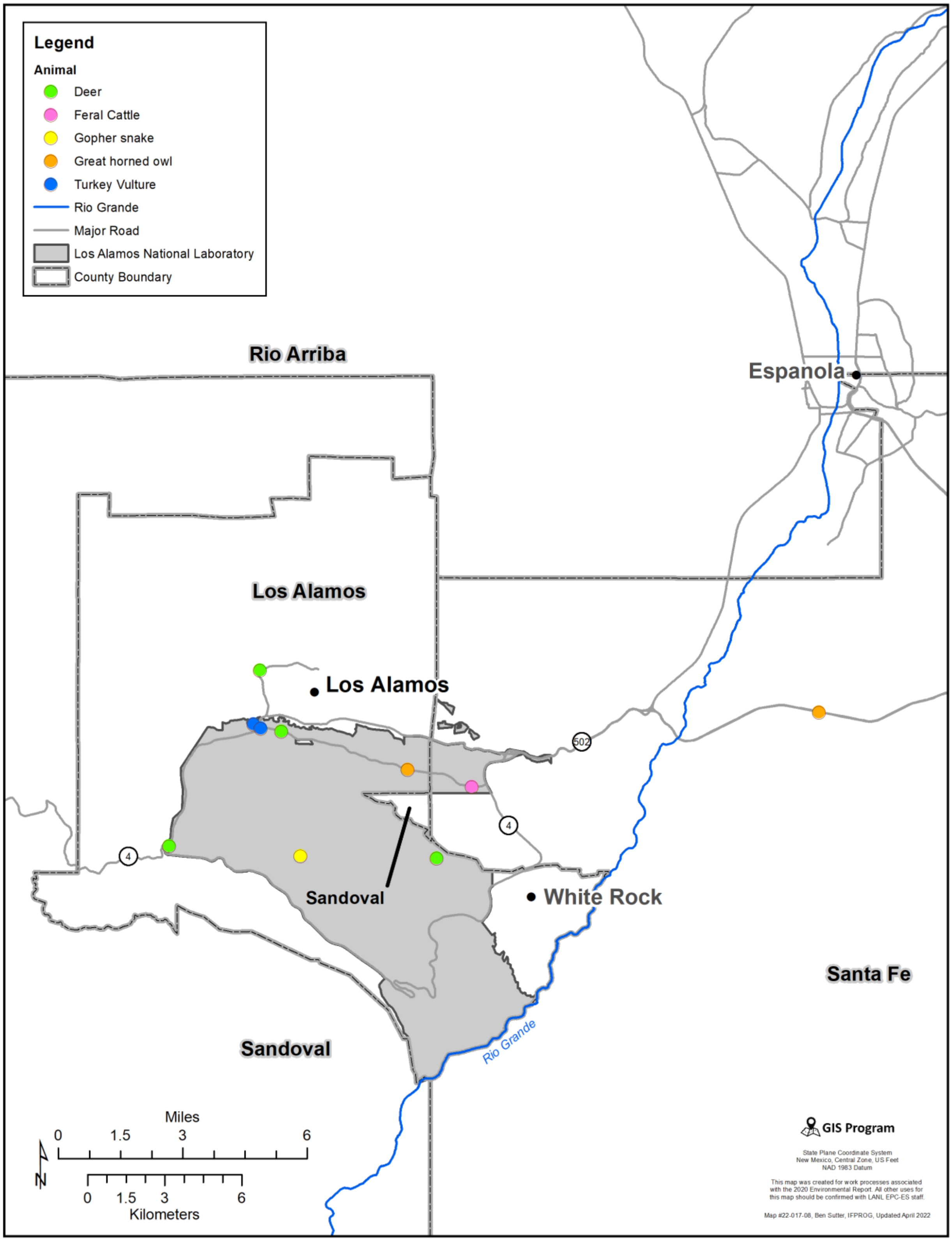


Figure 7-12. Locations of animals collected opportunistically from within and around the Laboratory in 2021.

Large Animal Monitoring Results

The 2021 large animal monitoring results are summarized as follows (see Tables S7-21 and S7-26 for individual results):

- The majority of radionuclides were not detected or were below the biota dose screening levels.
- Most inorganic element concentrations were below the regional statistical reference levels.
- PCBs were detected in the majority of samples, and all deer and cattle values were below the FDA red meat consumption guidelines.
- The majority of PFAS chemicals were not detected and those that were detected are within range of concentrations reported in the published literature for animal tissues collected from non-polluted sites.
- A gopher snake collected at the Dual-Axis Radiographic Hydrodynamic Test Facility contained the highest levels of PFAS chemicals.

Radionuclide Results in Large Animals

In 2021, except for strontium-90 and tritium, all remaining radionuclides were below the minimum detectable activity (most results) or below the regional statistical reference levels (Table S7-21). The deer from Area G with duplicate muscle and bone samples contained tritium levels of 330 and 334 picocuries per milliliter in muscle tissue and 326 and 348 picocuries per milliliter in bone. These values are higher than the regional statistical reference levels of 0.46 and 4.83 for muscle and bone, respectively, but are far below the biota dose screening level of 345,000 picocuries per milliliter. Elevated tritium levels have been documented in other animals sampled near Area G. In 2017, a great horned owl contained 14,800 picocuries per milliliter (Gaukler et al. 2018). These data suggest that some animals near Area G are incorporating tritium into their tissues from an environmental exposure. However, the levels observed are below the levels that cause adverse effects.

Four bone samples from deer and the feral cow contained strontium-90 activities (0.86 to 1.10 picocuries per gram) above the regional statistical reference level of 0.055 picocuries per gram. All activities were far below the biota dose screening level of 558 picocuries per gram.

In our analysis of results from deer between 2009 and 2021, there was a significant interaction between year and site, indicating that levels of tritium in deer muscle have differing trends over time in different locations (Generalized Linear Model, $p < 0.05$). Muscle tritium levels from onsite deer show an increasing trend when compared with perimeter deer; however, this result is driven by the deer collected from Area G in 2021 that contained 330 and 334 picocuries per milliliter in a duplicated sample. When these two results were removed from the dataset, there was no longer a significant interaction between site and year. There was also a significant trend in bone strontium-90 levels where levels are decreasing over time, and this was consistent between both onsite and perimeter deer (Generalized Linear Model, $p < 0.0001$).

All radionuclides were either not detected or were below their regional statistical reference levels in the turkey vultures and great horned owls (Table S7-22). Most radionuclides were not detected in the gopher snake collected from the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15; however, concentrations of strontium-90, uranium-234, and uranium-238 exceeded the regional statistical reference levels (Table S7-22). The relative isotopic abundance of uranium-234, uranium-235, and uranium-238 activities indicate that the uranium in the snake sample are depleted uranium from testing activities rather than natural uranium (U.S. Nuclear Regulatory Commission 2019) and is in line with other samples collected near the Dual-Axis Radiographic Hydrodynamic Test Facility. Currently, the regional statistical reference levels for gopher snake are based on a small sample size (n = 3). More data from background locations are needed to make robust assessments. However, levels of radionuclides observed in all animals were well below the biota dose screening levels.

Inorganic Element Results in Large Animals

Most inorganic elements in deer and a feral cow were below the regional statistical reference levels. Aluminum, barium, cadmium, lead, manganese, nickel, silver, and vanadium were higher than the regional statistical reference in one or more of the deer and cow samples (Table S7-23).

Most concentrations of inorganic elements in the muscle of deer collected from onsite did not differ from concentrations in deer collected from perimeter sites. Arsenic and silver were higher in onsite deer; however, these datasets contained 75% and 78% nondetected values (Generalized Linear Model, $p < 0.001$). Muscle lead concentrations are increasing over time, but this is consistent in both onsite and perimeter samples (Generalized Linear Model, $p < 0.0001$). As the majority of deer samples contain lead concentrations below the regional statistical reference level, this trend is not of concern. There was a significant interaction of year by location in deer antimony concentrations, indicating that the rate of change differed between onsite and perimeter locations (Generalized Linear Model, $p < 0.01$). Trends in these chemical concentrations will continue to be monitored.

In the gopher snake, turkey vultures, and great horned owls most inorganic elements were detected and were below the regional statistical reference levels, which is consistent with previous data. The gopher snake contained aluminum concentrations of 14 milligrams per kilogram, which is slightly above the regional statistical reference level of 12.2 milligrams per kilogram (Table S7-24). Antimony (7.6 milligrams per kilogram) was higher than the regional statistical reference level (0.132 milligrams per kilogram) in the great horned owl collected from a perimeter location (Table S7-24). Cadmium and iron (0.037 and 170 milligrams per kilogram, respectively) were slightly higher than the regional statistical reference levels (0.021 and 136 milligrams per gram, respectively) in one of the turkey vultures (Table S7-24). As previously mentioned, the regional statistical reference levels for these groups of animals are based on small sample sizes, and more data are needed to make robust assessments.

PCB Results in Large Animals

PCBs were detected in all but two deer samples. PCB concentrations in deer ranged from 0.0001 to 0.0012 milligrams per kilogram, three of which exceeded the regional statistical reference level of 0.0001 milligrams per kilograms (Table S7-25). Only one of the duplicate samples from the Area G deer had detected PCBs. Our observations are well below the U.S. Food and Drug Administration standard of 3 milligrams per kilogram for red meat consumption by humans (U.S. Food and Drug Administration 1987). There were no differences in total PCBs in deer onsite when compared with perimeter deer, nor were there changes over time between the sites (Generalized Linear Model, $p > 0.05$).

PCBs were detected in the gopher snake and great horned owl at 0.0003 and 0.0109 milligrams per kilogram, respectively (Table S7-26). The gopher snake and great horned owl contained

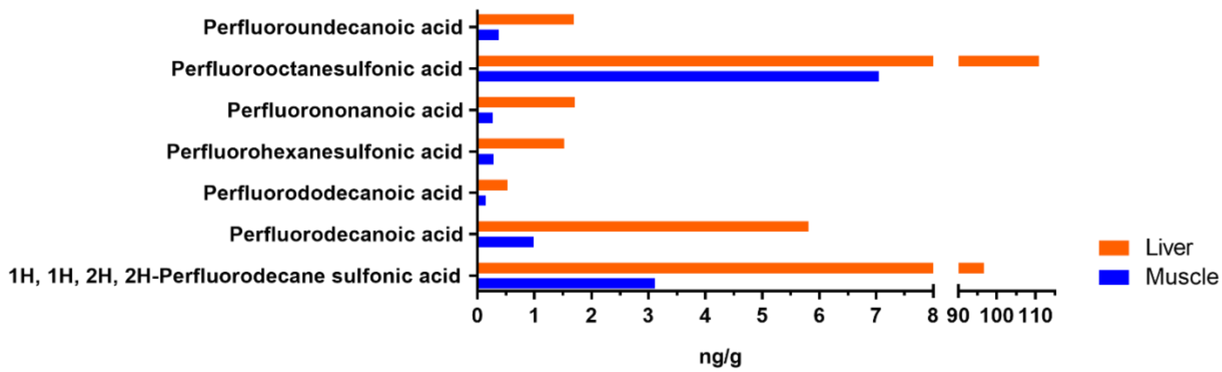
PCB levels that were below their respective regional statistical reference levels. The lowest observable adverse effect level of PCBs is between 1 and 30 milligrams per kilogram in avian eggs and 2–4 milligrams per kilograms in avian adult plasma (Harris and Elliott 2011). The levels observed here are well below the lowest observable adverse effect level for birds. The total PCB concentrations in our monitored animals are quite low overall. While there are no specific lowest observable adverse effect levels of PCBs for snakes, deer, and cattle, adverse effects in other animals are not observed until concentrations are above 1 milligram per kilogram (Batty et al. 1990, Harris and Elliott 2011).

PFAS Results in Large Animals

Perfluorooctanesulfonic acid was detected in one of the deer duplicate samples from Area G and a perimeter deer with concentrations of 0.201 and 0.205 nanograms per gram, respectively. No regional statistical reference levels are available for comparisons. No PFAS chemicals were detected in the feral cow.

Six PFAS chemicals were detected in the great horned owl sample collected near Pojoaque, New Mexico, including perfluorodecane sulfonate at 0.609 nanograms per gram, perfluorodecanoic acid at 0.412 nanograms per gram, perfluorododecanoic acid at 0.284 nanograms per gram, perfluorooctanesulfonic acid at 4.27 nanograms per gram, perfluorotridecanoic acid at 0.169 nanograms per gram, and perfluoroundecanoic acid at 0.216 nanograms per gram. Currently there are no regional statistical reference values available for comparisons.

The gopher snake collected at the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15 contained eight PFAS detections in the liver and seven detections in the muscle. The gopher snake liver sample contained perfluorobutanesulfonic acid at 15.9 nanograms per gram, but this PFAS chemical was not observed in the gopher snake muscle sample. PFAS concentrations were consistently higher in the liver samples compared to the muscle samples (see Figure 7-13); this observation is in accordance with mammalian studies in the published literature (Aas et al. 2014). The highest concentration detected was in the gopher snake liver sample for perfluorooctanesulfonic acid at 111 nanograms per gram. The gopher snake was collected on the south side of the Dual-Axis Radiographic Hydrodynamic Test Facility as a roadkill sample. As reported in a previous section, several PFAS chemicals were also detected in soil and sediment samples in the general area, including perfluorooctanesulfonic acid at 5.2 and 32 nanograms per gram. Not only are PFAS chemicals in the soil and sediment at the Dual-Axis Radiographic Hydrodynamic Test Facility, but these chemicals are appearing in biological tissues. While we do not currently have regional statistical reference values available for snake liver comparisons, PFAS concentrations in snake muscle exceeded the regional reference statistical levels for all detectable PFAS concentrations.



Note: ng/g = nanograms per gram

Figure 7-13. PFAS chemical concentrations in muscle and liver samples harvested from a road-killed gopher snake collected at the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15 in 2021.

Our observations (including the gopher snake) are within the ranges of PFAS concentrations observed in animal tissues from published studies, including studies that occurred away from point-source pollution and in the Antarctic, where global fallout is the primary source of PFAS in the environment (Aas et al. 2014, Bossi et al. 2015). As PFAS are recently emerging chemicals of concern, little is known about wildlife tissue concentrations and their relation to adverse effects.

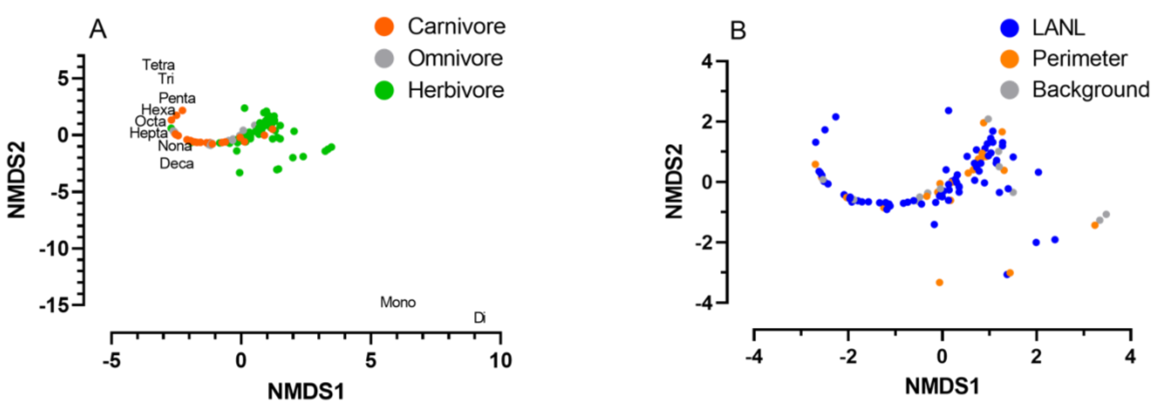
Special Assessment—PCB homolog analysis

There are 209 distinct PCB compounds, known as congeners. Living organisms are exposed to PCB compounds through uptake from soil, water, and food. PCB compounds that have the same number of chlorine atoms are said to belong to the same homolog group, ranging from monochlorinated biphenyl homologs, which contain one chlorine atom, to decachlorinated biphenyl homologs, which contain ten chlorine atoms. In general, animals eliminate more of the less-chlorinated PCB compounds from their bodies than the highly chlorinated PCB compounds, which are more readily stored in fat tissues. Animals that eat other animals ingest their prey's lifetime accumulation of stored PCBs. Because of this transport of the more highly chlorinated PCB compounds up food chains, these more highly chlorinated compounds are expected to dominate the results from higher trophic level animals when compared to lower trophic level animals (Khairy et al. 2021). We tested the hypothesis that carnivores and omnivores at and near the Laboratory would contain higher concentrations of the more chlorinated homolog groups than herbivores from similar locations.

We used PCB results from animal tissue samples collected from 2009 through 2021. We used non-metric multidimensional scaling with a Bray-Curtis dissimilarity matrix to assess differences in PCB homolog groups from various animals in relation to three feeding guilds – herbivores (deer, elk, and cattle), omnivores [bear, coyote, gray fox, and common raven (*Corvus corax*)], and carnivores [American badger (*Taxidea taxus*), American kestrel, bobcat, gopher snake, great horned owl, mountain lion, red-tailed hawk, and western screech owl]. We also used the non-metric multidimensional scaling results to assess differences of PCB homologs in relation to where the sample was collected—on Los Alamos National Laboratory property, perimeter locations, and background locations. We tested for differences in PCB homologs for feeding guilds and sample site locations with a nonparametric permutational multivariate analysis of variance. We used the package vegan (Oksanen et al. 2020) in the R statistical software version 3.5.3 for all data analyses (R Core Team 2021).

Results are presented as a biplot figure where the points on the plot are placed so that the distances among each pair of points correlates to the similarity or dissimilarity between those two samples in terms of PCB homolog results. We overlaid PCB homologs onto the non-metric multidimensional scaling biplot to visualize the PCB homolog associations with different feeding guilds. Results showed differences in the three feeding guilds in relation to PCB homologs, with the least difference seen between the carnivore and omnivore feeding guilds (see Figure 7-14, permutational multivariate analysis of variance, $p < 0.05$) and the most differences seen in the herbivore PCB homologs compared to the omnivores and carnivores (see Figure 7-14, permutational multivariate analysis of variance, $p < 0.05$). Differences were driven by the less chlorinated mono- and dichlorinated biphenyls. We did not see significant differences of PCB homologs in relation to where the sample was collected (see Figure 7-14, permutational multivariate analysis of variance, $p > 0.05$).

Our results showed that herbivores contained proportionally more of the lower chlorinated homolog groups when compared to omnivores and carnivores, suggesting biomagnification of PCB homologs in omnivores and carnivores. This observation was consistent among sampling locations (e.g., onsite, perimeter, and background) suggesting that this outcome was not affected by Laboratory operations.



Note: NMDS = non-metric multidimensional scaling

Figure 7-14. Non-metric multidimensional scaling results for 2009 through 2021. Points represent the PCB homolog composition from each animal sample and axes are arbitrary. (A) Differences were seen in the three feeding guilds in relation to PCB homologs (carnivore vs omnivore, omnivore vs herbivore, and carnivore vs herbivore). (B) PCB homolog composition for onsite, perimeter, and background locations are not significantly different.

Soil and Vegetation Monitoring

Monitoring Network

Institutional surface soil and vegetation samples are collected once every three years. The majority of onsite soil-sampling stations are located on undisturbed mesa tops close to and, if possible, downwind from major facilities or operations at the Laboratory. In 2021, we collected surface soil and vegetation from 16 onsite locations, 14 perimeter locations, and 6 regional background locations (see Figure 7-15). Many locations have been sampled for radionuclides since the early 1970s (Purtymun et al. 1980, Purtymun and Stoker 1987).

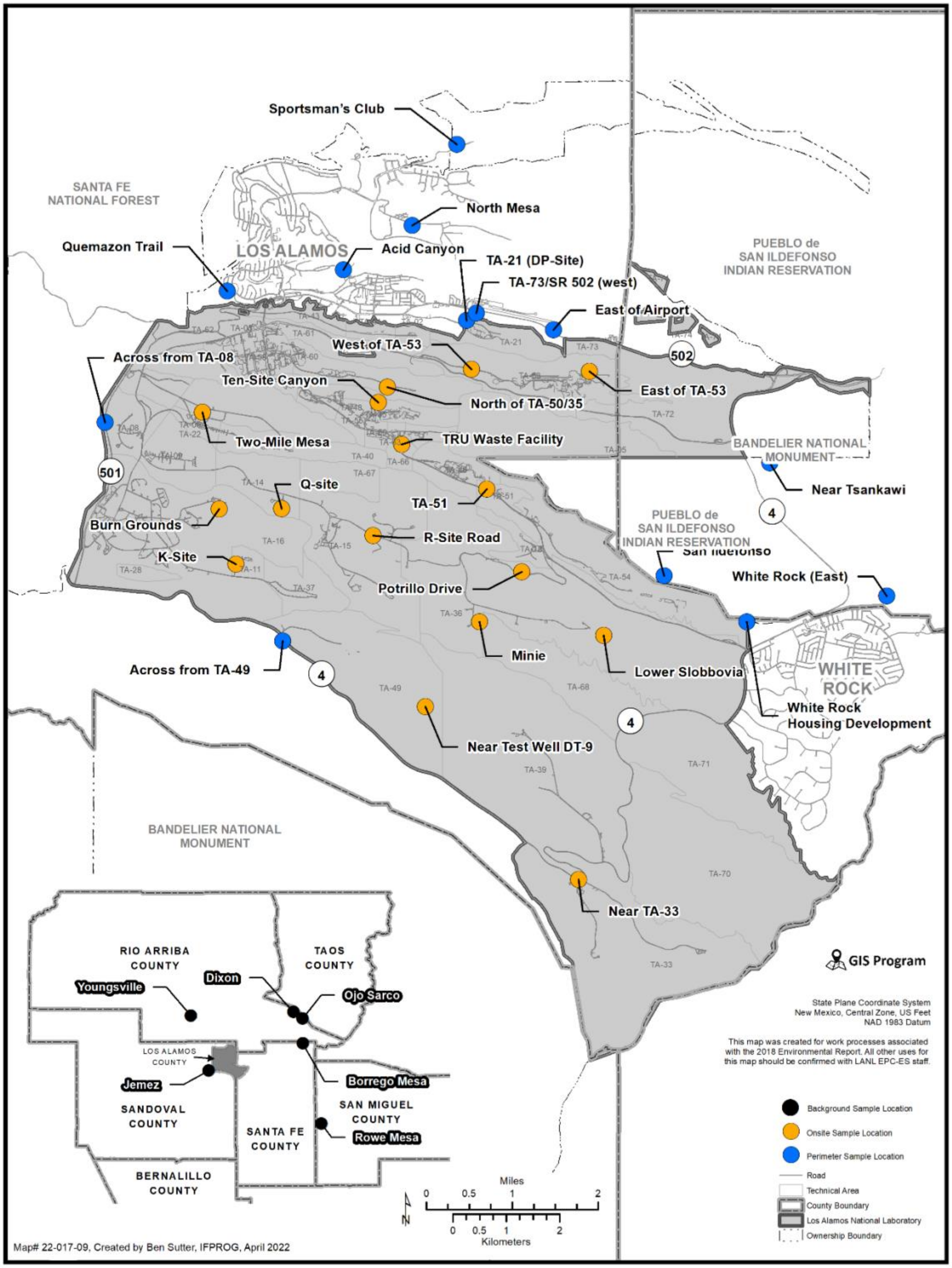


Figure 7-15. Onsite, perimeter, and regional (background) soil and vegetation sampling locations. The Otowi perimeter station is not shown but is about five miles east of the Laboratory, near the confluence of Los Alamos Canyon and the Rio Grande. Note: TA = Technical Area.

Onsite soil sampling locations include (1) west and (2) east of Technical Area 53 (Los Alamos Neutron Science Center); (3) near Technical Area 33 (former firing sites and current experimental sites); (4) near Test Well DT-9 at Technical Area 49 (former experimental site and current hazardous materials training facility); (5) north of Technical Areas 50 and 35 (Plutonium Facility and Radioactive Liquid Waste Treatment Facility); (6) Potrillo Drive at Technical Area 36 (firing sites that support explosive testing); (7) R-Site Road east at Technical Area 15 (explosives firing sites); (8) K-Site at Technical Area 11 (high-explosives processing and storage areas and firing sites); (9) Technical Area 51 (environmental research site of radioactive materials); (10) Two-Mile Mesa at Technical Area 06 (former radioactive materials processing facilities); (11) Lower Slobbovia at Technical Area 36 (explosives firing sites); (12) Minie at Technical Area 36 (explosives firing sites); (13) Q-site at Technical Area 14 (explosives firing sites); (14) Technical Area 16 (burning grounds); (15) Transuranic Waste Facility at Technical Area 63 (transuranic waste facility); and (16) Ten-Site Canyon at Technical Area 35 (received effluent from radioactive liquid waste treatment facility; see Figure 7-15).

All but one of the perimeter stations are located within 2.5 miles of the Laboratory boundary. Most of these locations are located in inhabited or publicly accessible areas to the north and east of the Laboratory. Los Alamos townsite locations include (1) North Mesa, (2) the Sportsman’s Club in Rendija Canyon, (3) along Quemazon Trail near Western Area, (4) east of the Los Alamos airport, (5) Acid Canyon; (6) near Technical Area 21 (former plutonium and tritium processing facilities); and (7) south side of NM 502 at Technical Area 73 (Technical Area 21 and its associated solid waste management units, including historical waste disposal sites). White Rock locations include (8) the new White Rock housing development area off of NM 4 (bordering Technical Area 54). Pueblo de San Ildefonso locations include (9) White Rock (east); (10) Pueblo de San Ildefonso Sacred Area lands directly north of Technical Area 54; (11) near the Otowi bridge over the Rio Grande; and (12) near Bandelier National Monument unit of Tsankawi at the intersection of NM 4 and East Jemez Road. West and southwest locations near the Laboratory include (13) west of Technical Area 08 and (14) south of Technical Area 49 (see Figure 7-15). Two sampling locations (Technical Area 21 and NM 502 at Technical Area 73) were previously labeled as onsite locations but were relabeled to perimeter locations as they are outside the Laboratory boundary.

Surface soil samples were collected from six regional background locations near (1) Ojo Sarco, (2) Dixon, and (3) Borrego Mesa (near Santa Cruz dam) to the northeast of the Laboratory; (4) Rowe Mesa (near Pecos) to the southeast of the Laboratory; (5) Youngsville to the northwest of the Laboratory; and (6) Jemez Springs to the southwest (see Figure 7-15).

Methods and Analyses

At each soil sampling location, five surface soil subsamples were collected at the center and in the corners of an approximately 10-meter by 10-meter square area. The subsamples were collected using a stainless-steel soil ring 10 centimeters in diameter pushed 5 centimeters into the ground. The five subsamples per location were combined and mixed thoroughly in a large plastic bag to form a composite sample. Composite samples were placed in polyethylene sample bottles, then labeled, sealed with chain-of-custody tape, placed on ice, and submitted to the Laboratory’s Sample Management Office. Samples were shipped under full chain of custody to the analytical laboratories ALS in Fort Collins, Colorado, for radionuclide and inorganic element analyses and GEL in Charleston, South Carolina, for PFAS analyses. These samples are analyzed for the radionuclides americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, tritium, uranium-234, uranium-235/236, and uranium-238; for 23 inorganic elements (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, sodium, selenium, silver, thallium, vanadium, and zinc); and for 37 PFAS chemicals.

A separate soil grab sample was collected near the center of each soil sample location from the 0- to 15-centimeter depth using stainless-steel scoops. Each grab sample was placed in an amber-colored glass sample bottle, then labeled, sealed with chain-of-custody tape, placed on ice, and submitted to the Laboratory's Sample Management Office. Samples were shipped under full chain of custody to the analytical laboratory GEL in Charleston, South Carolina, and analyzed for high explosives compounds, dioxins, furans, semi-volatile organic compounds, and volatile organic compounds. Grab soil samples were also shipped to Cape Fear Analytical, LLC in Wilmington, North Carolina, for PCB analyses.

Native overstory (e.g., trees and shrubs) were collected in the same general location that soil samples were collected (see Figure 7-15). During the years of institutional soil and vegetation monitoring, vegetation sample types are alternated. In 2021, overstory vegetation was collected and analyzed. Understory vegetation was last collected in 2018 (Gaukler et al. 2018). Overstory vegetation samples were clipped at approximately chest height then placed in a zippered plastic bag, labeled, sealed with chain-of-custody tape, placed on ice, and submitted to the Laboratory's Sample Management Office. All samples were shipped under full chain of custody to the analytical laboratories ALS in Fort Collins, Colorado, for radionuclide and inorganic elements analyses and GEL in Charleston, South Carolina, for PFAS analyses.

All soil chemical results were compared with the regional statistical reference level and with ecological screening levels. Vegetation chemical results were compared with the regional statistical reference levels, and radionuclide results were compared with biota dose screening levels. We statistically tested the results from our soil and vegetation analyses from 2012, 2015, 2018, and 2021. Generalized linear models were used to assess the effects of year, location (onsite, perimeter, and background), and the interaction of year by location. When there was a difference among locations, we used analyses of variance or Steel-Dwass tests to assess pairwise comparisons. We used a Kruskal-Wallis test to compare the levels of constituents that did not have results over multiple years (e.g., PCB congeners). Statistical analyses were not performed on datasets that contained 80 percent nondetects for a specific chemical or radionuclide (Helsel 2012).

The 2021 soil results are summarized as follows (see Tables S7-27 through S7-31 for individual results):

- The majority of radionuclides were below regional statistical reference levels, and all were below ecological screening levels.
- Uranium isotope activities varied among locations.
- Most inorganic elements were detected and were below the regional statistical reference levels.
- Lead concentrations exceeded the regional statistical reference levels and the no-effect ecological screening levels at six locations and are similar to previous results.
- The majority of inorganic elements were not changing over time and several elements had higher concentrations in soil samples collected from background locations.
- The most toxic dioxin compound (tetrachlorodibenzodioxin-2,3,7,8) was only detected in one soil sample collected at LANL.

- PCB congeners were detected in the majority of soil samples, and all were below ecological screening levels.
- There were no differences of PCB concentrations among locations.
- The majority of semi-volatile organic compounds was not detected.
- No volatile organic compounds were detected in soil samples.
- High explosives were only detected in two samples, both of which were collected at LANL.
- The majority of PFAS chemicals were not detected in soil samples.

Soil Monitoring Results

Radionuclide Results in Soil

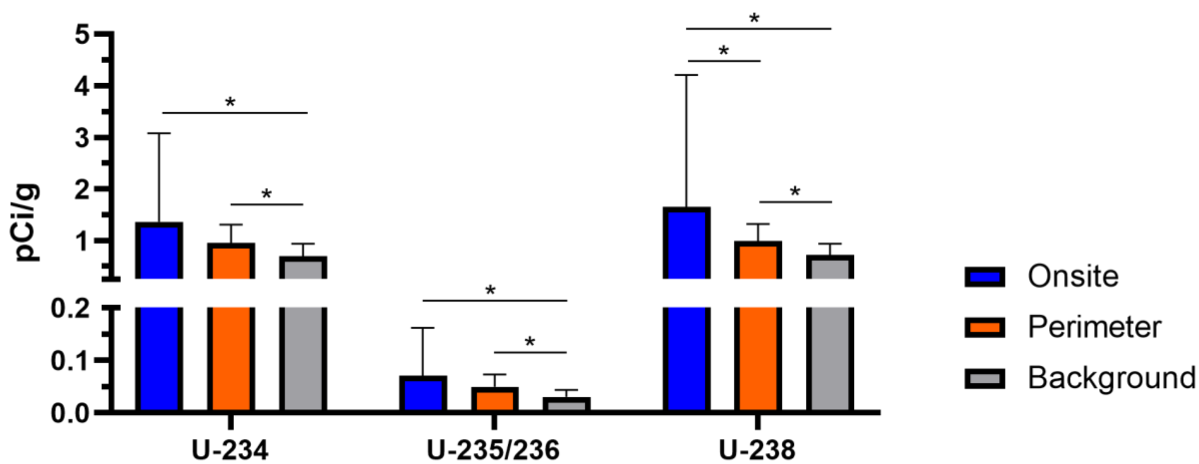
Uranium isotopes (uranium-234, uranium-235/236, and uranium-238) occur naturally in soil and were detected in all soil samples. Most of the other radionuclides were either not detected or were below regional statistical reference levels (Table S7-27). Six onsite and four perimeter locations contained one or more radionuclide levels that were higher than the regional statistical reference levels. The radionuclides most commonly detected above the regional statistical reference levels included americium-241, plutonium-239/240, and uranium-238. Onsite locations were in Technical Areas 15, 35, 36, 53, and 63, and perimeter locations included Acid Canyon, Quemazon trail, along State Road 502 (west), and near DP road by Technical Area 21. All detectable radionuclide activities were far below the no-effect ecological screening levels (Table S7-27).

One perimeter location, Acid Canyon, contained americium-241 (0.315 picocuries per gram), plutonium-239/240 (4.98 picocuries per gram) and strontium-90 (0.789 picocuries per gram) at levels that exceeded the regional statistical reference levels of 0.025, 0.064, and 0.416 picocuries per gram, respectively. These observations are in line with previous findings. Acid Canyon received radioactive waste from Laboratory operations between the mid-1940s and mid-1960s. The canyon has been remediated three times since then. However, residual radionuclides remain. Recent dose assessments within Acid Canyon are reported in Chapter 8 and in McNaughton et al. (2018).

There were no differences in trends or concentrations of americium-241, plutonium-238, plutonium-239/240, strontium-90, or tritium among locations (Generalized Linear Model, $p < 0.05$). There was a significant interaction of year by location in soil cesium-137 concentrations, indicating that the rate of change differed among locations (Generalized Linear Model, $p < 0.05$).

For uranium-234 and uranium-238 activities in soil, onsite locations had the highest activities and background locations had the lowest activities (Steel-Dwass, $p < 0.01$, see Figure 7-16). Additionally, uranium-235/236 was higher in soil collected from onsite and perimeter locations when compared with background locations (Steel-Dwass, $p < 0.01$, see Figure 7-16). There were no differences of uranium isotopes in soil over time (Generalize Linear Model, $p > 0.05$). The differences in uranium isotope activities among locations may be due to natural variation of uranium activities in different soil types; for example, Bandelier tuff, a common rock type in the sampling area, contains more uranium than other soil types (Longmire et al. 1995). Most soil samples contained a near 1:1 ratio of uranium-234 to uranium-238 activities, which indicates that these uranium activities are from naturally occurring sources (U.S. Nuclear Regulatory

Commission 2019). However, some locations, such as R-site Road and Lower Slobbovia, did have uranium isotope ratios that suggest a depleted uranium source (Table S7-27; U.S. Nuclear Regulatory Commission 2019). The concentrations observed at the LANL onsite locations in 2021 are within the range of Laboratory background concentrations from a previous study (Ryti et al. 1998) and all detectable radionuclide activities were far below the no-effect ecological screening levels.



Note: U = uranium and pCi/g = picocuries per gram

Figure 7-16. Uranium isotope activities in soil samples collected from 2012 through 2021 from onsite, perimeter, and background locations. Note the linear scale on the vertical axis. Column bars represent the mean and error bars represent standard deviation. A horizontal line with an asterisk indicates significant pairwise comparisons ($p < 0.05$).

Inorganic Element Results in Soil

Very few inorganic element results in soil exceeded the regional statistical reference levels (Table S7-28). Near Technical Area 21, antimony (1.7 milligrams per kilogram) exceeded the regional statistical reference level of 0.41 milligrams per kilogram but was well below the lowest no-effect ecological screening level. Mercury was detected in Acid Canyon soil at 0.077 milligrams per kilogram, which exceeded the regional statistical reference level of 0.043 milligrams per kilogram and the no-effect ecological screening level for the American robin of 0.013 milligrams per kilogram. Silver was detected (0.29 milligrams per kilogram) in soil at Technical Area 16, which slightly exceeded the regional statistical reference level of 0.202 milligrams per kilogram.

Lead concentrations at six locations exceeded the regional statistical reference level of 20.8 milligrams per kilogram. These locations are Acid Canyon, Quemazon Trail, along State Road 502 (west), at Technical Areas 51 and 63, and near DP road (near Technical Area 21). Lead near DP Road was detected at 130 milligrams per kilogram, while the other observations were less than 26 milligrams per kilogram. These observations all exceeded the no-effect ecological screening level (11 milligrams per kilogram) while the top two highest observations exceeded the low-effect ecological screening level (23 milligrams per kilogram) for the American robin (Table S7-28).

Lead has previously been detected above the regional statistical reference levels at Acid Canyon, Quemazon Trail, and near DP road (near Technical Area 21; Fresquez et al. 2016; Gaukler et al. 2019). In 2015, elevated lead (140 milligrams per kilogram) was detected in the soil sample collected from the location near DP Road (near Technical Area 21); this resulted from the demolition of a water tower in August of 2014 (Parsons 2014). The collapse of the tower onto the ground spread out fragments of lead-based paint from the tower. The elevated lead levels observed at this site in 2021 are likely still caused by the paint from the water tower. Two major sources of lead in soil are from auto emissions and lead-based paint. Studies conducted in urban areas have shown that lead levels in soil are highest around building foundations and within a few feet of busy streets (Rolfe et al. 1977, Singer and Hanson 1969). Although lead is not presently used in household paint or gasoline, it can persist in the soil for a long time. We do not know the reason for the elevated lead levels observed in Acid Canyon, Quemazon trail, or Technical Areas 51 and 63, but it is possible that the source of lead in Acid Canyon was from legacy waste discharges into the canyon.

There were no differences in trends or concentrations of antimony, lead, mercury, silver, or zinc among locations (Generalized Linear Model, $p < 0.05$). Most inorganic elements were not changing over time. Potassium, sodium, and selenium were increasing over time, and nickel was decreasing over time, but these trends were consistent among locations (Generalized Linear Model, $p < 0.05$).

For barium, background locations had the highest concentrations and soil collected from perimeter locations had the lowest concentrations (analysis of variance, $p < 0.05$). Similar to previous years, concentrations of several elements were higher in soil samples collected from background locations compared with onsite and/or perimeter samples, including aluminum, arsenic, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, selenium, thallium, and vanadium (analysis of variance or Steel-Dwass, $p < 0.05$). Power plants are one of the leading sources of air pollution (U.S. Environmental Protection Agency 2019). It is possible that releases from the Four Corners Power Plant (located in northeastern New Mexico) may explain why concentrations of some elements were higher in soil collected from background locations. These findings also may result from varying soil types and disturbance activities.

Dioxin and Furan Results in Soil

Dioxins and furans were first analyzed in soil as part of the institutional monitoring program in 2018. During 2021, some dioxin and furan compounds were detected above their regional statistical reference levels (Tables S7-29 and S7-30). Each compound was multiplied by its respective World Health Organization toxic equivalent factor (Van den Berg et al. 2006) and then compared with the tetrachlorodibenzodioxin-2,3,7,8 ecological screening levels. Similar to 2018 results, the soil sample collected from Technical Area 63 near the transuranic waste facility contained two dioxin and three furan compounds that exceeded only the no-effect ecological screening level and an additional four dioxin and four furan compounds that exceeded the low-effect ecological screening level for the montane shrew. Three other locations contained dioxin or furan compounds in soil samples that exceeded the no-effect ecological screening level: Ten-Site Canyon (onsite; two furan compounds), near Technical Area 21 (perimeter; one dioxin compound), and North Mesa (perimeter; two dioxin compounds). Owing to the high percentages of nondetects (>80%), statistical comparisons of dioxin and furan congeners among locations were not conducted (Helsel 2012). Overall, the detections and exceedances of dioxin and furan congeners are very low; 2.6 percent of the congeners evaluated exceeded the ecological screening levels. The number of locations with concentrations potentially associated with adverse effects at an individual level are minimal, and no impacts to populations or communities of plants and animals are expected.

PCB Results in Soil

Individual PCB compounds were analyzed in soil under the institutional monitoring program for the first time in 2021. PCB Aroclor mixtures were evaluated in previous years. PCBs were detected in most soil samples including samples from background locations. Soil samples from ten locations (six onsite and four from perimeter) exceeded the regional statistical reference level for total PCBs of 0.00046 milligrams per gram (Table S7-31). Ecological screening levels are only available for PCB Aroclor mixtures; therefore, we evaluated the proportions of PCB homologs from our results to determine the most similar Aroclor mixtures. PCB results from onsite and perimeter soil samples most closely resembled Aroclor mixture 1260. Total PCB concentrations detected in soil were below the lowest no-effect ecological screening level for Aroclor 1260 (Table S7-31). There were no differences in total PCB concentrations among sites (Kruskal-Wallis, $p < 0.05$).

Semi-Volatile Organic Compound Results in Soil

Soil samples were analyzed for 72 semi-volatile organic compounds. Only ten compounds had detectable concentrations at sampling locations. Di-n-butylphthalate was the most commonly detected semi-volatile organic compound at both onsite and perimeter locations ($n = 14$, range 0.025 to 0.622 milligrams per kilogram). Di-n-butylphthalate is commonly used to make synthetic materials softer and more flexible and is used in many consumer and industrial products. Di-n-butylphthalate exceeded the no-effect ecological screening level for the American robin (14 locations) and exceeded the low-effect ecological screening level for the American robin (10 locations). However, all observed concentrations were below the regional statistical reference level of 0.648 milligrams per kilogram.

Benzoic acid in soil samples at two onsite locations exceeded the no-effect ecological screening level for the montane shrew and deer mouse but were far below the low-effect ecological screening levels. All other detectable concentrations of semi-volatile organic compounds were below the no-effect ecological screening levels.

Volatile Organic Compound and High Explosives Results in Soil

Soil samples were analyzed for seven volatile organic compounds and 20 high explosive chemicals. None of the samples had detectable concentrations of volatile organic compounds. Only two onsite soil samples contained high explosive chemicals. Soil collected at the Minie firing site contained 1,3,5-triamino-2,4,6-trinitrobenzene at 34.2 milligrams per kilogram. Soil collected at the Technical Area 16 burn grounds contained 1,3,5-triamino-2,4,6-trinitrobenzene as well as amino-4,6-dinitrotoluene[2-] and amino-2,6-dinitrotoluene[4] at 6.86, 0.257, and 0.179 milligrams per kilogram, respectively. Both sites containing detectable concentrations of 1,3,5-triamino-2,4,6-trinitrobenzene exceeded the regional statistical reference level of 1.72 milligrams per kilogram. The detectable high explosive chemicals were well below the no-effect ecological screening levels.

PFAS Results in Soil

Most PFAS chemicals were not detected in soil samples collected from onsite and perimeter locations. Nine of 17 onsite locations and 6 of 13 perimeter locations had detectable concentrations of PFAS; only 5 chemicals total were detected out of the 37 chemicals analyzed per sample.

Most of the soil samples that contained detectable PFAS concentrations only contained one PFAS chemical; a maximum of three PFAS chemicals were detected within a single soil sample. The most common PFAS chemicals detected in soil were perfluorobutanoic acid (n = 6, range 0.209 to 0.448 nanograms per gram) and perfluorooctanesulfonic acid (n = 7, range 0.206 to 1.36 nanograms per gram). A soil sample collected from Acid Canyon contained 0.448 nanograms per gram of perfluorobutanoic acid, which slightly exceeded the regional statistical reference level of 0.408 nanograms per gram. Perfluorobutanoic acid is a common PFAS chemical observed in the environment (Ghisi et al. 2019). A soil sample collected from the Technical Area 16 burn grounds contained 1.36 nanograms per gram of perfluorooctanesulfonic acid, which exceeded the regional statistical reference level of 0.697 nanograms per gram. All remaining detectable concentrations of perfluorobutanoic acid and perfluorooctanesulfonic acid were below the regional statistical reference levels.

Perfluorooctanoic acid was detected in two onsite soil samples at 0.634 and 0.638 nanograms per gram, which exceeded the regional statistical reference level of 0.276 nanograms per gram. Perfluorodecane sulfonate and 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid were detected in one onsite soil sample each at 0.501 and 0.565 nanograms per gram, which exceeded the regional statistical reference levels of 0.228 and 0.538 nanograms per gram, respectively. 1H, 1H, 2H, 2H-perfluorododecanesulphonic acid was detected in soil collected from the Pueblo de San Ildefonso Sacred Area at 1.72 nanograms per gram, which exceeded the regional statistical reference level of 0.456 nanograms per gram.

Overall, few PFAS chemicals were observed in soil samples. Some of these observations exceeded the regional statistical reference levels, but all were below available ecological screening levels. Concentrations of total PFAS chemicals observed here are within the range of global observations of concentrations in soil collected from non-polluted sites (Brusseau et al. 2020).

Overstory Vegetation Monitoring Results

The 2021 overstory vegetation results are summarized as follows (see Tables S7-32 and S7-33 for individual results):

- Most radionuclide activities in vegetation were not detected or were below the regional statistical reference levels and all were far below biota dose screening levels.
- Strontium-90 was higher in plants collected from onsite and perimeter locations when compared with background locations.
- Uranium-234 and uranium-235/236 were higher in vegetation samples collected from onsite locations when compared with perimeter locations.
- Uranium-238 activity was higher in vegetation collected onsite when compared with background vegetation samples.
- The majority (99 percent) of inorganic elements in vegetation were below the regional statistical reference levels.
- Onsite vegetation contained less aluminum than perimeter and background vegetation samples, contained less iron than perimeter vegetation, and contained less magnesium than background vegetation.
- The majority (99 percent) of PFAS chemicals were not detected in overstory vegetation samples.

Radionuclide Results in Overstory Vegetation

All radionuclide activities in overstory vegetation, collected from onsite and perimeter locations, were either not detected (most results), below regional statistical reference levels, or far below biota screening levels (Table S7-32). These data are similar to previous results (Fresquez and Gonzales 2004, Gaukler et al. 2019).

No differences of americium-241, cesium-137, and plutonium-238 were observed among sites or over time (Generalized Linear Model, $p > 0.05$). Plutonium-239/240 and tritium are decreasing over time, and this is consistent among sites (Generalized Linear Model, $p < 0.05$). Strontium-90 was higher in onsite and perimeter overstory vegetation samples when compared with background and was not changing over time (Generalized Linear Model and Analysis of Variance, $p < 0.05$; see Figure 7-17). This is similar to the strontium-90 activities in overstory vegetation collected at Area G that is likely from global fallout, which is higher in areas with greater precipitation (Chawla et al. 2010).

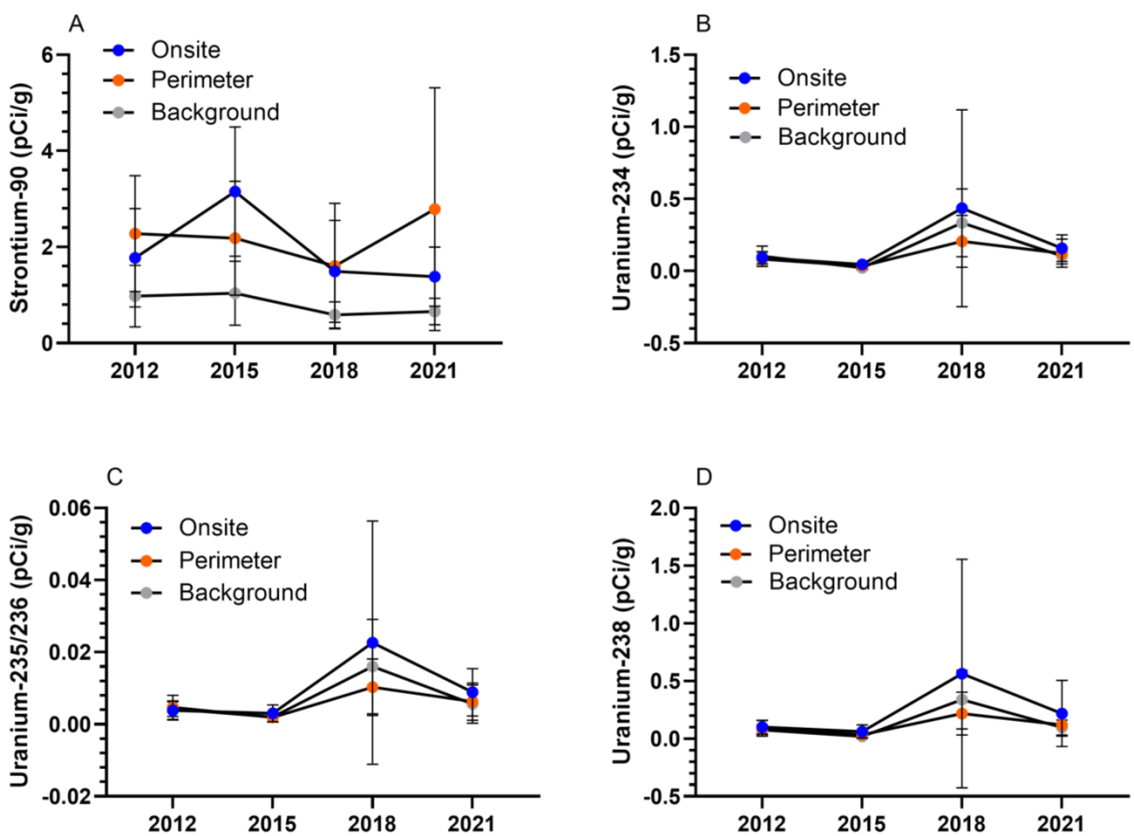


Figure 7-17. (A) Strontium-90, (B) uranium-234, (C) uranium-235/236, and (D) uranium-238 activities in overstory vegetation samples collected from 2012 through 2021 from onsite, perimeter, and from background locations. Note the linear scale on the vertical axis. Points represent the mean and error bars represent standard deviation. Error bars may appear absent on some points, as standard deviations are too small to plot. Note: pCi/g = picocuries per gram.

Uranium-234, 235/236, and 238 activities are increasing over time, and this was consistent among locations (Generalized Linear Model, $p < 0.05$). Additionally, uranium-234 and uranium-

235/236 activities were higher in overstory vegetation that was collected from onsite locations when compared with perimeter locations, and uranium-238 was higher in vegetation that was collected onsite when compared to perimeter and background locations (Generalized Linear Model, Analysis of Variance, and Steel-Dwass, $p < 0.05$; see Figure 7-17). Higher uranium activities in the vegetation sample collected at Lower Slobbovia is likely due to Laboratory operations (Table S7-32). However, differences in uranium activities in vegetation samples among sites could also be affected by natural variation of uranium isotope activities in soil or by aerosolized dust of uranium isotopes from natural sources or Laboratory operations. Vegetation samples are not rinsed prior to analyses. Although uranium isotope activities were higher in onsite overstory vegetation samples, the observed activities are far below the biota dose screening level that are protective of biota (Table S7-32).

Inorganic Element Results in Overstory Vegetation

Most inorganic element concentrations in overstory vegetation collected from onsite and perimeter locations were below regional statistical reference levels (Table S7-33). Antimony was detected slightly above the regional statistical reference level of 0.216 milligrams per kilogram in six onsite samples (range 0.220 to 0.260). At the Technical Area 16 burn ground location, manganese and zinc were detected at 308 and 52 milligrams per kilogram, respectively, which exceeded the regional statistical reference levels of 234 and 46.3 milligrams per kilogram, respectively.

As a result of the high percentage of nondetects (> 80 percent), we did not statistically compare beryllium, chromium, cobalt, lead, silver, and sodium concentrations over time or among locations. No differences were observed in arsenic and vanadium concentrations. Antimony was increasing over time while barium, cadmium, calcium, copper, magnesium, manganese, nickel, thallium, and zinc were decreasing; these observations are consistent among all locations (Generalized Linear Model, $p < 0.05$). Aluminum, iron, and magnesium concentrations varied by site. Onsite vegetation contained less magnesium than did background vegetation (Generalized Linear Model, $p < 0.05$). There was a significant interaction of year by location in mercury and selenium concentrations in vegetation, indicating that the rate of change differed among locations, but overall concentrations did not differ among sites (Generalized Linear Model, $p < 0.05$).

PFAS Results in Overstory Vegetation

Most PFAS chemicals were not detected in overstory vegetation samples collected on onsite and perimeter locations. Perfluorobutanoic acid was detected at 0.683 nanograms per gram near Technical Area 33 and methyl perfluorooctane sulfonamidoethanol[N-] at 0.779 nanograms per gram at Two-Mile Mesa at Technical Area 6. Two vegetation samples collected from Pueblo de San Ildefonso contained detectable PFAS concentrations. Near Tsankawi, vegetation contained 1.96, 2.03, and 0.817 nanograms per gram of ethyl perfluorooctane sulfonamidoethanol[N-], ethylperfluoro-1-octanesulfonamide[N-], and hexafluoropropylene oxide dimer acid GenX, respectively. Ethyl perfluorooctanesulfonamidoacetic acid[N-] was detected at 1.35 nanograms per gram in vegetation from the Pueblo de San Ildefonso Sacred Area. A vegetation sample collected along State Road 502 contained perfluoropentanoic acid and 9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid at 0.427 and 0.650 nanograms per gram, respectively. PFAS chemicals are a broad class of chemicals with varying uses, and therefore the specific uses and sources of some of these chemicals are unknown. However, perfluoropentanoic acid and perfluorobutanoic acid are common PFAS chemicals observed in the environment and are used in many consumer products, and in synthetic chemistry, respectively (Ghisi et al. 2019).

Overall, very few PFAS chemicals were detected in vegetation samples. The majority of the PFAS chemicals that were detected in overstory vegetation samples were above their respective regional statistical reference levels. The literature lacks reports of PFAS observations in non-agricultural plants; however, the concentrations observed here are unlikely to cause adverse effects.

Summary—PFAS Monitoring Results

Per- and polyfluoroalkyl substances (PFAS) are synthetic compounds found in many manufactured items such as cookware, food packaging, stain repellents, and fire-fighting foams. They repel oil, stains, grease, and water, and are fire-resistant. There are nearly 6,000 types of PFAS compounds. The widespread use of PFAS and their persistence in the environment means that the past and current uses of PFAS compounds can result in elevated PFAS levels in the environment and the accumulation of PFAS in animal tissues over time. PFAS also have possible impacts on human health.

In 2021, we collected 111 samples for PFAS analyses, including 46 soil samples, 38 vegetation samples, 15 small mammal samples, and 12 road-killed animal samples, on and off the Laboratory. Most of the samples were analyzed for a suite of 37 PFAS chemicals, while a few were analyzed for a suite of 14 PFAS chemicals.

Most of the soil samples that contained detectable PFAS concentrations only contained one PFAS chemical. The most common PFAS chemicals detected in soil were perfluorobutanoic acid and perfluorooctanesulfonic acid. Some of these observations exceeded the regional statistical reference levels, but all were far below available ecological screening levels.

PFAS chemicals were detected in nine vegetation samples. There was no dominant PFAS chemical present in vegetation; however, perfluoropentanoic acid was observed in four samples: two background locations, one perimeter location, and one onsite location. The majority of the PFAS chemicals that were detected in overstory vegetation samples were above their respective regional statistical reference levels.

We collected a total of 15 small mammals for PFAS analyses from five locations, including three onsite locations, one perimeter location at Pueblo de San Ildefonso in Los Alamos Canyon, and a background location in Española, NM. Four of the 15 animals did not contain any PFAS chemicals, and most small mammals contained only a single PFAS chemical. Perfluoroundecanoic acid was the most frequently detected PFAS chemical and was found in four small mammals (range 0.140 to 0.435 nanograms per gram). Some of the PFAS chemicals that were detected in small mammal samples were above their respective regional statistical reference levels.

We collected a total of nine samples for PFAS analyses from three deer, one feral cow, one great horned owl, and one gopher snake. Two deer, the cow, and the gopher snake were collected onsite, and one deer was collected from Los Alamos townsite. The owl was collected in Pojoaque, NM. One deer sample (from Area G) and the duplicate cow samples did not contain any detectable PFAS. Perfluorooctanesulfonic acid was the only PFAS chemical detected in two deer samples. The owl contained six detectable PFAS concentrations, including perfluorooctanesulfonic acid and perfluoroundecanoic acid. The gopher snake collected from the Dual-Axis Radiographic Hydrodynamic Test Facility contained the highest number and concentrations of PFAS chemicals. Our observations (including the gopher snake) are within the ranges of PFAS concentrations observed in animal tissues from published studies, including studies that occurred away from point-source pollution and in the Antarctic where global fallout is the primary source of PFAS in the environment (Aas et al. 2014, Bossi et al. 2015).

Overall, the majority of PFAS chemicals were not detected in soil, vegetation, and small and large animals. We observed more PFAS chemicals in soil when compared with vegetation. Additionally, there were no consistent patterns of PFAS distributions or detections between soil and vegetation at a site. Perfluorooctanesulfonic acid was the most commonly detected PFAS chemical in soil while there was no dominant chemical in vegetation. Perfluoroundecanoic acid was the most commonly detected PFAS chemical in small mammals and perfluorooctanesulfonic acid was the most commonly detected PFAS chemical in large animals; however, the great horned owl and gopher snake also contained perfluoroundecanoic acid.

The concentrations of detected PFAS chemicals were generally within the range of global observations of concentrations in soil and animals collected from non-polluted sites (Aas et al. 2014, Bossi et al. 2015, Brusseau et al. 2020). For most of our samples, the PFAS concentrations observed are suspected to be due to a non-point source, i.e., atmospheric deposition. We are exploring other potential sources for some of the PFAS chemicals detected in the different media. Anticipated sources are atmospheric deposition and historical use of PFAS-containing materials.

Please see the following sections for more detailed descriptions of PFAS results:

- Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15
- Sediment and Flood-Retention Structures
- Small Mammal Monitoring at Pueblo de San Ildefonso
- PFAS Results in Large Animals
- PFAS Results in Soil
- PFAS Results in Overstory Vegetation.

Biota Radiation Dose Assessment

The purpose of the biota dose assessment is to ensure that plant and animal populations are protected from the effects of Laboratory radioactive materials, as required by DOE Order 458.1 Admin Chg 1, Radiation Protection of the Public and the Environment. This assessment follows the guidance of the DOE standard, “A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota” (DOE 2019), and uses the standard DOE dose calculation program, RESRAD-BIOTA version 1.8.

What is a rad?

“Rad” is an acronym for radiation absorbed dose. A dose of 1 rad means that 1 gram of material absorbed 100 ergs of energy because of exposure to ionizing radiation. One rad is the same as 0.01 Gray. Different materials that receive the same exposure may not absorb the same amount of radiation.

Previous biota dose assessments were reported in the Annual Site Environmental Reports and concluded that biota doses for populations at the Laboratory are well below the DOE limits of 1 rad/day for terrestrial plants and aquatic animals and 0.1 rad/day for terrestrial animals (DOE 2019).

Plants receive doses from external radiation, and receive internal doses from radionuclides taken up through their roots, which in some cases penetrate material buried in material disposal areas. Animals also receive external dose, and in addition receive internal dose when they eat the plants. When a predator eats its prey, there is a possibility for bioaccumulation as the ingested material passes up the food chain. Bioaccumulation is accounted for by introducing “bioaccumulation factors” or “concentration ratios,” which are the ratios of the radionuclides in living tissue to the concentrations in the underlying soil and water.

The well-established concentration ratios provide the option of calculating the concentrations in living tissue from the concentrations in soil. Alternatively, the concentration ratios can be used to calculate the soil concentration from measured concentrations in biota tissue. The comparison of these two methods shows that in most cases the concentration ratios are conservative overestimates.

The biota doses reported below are calculated using site-representative values as described in Appendix F of the DOE standard, “A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota” (DOE 2019). Whenever the data allow alternative calculations of the dose from either soil or tissue data, the largest dose is reported below.

The source material potentially contributing to the biota doses at the Laboratory is legacy waste material. Ongoing remediation and radioactive decay generally result in decreasing concentrations over time, so a decreasing trend in biota dose is expected. However, ongoing operations and movement of soil or sediment may cause an accumulation of radioactive material, so key locations are reassessed annually.

Mesa-Top Facilities

Area G

This chapter reports new measurements of soil and vegetation around Material Disposal Area G, known as “Area G.” The results are generally comparable with previous years, though there is some year-to-year variation depending on the exact locations sampled. This year-to-year variation can be seen in the trend graphs of this chapter.

As recommended by the DOE standard (DOE 2019), this assessment uses the highest measured concentrations, and the resulting doses are reported in Table 7-2 and Table 7-3.

Table 7-2. Dose to Terrestrial Animals at Area G for 2021

	External		Internal		
Nuclide	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	Nuclide Total (rad/day)
Am-241	9.6E-10	9.6E-06	3.2E-07	7.4E-05	8.4E-05
Cs-137	2.4E-08	2.4E-05	3.1E-09	1.5E-06	2.6E-05
H-3	1.7E-04	3.3E-04	3.3E-04	3.3E-04	1.1E-03
Pu-238	1.1E-10	4.4E-07	2.3E-07	1.6E-05	1.7E-05
Pu-239	3.8E-10	1.5E-06	1.3E-06	8.6E-05	8.9E-05
Sr-90	4.0E-07	2.4E-05	3.2E-06	9.6E-05	1.2E-04
U-234	1.1E-08	1.1E-06	8.1E-06	3.1E-05	4.0E-05
U-235	1.4E-08	1.4E-06	3.5E-07	1.3E-06	3.1E-06

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
U-238	7.7E-07	7.7E-05	7.3E-06	2.7E-05	1.1E-04
Medium Total	1.7E-04	4.7E-04	3.5E-04	6.6E-04	**Overall Dose 1.6E-03**

DOE Limit: 0.1 rad / day for terrestrial animals

Table 7-3. Dose to Terrestrial Plants at Area G for 2021

Nuclide	External		Internal	Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Soil (rad/day)	
Am-241	9.6E-10	9.6E-06	1.4E-04	1.5E-04
Cs-137	2.4E-08	2.4E-05	1.5E-06	2.6E-05
H-3	1.7E-04	3.3E-04	3.5E-04	8.4E-04
Pu-238	1.1E-10	4.4E-07	4.9E-05	5.0E-05
Pu-239	3.8E-10	1.5E-06	4.2E-04	4.2E-04
Sr-90	4.0E-07	2.4E-05	9.6E-05	1.2E-04
U-234	1.1E-08	1.1E-06	3.1E-05	3.2E-05
U-235	1.4E-08	1.4E-06	1.3E-06	2.8E-06
U-238	7.7E-07	7.7E-05	2.8E-05	1.1E-04
Medium Total	1.7E-04	4.7E-04	1.1E-03	**Overall Dose 1.8E-03**

DOE Limit: 1.0 rad / day for terrestrial plants

At Area G, the largest dose contribution is from tritium, which is mostly concentrated near the southern edge of Area G, at locations 29-03 and 30-1 (see Figure 7-1). In 2021, tritium was detected in the soil, in the vegetation, and in a deer that was collected from within the fence at Area G; the cause of death is unknown. The tritium concentrations in the deer were similar in both bone and muscle and were about one third of the concentration used for Table 7-2.

The results in Table 7-2 show that the biota doses at Area G are well below the DOE limits of 0.1 rad/day for animals, and Table 7-3 shows the doses are also below the limit of 1 rad/day for plants. Overall, there are no measurable impacts to biota health.

Dual-Axis Radiographic Hydrodynamic Test Facility

The Dual-Axis Radiographic Hydrodynamic Test Facility biota dose assessment uses the same methods described in the previous section. The largest doses were calculated from the soil data, indicating that the tissue-to-soil concentration ratios are overestimates, as discussed above. The largest soil activities were entered into RESRAD-BIOTA, and the results are reported in Table 7-4 and Table 7-5.

Table 7-4. Dose to Terrestrial Animals at Dual-Axis Radiographic Hydrodynamic Test Facility for 2021

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
Am-241	1.4E-12	1.4E-08	4.8E-10	1.1E-07	1.3E-07

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
Cs-137	7.1E-09	7.1E-06	9.1E-10	4.6E-07	7.6E-06
H-3	1.4E-08	2.8E-08	2.8E-08	2.8E-08	9.7E-08
Pu-238	7.0E-13	2.8E-09	1.5E-09	1.0E-07	1.1E-07
Pu-239	1.7E-12	6.8E-09	6.0E-09	3.8E-07	4.0E-07
Sr-90	1.1E-07	6.5E-06	8.7E-07	2.6E-05	3.4E-05
U-234	3.8E-08	3.8E-06	2.9E-05	1.1E-04	1.4E-04
U-235	5.5E-08	5.5E-06	1.4E-06	5.2E-06	1.2E-05
U-238	2.9E-06	2.9E-04	2.7E-05	1.0E-04	4.2E-04
Medium Total	3.1E-06	3.1E-04	5.8E-05	2.4E-04	**Overall Dose 6.2E-04**

DOE Limit: 0.1 rad / day for terrestrial animals

Table 7-5. Dose to Terrestrial Plants at Dual-Axis Radiographic Hydrodynamic Test Facility for 2021

Nuclide	External		Internal	Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Soil (rad/day)	
Am-241	1.4E-12	1.4E-08	2.1E-07	2.3E-07
Cs-137	7.1E-09	7.1E-06	4.6E-07	7.6E-06
H-3	1.4E-08	2.8E-08	2.9E-08	7.1E-08
Pu-238	7.0E-13	2.8E-09	3.1E-07	3.2E-07
Pu-239	1.7E-12	6.8E-09	1.9E-06	1.9E-06
Sr-90	1.1E-07	6.5E-06	2.6E-05	3.3E-05
U-234	3.8E-08	3.8E-06	1.1E-04	1.1E-04
U-235	5.5E-08	5.5E-06	5.3E-06	1.1E-05
U-238	2.9E-06	2.9E-04	1.0E-04	3.9E-04
Medium Total	3.1E-06	3.1E-04	2.5E-04	**Overall Dose 5.6E-04**

DOE Limit: 1.0 rad / day for terrestrial plants

The largest dose contribution is from uranium, most of which is the result of Laboratory operations. The activities of the other radionuclides are consistent with natural background and global fallout.

Table 7-4 and Table 7-5 show that the biota doses are well below the DOE limits of 0.1 rad/day for animals and 1 rad/day for plants. There are no measurable impacts to biota health.

Sediment-Retention Sites in Canyons

Los Alamos Canyon Weir

The Los Alamos Canyon weir receives drainage from legacy materials at Technical Areas 01, 02, and 21. The soil and sediment trapped by the weir include slightly elevated activities of fission products (Cs-137 and Sr-90) and transuranic radionuclides (americium and plutonium). The largest doses were from natural uranium. As shown in Table 7-6 and Table 7-7 the doses are all less than 0.1% of the DOE limits.

Table 7-6. Dose to Terrestrial Animals in Los Alamos Canyon Weir for 2021

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
Am-241	9.6E-11	9.6E-07	3.2E-08	7.4E-06	8.4E-06
Cs-137	2.6E-08	2.6E-05	3.4E-09	1.7E-06	2.8E-05
Pu-238	4.0E-12	1.6E-08	8.4E-09	5.9E-07	6.1E-07
Pu-239	1.6E-11	6.6E-08	5.8E-08	3.7E-06	3.8E-06
Sr-90	4.0E-08	2.4E-06	3.2E-07	9.5E-06	1.2E-05
U-234	8.1E-09	8.1E-07	6.0E-06	2.3E-05	3.0E-05
U-235	8.7E-09	8.7E-07	2.2E-07	8.1E-07	1.9E-06
U-238	4.7E-07	4.7E-05	4.5E-06	1.7E-05	6.9E-05
Medium Total	5.5E-07	7.8E-05	1.1E-05	6.4E-05	**Overall Dose 1.5E-04**

DOE Limit: 0.1 rad / day for terrestrial animals

Table 7-7. Dose to Terrestrial Plants in Los Alamos Canyon Weir for 2021

Nuclide	External		Internal	Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Soil (rad/day)	
Am-241	9.6E-11	9.6E-07	1.4E-05	1.5E-05
Cs-137	2.6E-08	2.6E-05	1.7E-06	2.8E-05
Pu-238	4.0E-12	1.6E-08	1.8E-06	1.8E-06
Pu-239	1.6E-11	6.6E-08	1.8E-05	1.8E-05
Sr-90	4.0E-08	2.4E-06	9.5E-06	1.2E-05
U-234	8.1E-09	8.1E-07	2.3E-05	2.4E-05
U-235	8.7E-09	8.7E-07	8.2E-07	1.7E-06
U-238	4.7E-07	4.7E-05	1.7E-05	6.5E-05
Medium Total	5.5E-07	7.8E-05	8.6E-05	**Overall Dose 1.7E-04**

DOE Limit: 1 rad/day for terrestrial plants

Pajarito Canyon Flood-Retention Structure

The Pajarito Canyon flood-retention structure does not receive significant quantities of LANL radionuclides. During 2021, any contribution from DOE operations was indistinguishable from background. The total biota dose in Pajarito Canyon is much less than 1 percent of the DOE limits and has no measurable impact on biota health.

Site-Wide Assessment

Every three years, soil and vegetation samples are collected from selected locations throughout the Laboratory, and these are used for the site-wide assessment shown in Table 7-8 and Table 7-9.

Table 7-8. Dose to Terrestrial Animals Site-Wide for 2021

Nuclide	External Water (rad/day)	External Soil (rad/day)	Internal Water (rad/day)	Internal Soil (rad/day)	Nuclide Total (rad/day)
Am-241	9.3E-11	9.3E-07	3.1E-08	7.2E-06	8.1E-06
Cs-137	2.2E-08	2.2E-05	2.9E-09	1.4E-06	2.4E-05
H-3	2.4E-05	4.9E-08	4.8E-05	4.8E-08	7.2E-05
Pu-238	2.8E-12	1.1E-08	5.9E-09	4.1E-07	4.3E-07
Pu-239	3.5E-10	1.4E-06	1.2E-06	8.0E-05	8.3E-05
Sr-90	7.6E-07	4.6E-05	6.1E-06	1.8E-04	2.4E-04
U-234	8.1E-08	8.1E-06	6.0E-05	2.3E-04	3.0E-04
U-235	1.1E-07	1.1E-05	2.9E-06	1.1E-05	2.5E-05
U-238	8.3E-06	8.3E-04	7.9E-05	3.0E-04	1.2E-03
Medium Total	3.4E-05	9.2E-04	2.0E-04	8.1E-04	**Overall Dose 2.0E-03**

DOE Limit: 0.1 rad / day for terrestrial animals

Table 7-9. Dose to Terrestrial Plants Site-Wide for 2021

Nuclide	External Water (rad/day)	External Soil (rad/day)	Internal Soil (rad/day)	Nuclide Total (rad/day)
Am-241	9.3E-11	9.3E-07	1.4E-05	1.5E-05
Cs-137	2.2E-08	2.2E-05	1.4E-06	2.4E-05
H-3	2.4E-05	4.9E-08	5.1E-08	2.4E-05
Pu-238	2.8E-12	1.1E-08	1.3E-06	1.3E-06
Pu-239	3.5E-10	1.4E-06	3.9E-04	3.9E-04
Sr-90	7.6E-07	4.6E-05	1.8E-04	2.3E-04
U-234	8.1E-08	8.1E-06	2.3E-04	2.4E-04
U-235	1.1E-07	1.1E-05	1.1E-05	2.2E-05
U-238	8.3E-06	8.3E-04	3.0E-04	1.1E-03
Medium Total	3.4E-05	9.2E-04	1.1E-03	**Overall Dose 2.1E-03**

DOE Limit: 1.0 rad / day for terrestrial plants

The largest dose contribution is from uranium at Technical Area 15, though the total biota dose is far below the DOE limits.

Animals at All Other Locations

Road-Killed Animals

The site-wide assessment is supported by data from road-killed animals such as deer that roam throughout the site. Most of the data are consistent with naturally occurring radioactivity and global fallout, though there are some exceptions as follows.

- The deer collected on September 20, 2021, at Area G is discussed in the Area G section above.
- Measurements of plutonium-238 that are slightly above background were affected by small amounts of contamination at the analytical laboratory.

- Global fallout is slightly higher on the Pajarito Plateau than in the Rio Grande valley because of the increased snow and rainfall closer to the mountains. The animal data are consistent with the patterns of global fallout in the soil and vegetation.
- Generally, the concentrations are consistent with the soil data and the resulting doses are much less than 1 percent of the DOE limits. There is no measurable impact to the health of these animals from radioactive material.

Conclusion

Previous biota dose assessments have shown that biota doses at LANL are far below the DOE limits. This 2021 assessment confirms the previous assessments and shows that there are no harmful effects from radionuclides released by Laboratory operations on the health of biota populations at LANL.

Biological Resources Management Program

We monitor federally listed, threatened, or endangered species and migratory bird species; provide guidelines and requirements for Laboratory operations to minimize impacts to sensitive species and their habitats and ensure that all Laboratory operations comply with federal and state regulatory requirements.

Threatened and Endangered Species Surveys

In 2021, we completed surveys for three species protected under the Endangered Species Act: the Mexican spotted owl (*Strix occidentalis lucida*), the southwestern willow flycatcher (*Empidonax traillii extimus)*, and the Jemez Mountains salamander (*Plethodon neomexicanus*).

Mexican spotted owl

The Mexican spotted owl generally inhabits mixed conifer, ponderosa pine (*Pinus ponderosa*), and gambel oak (*Quercus gambelii*) forests in mountains and canyons (U.S. Fish and Wildlife Service 2012). Mexican spotted owls in the Jemez Mountains of northern New Mexico prefer cliff faces in canyons for their nest sites (Johnson and Johnson 1985).

Under the Laboratory's Threatened and Endangered Species Habitat Management Plan, Mexican spotted owl habitat has been identified based on a combination of cliff habitat and forest characteristics (LANL 2022). Habitats of threatened and endangered species are called areas of environmental interest at LANL. Currently, five Mexican spotted owl areas of environmental interest span seven canyons at the Laboratory.

Surveys for breeding Mexican spotted owls are conducted every year in areas of environmental interest. In 2021, we detected Mexican spotted owls in the Mortandad and Three-Mile canyon areas of environmental interest. We confirmed occupancy of both sites by breeding pairs, but they did not successfully fledge any young. This is likely due to lower-than-average precipitation during the 2020 monsoon and winter seasons that limited the availability of food in early 2021 (Yang et al. 2021; Stanek et al. 2022). Mexican spotted owls have occupied these two sites in previous years (Thompson et al. 2021).

Southwestern willow flycatcher

The Southwestern willow flycatcher is found in close association with dense stands of willows (*Salix* spp.), arrowweed (*Pluchea* sp.), buttonbush (*Cephalanthus occidentalis*), tamarisk (*Tamarix* sp.), Russian olive (*Elaeagnus angustifolia*), and other riparian vegetation, often with a scattered overstory of cottonwood (*Populus* sp.; U.S. Fish and Wildlife Service 2002).

Under the Laboratory's Threatened and Endangered Species Habitat Management Plan, Southwestern willow flycatcher habitat has been identified based on the presence of riparian habitat with suitable wetland vegetation (LANL 2022). There is only one area of environmental interest for the southwestern willow flycatcher at the Laboratory, located in the bottom of Pajarito Canyon. There were no detections in 2021.

Jemez Mountains salamander

The Jemez Mountains salamander occurs predominantly at elevations between 7,000 and 11,000 feet in mixed-conifer and spruce-fir forests, consisting primarily of Douglas fir (*Pseudotsuga menziesii*), blue spruce (*Picea pungens*), Engelmann spruce (*Picea Engelmannii*), white fir (*Abies concolor*), limber pine (*Pinus flexilis*), ponderosa pine, Rocky Mountain maple (*Acer glabrum*), and aspen (*Populus tremuloides*; Degenhardt et al. 1996).

Under the Laboratory's Threatened and Endangered Species Habitat Management Plan, Jemez Mountains salamander habitat has been identified based on a geographical information systems analysis and a field-validated inspection of suitable habitat components (LANL 2022). Currently, there are five Jemez Mountains salamander areas of environmental interest at the Laboratory in four canyons. We conduct surveys when suitable environmental conditions are met. One survey was conducted in 2021 on LANL property, and no salamanders were detected.

Migratory Bird Monitoring

Breeding Season Bird Banding at the Sandia Wetlands

We have been operating a bird banding station in the Sandia Canyon wetland since 2014. This wetland contains primarily broadleaf cattail (*Typha latifolia*), lanceleaf cottonwood (*Populus acuminata*) narrowleaf willow (*Salix exigua*), and Russian olive (N3B 2019). The Sandia Wetlands support numerous species of breeding birds, including many species of conservation concern. The purpose of this project is to monitor the species, age classes, breeding status, and return rates of songbirds using the area around the wetland.

Beginning in May each year, we operate the bird banding station during the bird breeding season using a protocol called Monitoring Avian Productivity and Survivorship (DeSante et al. 2021), administered by The Institute for Bird Populations. Use of the Monitoring Avian Productivity and Survivorship protocol is a continent-wide collaborative effort among public agencies, non-governmental groups, and individuals. By following a standard protocol, we produce data that can be compared among sites.

During banding sessions, we deploy 12 mist nets that are 12 meters long with 30-millimeter mesh in and around the wetland. A standard U.S. Geological Survey uniquely numbered aluminum band is put on each captured bird. All birds are identified, aged, sexed, weighed, measured, fat scored, and checked for signs of molting feathers. We use the aging and sexing criteria provided in the Identification Guide to North American Birds (Pyle 1997).

A total of 1,730 birds representing 76 species have been captured during the breeding seasons of 2014 through 2021. In 2021, we captured 156 birds representing 37 species. The most commonly captured species in 2021 was the Pygmy nuthatch (*Sitta pygmaea*). The most commonly recaptured and second most commonly captured bird overall at this site was the Western wood-pewee (*Contopus sordidulus*).

Fall Migration Bird Banding at Pajarito Wetlands

Biologists at the Laboratory also monitor birds during fall migration on Laboratory property. During the fall of 2021, we completed the twelfth year of monitoring birds during fall migration. Birds were captured at a mist-netting station located in a wetland and riparian complex in Technical Area 36 on the north side of Pajarito Road.

The fall banding station uses 14 mist nets that are 12 meters long with 30-millimeter mesh. A uniquely numbered aluminum band is put on each bird. All birds are identified, aged, sexed, weighed, measured, fat scored, and checked for signs of molting feathers. The aging and sexing criteria are based on the Identification Guide to North American Birds (Pyle 1997).

Since 2010 when the fall banding station was established, 5,008 birds have been captured. During the fall of 2019 we captured the highest number of birds totaling 1,375 birds, while the following year (2020) we captured the lowest overall number at 193 birds. In 2021, we captured 321 birds representing 38 species. The most commonly captured bird species at this site in 2021 were house finches (*Haemorhous mexicanus*) and chipping sparrows (*Spizella passerina*). The chipping sparrow was also the most recaptured bird species in 2021 at the fall station.

Bird Monitoring at Open-Detonation and Open-Burn Firing Sites

We began bird population monitoring in 2013 for two open detonation sites and at the open burn grounds as part of a Resource Conservation and Recovery Act permitting process (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock et al. 2017, 2018, 2019, 2020). Open detonation sites are locations at the Laboratory where explosives are set off. The open burn grounds is a facility where materials are ignited for self-sustained combustion (for example, to remove residues of high explosives). The two open detonation sites included in the permitting process are Minie site at Technical Area 36 and Technical Area 39 Point 6; the open burn grounds is in Technical Area 16. Together these are referred to as the treatment sites. The ongoing objective of the population monitoring is to determine whether Laboratory operations at these sites impact bird species richness (the number of different species present), species diversity (a combination of the number of species present and their relative abundance), or composition (the presence or absence of each individual species).

Point-Count Surveys

Biologists at the Laboratory use point count methodology to survey birds along transects at the three treatment sites and compare the results to surveys conducted in control sites of similar habitats in less developed areas. The habitat type at Technical Area 36 and Technical Area 39 is a two-needle pinyon pine (*Pinus edulis*) and one-seed juniper woodland habitat referred to as pinyon-juniper. The habitat type at Technical Area 16 is a forested ponderosa pine habitat referred to as ponderosa pine. Surveys reported here are conducted in the summer during the bird breeding season.

A total of 778 birds representing 58 species were recorded at the three treatment sites combined in 2021 (Gadek and Velardi 2021). The species richness and diversity at the treatment sites were statistically different from their associated controls for Technical Area 36 (Minie) and Technical Area 16, but not for Technical Area 39 (see Figure 7-18 and Figure 7-19). The species diversity at all three treatment sites has been slightly diverging from the controls over the past few years. Diversity has remained higher at the treatment sites compared to the controls.

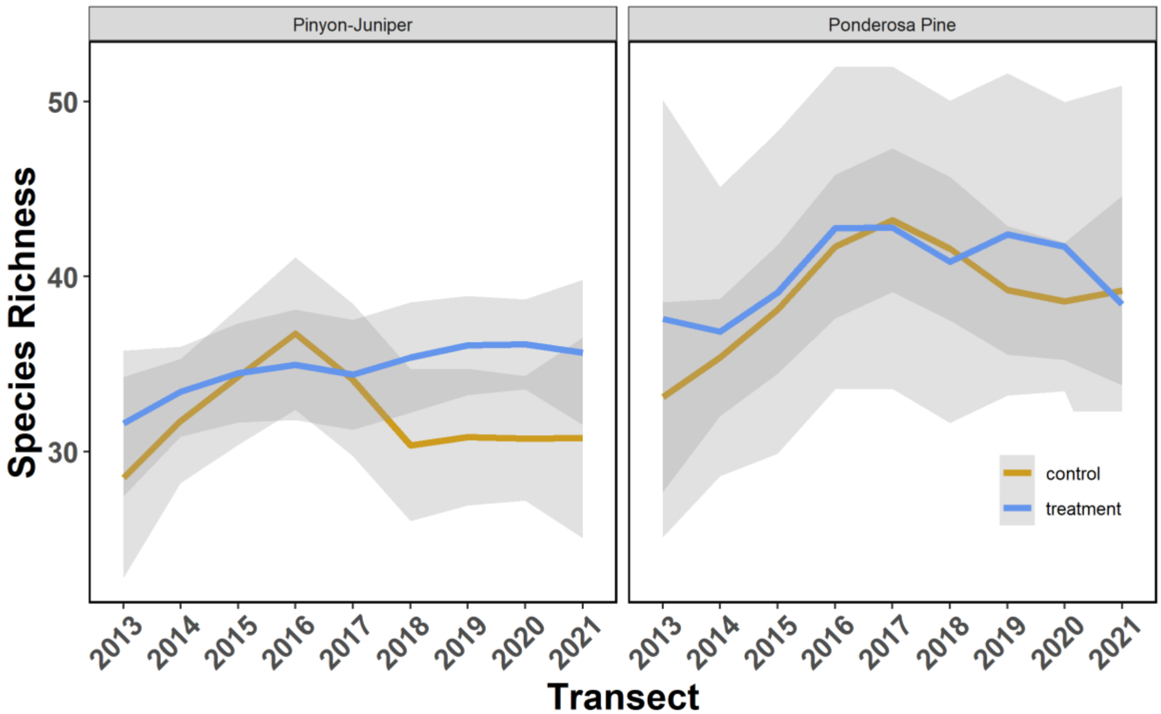


Figure 7-18. Species richness values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% confidence intervals.

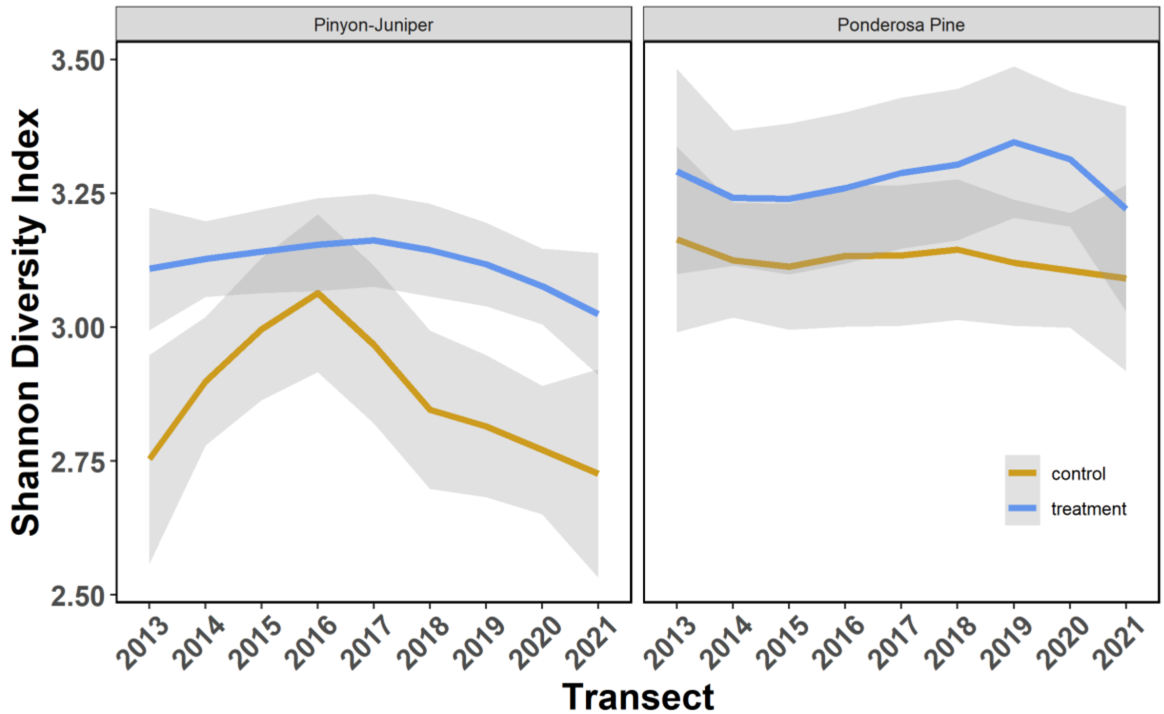


Figure 7-19. Abundance values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% confidence intervals.

Avian Nest Box Use and Success

The Laboratory's avian nest box network, including the three treatment sites, had 365 monitored nest boxes in 2021. Of those, 110 contained active nests and 49 of those nests fledged young successfully. This was an overall occupancy rate of 30 percent with a 45 percent success rate for active nests.

During the 2021 nesting season, 15 nest boxes at each treatment site were actively monitored. Both the occupancy and success rates for 2021 were the lowest recorded since the start of nest box monitoring at firing sites in 2015. There were three nests that fledged young at Technical Area 36 (Minie), four at Technical Area 16, and zero at Technical Area 39. Occupancy rates at Technical Area 39 were low in comparison to the other treatment sites and the overall network. Technical Area 39 is the lowest elevation treatment site, and occupancy has been decreasing over time at both this site and other areas of the avian nest box network at a similar elevation. Wysner et al. (2019) found that western bluebirds, one of the target species of the network, have increased the elevation at which they nest over time, which may be affecting use of the lower-elevation sites. Occupancy and success rates at the other two treatment sites seem to be fluctuating in the same manner as the overall network and have not displayed a decreasing trend over time.

The results from 2021 continue to indicate that operations at the three treatment sites are not negatively affecting their local bird populations.

Quality Assurance

The Soil, Foodstuffs, and Biota Program collects samples according to written, standard quality assurance and quality control procedures and protocols. These procedures and protocols are identified in the Laboratory's *Implementation of the Soil, Foodstuffs, and Biota Program, Quality Assurance Project Plan* (EPC-ES-QAPP-001) and in the following Laboratory procedures:

- Soil and Vegetation Sampling for the Environmental Surveillance Program (EPC-ES-TP-003)
- Soil and Vegetation Sampling at Facility Sites (EPC-ES-TP-006)
- Soil Sampling for Land Transfer and Conveyance and Other Special Projects (EPC-ES-TP-017)
- Produce Sampling (EPC-ES-TP-004)
- Roadkill Sampling (EPC-ES-TP-007)
- Crayfish Sampling (EPC-ES-TP-008)
- Benthic Macroinvertebrate Sampling (EPC-ES-TP-013)
- Fish Sampling (EPC-ES-TP-005)
- Managing and Sampling Honeybee Hives (EPC-ES-TP-219)
- Live Trapping of Small Mammals (EPC-ES-TP-201)
- Sediment Sampling in Reservoirs and Rivers (EPC-ES-TP-035)
- General PFAS Sampling Guidance for the Soil, Foodstuffs, and Biota Program (EPC-ES-GUIDE-015).

The Soil, Foodstuffs, and Biota program collects biological samples under approved New Mexico Game and Fish Scientific Collection Permits, as well as approved Institutional Animal Care and Use Committee protocols.

In addition, procedures and protocols for biota dose assessment can be found in the *Technical Project Plan for Biota Dose Assessment* (EPC-ES-TPP-002).

These procedures ensure that (1) the collection, processing, and chemical analysis of samples, (2) the validation and verification of data, and (3) the tabulation of analytical results are conducted in a consistent manner from year to year. Locations and samples have unique identifiers to provide chain-of-custody control from the time of collection through analysis and reporting.

The Biological Resources program collects field data according to written quality control procedures:

- Institutional Animal Care and Use Committee Operations (EPC-ES-AP-014)
- Threatened and Endangered Species Surveys (EPC-ES-TP-203)
- Avian Monitoring (EPC-ES-TP-205).

In addition to these procedures, some parts of our work require the following federal and state permits. These permits are individual permits and not institutional. Personnel working as wildlife biologists at LANL must have the training and background to be able to obtain such permits.

- Federal bird banding permits issued by the U.S. Geological Survey's bird banding laboratory.
- Federal recovery permits to survey or handle federally listed species issued by the U.S. Fish and Wildlife Service.
- State permits for scientific research issued by the New Mexico Department of Game and Fish.
- Surveys for federally listed species follow specific protocols set forth by the U.S. Fish and Wildlife Service and training to these protocols are a prerequisite to obtaining a permit.

The Health Physics program calculates dose to nonhuman biota according to a written quality control procedure:

- Calculating Dose to Nonhuman Biota (EPC-ES-TP-001).

Field Sampling Quality Assurance

Overall, quality of field sampling is maintained through the rigorous use of carefully documented procedures, listed above, which govern all aspects of the sample collection program.

Samples are collected under full chain-of-custody procedures to minimize the chance of data transcription errors. Once collected, samples are hand-delivered to the Laboratory's Sample Management Office, which ships the samples via express mail directly to an external analytical laboratory under full chain-of-custody control. Sample Management Office personnel track all samples. Upon receipt of data from the analytical laboratory (electronically and in hard copy), the completeness of the field sample process and other variables is assessed. A quality assessment document is created, attached to the data packet, and provided in the data package. Field data completeness for sample collection in 2021 was 97 percent. Small mammal sampling was the only event where 100 percent of samples were not collected; this was due to poor trapping success despite numerous sampling attempts.

Analytical Laboratory Quality Assessment

In 2021, ALS in Fort Collins, Colorado, reported a cross-contamination issue which led to rejecting tritium results in ten soil samples collected around the Dual Axis Radiographic Hydrodynamic Test Facility. Additionally, calcium results in three small mammal samples from background were exceptionally low and without explanation for the observations; therefore, the calcium results for these animals were rejected. Therefore, in total, we lost analytical results from 13 samples in 2021 owing to analytical problems.

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Chapter 8: Public Dose and Risk Assessment

U.S. Department of Energy regulations limit the total annual radiological dose to any member of the public from Los Alamos National Laboratory (LANL or the Laboratory) operations to 100 millirem. Furthermore, doses must be as low as reasonably achievable. The annual dose received by any member of the public from airborne emissions of radionuclides is limited by Clean Air Act regulations to 10 millirem.

The objective of this chapter is to use environmental sampling data collected from air, water, soil, and foodstuffs to answer the question, "What are the potential doses and risks to the public from the Laboratory's operations?" All known radionuclides released in significant quantities from LANL are reported and used in dose calculations. The assessments show that during 2021 all doses to the public were far below all regulatory limits and guidance and that the public is well protected. Radiological doses to the public from Laboratory operations are less than 1 millirem per year, and health risks are indistinguishable from zero.

Contents

Introduction

In this chapter, dose and risk from radiological and chemical sources are assessed to ensure the public is protected and to demonstrate compliance with federal regulations and U.S. Department of Energy (DOE) orders. The data reported here and in the previous chapters are considered in the context of public exposure, using standard methods to calculate the potential effects of radiological dose and risk. These methods do not include tribal-specific exposure scenarios. The results are compared with regulatory limits and international standards.

Radiological Materials

Overview of Radiological Dose

Radiological dose is the primary measure of harm from radiation. We calculate doses using the standard DOE and U.S. Environmental Protection Agency methods (DOE 2020, DOE 2021, EPA 2020). In this chapter, we assess doses to the public. Doses to plants and animals are assessed in Chapter 7.

DOE regulations limit the total annual dose to any member of the public from the Laboratory operations to 100 millirem. Furthermore, doses must be as low as reasonably achievable (LANL 2020). The annual dose received by any member of the public from airborne emissions of radionuclides is limited to 10 millirem by the *National Emission Standards for Hazardous Air Pollutants Other Than Radon From Department of Energy Facilities*, Title 40, Part 61, Subpart H, of the Code of Federal Regulations. The annual dose from community drinking water supplies is limited under the Safe Drinking Water Act to 4 millirem (*National Primary Drinking Water Regulations*, Title 40 Part 141 of the Code of Federal Regulations).

To contextualize these limits, the dose from natural background and from medical and dental procedures is about 800 millirem per year (See Figure 8-1). In contrast, doses from Laboratory operations are typically less than 1 millirem per year. The origins and reasons for the Los Alamos background dose are discussed briefly in the section Dose from Naturally Occurring Radiation and in detail in the paper by Gillis et al. (2014).

Overview of Exposure Pathways

Potential doses to the public from radionuclides associated with Laboratory operations are calculated by evaluating all exposure pathways. Total dose is the sum of three principal exposure pathways: (1) direct-penetrating (photon or neutron) radiation, (2) inhalation of airborne radioactive particles, and (3) ingestion of radionuclides in water or food.

Direct-Penetrating Radiation

We monitor direct-penetrating radiation from photons and neutrons at 85 locations in and around the Laboratory (See Chapter 4). Direct-penetrating radiation from Laboratory sources contributes to a measurable dose only within about one kilometer of the source. At distances more than one kilometer, dispersion, scattering, and absorption of the photons and neutrons attenuate the dose to much less than 0.1 millirem per year, which cannot be distinguished from natural background radiation. The only measurable above-background doses from direct-penetrating radiation come from Technical Area 53 and Technical Area 54, as reported in Chapter 4.

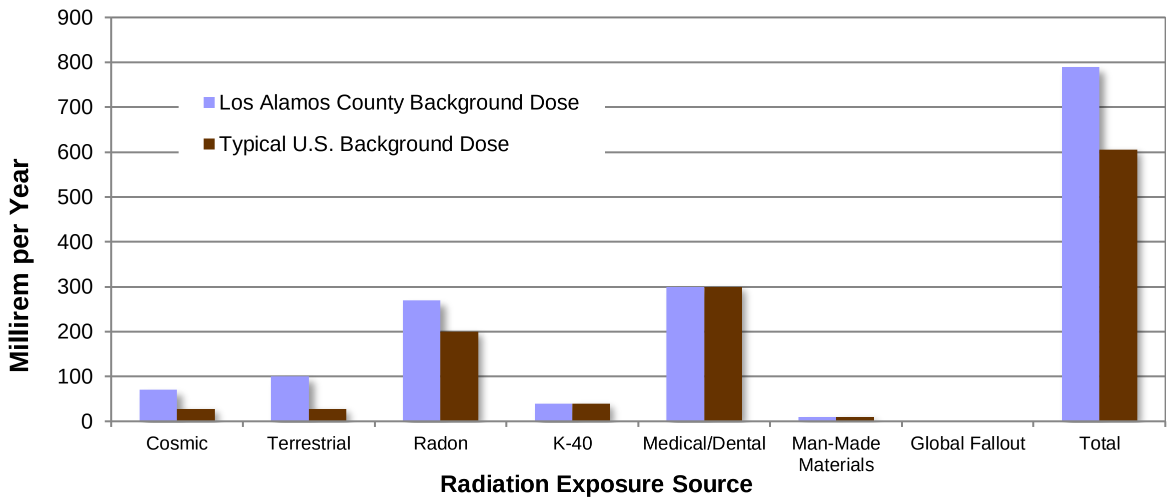


Figure 8-1. The average Los Alamos County radiation background dose compared with average U.S. radiation background dose (Gillis et al. 2014). Note: K-40 = Potassium-40

Inhalation

At distances of more than one kilometer from Laboratory sources, any dose related to current Laboratory operations is almost entirely from inhaled airborne radioactive emissions. Whenever possible, we calculate doses using the airborne radioactivity levels measured by the environmental air-sampling network reported in Chapter 4 (the Ambient Air Sampling for Radionuclides section). Where local levels of airborne radioactivity are too small to measure or cannot be measured by the environmental air-monitoring station methods, doses are calculated using a model called Clean Air Act Assessment Package-1988, PC Version 4.1 (CAP88) (EPA 2013, 2020). CAP88 is an atmospheric-dispersion and dose-calculation computer code that combines stack emissions data with meteorological data to calculate dose.

Some of the radionuclide emissions from Technical Area 53 are short-lived and cannot be measured by the environmental air-monitoring stations. These emissions are measured at the stacks as reported in Chapter 4, Exhaust Stack Sampling for Radionuclides, and the resulting estimated doses are calculated with CAP88.

The air-pathway dose assessment is described in detail in an annual air emissions report (Fuehne and Lattin 2022) and in Chapter 4.

Ingestion

Exposure through ingestion occurs when consuming liquids and food that contain radionuclides. The ingestion pathway includes drinking local water or beverages prepared with local water, eating locally grown food, and eating meat from either domesticated or hunted animals that eat local vegetation or drink local water. Measurements from groundwater are reported in Chapter 5, measurements from surface water and sediment are reported in Chapter 6, and measurements from soil, plants, and animals are reported in Chapter 7 and here.

Dose from Naturally Occurring Radiation

Near Los Alamos, naturally occurring sources of radioactivity include (1) cosmic rays, (2) direct-penetrating radiation from terrestrial sources, (3) radon gas, and (4) elements that occur naturally inside the human body, such as potassium-40 (See Figure 8-1). Annual doses from cosmic radiation range from 50 millirem at lower elevations near the Rio Grande to about 90 millirem in the higher elevations west of Los Alamos (Bouville and Lowder 1988, Gillis et al. 2014). Annual background doses from external gamma radiation (from natural terrestrial sources such as uranium and thorium and their decay products) range from about 50 millirem to 150 millirem (DOE 2012).

The inhalation of naturally occurring radon and its decay products constitutes a large proportion of the annual dose for members of the public. Nationwide, the average annual dose from radon is about 200 millirem to 300 millirem (NCRP 1987). In Los Alamos County, the average residential radon concentration results in an annual dose of about 300 millirem (Whicker 2009).

An additional 30 millirem per year results from naturally occurring radioactive materials in the body, such as potassium-40, which is present in all food and living cells.

Human-made sources of radiation also raise the total average annual background dose (Gillis et al. 2014). Members of the U.S. population receive an average annual dose of 300 millirem from medical and dental uses of radiation (NCRP 2009). An other 10 millirem per year comes from man-made products, such as stone or adobe walls.

In total, the average annual dose from sources other than Laboratory operations is about 800 millirem for a typical Los Alamos County resident. Figure 8-1 compares the average radiation background in Los Alamos County with the average background dose in the United States.

Generally, any additional dose of less than 0.1 millirem per year cannot be distinguished from the dose generated by background levels of radiation.

Dose from Water

We report measurements from water in Chapters 5 and 6. Local drinking water contains no measurable radioactivity from current or historical Laboratory operations. For further information regarding Los Alamos County drinking water quality, refer to the Los Alamos Department of Public Utilities “2022 Annual Drinking Water Quality Report” (Los Alamos County 2022). Furthermore, dose from water does not include surface water because it is not a source of drinking water in Los Alamos County. The dose pathway from surface water to humans is through foodstuffs, which are discussed in the following sections.

Dose from Soil and Foodstuff

Monitoring Network

The Soil, Foodstuffs, and Biota program collects soil, vegetation, and foodstuff samples from onsite locations on Laboratory land, offsite near the perimeter of the Laboratory, and regionally up to 80 kilometers from the Laboratory. The results, reported in Chapter 7, are used to calculate potential doses to the public.

Dose from Soil

Radioactive materials in soil can contribute to dose by any of the exposure pathways discussed above. The potential doses are calculated using the RESRAD family of codes (https://resrad.evs.anl.gov/).

In 2021, soil and vegetation samples were collected from 36 locations (Chapter 7, Figure 7-15). The results, which are similar to previous years, are reported in Chapter 7. The only offsite location with radionuclide concentrations above background was in Acid Canyon, where americium-241, plutonium-239, and strontium-90 concentrations exceeded the regional statistical reference levels. Potential doses in Acid Canyon are less than 0.1 millirem per year (McNaughton et al. 2018).

Dose from Food

The Soil, Foodstuffs, and Biota program monitors constituents in a wide variety of foodstuffs to determine whether Laboratory operations are affecting human health via the food chain. Foodstuffs samples are collected once every three years and most recently in 2019. We collect foodstuffs from Laboratory sites, surrounding communities (that is, perimeter locations), areas downstream of the Laboratory irrigated with Rio Grande water, and from background locations more than nine miles from the Laboratory that represent worldwide fallout or natural levels. In 2019, wild foods, fruits, and vegetables (hereafter referred to as crops) were collected from the Laboratory and from gardens and farms in the Los Alamos town site, White Rock/Pajarito Acres, Pueblo de San Ildefonso (perimeter locations), Pueblo de Cochiti (downstream of LANL), and regional background locations. Eggs, milk, and tea also were collected from select locations. Additionally, deer and elk samples are collected annually, primarily as roadkill or hunter donations (See Chapter 7).

DOE Standard 1196 (DOE 2021) is used to calculate the dose from ingestion of locally grown food.

In Chapter 7, analytical results are reported for a deer that had been commonly observed for six years inside the fence of Area G where hunting is not allowed. Duplicate samples were collected from the deer, and the tritium concentrations were 330 and 334 ± 25 pCi/mL in the muscle and 326 and 348 ± 26 pCi/mL in bone, indicating that tritium was uniform throughout the body. This uniformity supports the observations that the deer had been in Area G for years. Hypothetically, an individual who ate one pound of this venison would ingest less than 0.01 millirem.

Overall, the data for foodstuffs demonstrate that the individual dose from eating local or regional foodstuffs, including crops, eggs, milk, tea, deer, and elk is less than 0.01 millirem per year. Radionuclide concentrations in publicly available food are consistent with global fallout or naturally occurring material, and any contributions from the Laboratory are too small to measure. Therefore, conclusion is that the ingestion dose from LANL operations is generally less than 0.01 millirem per year and is consistent with zero.

Radiological Dose Results

The objective of this section is to calculate the all-pathway doses to the public from Laboratory operations.

As required by DOE Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, we calculated doses from the Laboratory to the following members of the public:

- total human population within 80 kilometers (50 miles) of the Laboratory, and
- hypothetical "maximally exposed individual."

To identify the location of and the total dose to the hypothetical maximally exposed individual, the following are considered:

- air-pathway dose,
- onsite dose at publicly accessible locations,
- other publicly accessible locations with measurable doses, and
- offsite dose.

Collective Dose to the Population within 80 Kilometers

The collective population dose from Laboratory operations is the sum of the doses for each member of the public within an 80-kilometer radius of the Laboratory (DOE 2020). Outside of Los Alamos County, the doses are too small to measure directly, so the collective dose is calculated by modeling the transport of radioactive air emissions using CAP88. As discussed in the sections "Dose from Water" and "Dose from Soil and Foodstuff," the dose from the other pathways is consistent with zero.

The 2021 collective population dose to people living within 80 kilometers of the Laboratory was 0.08 person-rem, approximately 60 percent from tritium, presumed to be oxidized, and 40 percent from short-lived activation products (Fuehne and Lattin 2022). This dose is less than 0.001 millirem per person and is much less than the background doses shown in Figure 8-1.

Collective population doses for recent years are shown in Figure 8-2. The trend-line for the past 10 years shows a general decrease, which is the result of improved engineering controls at the Los Alamos Neutron Science Center and the tritium facilities.

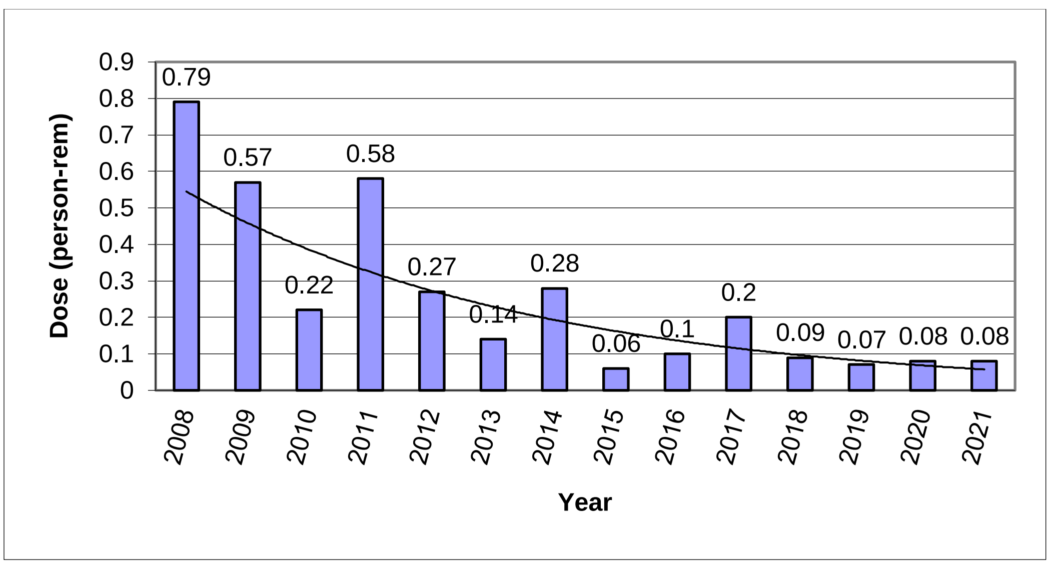


Figure 8-2. Annual collective dose (person-rem) to the population within 80 kilometers of the Laboratory

Dose to the Maximally Exposed Individual

The "maximally exposed individual" is a hypothetical member of the public who receives the greatest possible dose from Laboratory operations (DOE 2020). We consider all exposure pathways that could cause a dose and all publicly accessible locations, both within the Laboratory boundary (onsite) and outside the boundary (offsite).

Maximally Exposed Individual Offsite Dose

The air-pathway dose calculations are described in the annual air emissions report (Fuehne and Lattin 2022). In 2021, the offsite location of the hypothetical maximally exposed individual was at 132 DP Road, close to environmental air-monitoring station 326 (Chapter 4, Figure 4-1). The total offsite dose for the maximally exposed individual during 2021 was 0.50 millirem (Fuehne and Lattin 2022).

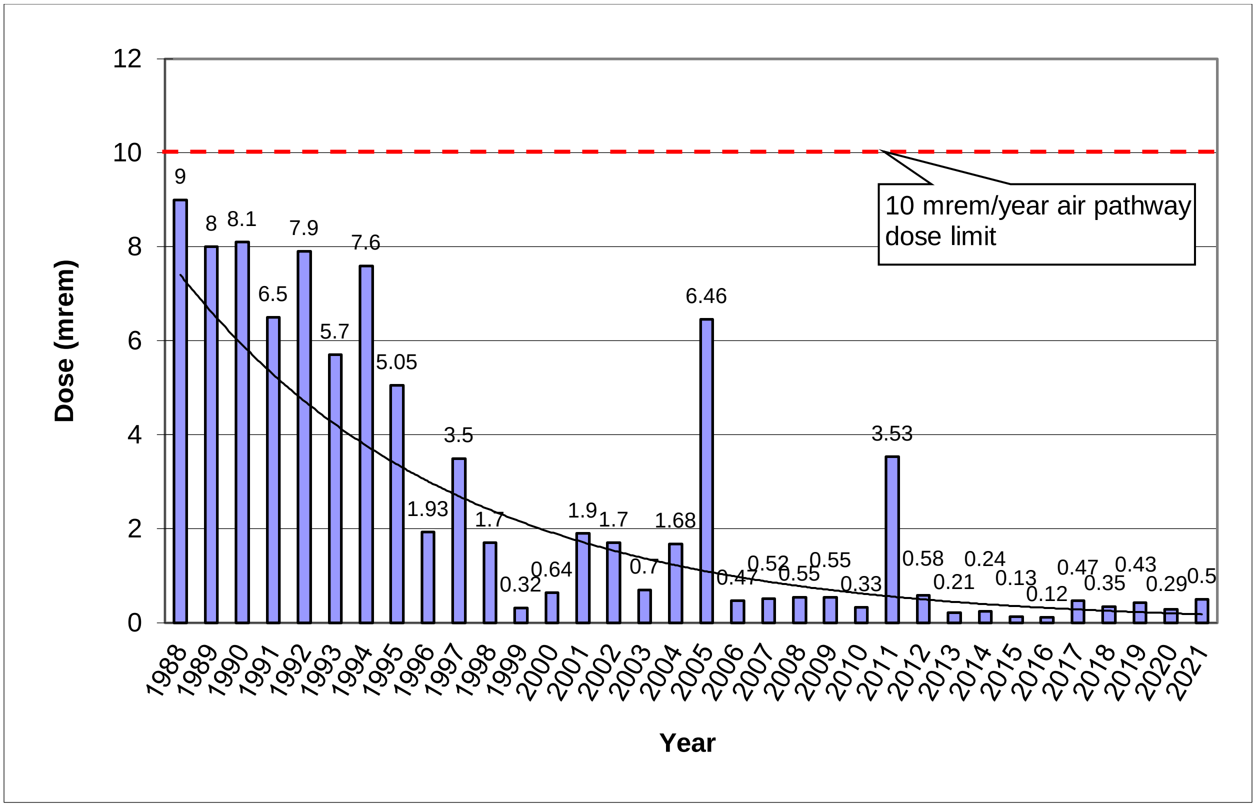
Contributions to this annual dose were from short-lived activation products from the Los Alamos Neutron Science Center (0.003 millirem), other stack emissions (0.001 millirem), environmental measurements at the environmental air-monitoring station (0.246 millirem), and the potential dose contribution from unmonitored stacks (0.252 millirem).

During 2021, a historical waste disposal site called the Middle DP Road site was remediated. At the same time, there was extensive construction work along DP Road. Both of these activities could have contributed to resuspended dust sampled at the nearby air-monitoring station number 326. This dust is assumed to be respirable, and the resulting dose is calculated according to the methods in *National Emission Standards for Hazardous Air Pollutants Other Than Radon From Department of Energy Facilities,* Title 40 Part 61 of the Code of Federal Regulations.

Comparison with Previous Years

The annual maximally exposed individual doses are shown in Figure 8-3. The general downward trend is the result of improved engineering controls.

As described in previous annual site environmental reports, the 6.46-millirem dose in 2005 resulted from a leak at Technical Area 53, and the 3.53-millirem dose in 2011 was from the remediation of Material Disposal Area B. The 2019 maximally exposed individual location was the same as the 2011 location and was the result of resuspended material that remained after the remediation of Material Disposal Area B. The 2021 maximally exposed individual location was the same as the 2020 location and was the result of resuspended material from the construction along DP Road and might include resuspended material from the remediation of the Middle DP Road site.



Note: mrem = millirem

Figure 8-3. Annual maximally exposed individual dose

Maximally Exposed Individual Onsite Dose

The onsite locations where a member of the public could receive a measurable dose are on or near publicly accessible roads (McNaughton et al. 2013). The only location with a measurable Laboratory-generated dose is at East Jemez Road near Technical Area 53. As reported in Chapter 4 (the Monitoring for Gamma and Neutron Direct-Penetrating Radiation section), at this location in 2021, the neutron dose was 0.6 millirem and the gamma dose was 0.1 millirem for a total of 0.7 millirem. The contribution from stack emissions was less than 0.01 millirem. These are the doses that would be received by a hypothetical individual at this location 24 hours per day for 365 days per year. However, members of the public, such as joggers, bus drivers, or cyclists, spend no more than 1/40 of their time at this location (NCRP 2005). Therefore, the onsite dose for a maximally exposed individual is 0.7/40 ≈ 0.02 millirem, which is less than the offsite dose for a maximally exposed individual described in the previous section.

Other Locations with Measurable Dose

As reported in Chapter 4, neutron dose was measured in Cañada del Buey, north of Technical Area 54, Area G, and near the Pueblo de San Ildefonso boundary. Transuranic waste at Area G emits neutrons while awaiting shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. After subtracting background, the measured neutron dose in Cañada del Buey in 2021 was 4 millirem. After applying the standard factor of 1/20 for occasional occupancy (NCRP 2005), the individual neutron dose in 2021 was 4/20 ≈ 0.2 millirem. The contribution from Laboratory stack emissions was less than 0.001 millirem. Within the boundaries of Area G, the average air concentration of plutonium was 1 attocuries per cubic meter (Chapter 4, Table 4-4), and the average uranium-234, -235, and -238 concentrations were 9, 1, and 10 attocuries per cubic meter, respectively (Chapter 4, Table 4-5). Using the dose conversion factors from DOE Standard 1196 (DOE 2021), and assuming 1/20 occupancy, the annual dose both within and near Area G was less than 0.001 millirem from air concentrations of transuranic materials.

Thus, in 2021, the total dose in Cañada del Buey was 0.2 millirem.

Maximally Exposed Individual Summary

At the offsite location for the maximally exposed individual, 132 DP Road, the direct-penetrating radiation and ingestion doses are consistent with zero, so the largest all-pathway dose for 2021 was the same as the air-pathway dose of 0.5 millirem.

The dose of 0.5 millirem in 2021 is far below the 10 millirem annual air-pathway limit in the *National Emission Standards for Hazardous Air Pollutants Other Than Radon From Department of Energy Facilities*, Title 40, Part 61, Subpart H of the Code of Federal Regulations, and the 100 millirem all pathway DOE limit (DOE 2020). The dose for the maximally exposed individual is less than 0.1 percent of the average U.S. background radiation dose shown in Figure 8-1.

Conclusion

The doses to the public from Laboratory operations are summarized in Table 8-1. Doses are below all regulations and standards.

Table 8-1. LANL Radiological Doses for Calendar Year 2021

Pathway	Dose to Maximally Exposed Individual (millirems per year)	Percentage of DOE 100-millirem-per-year Limit	Estimated Population Dose (person-rem)	Number of People within 80 kilometers	Estimated Background Population Dose (person-rem)
Air	0.5	0.5%	0.08	n/a*	n/a
Water	< 0.1	< 0.1%	0	n/a	n/a
Other pathways (foodstuffs, soil, etc.)	< 0.1	< 0.1%	0	n/a	n/a
All pathways	0.5	0.5%	0.08	~ 343,000	~ 268,000†

** n/a = Not applicable. Background population dose is not calculated for individual exposure pathways.*
† Background population dose is equal to the number of people multiplied by the dose per person based on 780 millirem per person as shown in Figure 8-1.

Nonradiological Materials

This section summarizes the potential human health risk from nonradiological materials released from the Laboratory in 2021. Air emissions are reported in Chapters 2 and 4; groundwater is reported in Chapter 5; surface water and sediment are reported in Chapter 6; and soil, plants, and animals are reported in Chapter 7. Foodstuffs are reported in this chapter, and the results from all chapters are summarized below.

Results Summary

Air

The data reported in Chapters 2 and 4 show that in general the Los Alamos air quality is good and below all applicable state and federal air quality standards. The Laboratory's emissions of regulated pollutants are below the amounts allowed in LANL's Title V Operating Permit. There are no measurable health effects to the public from Laboratory air emissions.

Groundwater

Groundwater data are reported in Chapter 5.

Los Alamos County monitors its water supply in compliance with the Safe Drinking Water Act. We analyzed additional samples from Los Alamos County water supply wells in 2021. No water supply wells showed detections of Laboratory-related constituents above an applicable drinking water standard. The drinking water supply meets New Mexico Environment Department and U.S. Environmental Protection Agency drinking water standards (Los Alamos County 2022).

Additional supplemental water sampling was conducted in the City of Santa Fe's Buckman Well Field. No Laboratory-related constituents were present above state or federal drinking water quality standards in this drinking water supply.

Within Laboratory boundaries, hexavalent chromium from the Laboratory has been detected above the New Mexico groundwater standard (50 micrograms per liter) in the regional aquifer below Mortandad Canyon. As described in Chapter 5, the Laboratory has begun interim measures to control migration of this chromium plume.

Los Alamos County drinking water contains 5 micrograms per liter of naturally occurring chromium unrelated to the Laboratory (Los Alamos County 2022).

Surface Water and Sediment

The concentrations of chemicals in surface water and sediment are reported in Chapter 6. The sediment data verify the conceptual model that, compared with previous deposits, movement and addition of sediment from repeated flood events results in lower concentrations of Laboratory-related constituents in newer sediment deposits. The data also show that the human health risk assessments in the canyon investigation reports (See Chapter 6) represent an upper bound of potential risks. Human exposure scenarios were discussed in the investigation reports. The conclusions in the investigation reports—that there were no human health risks—remain accurate because the constituent concentrations decrease with time.

In Chapter 6, we compared unfiltered storm water concentrations with drinking water standards as screening levels. However, storm water is not a drinking water source and, therefore, is not a significant pathway to human exposure. The plant and animal measurements reported in Chapters 7 and 8 confirm no significant uptake into the food chain.

Chapter 6 presents data for polychlorinated biphenyls (PCBs) in the surface water of the Pajarito Plateau. The foodstuffs could use this water are primarily terrestrial animals, such as deer and elk. The data reported in Chapter 7 show that the concentrations of PCBs in deer and elk are far below the human health screening values and are not associated with adverse human-health effects.

The only aquatic animals eaten by people that may be influenced by surface water runoff from the Laboratory are in the Rio Grande and Cochiti Reservoir. In the Rio Grande, PCB concentrations in aquatic animals are similar upstream and downstream of LANL influence (Chapter 7). There is no detectable contribution from the Laboratory to PCB concentrations in aquatic animals in the Rio Grande.

We conclude there is no measurable risk to the public from exposure to surface water and sediment resulting from either current or legacy Laboratory releases.

Soil, Plants, and Animals

Soil and biota sampling results are reported in Chapter 7. The results are similar to previous years. At offsite locations in 2021, chemical concentrations above human-health–based screening criteria were not detected.

Conclusion

The environmental data collected in 2021 show that at present there is no measurable risk to the public from materials released from the Laboratory. In all cases, the public doses and risks from LANL operations are much smaller than the regulatory limits and the naturally occurring background levels.

Quality Assurance

Quality assurance for the dose calculations is described in procedure EPC-ES-TPP-006, “Environmental Human Dose Assessment.”

The Soil, Foodstuffs, and Biota program collects samples according to written, standard quality assurance and quality control procedures and protocols. These procedures and protocols are identified in the Laboratory’s *Implementation of the Soil, Foodstuffs, and Biota Program, Quality Assurance Project Plan* (EPC-ES-QAPP-001) and in the following Laboratory procedures pertaining to foodstuffs collections:

- *Produce Sampling* (EPC-ES-TP-004)
- *Road Kill Sampling* (EPC-ES-TP-007)
- *Crayfish Sampling* (EPC-ES-TP-008)
- *Fish Sampling* (EPC-ES-TP-005)

References

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Appendix A: Standards and Screening Levels for Radionuclides and Other Chemicals in Environmental Samples

General Formation of a Standard or Screening Level

A standard is a reference value designed to protect a target group from a harmful level of exposure to a chemical. It may be used as a regulatory limit. Regulatory agencies, such as the U.S. Environmental Protection Agency, typically define standards.

In developing standards, agencies consider

- pathways of exposure to target groups,
- exposure scenarios, and
- the length of time target groups are exposed.

A target group may refer to, for example, the general public, animals, or a sensitive population such as children. Possible pathways of exposure include inhalation of air or ingestion of water, soil, animals, or plants. Exposure scenarios describe the activities of a target group at a site that influence both the likelihood and length of exposures. Examples of exposure scenarios include resident (someone living on a site) and worker (someone disturbing soil during construction activities at a site).

A screening level is a chemical concentration that, when exceeded in a sample, indicates that the sampled location might warrant further investigation or action. Screening levels may be calculated by a regulatory agency or by another party.

Throughout this *Annual Site Environmental Report*, levels of radioactive and chemical constituents in air, water, soil, and sediment samples are compared with standards or other guidance established by regulations of federal and state agencies. For environmental samples and chemicals that do not have standards or guidance, levels are compared with screening levels.

DOE Radiation Dose Limits

DOE Order 458.1, Administrative Change 4, *Radiation Protection of the Public and the Environment,* describes radiation protection standards for the public, referred to as public dose limits (See Table A-1). DOE's public dose limits apply to the effective dose that a member of the public receives from DOE operations. For all exposure pathways combined, the total limit is 100 millirem per year.

Table A-1. DOE Public Dose Limits for External and Internal Exposures

Exposure Pathway	Dose Equivalent at Point of Maximum Probable Exposure
All pathways	100 millirem per year
Air pathway only*	10 millirem per year
Drinking water	4 millirem per year

** Defined by U.S. Environmental Protection Agency's regulations issued under the Clean Air Act (Code of Federal Regulations Title 40, Part 61, Subpart H).*

For water, radionuclide levels are compared with DOE's derived concentration standards (DOE 2021; See Table A-2) to evaluate the potential for impacts to members of the public. The derived concentration standards for water (in picocuries per liter) are the concentrations that would result in a dose of 100 millirem per year if a Reference Person (as defined in the standard) consumed the water.

The DOE has also defined biota dose limits that apply to populations of animals and plants. For details, refer to DOE Standard 1153 (DOE 2019).

Table A-2. DOE-Derived Concentration Standards for Radionuclide Levels in Water

Nuclide	Derived Concentration Standard for Water, in picocuries per liter
Hydrogen-3	2,600,000
Beryllium-7	2,500,000
Strontium-89	39,000
Strontium-90	1700
Cesium-137	4100
Uranium-234	1200
Uranium-235	1300
Uranium-238	1400
Plutonium-238	430
Plutonium-239	400
Plutonium-240	400
Americium-241	740

Clean Air Act Radiation Dose Limits for DOE Facilities

For air emissions, in addition to the DOE standards, in 1985 and 1989 the U.S. Environmental Protection Agency established the "National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities," in Title 40, Part 61, Subpart H of the Code of Federal Regulations. This Clean Air Act regulation states that emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose of 10 millirem per year. DOE has adopted this as a dose limit (See Table A-1). The regulation requires monitoring of all release points that can produce a dose of 0.1 millirem per year to a member of the public.

National Pollutant Discharge Elimination System Permits

The types of monitoring required under the National Pollutant Discharge Elimination System and the limits established for sanitary and industrial outfalls can be found at http://water.epa.gov/polwaste/npdes.

Drinking Water Standards

For chemical constituents in drinking water, the U.S. Environmental Protection Agency issue regulations and standards under the federal Safe Drinking Water Act, which the New Mexico Environment Department adopt.

Radioactivity in drinking water is regulated by U.S. Environmental Protection Agency regulations contained in Title 40, Part 141 of the Code of Federal Regulations and by the New Mexico Drinking Water Regulations, Sections 206 and 207. These regulations stipulate that combined radium-226 and radium-228 activity in drinking water may not exceed 5 picocuries per liter. Gross-alpha activity (including radium-226 but excluding radon and uranium) may not exceed 15 picocuries per liter.

For man-made beta- and photon-emitting radionuclides, U.S. Environmental Protection Agency drinking water standards are limited to levels that would result in doses not exceeding 4 millirem per year.

Surface Water Standards

Levels of radionuclides in surface water samples may be compared with either the DOE-derived concentration standards (DOE 2021) or the New Mexico Water Quality Control Commission stream standards. The concentrations of nonradioactive constituents may be compared with the New Mexico Water Quality Control Commission stream standards, which are available at https://www.env.nm.gov/surface-water-quality/wqs/. The New Mexico Water Quality Control Commission groundwater standards can also be applied in cases where discharges could affect groundwater.

Soils and Sediment Screening Levels

If chemical or radionuclide levels in soil exceed regional statistical reference levels (regional background levels), the levels are then compared with screening levels. The human health screening levels for soil from publicly accessible locations are the levels that would produce (1) a dose of 15 millirem or greater to an individual for radionuclides, (2) an estimated excess cancer risk of 1 x 10^{-5} for cancer-causing chemicals, or (3) a hazard quotient greater than 1 for hazardous chemicals that do not cause cancer. The screening levels differ for different exposure scenarios. Soil and sediment screening levels are mostly used in evaluating sites for remediation. Screening levels for radionuclides are found in a Laboratory document (LANL 2015); screening levels for nonradionuclides are found in a New Mexico Environment Department document (NMED 2021).

Foodstuffs Standards and Screening Levels

Federal standards exist for radionuclides and selected nonradionuclides (for example, mercury and polychlorinated biphenyls [PCBs]) in foodstuffs. The Laboratory has established screening levels for radionuclides. If levels in foodstuffs exceed regional statistical reference levels, they are then compared with screening levels and existing standards. The Laboratory has established a screening level of 1 millirem per year for activities of individual radionuclides in individual foodstuffs (for example, fish and crops), assuming a residential scenario. The U.S. Environmental Protection Agency has established screening levels for mercury and PCBs in fish (EPA 2018).

Biota (Wild Animals and Plants) Standards and Screening Levels

If radionuclide or chemical levels in biota exceed regional statistical reference levels, the levels are then compared with screening levels. For radionuclides in biota, the Laboratory sets screening levels at 0.1 rad per day for terrestrial plants and aquatic biota and 0.01 rad per day for terrestrial animals, which is 10 percent of the DOE standard (DOE 2019). If a chemical in biota tissue exceeds the regional statistical reference level, detected concentrations in the tissue are compared with lowest observed adverse effect levels reported in published literature, if available, and concentrations in the soil at the place of collection are compared with ecological screening levels (LANL 2020).

References

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Appendix B: Units of Measurement

Throughout the *Annual Site Environmental Report*, the U.S. customary (English) system of measurement has generally been used. For units of radiation activity, exposure, and dose, U.S. customary units (curie, roentgen, rad, and rem) are retained as the primary measurement because current standards are written in terms of these units. The equivalent units from the International System of Units are the becquerel, coulomb per kilogram, gray, and sievert, respectively. Table B-1 presents factors for converting U.S. customary units into units from the International System of Units (metric).

Table B-1. Approximate Conversion Factors for Selected U.S. Customary Units

Multiply U.S. Customary (English) Unit	by	to Obtain International System of Units (Metric) Unit
degrees Fahrenheit	5/9 (first subtract 32)	degrees Celsius
inches	2.54	centimeters
cubic feet	0.028	cubic meters
acres	0.4047	hectares
ounces	28.3	grams
pounds	0.453	kilograms
miles	1.61	kilometers
gallons	3.785	liters
feet	0.305	meters
parts per million	1	micrograms per gram
parts per million	1	milligrams per liter
square miles	2.59	square kilometers
picocuries	37	millibecquerel
rad	0.01	gray
millirem	0.01	millisievert

Table B-2 presents prefixes used in this report to define fractions or multiples of the base units of measurements. Scientific notation is used in this report to express very large or very small numbers. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from the number. If the value given is 2.0×10^3, the decimal point should be moved three numbers (insert zeros if no numbers are given) to the right of its present location. The number would then read 2000. If the value given is 2.0×10^{-5}, the decimal point should be moved five numbers to the left of its present location. The result would be 0.00002.

Table B-2. Prefixes Used with International System of Units (Metric) Units

Prefix	Factor	Symbol
mega	1,000,000 or 10^6	M
kilo	1000 or 10^3	k
centi	0.01 or 10^{-2}	c
milli	0.001 or 10^{-3}	m
micro	0.000001 or 10^{-6}	µ
nano	0.000000001 or 10^{-9}	n
pico	0.000000000001 or 10^{-12}	p
femto	0.000000000000001 or 10^{-15}	f
atto	0.000000000000000001 or 10^{-18}	a

Data Handling of Radiochemical Samples

Measurements of radioactivity in samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values are sometimes obtained that are lower than the minimum detection limit of the analytical technique, and results for individual measurements can be negative numbers. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative values are included in the population calculations (Gilbert 1975).

For individual measurements, uncertainties are reported as one standard deviation. The standard deviation is estimated from the propagated sources of analytical error.

Standard deviations for the ambient air monitoring network station and group (offsite regional, offsite perimeter, and onsite) means are calculated using the standard equation

$$s = (\Sigma (c_i - \bar{c})^2 / (N - 1))^{1/2}$$

where

c_i = sample i,
$\bar{c}$ = mean of samples from a given station or group, and
N = number of samples in the station or group.

This value is reported as one standard deviation for the station and group means.

Reference

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Appendix C: Descriptions of Technical Areas and Their Associated Programs

Locations of the technical areas operated by Los Alamos National Laboratory (LANL or the Laboratory) in Los Alamos County are shown in Figure 1-3 in Chapter 1. The main programs conducted at each of the areas are listed in this appendix.

Technical Area	Location and Activities
00 (offsite facilities)	The Technical Area 00 designation is assigned to structures leased by the U.S. Department of Energy outside the Laboratory's boundaries in the Los Alamos townsite and White Rock.
02 (Omega Site or Omega West Reactor)	Omega West Reactor, an 8-megawatt nuclear research reactor, was at Technical Area 02. The reactor was decontaminated and decommissioned in 2002. It is now the location of the Omega West Monument and interpretive panels. The monument commemorates the historic reactors and other historical events that took place at Technical Area 02.
03 (Core Area or South Mesa Site)	Technical Area 03 is the Laboratory's core scientific and administrative area and contains approximately half of the Laboratory's employees and total floor space. It is the location of many key Laboratory facilities, including the Chemistry and Metallurgy Research Building, the Sigma Complex, the machine shops, the Material Sciences Laboratory, and the Nicholas C. Metropolis Center for Modeling and Simulation.
05 (Beta Site)	Between East Jemez Road and the Pueblo de San Ildefonso, Technical Area 05 contains physical support facilities and an electrical substation. It is also the site of the Laboratory's interim measure to control chromium plume migration in the regional aquifer.
06 (Twomile Mesa Site)	Technical Area 06 is in the northwestern part of the Laboratory and is mostly undeveloped. It contains a meteorological tower, gas-cylinder-staging buildings, the Western Technical Area Substation, and buildings awaiting demolition.
08 (GT Site or Anchor Site West)	Located along West Jemez Road, Technical Area 08 is a testing site where nondestructive dynamic testing techniques are used to ensure the quality of materials in items ranging from test weapons components to high-pressure dies and molds. Techniques used include radiography, radioisotope techniques, ultrasonic and penetrant testing, and electromagnetic test methods.
09 (Anchor Site East)	Technical Area 09 is on the western edge of the Laboratory. Fabrication feasibility and the physical properties of explosives are explored at this technical area, and new organic compounds are investigated for possible use as explosives.
11 (K-Site)	Technical Area 11 is used for testing explosives components and systems, including vibration analysis and drop-testing materials and components under a variety of extreme physical environments. Facilities are arranged so that testing can be controlled and observed remotely, allowing devices that contain explosives, radioactive materials, and nonhazardous materials to be safely tested and observed.
14 (Q-Site)	Technical Area 14 is in the northwestern part of the Laboratory and is one of 14 firing areas. Most operations are remotely controlled and involve detonations, certain types of high-explosives machining, and permitted burning.
15 (R-Site)	Technical Area 15 is in the central portion of the Laboratory; it is used for high-explosives research, development, and testing, mainly through hydrodynamic testing and dynamic experimentation. It contains two firing sites: the Dual-Axis Radiographic Hydrodynamic Test Facility, which has an intense high-resolution, dual-machine radiographic capability, and Building 306, a multipurpose facility where primary diagnostics are performed.

Descriptions of Technical Areas and Their Associated Programs

Technical Area	Location and Activities
16 (S-Site)	Technical Area 16 is in the western part of the Laboratory and includes the Weapons Engineering Tritium Facility, a state-of-the-art tritium processing facility. It is also the location of high-explosives research, development, and testing; the High Explosives Wastewater Treatment Facility; the Tactical Training Facility; and the Indoor Firing Range.
18 (Pajarito Site)	Technical Area 18 is in Pajarito Canyon and was the location of the Los Alamos Critical Experiment Facility, a general-purpose nuclear experiments facility. All operations here have ceased. The technical area, including the Pond Cabin and the Slotin Building, is now part of the Manhattan Project National Historical Park.
21 (DP Site)	Technical Area 21 is on the northern border of the Laboratory, next to the Los Alamos townsite. The former radioactive materials (including plutonium) processing facility was in the western part of Technical Area 21. The Tritium Systems Test Assembly and the Tritium Science and Fabrication Facility were in the eastern part. Operations from these facilities have been transferred and demolition was completed in 2010.
22 (TD Site)	Technical Area 22 is in the northwestern portion of the Laboratory and houses the Detonator Production Facility. Research, development, and fabrication of high-energy detonators and related devices are conducted at this facility.
28 (Magazine Area A)	Technical Area 28 is near the southern edge of the Laboratory and was an explosives storage area. It contains five empty storage magazines that are being decontaminated and decommissioned.
33 (HP Site)	Technical Area 33 is a remotely located technical area at the southeastern boundary of the Laboratory. It is used for experiments that require isolation but do not require daily oversight. The National Radioastronomy Observatory's Very Long Baseline Array telescope is here.
35 (Ten Site)	Technical Area 35 is in the north-central portion of the Laboratory; it is used for nuclear safeguards research and development, primarily in the areas of lasers, physics, fusion, materials development, and biochemistry and physical chemistry research and development. The Target Fabrication Facility, located here, conducts precision machining and target fabrication, polymer synthesis, and chemical and physical vapor deposition. Additional activities include research in reactor safety, optical science, and pulsed-power systems, as well as metallurgy, ceramic technology, and chemical plating. Additionally, some Biosafety Level 1 and 2 laboratories are here.
36 (Kappa Site)	Technical Area 36 is a remotely located area in the eastern portion of the Laboratory; it has four active firing sites that support explosives testing. The sites are used for a wide variety of nonnuclear ordnance tests.
37 (Magazine Area C)	Technical Area 37, used as an explosives storage area, is along the eastern perimeter of Technical Area 16.
39 (Ancho Canyon Site)	Technical Area 39, at the bottom of Ancho Canyon, is used to study the behavior of nonnuclear weapons (primarily by photographic techniques) and various phenomenological aspects of explosives.
40 (DF Site)	Technical Area 40 is centrally located within the Laboratory and is used for general testing of explosives or other materials and development of special detonators for initiating high-explosives systems.
41 (W-Site)	Technical Area 41 is in Los Alamos Canyon; it is no longer actively used. Many buildings have been decontaminated and decommissioned; the remaining structures include historic properties.
43 (Bioscience Facilities)	Technical Area 43 is adjacent to the Los Alamos Medical Center at the northern border of the Laboratory; it is the location of the Bioscience Facilities (formerly called the Health Research Laboratory). The Bioscience Facilities have Biosafety Level 1 and 2 laboratories and are the focal point of bioscience and biotechnology at LANL. Research performed at the Bioscience Facilities includes structural, molecular, and cellular radiobiology; biophysics; radiobiology; biochemistry; and genetics.

Descriptions of Technical Areas and Their Associated Programs

Technical Area	Location and Activities
46 (WA Site)	Technical Area 46 is between Pajarito Road and the Pueblo de San Ildefonso. It is one of the Laboratory's basic research sites. Activities have focused on applied photochemistry operations and have included development of technologies for laser isotope separation and laser enhancement of chemical processes. The Sanitary Wastewater Systems Plant is also here.
48 (Radiochemistry Site)	Technical Area 48 is in the north-central portion of the Laboratory. It supports research and development in nuclear and radiochemistry, geochemistry, production of medical radioisotopes, and chemical synthesis. Hot cells are used to produce medical radioisotopes.
49 (Frijoles Mesa Site)	Technical Area 49 is near Bandelier National Monument. It is used as a training area and for outdoor tests on materials and equipment components that involve generating and receiving short bursts of high-energy, broad-spectrum microwaves. The National Park Service operates the Interagency Wildfire Center and helipad near the entrance to the technical area.
50 (Waste Management Site)	Technical Area 50 is near the center of the Laboratory; it is the location of waste management facilities, including the Radioactive Liquid Waste Treatment Facility and the Waste Characterization, Reduction, and Repackaging Facility. The Actinide Research and Technology Instruction Center is also here.
51 (Environmental Research Site)	Technical Area 51 is on Pajarito Road in the eastern portion of the Laboratory; it is used for research and experimental studies on the long-term impacts of radioactive materials on the environment. Various types of waste storage and coverings are studied here.
52 (Reactor Development Site)	Technical Area 52 is in the north-central portion of the Laboratory. A wide variety of theoretical and computational research and development activities related to nuclear reactor performance and safety, as well as to several environmental, safety, and health activities, are carried out here.
53 (Los Alamos Neutron Science Center)	Technical Area 53 is in the northern portion of the Laboratory and includes the Los Alamos Neutron Science Center. This facility houses one of the largest research linear accelerators in the world and supports basic and applied research programs. Basic research includes studies of subatomic and particle physics, atomic physics, neutrinos, and the chemistry of subatomic interactions. Applied research includes materials science studies that use neutron spallation and contribute to defense programs. The facility also irradiates targets for medical isotope production.
54 (Waste Disposal Site)	Technical Area 54 is on the eastern border of the Laboratory and is one of the largest technical areas at the Laboratory. Its primary function is management of solid radioactive and hazardous chemical wastes, including storage.
55 (Plutonium Facility Complex Site)	Technical Area 55 is in the center of the Laboratory along Pajarito Road and includes the Plutonium Facility Complex. The Plutonium Facility provides chemical and metallurgical processes for recovering, purifying, and converting plutonium and other actinides into many compounds and forms. Radiological operations in the Radiological Laboratory/Utility/Office Building began in 2014.
57 (Fenton Hill Site)	Technical Area 57 is about 20 miles west of the Laboratory on land administered by the U.S. Forest Service. The Laboratory has used this site since 1974, and the site is subject to an interagency agreement between the U.S. Department of Energy and the U.S. Forest Service. The site was originally developed for the Hot Dry Rock geothermal energy program, which was terminated in 1995, and subsequently used for astronomical studies. In 2012, the Laboratory demolished and removed several small structures, trailers, equipment pads, and equipment and implemented site stabilization. Some astronomy activities may continue.
58 (Twomile North Site)	Technical Area 58 is near the Laboratory's northwest border on Twomile Mesa North; it is forested area reserved for future use because of its proximity to Technical Area 03. The technical area houses the protective force running track, a few Laboratory-owned storage trailers, and a temporary storage area.

Descriptions of Technical Areas and Their Associated Programs

Technical Area	Location and Activities
59 (Occupational Health Site)	Technical Area 59 is on the south side of Pajarito Road adjacent to Technical Area 03. It is the location of staff who provide support services in health physics, risk management, industrial hygiene and safety, policy and program analysis, air quality, water quality and hydrology, hazardous and solid waste analysis, and radiation protection. The medical facility here includes a clinical laboratory and provides bioassay sample analytical support.
60 (Sigma Mesa)	Technical Area 60 is southeast of Technical Area 03 and is primarily used for physical support and infrastructure activities. The Nevada Test Site Test Fabrication Facility and a test tower are also here. This facility is used as a waste storage area.
61 (East Jemez Site)	Technical Area 61 is in the northern portion of the Laboratory. It contains physical support and infrastructure facilities, including a sanitary waste transfer station operated by Los Alamos County, a photovoltaic array, and sewer pump stations. This is the former site of the Los Alamos County landfill, which is now closed and capped.
62 (Northwest Site)	Next to Technical Area 03 and West Jemez Road in the northwest corner of the Laboratory; Technical Area 62 serves as a forested buffer zone. This technical area is reserved for future use.
63 (Pajarito Service Area)	Techncial Area 63 is in the north-central portion of the Laboratory; it contains physical support and infrastructure facilities and the Transuranic Waste Facility.
64 (Central Guard Site)	Technical Area 64 is in the north-central portion of the Laboratory and provides offices and storage space.
66 (Central Technical Support Site)	Technical Area 66 is on the southeast side of Pajarito Road in the center of the Laboratory. The Advanced Technology Assessment Center, the only facility at this technical area, provides office and technical space for technology transfer and other industrial partnership activities.
67 (Pajarito Mesa Site)	Technical Area 67 is a forested buffer zone in the north-central portion of the Laboratory and has no operations or facilities.
68 (Water Canyon Site)	In the southern portion of the Laboratory, Technical Area 68 comprises 20 acres of land converted into a testing area for detecting materials of interest.
69 (Anchor North Site)	In the northwestern corner of the Laboratory, Technical Area 69 serves as a forested buffer zone. The Emergency Operations Center is here.
70 (Rio Grande Site)	Technical Area 70 is on the southeastern boundary of the Laboratory. It is an undeveloped technical area that serves as a buffer zone and includes part of the White Rock Canyon Reserve.
71 (Southeast Site)	Technical Area 71 is on the southeastern boundary of the Laboratory and is adjacent to White Rock to the northeast. It is an undeveloped technical area that serves as a buffer zone for the High Explosives Test Area. Part of the White Rock Canyon Reserve is here.
72 (East Entry Site)	Technical Area 72 is along East Jemez Road on the northeastern boundary of the Laboratory and used by protective force personnel for required firearms training and practice purposes.
73 (Airport Site)	Along the northern boundary of the Laboratory, Technical Area 73 is adjacent to NM 502. Los Alamos County manages, operates, and maintains the community airport under a leasing arrangement with the U.S. Department of Energy. Use of the airport by private individuals is permitted with special restrictions.
74 (Otowi Tract)	Technical Area 74 is in a forested area in the northeastern corner of the Laboratory. A large portion of this technical area has been conveyed to Los Alamos County or transferred to the Department of the Interior in trust for the Pueblo de San Ildefonso and is no longer part of the Laboratory.

Appendix D:
Related Websites

For more information on environmental topics at Los Alamos National Laboratory (LANL or the Laboratory), visit the following websites.

Current and past environmental reports and supplemental data tables	*https://www.lanl.gov/environment/environmental-report.php*
The Laboratory's website	*https://www.lanl.gov*
U.S. Department of Energy/National Nuclear Security Administration Los Alamos Field Office	*https://www.energy.gov/nnsa/locations* *https://www.energy.gov/contact-us/mailing-addresses-and-information-numbers-operations-field-and-site-offices*
U.S. Department of Energy Environmental Management Los Alamos Field Office	*https://energy.gov/em-la/environmental-management-los-alamos-field-office*
U.S. Department of Energy website	*https://www.energy.gov*
The Laboratory's environmental stewardship pages	*https://www.lanl.gov/environment/index.php*
The Laboratory's environmental monitoring pages	*https://www.lanl.gov/environment/protection/monitoring/index.php*
N3B – Los Alamos Legacy Cleanup Contract website	*https://n3b-la.com*
The Laboratory's Electronic Public Reading Room website	*https://eprr.lanl.gov*
Los Alamos Legacy Cleanup Contract Electronic Public Reading Room website	*https://ext.em-la.doe.gov/EPRR*
The Laboratory's environmental database	*https://www.intellusnm.com*

The following Los Alamos National Laboratory organizations perform environmental surveillance, ensure environmental compliance, and provide environmental data for this report:

Associate Directorate for Environment, Safety, Health, Quality, Safeguards, and Security
Environmental Protection and Compliance Division

N3B Los Alamos
Environmental Remediation Program

Previous reports in the series are LA-UR-21-28555, LA-UR-20-26673, LA-UR-19-28565, LA-UR-17-27987, LA-UR-16-26788, LA-UR-15-27513, LA-UR-14-27564, LA-UR-13-27065, LA-14427-ENV, LA-13775-ENV, LA-13861-ENV, LA-13979-ENV, LA-14162-ENV, LA-14239-ENV, LA-14304-ENV, LA-14341-ENV, LA-14369-ENV, LA-14407-ENV, LA-14427-ENV, LA-14445-ENV, LA-14461-ENV.

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