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NNSA
National Nuclear Security Administration

NEVADA NATIONAL
NNSS
SECURITY SITE

September 2021

2020

Environmental Report

DOE/NV/03624--1210

NEVADA NATIONAL NNSS SECURITY SITE

2020 Environmental Report

This report was prepared for:

U.S. Department of Energy
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By:

Mission Support and Test Services LLC
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Contributing Subject Matter Experts

More than 30 individuals are subject matter experts from across multiple organizations and authored, co-authored, or contributed information to the chapters within this NNSSER. They are thanked and acknowledged for their support, and are identified at the beginning of each chapter.

Contributing Organizations

MSTS

Multiple departments and groups within MSTS provided subject matter experts to contribute text and data on the annual activities related to onsite radiological and non-radiological monitoring of air, water, and biota; radiological dose assessments; waste management; hazardous materials management; ecological monitoring; site sustainability; and occurrence reporting. MSTS subject matter experts also provided the descriptions of the hydrology, geology, ecology, and cultural resources of the NNSS, which are included in *Attachment A: Site Description*.

Navarro Research and Engineering, Inc. (Navarro)

Navarro provided data and discussion in Chapters 5 and 11 regarding their design, sampling, and analysis results associated with groundwater sampling and monitoring at the NNSS, which addresses the legacy contamination of historical nuclear underground test areas (UGTAs). In Chapter 10, Navarro provided information on their administration of the Radioactive Waste Acceptance Program and related activities. In Chapter 11, Navarro provided summary information of their characterization and remediation work towards state-approved closure of UGTA, Industrial, and Soils corrective action sites, and post-closure monitoring activities. In Chapter 14, Navarro collaborated with MSTS in providing data quality assurance programmatic information and quality performance related to the UGTA groundwater samples.

Desert Research Institute (DRI)

The DRI Division of Hydrologic Sciences authored Chapters 7 and 15, reporting on their offsite radiological monitoring of air and groundwater within communities surrounding the NNSS, and on their data quality assurance program. The Division of Earth and Ecosystem Sciences authored Chapter 12, summarizing their annual activities managing cultural resources on the NNSS, and also provided the description of the prehistory and history of the NNSS, which is included in *Attachment A: Site Description*.

Nye County

Nye County provided the discussion in Chapter 7 of their sampling of wells under the Nye County Tritium Sampling and Monitoring Program.

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ARL/SORD provided summary descriptions of the NNSS climate that are included in *Attachment A: Site Description*.

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EnviroStat

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ES&H Support Staff

The following individuals within MSTS ES&H are responsible for the numerous tasks that are integral to the planning, collection, processing, quality assurance, and quality control of much of the environmental data provided in this NNSSER.

Elizabeth Burns was responsible for planning and developing sampling documentation, radiological monitoring data verification, validation, and review; quality assurance oversight; administration of the data management system; and assisted with field sampling.

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Catherine D. Castaneda was responsible for supporting laboratory processing and sample shipments to the commercial environmental analytical laboratories.

Lynn N. Jaussi assisted with sampling activities, and managed laboratory operations for sample screening and processing.

MSTS Report Production and Distribution Support Personnel

The following individuals were responsible for improving the quality, appearance, and timely production and distribution of this NNSSER.

Ashley Burns and **Allison Lawson** of the Geographic Information Systems (GIS) group worked with the authors to produce the high-quality GIS-generated maps and figures (provided in map projection: Universal Transverse Mercator [Zone 11, meters] North American Datum 1983).

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Margaret Townsend conducted the necessary classification review of this document, and in the process, made numerous improvements to its clarity, readability, and accuracy.

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Chapter 1: Introduction

Theodore J. Redding
Mission Support and Test Services, LLC

Charles B. Davis
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1.1 Site Location

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) directs the management and operation of the Nevada National Security Site (NNSS). The NNSS is located in Nye County in south-central Nevada (Figure 1-1). The southeast corner of the NNSS is about 88 kilometers (km) (55 miles [mi]) northwest of the center of Las Vegas in Clark County. By highway, it is about 105 km (65 mi) from the center of Las Vegas to Mercury. Mercury, at the southern end of the NNSS, is the main base camp for worker housing and administrative operations at the NNSS.

The NNSS encompasses about 3,522 square kilometers (km^2) (1,360 square miles [mi^2]) based on the most recent land survey. It varies from 46 to 56 km (28 to 35 mi) in width from west to east and from 64 to 88 km (40 to 55 mi) from north to south. The NNSS is surrounded on all sides by lands managed by the federal government. It is bordered on the west and north by the Nevada Test and Training Range (NTTR), on the east by an area used by both the NTTR and the Desert National Wildlife Refuge, and on the south and southwest by lands managed by the Bureau of Land Management. The combination of the NTTR and the NNSS represents one of the largest unpopulated land areas in the United States, comprising some 14,200 km^2 (5,470 mi^2).

1.2 Environmental Setting

The NNSS is located in the southern part of the Great Basin, the northern-most subprovince of the Basin and Range Physiographic Province. NNSS terrain is typical of the Basin and Range Physiographic Province, characterized by generally north–south trending mountain ranges and intervening valleys. These mountain ranges and valleys, however, are modified on the NNSS by very large volcanic calderas. The principal valleys are Frenchman Flat, Yucca Flat, and Jackass Flats (Figure 1-2). Yucca and Frenchman Flat are topographically and hydrographically closed and contain dry lake beds, or playas, at their lowest elevations. Jackass Flats is topographically and hydrographically open, and surface water from this basin flows off the NNSS to the south via the Fortymile Wash. The dominant highlands are Pahute Mesa and Rainier Mesa (high volcanic plateaus), Timber Mountain (a resurgent dome of the Timber Mountain caldera complex), and Shoshone Mountain. In general, the highland areas are steep and dissected, and the slopes in the lowland areas are gentle. The lowest elevation on the NNSS is 823 meters (m) (2,700 feet [ft]) in Jackass Flats in the southeast, and the highest elevation is 2,341 m (7,680 ft) on Rainier Mesa in the north-central region.

> Throughout this document, the definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

The topography of the NNSS has been altered by historical DOE actions, particularly underground nuclear testing. The principal effect of testing was the creation of numerous collapse sinks (subsidence craters), the majority of which are in the Yucca Flat basin, with fewer in the Pahute and Rainier mesas. Shallow detonations that created surface disruptions were also performed during the ***Plowshare Program*** to explore the potential uses of nuclear devices for large-scale excavation.

The reader is directed to *Attachment A: Site Description*, a file on the compact disc of this report, where the geology, hydrology, climatology, ecology, and cultural resources of the NNSS are described.

1.3 Site History

The history of the NNSS and its current missions direct the focus and design of environmental monitoring and surveillance activities on and near the site. Between 1940 and 1950, the area known as the NNSS was under the jurisdiction of Nellis Air Force Base and was part of the Nellis Bombing and Gunnery Range. In 1950, the site was established as the primary location for testing the nation's nuclear explosive devices. It was named

Figure 1-1. NNSS vicinity map

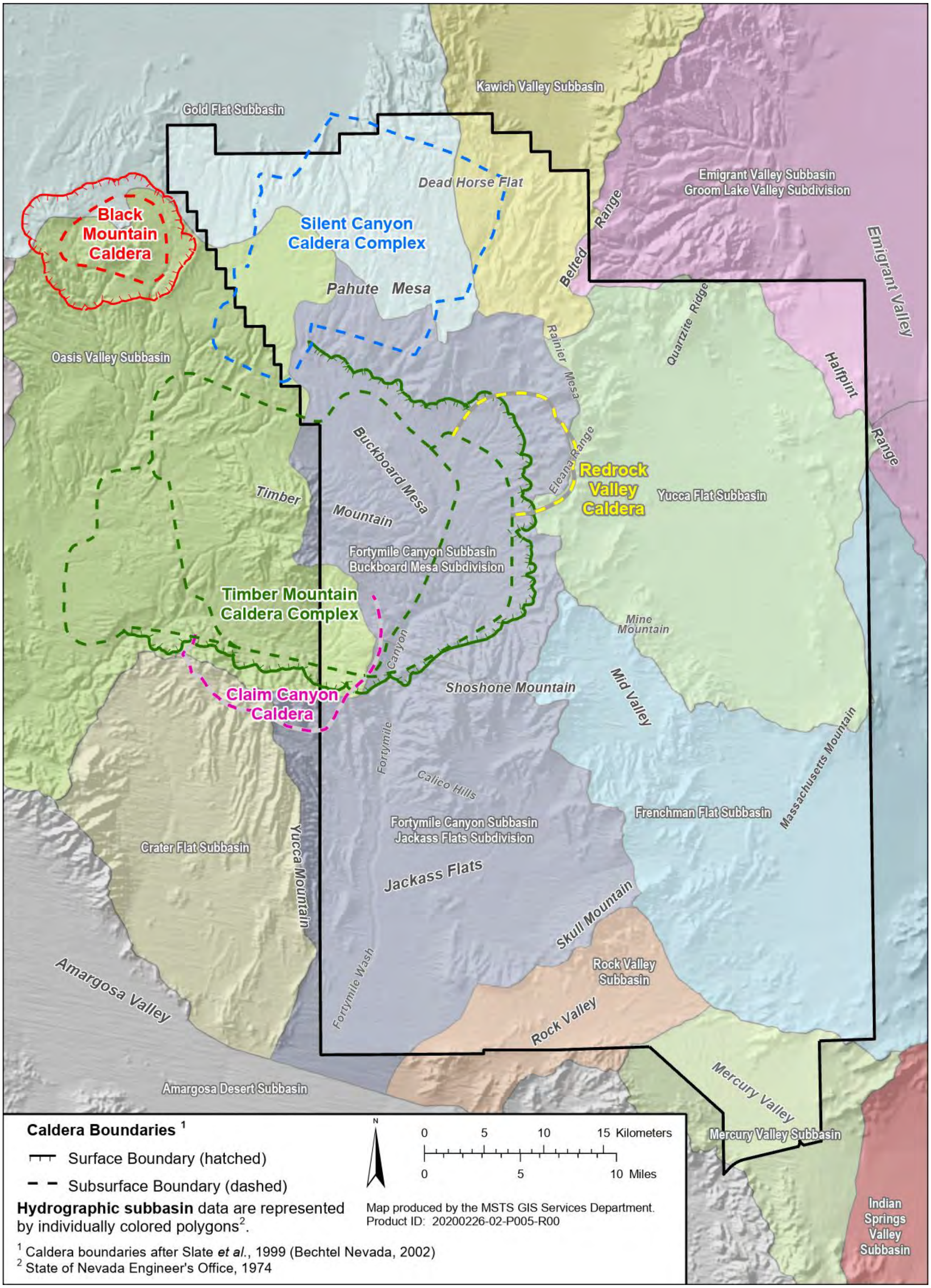


Figure 1-2. Major topographic features, calderas, and hydrographic subbasins of the NNSS

the Nevada Test Site (NTS) in 1951 and supported nuclear testing from 1951 to 1992. The types of tests conducted during this period are briefly described below. In 2010, the NTS was renamed the NNSS to reflect the diversity of nuclear, energy, and homeland security activities now conducted at the site. Experiments involving nuclear material are conducted at the NNSS, and are currently limited to ***subcritical experiments***.

Atmospheric Tests – The first test, an atmospheric nuclear explosive test, was conducted on the NTS in 1951. Tests conducted through the 1950s were predominantly atmospheric tests. They involved a nuclear explosive device detonated either on the ground surface, on a steel tower, suspended from tethered balloons, dropped from an aircraft, or placed on a rocket. Several tests, categorized as “safety experiments” and “storage-transportation tests,” involved the destruction of a nuclear device with non-nuclear explosives. Some of these resulted in the dispersion of plutonium in the test vicinity. One of these test areas lies just north of the NNSS boundary at the south end of the NTTR, and four others are at the north end of the NTTR. The last above-ground test occurred in 1962.

Underground Tests – The first underground nuclear explosive test was a cratering test conducted in 1951. The first contained underground test was in 1957. Testing was discontinued during a bilateral moratorium that began October 1958, but was resumed in September 1961, after the Union of Soviet Socialist Republics resumed nuclear testing. After late 1962, nearly all tests were conducted in sealed vertical shafts drilled into Yucca Flat and Pahute Mesa or in horizontal tunnels mined into Rainier Mesa and Shoshone Mountain. From 1951 to 1992, a total of 828 underground nuclear tests were conducted at the NNSS. Approximately one-third of them were detonated near or in the ***saturated zone***.

Cratering Tests – Five earth-cratering (shallow-burial) nuclear explosive tests were conducted from 1962 through 1968 as part of the Plowshare Program that explored peaceful uses of nuclear explosives. The first and highest yield Plowshare crater test, Sedan, was detonated at the northern end of Yucca Flat. The second highest yield crater test was Schooner, located on Pahute Mesa. Mixed fission products, ***tritium***, and plutonium from these tests were entrained in the soil ejected from the craters and deposited on the ground surrounding the craters.

Other Tests – Other nuclear-related experiments at the NNSS have included the BREN [Bare Reactor Experiment–Nevada] series in the early 1960s, conducted in Area 4. These tests were performed with a 14-million electron volt neutron generator mounted on a 465 m (1,527 ft) steel tower to produce neutron and gamma radiation for the purpose of estimating the radiation doses received by survivors of Hiroshima and Nagasaki. The tower was moved in 1966 to Area 25 and used for conducting Operation HENRE [High-Energy Neutron Reactions Experiment], jointly funded by the U.S. Department of Defense (DoD) and the Atomic Energy Commission (AEC) to provide information for the AEC’s Division of Biology and Medicine. From 1959 through 1973, open-air nuclear reactor, nuclear engine, and nuclear furnace tests were conducted in Area 25, and tests with a nuclear ramjet engine were conducted in Area 26. Erosion of metal cladding on the reactor fuel released some fuel particles that caused negligible deposition of ***radionuclides*** on the ground. Most of the radiation released from these tests were gaseous radioactive fission products.

Fact sheets on many of the historical tests mentioned above can be found at http://www.nnss.gov/pages/resources/library/FactSheets.html. All nuclear device tests are listed in *United States Nuclear Tests, July 1945 through September 1992* (NNSA/NFO 2015).

1.4 Mission

NNSA/NFO directs facility management and program operations at the NNSS North Las Vegas Facility (NLVF) and the Remote Sensing Laboratory–Nellis (RSL-Nellis) in Nevada and as well as selected operations at five sites outside of Nevada: RSL-Andrews in Maryland, Livermore Operations and the Special Technologies Laboratory in California, and Los Alamos Operations and Sandia National Laboratories in New Mexico. Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories are the principal organizations that sponsor and implement the nuclear weapons programs at the NNSS. Mission Support and Test Services, LLC, is the Management and Operating Contractor accountable for the successful execution of work and ensuring compliance with environmental regulations. The three major NNSS missions currently include National Security/Defense, Environmental Management, and Nondefense. The programs that support these missions are listed in the following text box.

NNSS Missions and Programs

National Security/Defense Missions

Stockpile Stewardship and Management Program – Conducts operations in support of defense-related nuclear and national security experiments and maintains the capability to resume underground nuclear weapons testing, if directed.

Nuclear Emergency Response, Nonproliferation, and Counterterrorism Programs – Provides support facilities, training facilities, and capabilities for government agencies involved in emergency response, nonproliferation technology development, national security technology development, and counterterrorism activities.

Strategic Partnership Program – Provides support facilities and capabilities for other DOE programs and federal agencies/organizations involved in defense-related activities.

Environmental Management Missions

Environmental Restoration Program – Characterizes and remediates the environmental legacy of nuclear explosive and other testing at NNSS and NTTR locations, and develops and deploys technologies that enhance environmental restoration.

Waste Management Program – Manages and safely disposes of ***low-level waste***, ***mixed low-level waste***, and classified waste/matter received from DOE- and DoD-approved facilities throughout the U.S. and wastes generated in Nevada by NNSA/NFO. Safely manages and characterizes ***hazardous*** and ***transuranic wastes*** for offsite disposal.

Nondefense Missions

General Site Support and Infrastructure Program – Maintains the buildings, roads, utilities, and facilities required to support all NNSS programs and to provide a safe environment for NNSS workers.

Conservation and Renewable Energy Programs – Operates the pollution prevention program and supports renewable energy and conservation initiatives at the NNSS.

Other Research and Development – Provides support facilities and NNSS access to universities and organizations conducting environmental and other research unique to the regional setting.

1.5 Primary Facilities and Activities

NNSS facilities and centers that support the National Security/Defense missions include the U1a Complex, Big Explosives Experimental Facility, Device Assembly Facility (DAF), Dense Plasma Focus (DPF) Facility, Joint Actinide Shock Physics Experimental Research (JASPER) Facility, Nonproliferation Test and Evaluation Complex (NPTEC), the National Criticality Experiments Research Center (located within the DAF), the Radiological/Nuclear Countermeasures Test and Evaluation Complex (RNCTEC), and the Radiological/Nuclear Weapons of Mass Destruction Incident Exercise Site (known as the T-1 Site). NNSS facilities that support Environmental Management missions include the ***Area 5 Radioactive Waste Management Complex (RWMC)*** and the Area 3 Radioactive Waste Management Site (RWMS) (Figure 1-3).

The primary NNSS activity in 2020 continued to be ensuring that the U.S. stockpile of nuclear weapons remains safe and reliable. Other 2020 NNSS activities included experiments aimed at improving arms control and nonproliferation treaty verification; weapons of mass destruction first responder training; the controlled release of hazardous material at NPTEC; remediation of legacy contamination sites; processing of waste destined for the Waste Isolation Pilot Plant in Carlsbad, New Mexico, or the Idaho National Laboratory in Idaho Falls, Idaho; and disposal of low-level and mixed low-level radioactive waste.

1.6 NNSS COVID-19 Pandemic Response

In the midst of the coronavirus disease 2019 (COVID-19) pandemic, the NNSS community has responded with agility and resilience. The NNSS workforce, in mid-March 2020, maximized teleworking for approximately 3,200 personnel. The team has provided guidance and led support to surrounding communities in response to COVID-19 while maintaining the continued operational work stance. Discussion of impacts to Mission, Programs, and Operations are included throughout this report, as applicable.

Community – The NNSS donated more than $200,000 to educational and social causes, e.g., University of Nevada at Las Vegas, Clark County School District (Chromebooks to at-risk students); Spread the Word (promotes literacy); Three Square Food Bank; American Red Cross; and Las Vegas Global Alliance.

Security – NNSS and outlying personnel, material, and cyber security continued to provide the necessary controls to keep us productive and secure.

Fire and Rescue – These highly skilled personnel continued to respond to medical emergencies, wildland fires, vehicle fires and accidents, vehicle rescues, and hazardous materials incidents.

Operations Command Center – The Operations Command Center's highly skilled team continued to implement emergency notifications and protective actions, and oversaw NNSS access as well as mission scheduling and deconfliction for NNSS activities.

The COVID-19 Monitoring Team – The COVID-19 monitoring team, a subset of the Emergency Operations Center, was responsible for keeping track of employees, creating workplace COVID-19 mitigation plans, assisting with COVID-19 personal protective equipment and cleaning supply management and distribution, communicating information to the workforce, as well as providing DOE and NNSA information updates and ensuring compliance with regulations.

Occupational Medicine – The Occupational Medicine organization continued to provide Medical services consistent with safe work practices. The team established a drive-thru flu vaccination process to minimize people in the clinics and maximize social distancing. They coordinated with Federal and state agencies to develop and implement an aggressive complex-leading COVID-19 vaccination program, which through mid-2021 had administered over 4,000 total vaccinations. The Occupational Medicine team continues to provide a critical resource for ongoing support, questions, and concerns related to COVID-19, variants, and a multitude of other health-related concerns.

NNSS Workforce – Highly proficient and professional, they continued adhering to established protocols and guidance, including maximizing telework capabilities, practicing "social distancing," wearing face coverings, and other cleanliness and hygiene protocols while managing projects and coordinating subcontractors for the continued safe operations at the NNSS and outlying sites.

1.7 Scope of this Environmental Report

This report summarizes the NNSA/NFO environmental protection and monitoring programs data and the compliance status for calendar year 2020 at the NNSS and at its two support facilities, the NLVF and RSL-Nellis. This report also addresses environmental restoration projects conducted by the Environmental Management Nevada Program Office at the Tonopah Test Range (TTR).

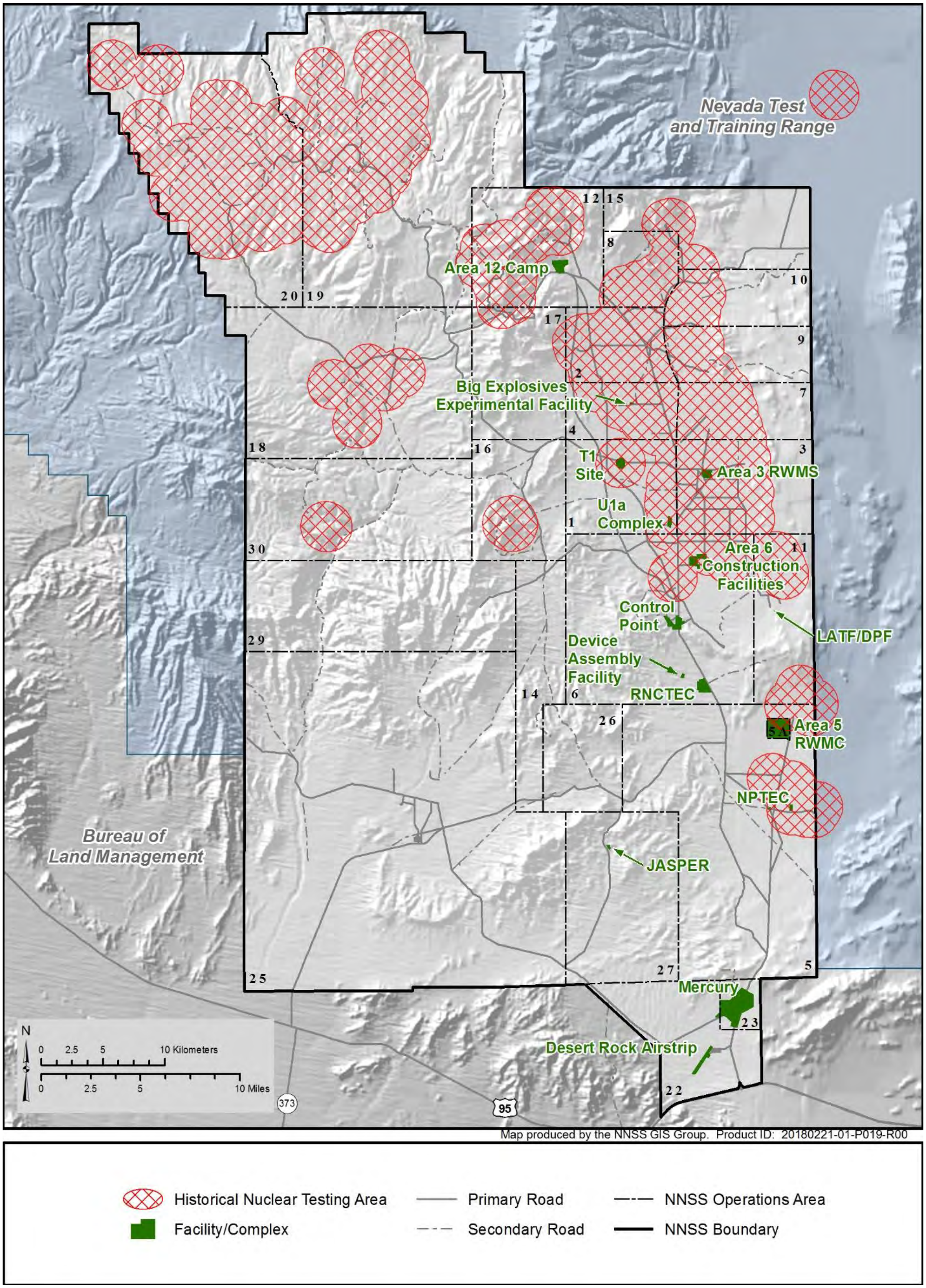


Figure 1-3. NNSS operational areas, principal facilities, and past nuclear testing areas

The Environmental Management Nevada Program Office is responsible for addressing environmental restoration sites on the NTTR and TTR if they are listed in the Federal Facility Agreement and Consent Order. The DOE/NNSA Sandia Field Office produces the TTR annual site environmental reports, which are posted at http://www.sandia.gov/news/publications/environmental/index.html.

1.8 Populations Near the NNSS

The population of the area surrounding the NNSS is predominantly rural. The most recent population estimates for Nevada communities are for 2019 and are provided by the Nevada State Demographer's Office (2020). The most recent population estimate for Nye County is 48,414, and the largest Nye County community is Pahrump (41,482), located approximately 80 km (50 mi) south of the NNSS Control Point facility (near the center of the NNSS). Other Nye County communities include Tonopah (1,823), Amargosa (1,433), Beatty (935), Round Mountain (744), Gabbs (133), and Manhattan (133). Lincoln County to the east of the NNSS includes a few small communities, including Caliente (1,133), Panaca (824), Pioche (809), and Alamo (707), and Esmeralda County includes Goldfield (288) and Silver Peak (101). Clark County, southeast of the NNSS, is the major population center of Nevada and has an estimated population of 2,320,107. The total annual population estimate for all Nevada counties, cities, and towns is 3,145,184.

The Mojave Desert, which includes Death Valley National Park, lies along the southwestern border of Nevada. This area is still predominantly rural; however, tourism at Death Valley National Park increases the population during holiday periods when the weather is mild.

The extreme southwestern region of Utah is more developed than the adjacent portion of Nevada. The latest population estimates for Utah communities are taken from the U.S. Census Bureau (2019) of the U.S. Department of Commerce. Southern Utah's largest community is St. George, located 220 km (137 mi) east of the NNSS, with an estimated population of 89,587. The next largest town, Cedar City, is located 280 km (174 mi) east-northeast of the NNSS and has an estimated population of 34,764.

The northwestern region of Arizona is mostly rangeland except for that portion in the Lake Mead recreation area. In addition, several small communities lie along the Colorado River. The largest towns in the area are Bullhead City, 165 km (103 mi) south-southeast of the NNSS, with an estimated population of 41,573, and Kingman, 280 km (174 mi) southeast of the NNSS, with an estimated population of 31,930 (Arizona Department of Administration 2020).

1.9 Understanding Data in This Report

1.9.1 Scientific Notation

Scientific notation is used in this report to express very large or very small numbers. A very small number is expressed with a negative exponent, for example 2.0×10^{-5}. To convert this number from scientific notation to a more traditional number, the decimal point must be moved to the left by the number of places equal to the exponent (5 in this case). The number thus becomes 0.00002.

Very large numbers are expressed in scientific notation with a positive exponent. The decimal point should be moved to the right by the number of places equal to the exponent. The number 1,000,000,000 could be presented in scientific notation as 1.0×10^{9}.

Table 1-1. Unit prefixes

Prefix	Abbreviation	Meaning
mega-	M	1,000,000 (1×10^{6})
kilo-	k	1,000 (1×10^{3})
centi-	c	0.01 (1×10^{-2})
milli-	m	0.001 (1×10^{-3})
micro-	µ	0.000001 (1×10^{-6})
nano-	n	0.000000001 (1×10^{-9})
pico-	p	0.000000000001 (1×10^{-12})

1.9.2 Unit Prefixes

Units for very small and very large numbers are commonly expressed with a prefix. The prefix signifies the amount of the given unit. For example, the prefix k, or kilo-, means 1,000 of a given unit. Thus 1 kg (kilogram) is 1,000 g (grams). Other prefixes used in this report are listed in Table 1-1.

1.9.3 Units of Radioactivity

Much of this report deals with levels of ***radioactivity*** in various environmental media. The basic unit of radioactivity used in this report is the ***curie*** (Ci) (Table 1-2). The curie describes the amount of radioactivity present, and amounts are usually expressed in terms of fractions of curies in a given mass or volume (e.g., picocuries per liter). The curie is historically defined as 37 billion nuclear disintegrations per second, the rate of nuclear disintegrations that occur in 1 gram of radium-226. For any other radionuclide, 1 Ci is the quantity of the radionuclide that decays at this same rate. Nuclear disintegrations produce spontaneous emissions of ***alpha*** or ***beta particles***, ***gamma radiation***, or combinations of these.

Table 1-2. Units of radioactivity

Symbol	Name
Ci	curie
cpm	counts per minute
mCi	millicurie (1×10^{-3} Ci)
μCi	microcurie (1×10^{-6} Ci)
nCi	nanocurie (1×10^{-9} Ci)
pCi	picocurie (1×10^{-12} Ci)

1.9.4 Units of Radiological Dose

The amount of ***ionizing radiation*** energy absorbed by a living organism is expressed in terms of radiological ***dose***. Radiological dose in this report is usually written in terms of ***effective dose equivalent (EDE)*** and reported numerically in units of millirem (mrem) (Table 1-3). Millirem is a term that relates ionizing radiation to biological effect or risk to humans. A dose of 1 mrem has a biological effect similar to the dose received from an approximate 1-day ***exposure*** to natural ***background*** radiation. An acute (short-term) dose of 100,000 to 400,000 mrem can cause radiation sickness in humans. An acute dose of 400,000 to 500,000 mrem, if left untreated, results in death approximately 50% of the time. Exposure to lower amounts of radiation (1,000 mrem or less) produces no immediate observable effects, but long-term (delayed) effects are possible. The average person in the United States receives an annual dose of approximately 300 mrem from exposure to naturally produced radiation. Medical and dental X-rays, air travel, and tobacco smoking add to this total.

Table 1-3. Units of radiological dose

Symbol	Name
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
μR	microroentgen (1×10^{-6} R)

The unit "***rad***," for radiation ***absorbed dose***, is also used in this report. The rad is a measure of the energy absorbed by any material, whereas a "***rem***," for "roentgen equivalent man," relates to both the amount of radiation energy absorbed by humans and its consequence. A ***roentgen (R)*** is a measure of radiation exposure. Generally speaking, 1 R of exposure will result in an EDE of 1 rem. Additional information on radiation and dose terminology can be found in the Glossary (Appendix B).

1.9.5 International System of Units for Radioactivity and Dose

In some instances in this report, radioactivity and radiological dose values are expressed in other units in addition to Ci and rem. These units are the ***becquerel (Bq)*** and the ***sievert (Sv)***, respectively. The Bq and Sv belong to the ***International System of Units (SI)***, and their inclusion in this report is mandated by DOE. SI units are the internationally accepted units and may eventually be the standard for reporting both radioactivity and radiation dose in the United States. One Bq is equivalent to one nuclear disintegration per second.

Table 1-4. Conversion table for SI units

To Convert From	To	Multiply By
becquerel (Bq)	picocurie (pCi)	27
curie (Ci)	becquerel (Bq)	3.7×10^{10}
gray (Gy)	rad	100
millirem (mrem)	millisievert (mSv)	0.01
millisievert (mSv)	millirem (mrem)	100
picocurie (pCi)	becquerel (Bq)	0.03704
rad	gray (Gy)	0.01
sievert (Sv)	rem	100

The unit of radiation absorbed dose (rad) has a corresponding SI unit called the ***gray (Gy)***. The roentgen measure of radiation exposure has no SI equivalent. Table 1-4 provides the multiplication factors for converting to and from SI units.

1.9.6 Radionuclide Nomenclature

Radionuclides are frequently expressed with the one- or two-letter chemical symbol for the element. Radionuclides may have many different ***isotopes***, which are usually shown by a superscript to the left of the symbol. This number is the atomic weight of the isotope (the number of protons and neutrons in the nucleus of the ***atom***). Radionuclide symbols, many of which are used in this report, are shown in Table 1-5 along with the ***half-life*** of each radionuclide. The half-life is the time (measured in years [yr], days [d], hours [h], or seconds [s]) required for one-half of the radioactive atoms in a given amount of material to decay. For example, after one half-life, half of the original atoms will have decayed; after two half-lives, three-fourths of the original atoms will have decayed; and, after three half-lives, seven-eighths of the original atoms will have decayed, and so on. The notation $^{226+228}$Ra and similar notations in this report (e.g., $^{239+240}$Pu) are used when the analytical method does not distinguish between the isotopes, but reports the total amount of both.

1.9.7 Units of Measurement

Both metric and non-metric units of measurement are used in this report. Metric system and U.S. customary units and their respective equivalents are shown in Table 1-6.

1.9.8 Measurement Variability

There is always ***uncertainty*** associated with the measurement of environmental contaminants. For radioactivity, a major source of uncertainty is the inherent randomness of ***radioactive decay*** events.

Uncertainty in analytical measurements is also a consequence of variability related to collecting and analyzing the samples. This variability is associated with reading or recording the result, handling or processing the sample, calibrating the counting instrument, and numerical rounding.

The uncertainty of a measurement is denoted by following the result with an uncertainty value, which is preceded by the plus-or-minus symbol, ±. This uncertainty value gives information on what the measurement might be if the same sample were analyzed again under identical conditions. The uncertainty value implies that approximately 95% of the time, the average of many measurements would give a value somewhere between the reported value minus the uncertainty value and the reported value plus the uncertainty value. If the reported concentration of a given constituent is smaller than its associated uncertainty (e.g., 40 ± 200), then the sample may not contain that constituent.

Table 1-5. Radionuclides and their half-lives (in alphabetical order by symbol)

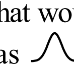
Symbol	Radionuclide	Half-Life [(a)]
^{241}Am	americium-241	432.2 yr
^{7}Be	beryllium-7	53.22 d
^{14}C	carbon-14	5.70×10^3 yr
^{36}Cl	chlorine-36	3.01×10^5 yr
^{134}Cs	cesium-134	2.1 yr
^{137}Cs	cesium-137	30.2 yr
^{51}Cr	chromium-51	27.7 d
^{60}Co	cobalt-60	5.3 yr
^{152}Eu	europium-152	13.5 yr
^{154}Eu	europium-154	8.6 yr
^{155}Eu	europium-155	4.8 yr
^{3}H	tritium	12.3 yr
^{129}I	iodine-129	1.6×10^7 yr
^{131}I	iodine-131	8 d
^{40}K	potassium-40	1.3×10^8yr
^{85}Kr	krypton-85	10.8 yr
^{212}Pb	lead-212	10.6 hr
^{238}Pu	plutonium-238	87.7 yr
^{239}Pu	plutonium-239	2.4×10^4 yr
^{240}Pu	plutonium-240	6.5×10^3 yr
^{241}Pu	plutonium-241	14.4 yr
^{226}Ra	radium-226	1.6×10^3 yr
^{228}Ra	radium-228	5.75 yr
^{220}Rn	radon-220	56 s
^{222}Rn	radon-222	3.8 d
^{103}Ru	ruthenium-103	39.3 d
^{106}Ru	ruthenium-106	373.6 d
^{125}Sb	antimony-125	2.8 yr
^{113}Sn	tin-113	115 d
^{90}Sr	strontium-90	28.8 yr
^{99}Tc	technetium-99	2.1×10^5 yr
^{232}Th	thorium-232	1.4×10^{10} yr
U [(b)]	uranium total	- - - [(c)]
^{234}U	uranium-234	2.4×10^5 yr
^{235}U	uranium-235	7×10^8 yr
^{238}U	uranium-238	4.5×10^9 yr
^{65}Zn	zinc-65	244.1 d
^{95}Zr	zirconium-95	63.98 d

(a) Source: International Commission on Radiological Protection (2008)
(b) Total uranium may also be indicated by U-natural (U-nat) or U-mass
(c) Natural uranium is a mixture dominated by ^{238}U; thus, the half-life is approximately 4.5×10^9 years

Table 1-6. Metric and U.S. customary unit equivalents

Metric Unit	U.S. Customary Equivalent Unit	U.S. Customary Unit	Metric Equivalent Unit
Length			
1 centimeter (cm)	0.39 inches (in.)	1 inch (in.)	2.54 centimeters (cm)
1 millimeter (mm)	0.039 inches (in.)		25.4 millimeters (mm)
1 meter (m)	3.28 feet (ft)	1 foot (ft)	0.3048 meters (m)
	1.09 yards (yd)	1 yard (yd)	0.9144 meters (m)
1 kilometer (km)	0.62 miles (mi)	1 mile (mi)	1.6093 kilometers (km)
Volume			
1 liter (L)	0.26 gallons (gal)	1 gallon (gal)	3.7853 liters (L)
1 cubic meter (m^3)	35.32 cubic feet (ft^3)	1 cubic foot (ft^3)	0.028 cubic meters (m^3)
	1.31 cubic yards (yd^3)	1 cubic yard (yd^3)	0.765 cubic meters (m^3)
Weight			
1 gram (g)	0.035 ounces (oz)	1 ounce (oz)	28.35 gram (g)
1 kilogram (kg)	2.21 pounds (lb)	1 pound (lb)	0.454 kilograms (kg)
1 metric ton (mton)	1.10 short ton (2,000 lb)	1 short ton (2,000 lb)	0.90718 metric ton (mton)
Area			
1 hectare	2.47 acres	1 acre	0.40 hectares
1 square meter (m^2)	10.76 square feet (ft^2)	1 square foot (ft^2)	0.09 square meters (m^2)
Radioactivity			
1 becquerel (Bq)	2.7×10^{-11} curie (Ci)	1 curie (Ci)	3.7×10^{10} becquerel (Bq)
Radiation dose			
1 rem	0.01 sievert (Sv)	1 sievert (Sv)	100 rem
Temperature			
°C = (°F − 32)/1.8		°F = (°C × 1.8) + 32	

1.9.9 Mean and Standard Deviation

The mean of a set of data is the usual average of those data. The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual sample results; it is defined as the square root of the average squared difference of individual data values from the mean. This variation includes both measurement variability and actual variation between monitoring periods (weeks, months, or quarters, depending on the particular analysis). The sample mean and standard deviation are estimates of the average and the variability that would be seen in a large number of repeated measurements. If the distribution shape were "normal" (i.e., shaped as ), about 67% of the measurements would be within the mean ± SD, and 95% would be within the mean ± 2 SD.

1.9.10 Standard Error of the Mean

Just as individual values are accompanied by counting uncertainties, mean values (averages) are accompanied by uncertainty. The standard deviation of the distribution of sample mean values is known as the standard error of the mean (SE). The SE conveys how accurate an estimate the mean value is based on the samples that were collected and analyzed. The ± value presented to the right of a mean value is equal to 2 × SE. The ± value implies that approximately 95% of the time, the average of many calculated means will fall somewhere between the reported value minus the 2 × SE value and the reported value plus the 2 × SE value.

1.9.11 Median, Maximum, and Minimum Values

Median, maximum, and minimum values are reported in some sections of this report. A median value is the middle value when all the values are arranged in order of increasing or decreasing magnitude. For example, the median of the numbers 1 2 3 3 4 5 5 5 6 is 4. The maximum is 6 and the minimum is 1. With an even number of numbers, the median is the average of the middle two.

1.9.12 Less Than (<) Symbol

A "less than" symbol (<) indicates that the measured value is smaller than the number given. For example, <0.09 would indicate that the measured value is less than 0.09. In this report, < is often used in reporting the amounts of nonradiological contaminants in a sample when the measured amounts are less than the analytical laboratory's reporting limit for that contaminant in that sample. For example, if a measurement of benzene in sewage lagoon pond water is reported as <0.005 milligrams per liter, this implies that the measured amount of benzene present, if any, was not found to be above this level. For some constituents the notation "ND" is used to indicate that the constituent in question was not detected. For organic constituents in particular, this could mean that the compound could not be clearly identified, the level (if any) was lower than the reporting limit, or (as often happens) both. In (many chapters of) this report measurements of radionuclide concentrations are reported whether or not they are below a reporting limit, which is often called the ***minimum detectable concentration***.

1.9.13 Negative Radionuclide Concentrations

There is always a small amount of natural radiation in the environment. The instruments used in the laboratory to measure radioactivity in environmental media are sensitive enough to measure the natural, or background, radiation along with any contaminant radiation in a sample. To obtain an unbiased measure of the contaminant level in a sample, the natural, or background, radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radioactive emissions and the very low concentrations of some contaminants, it is possible to obtain a background measurement that is larger than the actual contaminant measurement. When the larger background measurement is subtracted from the smaller contaminant measurement, a negative result is generated. Negative results are reported because they are useful when conducting statistical evaluations of the data.

1.10 References

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Chapter 2: Compliance Summary

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Environmental regulations pertinent to operations at the Nevada National Security Site (NNSS), the North Las Vegas Facility (NLVF), and the Remote Sensing Laboratory–Nellis (RSL-Nellis) include federal, state, and local environmental regulations; site-specific permits; and binding interagency agreements. The environmental regulations dictate how the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) conducts operations to ensure the protection of the environment and the public. In 2020, NNSA/NFO operated in compliance with the requirements defined in this framework, and as negotiated with the Nevada Division of Environmental Protection (NDEP) and other environmental regulatory authority related to impacts due to the coronavirus 2019 (COVID-19) pandemic. Due to the impacts of COVID-19, NNSA/NFO negotiated certain deviations from permit requirements to regulatory required inspections and monitoring of the Device Assembly Facility, Yucca Lake, and Mercury sewage lagoons, the NNSS water systems operations, the Resource Conservation and Recovery Act (RCRA)-permitted facilities/units, and the solid waste permit facilities/units. The deviations were authorized by NDEP in a letter dated April 6, 2020. Instances of noncompliance are reported to regulatory agencies and corrected; they are also reported in this chapter.

As in previous years, radiological air emissions from current and past NNSA/NFO operations were well below the U.S. Environmental Protection Agency (EPA) ***dose***[1] limit set for the public, and the DOE dose limits set for the public and for plants and animals on or adjacent to the NNSS. Emissions of non-radiological air pollutants from permitted equipment/facilities at the NNSS and RSL-Nellis were within permit limits.

No man-made ***radionuclides*** were detected in any of the three state-permitted ***public water systems*** (PWSs) on the NNSS. Water samples from the NNSS PWSs met National Primary Drinking Water Standards (health standards) and met all Nevada Secondary Drinking Water Standards (related to taste, odor, and visual aspects).

Required groundwater monitoring at three NNSS wells near the ***Area 5 Radioactive Waste Management Complex (RWMC)*** continued to demonstrate that groundwater quality is not affected by disposal of low-level radioactive waste (LLW), mixed low-level radioactive waste (MLLW), and classified waste that contains hazardous and/or radioactive constituents. All wastewater discharges at the NNSS, NLVF, and RSL-Nellis met site-specific state permit requirements, including those of a National Pollutant Discharge Elimination System (NPDES) permit issued for groundwater pumping activities at the NLVF.

On July 3, 2019, the U.S. Department of Energy Environmental Management (EM) Nevada Program and NNSA/NFO notified NDEP that a classified waste stream had been transported from the Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee, and disposed at the Area 5 RWMC. Subsequent communications determined that between January 2013 to December 2018, there were 10 shipments of NNSS Waste Acceptance Criteria (WAC) non-compliant shipments involving 33 waste containers that had been shipped from Y-12 to the

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

NNSS and had been disposed at the Area 5 RWMC. On June 15, 2020, NDEP issued to NNSA/NFO a Finding of Alleged Violation (FOAV) and Order citing the 33 waste containers received from Y-12.

On April 13, 2020, the NNSA/NFO received a Notice of Violation (NOV) and report from EPA Region 9 that provided the results of a RCRA Compliance Evaluation Inspection (CEI) conducted in August 2019. The report detailed three items as areas of potential violations and one item as an area of concern. The potential violations addressed in the CEI were 1) lack of confirmatory data regarding the status of the waste associated with an LLW profile, 2) adequacy of groundwater monitoring data in past submittals of groundwater reports, and 3) the hazardous waste compliance status of the Y-12 waste containers. The area of concern addressed in the CEI was the location of groundwater monitoring wells and the constituents tested in the groundwater monitoring program.

Following a series of collaborative conversations, on June 22, 2021, the DOE and the State of Nevada reached a mutually beneficial resolution to all regulatory actions resulting from the July 2019 waste issue. The final agreement (Table 2-7) builds upon the Department's continued commitment to enhancing the rigor of its waste management activities for the protection of the DOE workforce, the public, and the environment.

Nineteen hazardous substance spills occurred in 2020: 17 at the NNSS, 1 at the NLVF, and 1 at RSL-Nellis. One sewage overflow was reportable (Table 2-7), and the other spills were small-volume releases either to containment areas or to other surfaces. All spills were cleaned up.

One spill occurred in late 2019 that was not included in this report, and was reported to NDEP because it exceeded the 25-gallon threshold for petroleum products. Six cubic yards of contaminated soil were removed, but some contaminated soil remained, and a use restriction was recorded in the NNSS GIS [geographic information system] application.

2.1 Compliance with Requirements

The federal, state, and local environmental statutes and regulations under which NNSA/NFO operates are summarized in Table 2-1, along with a discussion of NNSA/NFO's compliance status with each. In addition, the EPA offers the Enforcement and Compliance History Online website to search for facilities and assess their compliance with environmental regulations and to investigate pollution sources, examine and create enforcement-related maps, or explore the state's performance (https://echo.epa.gov/).

Abbreviations for Regulators

Federal	
ACHP	Advisory Council on Historic Preservation
CEQ	Council on Environmental Quality
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
EPA	U.S. Environmental Protection Agency
FWS	U.S. Fish and Wildlife Service
State/County	
CCDAQ	Clark County Division of Air Quality
NDEP	Nevada Division of Environmental Protection
NDA	Nevada Department of Agriculture
NDOF	Nevada Department of Forestry
NDOW	Nevada Department of Wildlife
NSHPO	Nevada State Historic Preservation Office

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
General Environmental Protection, Management, and Sustainability	
National Environmental Policy Act (NEPA), 42 USC 4321 et seq. (1969) **• CEQ: 40 CFR 1500-1508 • DOE: 10 CFR 1021, DOE P 451.1**	
NEPA requires federal agencies to consider environmental and related social and economic effects and reasonable alternatives before making a decision to implement a major federal action. Title 10 ***Code of Federal Regulations (CFR)*** Part 1021, *National Environmental Policy Act Implementing Procedures*, establishes procedures that the DOE shall use to comply with NEPA. DOE Policy DOE P 451.1, *National Environmental Policy Act Compliance Program,* establishes DOE internal requirements and responsibilities for implementing NEPA.	The NNSA/NFO NEPA Compliance Officer reviews Environmental Evaluation Checklists, which are required for all proposed projects/activities on the NNSS, and determines if the activity's environmental impacts require additional NEPA analysis and documentation. In 2020, 50 proposed projects/activities required analysis and documentation under NEPA compliance procedures, and 50 were exempt from any further NEPA review (Section 2.3).

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
<u>Departmental Sustainability (DOE O 436.1)</u>	
The NNSS' Management and Operating contractor, Mission Support and Test Services, LLC (MSTS), is responsible for environmental compliance. Requirements are documented in the MSTS Prime Contract, which includes Department of Energy Acquisition Regulation Clause 970.5204-2 Laws, Regulations, and DOE Directives requiring compliance with all applicable laws and regulations. DOE O 436.1, *Departmental Sustainability*, includes DOE Sustainability goals.	DOE Sustainable Environmental Stewardship goals are outlined in DOE's most current *Site Sustainability Plan Guidance Document* and incorporated into NNSA/NFO's Site Sustainability Plan. In December 2020, progress toward reaching 2020 goals was reported in the Fiscal Year (FY) 2021 NNSA/NFO Site Sustainability Plan. NNSA/NFO met 11 of the 19 long-term DOE sustainability goals in 2020 and continues to work toward achieving the remaining eight (Chapter 3).
Air Quality	
<u>Clean Air Act, 42 USC 7401 et seq. (1970)</u> **• EPA: 40 CFR 50, 60, 61, 63, 80, 82, and 98 • NDEP: NAC 445B**	
The Clean Air Act and Nevada's Air Control laws regulate air pollutant release through permits and air quality limits. Radionuclide emissions are regulated via National Emission Standards for Hazardous Air Pollutants (NESHAP) authorizations. Emissions of ***criteria pollutants*** are regulated via National Ambient Air Quality Standards authorizations. Criteria and ***designated pollutants*** emitted from various industrial categories of facilities are regulated via New Source Performance Standards authorizations. The Clean Air Act also establishes production limits and a schedule for the phase-out of ***ozone depleting substances***. Nevada Administrative Code (NAC) Chapter 445B, *Air Controls,* enforces Clean Air Act regulations and requires fugitive dust control and open burn authorizations.	No major source of air pollutants occurs at the NNSS. Federal and state air quality regulations are met through a State of Nevada Class II Air Quality Operating Permit and various project-specific state-issued permits (Table 2-2). NESHAP compliance activities include radionuclide air monitoring, reporting asbestos abatement, monitoring and reporting emissions from generators and boilers, and management of gasoline/diesel storage tanks. National Ambient Air Quality Standards emission limits (except ozone and lead) are based on published values for similar industries and operational data specific to the NNSS. Some screens, conveyor belts, bulk fuel storage tanks, and generators are subject to New Source Performance Standards. At the NLVF and RSL-Nellis, air quality regulations are met through Clark County Minor Source permits. NNSA/NFO pays annual state fees based on all sources' "***potential to emit***." Nevada's Bureau of Air Pollution Control inspects permitted NNSS facilities and Clark County inspects NLVF and RSL-Nellis permitted equipment. All approvals, notifications, requests for additional information, and reports required under the Clean Air Act are submitted to NDEP, Clark County, and/or EPA Region 9. In 2020, all applicable requirements for monitoring, operating, and reporting for the Class II Air Quality Operating Permit (NDEP) were met. In 2020, monitored radioactive air emissions were below NESHAP limits (Section 4.1). All non-radiological air emission limits, monitoring, record keeping, training, and reporting requirements of state and county air permits were met at the NNSS (Section 4.2) and RSL-Nellis. One non-emissions deviation report, involving reporting more hours than actual operating hours, was submitted for the NLVF.
Water Quality	
<u>Clean Water Act, 33 USC 1251 et seq. (1972)</u> **• EPA: 40 CFR 109-140, 230, 231, 401, and 403 • NDEP: NAC 444, 445A, and 534**	
The Clean Water Act and Nevada's Water Pollution Control laws seek to improve surface water quality by establishing standards and a system of permits. They prohibit the	NNSA/NFO does not hold an NPDES permit for NNSS operations because there are no discharges to waters of the U.S. on or off the NNSS from NNSA/NFO activities. Wastewater discharges are managed on the NNSS in

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
discharge of contaminants from ***point sources*** to waters of the U.S. without an NPDES permit. NAC 444, *Sanitation (Sewage Disposal)*, and NAC 445A, *Water Controls (Water Pollution Control)*, regulate the collection, treatment, and disposal of wastewater and sewage. NAC 534, *Underground Water and Wells*, regulates the drilling, construction, and licensing of new wells and the reworking of existing wells to prevent the waste and contamination of groundwater. The NLVF and RSL-Nellis implement a Spill Prevention, Control, and Countermeasure Plan required by the EPA to ensure that petroleum and non-petroleum oil products do not pollute waters of the U.S. via discharge into the Las Vegas Wash. In addition to federal and state laws, the NLVF and RSL-Nellis are regulated by the City of North Las Vegas and the Clark County Water Reclamation District (CCWRD), respectively.	accordance with NDEP-issued permits that include the E Tunnel Waste Water Disposal System, active and inactive sewage lagoons, septic tanks, septic tank pumpers, and a septic tank pumping contractor's license (Section 5.2). In response to the COVID-19 pandemic, NNSA/NFO negotiated certain deviations from permit requirements to regulatory required inspections and monitoring, which were authorized by NDEP in a letter dated April 6, 2020. NNSA/NFO reports unplanned releases of hazardous substances to NDEP as required under NAC 445A. No such releases occurred in 2020 (Section 2.5). NNSA/NFO complies with NAC 534 for Underground Test Area (UGTA) activities. UGTA wells are maintained in compliance with the Clean Water Act and are regulated by the state through the *UGTA Fluid Management Plan,* an agreement between NNSA/NFO and NDEP. In 2020, UGTA well drilling fluids were monitored and managed in accordance with the plan (Section 5.1.3.8.3). The NLVF operates under a Class II Authorization to Discharge Permit issued by the City of North Las Vegas for sewer discharges, an NPDES DeMinimis permit for surface water discharge, and a No Exposure Waiver for exclusion from NPDES storm water permitting. Storm water is not contaminated by exposure to industrial activities or materials (Section A.1.2). CCWRD determined that the annual submission of a Zero Discharge Form for RSL-Nellis is sufficient to verify compliance with the Clean Water Act (Section A.2.2). In 2020, all water chemistry parameters and contaminants that required monitoring in wastewater discharges and sewage lagoons were within permit limits, and all required inspections of wastewater systems were conducted, as negotiated with NDEP in response to the COVID-19 pandemic.
<u>Safe Drinking Water Act, 42 USC 300f et seq. (1974)</u> **• EPA: 40 CFR 141-149 • NDEP: NAC 445A**	
The Safe Drinking Water Act protects the quality of drinking water in the U.S. and authorizes the EPA to establish safe standards of purity. It requires all owners or operators of PWSs to comply with National Primary Drinking Water Standards (health standards). State governments are authorized to set Secondary Standards related to taste, odor, and visual aspects. NAC 445A requires that PWSs meet both primary and secondary water quality standards. The Safe Drinking Water Act standards for radionuclides currently apply only to PWSs designated as ***community water systems.*** Although not required under the act, all potable water supply wells on the NNSS are monitored for radionuclides in accordance with DOE O 458.1, *Radiation Protection of the Public and the Environment*.	The NNSS supplies drinking water from onsite wells that comply with all applicable federal and state water quality standards. Three PWSs on the NNSS are permitted by the state as ***non-community water systems.*** Each source is sampled according to a monitoring cycle that identifies specific contaminants and sampling frequency, ranging from monthly, quarterly, or once every 1, 3, 6, or 9 years. NDEP also permits two potable water-hauling trucks on the NNSS. The trucks are monitored monthly for coliform bacteria and results are submitted to NDEP throughout the year as they are acquired. In response to the COVID-19 pandemic, NNSA/NFO negotiated certain deviations from permit requirements to regulatory required inspections and monitoring, which were authorized by NDEP in a letter dated April 6, 2020. In 2020, no man-made radionuclides from NNSA/NFO activities were detected in NNSS drinking water wells, the

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation (a)(b)	2020 Compliance Status
	PWSs met all applicable primary and secondary drinking water standards, and potable water hauling trucks tested negative for coliform bacteria (Sections 5.1.3.7 and 5.2.1). Water used at both the NLVF and RSL-Nellis is supplied by the City of North Las Vegas and meets or exceeds federal drinking water standards; no monitoring or reporting of water quality is required.
Energy Independence and Security Act of 2007 (Pub. L. 110-140)	
Section 438 of the act addresses storm water management and requires any development/redevelopment project involving a federal facility with a footprint over 5,000 gross square feet to maintain or restore, to the maximum extent feasible, the predevelopment hydrology of the property with regard to the rate, temperature, volume, and duration of storm water flow.	Storm water management strategies are addressed and incorporated into site design and building construction to meet requirements from the act for new developments.
Radiation Protection	
Radiation Protection of the Public and the Environment (DOE O 458.1 Change 4) **• DOE-STD-1196-2011 and DOE-STD-1153-2019**	
DOE O 458.1 Change 4 requires DOE/NNSA sites to implement an environmental radiological protection program. It establishes requirements for (1) measuring ***radioactivity*** in the environment, (2) documenting the ***ALARA*** [as low as reasonably achievable] process for operations, (3) using mathematical models for estimating doses, (4) releasing property having residual radioactive material, and (5) maintaining records to demonstrate compliance. The EPA's ***Clean Air Package 1988 (CAP88)*** (version 4.0) and the ***Derived Concentration Standards***, as defined in DOE-STD-1196-2011, *Derived Concentration Technical Standard*, are used in the design and conduct of environmental radiological protection programs. The order sets a radiation dose limit of 100 millirem/year (mrem/yr) (1 millisievert/year [mSv/yr]) above ***background*** levels to individuals in the general public from all pathways of ***exposure*** combined. It also calls for the protection of aquatic and terrestrial plants and animals from radiological impacts through the use of DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, which was updated under DOE-STD-1153-2019 of the same title.	NNSA/NFO has in place a radiological monitoring program and protection procedures that satisfy the requirements for a site-specific radiological protection program. Routine radiological monitoring of air, water, and biota, as well as project-specific monitoring and NESHAP evaluations of projects, are conducted. Monitoring and evaluation results document NNSA/NFO's compliance with the radiological dose limits set by DOE for the public and biota from several exposure pathways that include predominately inhalation and the ingestion of hunted NNSS game animals. Results of radiological monitoring and protective measures are described in several chapters of this report. As in previous years, the calculated dose to the public and to the biota from NNSA/NFO operations in 2020 was below all DOE dose limits set by DOE O 458.1 and DOE-STD-1153-2019, respectively. CAP88 and RESRAD-Biota models and Derived Concentration Standards defined in DOE-STD-1196-2011 were used to estimate dose to humans and biota based on radiological monitoring results (Sections 4.1 and 5.1, Chapters 6, 8, 9).
Waste Management and Environmental Corrective Actions	
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601 et seq (1980) **• EPA: 40 CFR 300, 302, and 355**	
CERCLA provides a framework for the cleanup of waste sites containing hazardous substances and an emergency response program in the event of a release of a hazardous substance to the environment (Emergency Planning and Community Right-to-Know Act).	No hazardous waste cleanup operations on the NNSS are regulated under CERCLA. Instead, they are regulated under the Resource Conservation Recovery Act (listed below). NNSA/NFO complies with the Emergency Planning and Community Right-to-Know Act (listed below) under CERCLA.
Resource Conservation Recovery Act (RCRA), 42 USC 6901 et seq. (1976) **• EPA: 40 CFR 259-282 • NDEP: NAC 444.570-7499, 444.850-8746, and 459.9921-999**	
RCRA and Nevada laws NAC 444.850–8746, *Disposal of Hazardous Waste;* NAC 444.570–7499, *Solid Waste*	NNSA/NFO generates HW (which includes MLLW) and operates a permitted HW management facility under

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
Disposal; and NAC 459.9921–999, *Storage Tanks*, regulate the generation, storage, transportation, treatment, and disposal of ***solid*** and ***hazardous waste (HW)*** to prevent contaminants from leaching into the environment from landfills, underground storage tanks, surface impoundments, and HW disposal facilities. RCRA also requires HW generators to have a program to reduce the amount and toxicity of HW, and federal facilities to have a procurement process to ensure that they purchase product types that satisfy the EPA-designated minimum percentages of recycled material.	RCRA Part B Permit NEV HW0101 issued by NDEP (Chapter 10). In accordance with the permit, NNSA/NFO also monitors groundwater from three wells (one downgradient and two upgradient of MLLW disposal cells [Section 10.3]) and conducts post-closure monitoring for HW sites that were closed under RCRA prior to enactment of the Federal Facility Agreement and Consent Order (Chapter 11). NNSA/NFO prepares a Hazardous Waste Report of all HW and MLLW volumes generated and disposed annually at the NNSS. In response to the COVID-19 pandemic, NNSA/NFO negotiated certain deviations from permit requirements to regulatory required inspections and monitoring, which were authorized by NDEP in a letter dated April 6, 2020. Discussion of the NDEP FOAV and Order, and the EPA NOV resulting from the August 2019 CEI are provided in this chapter and Chapter 10.
<u>Federal Facility Agreement and Consent Order (FFACO), as amended</u> **• FFACO • NDEP**	
The FFACO was agreed to by the State of Nevada, DOE's EM Nevada Program, the U.S. Department of Defense, and DOE Legacy Management in 1996. Pursuant to Section 120(a) (4) of CERCLA and to Sections 6001 and 3004(u) of RCRA, the FFACO addresses the environmental corrective actions of historically contaminated sites for which the DOE is responsible for cleanup and closure.	The EM Nevada Program is responsible for the cleanup and closure of more than 3,000 corrective action sites (CASs) identified in Nevada. Program activities follow a formal work process described in the FFACO. The State of Nevada is a participant throughout the closure process, and the Nevada Site Specific Advisory Board is kept informed of the progress made. The board is a formal volunteer group of interested citizens who provide informed recommendations to the EM Nevada Program. In 2020, the EM Nevada Program met all of the 2020 FFACO milestones for the characterization, remediation, closures, and post-closure monitoring and inspection of historically contaminated CASs. To date, 2,949 of the 3,044 CASs have been closed (Chapter 11).
<u>Radioactive Waste Management (DOE O 435.1 Change 2)</u> **• DOE M 435.1-1 Change 2**	
DOE O 435.1 Change 2, *Radioactive Waste Management*, requires all DOE radioactive waste be managed in a manner that is protective of the worker, public health and safety, and the environment. It directs how radioactive waste management operations are conducted on the NNSS. DOE M 435.1-1 Change 3, *Radioactive Waste Management Manual*, specifies that operations at radioactive waste management facilities must not contribute a dose to the general public in excess of 10 mrem/yr through the air pathway and 25 mrem/yr through all exposure pathways.	The Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) operate as Category II Non-Reactor Nuclear Facilities. Both are designed and operated to manage and safely dispose of LLW, MLLW, classified non-radioactive waste, and classified non-radioactive hazardous waste generated by NNSA/NFO, other DOE and selected U.S. Department of Defense operations, and to manage and safely store ***transuranic*** and mixed transuranic wastes generated on the NNSS for eventual shipment to the Waste Isolation Pilot Plant in New Mexico. In accordance with this order, ***Performance Assessments*** and ***Composite Analyses*** for both RWMSs are reviewed and submitted annually to EM Nevada Program. The Disposal Authorization Statements for both RWMSs also require annual reviews to track secondary or minor unresolved issues to resolution. Waste Acceptance Criteria for wastes disposed at the RWMSs are maintained and the volumes are tracked. Although not required by this DOE order, ***vadose zone***

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
	monitoring at both RWMSs is performed to validate the performance assessment criteria of the RWMSs. In response to the COVID-19 pandemic, NNSA/NFO negotiated certain deviations from permit requirements to regulatory required inspections and monitoring, which were authorized by NDEP in a letter dated April 6, 2020. In 2020, all key documents and analyses were current and all required management practices were followed (Chapter 10). The radiological dose to the public in 2020 from the Area 3 and 5 RWMSs from all pathways was negligible (Section 10.4).
Hazardous Materials Control and Management	
Emergency Planning and Community Right-to-Know Act (EPCRA), 42 USC 11001 et seq. (1986) **• EPA: 40 CFR 300, 302, 355, 370, and 372**	
EPCRA requires that federal, state, and local emergency planning authorities be provided information regarding the presence and storage of hazardous substances and their planned and unplanned environmental releases, including provisions and plans for responding to emergency situations involving hazardous materials. EPCRA identifies the threshold quantities of chemicals released or stored, which trigger the reporting of this information to these authorities.	Some NNSA/NFO facilities store or use chemicals in quantities exceeding threshold quantities under EPCRA. NNSA/NFO complies with all reporting and emergency planning requirements under EPCRA and with the requirements of several state-issued hazardous materials permits: a site-wide NNSS permit, one for NLVF, and one for RSL-Nellis. In 2020, NNSA/NFO adhered to all EPCRA reporting requirements (Section 2.4.4.1). The Nevada Combined Agency Report, containing updated chemical inventories for NNSA/NFO facilities, was submitted to the State Fire Marshal, and a Toxic Release Inventory Report was submitted to EPA identifying the types and quantities of toxic chemicals that were either released by NNSA/NFO operations into the environment or released for disposal or recycling. Toxic chemicals released from the NNSS in 2020 included lead, mercury, and polycyclic aromatic hydrocarbons (PACs) (Section 2.4.4.1). No releases at NLVF or RSL-Nellis exceeded reportable thresholds in 2020 (Sections A.1.5 and A.2.4).
State of Nevada Chemical Catastrophe Prevention Act (NRS 459.380–3874) **• NDEP: NAC 459.952-95528**	
This act directs NDEP to develop and implement a program called the Chemical Accident Prevention Program (CAPP). It requires registration of facilities with highly hazardous substances above listed thresholds.	The NNSS is a registered CAPP facility. An oleum release process is located at the Nonproliferation Test and Evaluation Complex (NPTEC) in Area 5. NNSA/NFO submits an annual CAPP Registration report. For the reporting period, no highly hazardous substance was stored at NPTEC in quantities that exceeded reporting thresholds. The annual compliance inspection at NPTEC conducted by NDEP found that the NNSS CAPP was meeting regulatory requirements (Section 2.4.4.2).
Toxic Substances Control Act (TSCA), 15 USC 2601 et seq. (1976) **• EPA: CFR 700-763 • NDEP: NAC 444.842-8746**	
TSCA regulates the manufacture, use, and distribution of chemical substances that enter the consumer market. Because the NNSS does not produce chemicals, compliance is primarily directed toward the management of ***polychlorinated biphenyls (PCBs)***.	At the NNSS, remediation activities and maintenance of fluorescent light ballasts can result in the onsite disposal of PCB-contaminated waste or the offsite disposal of larger quantities of PCB waste. NNSS also receives radioactive waste for onsite disposal that may contain regulated levels

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
NAC 444 enforces the federal requirements for the handling, storage, and disposal of PCBs and contains record-keeping requirements for PCB activities.	of PCBs. The onsite disposal of all PCB wastes and record-keeping requirements for PCB activities are regulated by the state. In 2020, PCBs were managed in compliance with TSCA and state regulations (Section 2.4.2).
<u>Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), 7 USC 136 et seq. (1996)</u> **• EPA: CFR 162-171 • NDA: NAC 555**	
FIFRA governs the manufacture, use, storage, and disposal of pesticides (including herbicides and other biocides) as well as the pesticide containers and residuals. It specifies procedures and requirements for pesticide registration, labeling, classification, and certification of applicators. NAC 555, *Nevada Control of Insects, Pests, and Noxious Weeds,* regulates the certification of registered pesticide and herbicide applicators in Nevada. NDA has the primary role to enforce FIFRA in Nevada.	The use of pesticides classified as "restricted-use pesticides" is regulated. Beginning in 2015, only non-restricted-use pesticides are applied under the direction of a State of Nevada–certified applicator. In 2020, NNSA/NFO complied with all FIFRA requirements (Section 2.4.3).
Cultural Resources	
<u>National Historic Preservation Act (NHPA), as amended, 54 USC 300101 et seq. (1966)</u> **• ACHP: 36 CFR 800**	
The NHPA, as amended, identifies, evaluates, and protects historic properties eligible for listing in the National Register of Historic Places (NRHP). Such properties can be archeological sites, historic structures, documents, records, or objects. The act requires federal agencies to develop and implement a Cultural Resources Management Plan, to identify and evaluate the eligibility of historic properties for long-term management as well as for future project-specific planning, and to maintain archaeological collections and their associated records at professional standards.	NNSA/NFO has established a Cultural Resources Management Program at the NNSS, which is implemented by the Desert Research Institute. The Cultural Resources Management Program ensures compliance with all regulations pertaining to cultural resources on the NNSS. Before initiating land-disturbing activities or building and structure modifications, archaeologists conduct surveys and historical evaluations to identify important cultural resources, evaluate significance, and assess potential impacts. Consultation with Native American representatives is conducted to identify resources that may be of spiritual or cultural significance. NNSA/NFO's long-term management strategy includes (1) monitoring NRHP-listed and eligible properties to determine if environmental factors or NNSA/NFO activities are affecting the integrity or other aspects of eligibility, and (2) taking corrective actions or identifying alternative approaches as necessary. Determinations of NRHP eligibility, effect, and mitigation are conducted in consultation with Nevada State Historic Preservation Office (SHPO), the 16 Tribes culturally affiliated with the NNSS lands and, in some cases, the federal ACHP. To date, more than 1,400 NRHP-eligible sites/facilities on the NNSS have been identified. In 2020, field surveys and historical evaluations for nine NNSS projects were conducted; 27 cultural resources were identified, 25 of which were determined eligible for the NRHP (Sections 12.1 and 12.2).
<u>Antiquities Act (16 U.S.C. 431-433), Archaeological Resources Protection Act, as amended (16 USC 470aa–mm)</u> **• DOI: 18 CFR 1312, 36 CFR 79, and 43 CFR 7**	
The Antiquities Act and the Archaeological Resources Protection Act, as amended, protect archaeological resources that remain in or on federal and American Indian lands and ensures that their confidentiality and characteristics are maintained. These laws require the issuance of a federal archaeology permit to qualified archaeologists to inventory,	Archaeologists working at the NNSS meet federal standards for professional qualifications. Procedures are in place to maintain the confidentiality of site locations and other information. A preservation in place policy is utilized, when possible, for identified cultural properties. In the event of

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [a][b]	2020 Compliance Status
excavate, or remove archaeological resources and requires notification to American Indian tribes of these activities.	vandalism, NNSA/ NFO investigates any impacts that may occur. The Cultural Resources Management Program curates archaeological collections from the NNSS in accordance with 36 CFR 79, *Curation of Federally Owned and Administered Archeological Collections*, and conducts American Indian consultations related to places and items of importance to the 16 Tribes culturally affiliated with NNSS lands (Section 12.6).
American Indian Religious Freedom Act, as amended (42 USC 1996)	
This law established the government policy to protect and preserve for American Indians their inherent right of freedom to believe, express, and exercise the traditional religions, including but not limited to access to sites, use and possession of sacred objects, and the freedom to worship through ceremonial and traditional rites.	Locations exist on the NNSS that have religious significance to Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone. Access is provided by NNSA/NFO in accordance with safety and health standards (Section 12.6).
Native American Graves Protection and Repatriation Act, as amended (25 USC 3001–3013) **• DOI: 43 CFR 10**	
The Native American Graves Protection and Repatriation Act, as amended, requires federal agencies to return certain types of Native American cultural items to lineal descendants and culturally affiliated American Indian tribes. The specified cultural items include human remains, funerary objects, sacred objects, and objects of cultural patrimony.	The NNSS artifact collection is subject to the act. The required inventory and summary of NNSS cultural materials accessioned into the NNSS Archaeological Collection was completed in the 1990s. The inventory list and summary was distributed to the tribes affiliated with the NNSS and adjacent lands. Consultations followed, and all artifacts the tribes requested were repatriated to them. This repatriation process was completed in 2002; it will be repeated for any new additions to the collection (Sections 12.5 and 12.6).
Biological Resources	
Endangered Species Act, 16 USC 1531-1544 (1973) **• FWS: 50 CFR 17**	
The Endangered Species Act provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The law also prohibits any action that causes a "***taking***" of any listed species of endangered fish or wildlife.	The threatened desert tortoise is the only species protected under the Endangered Species Act that may be impacted by NNSS operations. NNSS activities within tortoise habitat are conducted so as to comply with the terms and conditions of a Biological Opinion issued by FWS to NNSA/NFO. NNSS activities were covered by an Opinion issued by the FWS to cover the term of August 27, 2019, through 2029. The allowable cumulative take under the new Biological Opinion is 31 tortoises killed/injured, 440 moved, and 3,000 acres of habitat disturbed. In 2020, take totals were 0 killed on roads, 32 moved out of harm's way, and 24.4 acres disturbed. All requirements of the Biological Opinion were met (Chapter 13).
Nevada Department of Wildlife **• NDOW: NAC 503 •NDOF: NAC 527**	
NDOW regulations identify protected and unprotected Nevada animal species and prohibit the harm of protected species without special permit. NAC 503, *Hunting, Fishing and Trapping; Miscellaneous Protective Measures*, also identifies game animals, which are managed by the state. NDOF regulations prohibit removal or destruction of state-protected plants without special permit.	State-managed and state-protected species are monitored under the Ecological Monitoring and Compliance (EMAC) Program. Some species are collected for ecological studies under an NDOW scientific collection permit. In 2020, monitoring of raptors and mule deer was conducted. In response to the COVID-19 pandemic, NDOW distributed a letter dated April 7, 2020, to scientific collection permittees that directed the suspension of all capturing and handling of

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
	bats, "…out of an abundance of caution for the health and well-being of both bats and people…". NNSS biologists continued collaboration with other agency biologists with desert bighorn, pronghorn antelope, western burrowing owl, and mountain lion studies on and near the NNSS (Section 13.3).
<u>Migratory Bird Treaty Act (MBTA), 16 USC 703-712 (1918)</u> **• FWS: 50 CFR 21 •NDOW: NRS 503.050**	
The MBTA implements various treaties and conventions between the U.S. and Canada, Japan, Mexico, and the former Soviet Union for the protection of migratory birds. It prohibits the purposeful harming of any migratory bird, their nest, or eggs without authorization by the Secretary of the Interior. Memorandum M-37050 issued December 22, 2017, by the U.S. Department of the Interior, Office of the Solicitor, ruled that the incidental harm to migratory birds from otherwise legal activities does not violate this act. Nevada wildlife laws protect birds included under the MBTA from purposeful harm.	Although not required under the MBTA, the EMAC Program reviews construction and demolition projects and conducts field surveys to reduce any incidental harm to migratory birds and their nests/eggs. Biologists periodically collect game birds for radiological analysis under an FWS-issued migratory bird scientific collection permit. Migratory birds found injured or dead are reported to regulators. Biologists transfer injured raptors, upon direction from the FWS, to a licensed rehabilitator, and mitigation measures to reduce accidental mortalities are pursued. In 2020, 8 migratory birds were found dead, the lowest number of mortalities recorded since 2012; 6 of the deaths were due to human activities (e.g., electrocution on power lines, stuck in a glue trap) (Section 13.3).
<u>Responsibilities of Federal Agencies to Protect Migratory Birds</u> **• E.O. 13186**	
This Executive Order (E.O.) directs federal agencies to take certain actions to further implement the MBTA if agencies have, or are likely to have, a measurable negative effect on migratory bird populations. It also directs federal agencies to conduct actions, as practicable, to benefit the health of migratory bird populations.	The MSTS Power Operations organization installed bird guards, protective covers, and other retrofits on power poles to reduce avian mortality. Biologists maintained an Avian Protection Plan that was developed in cooperation with the FWS. The focus of the plan is to reduce operational and avian risks from avian interactions with electric transmission and distribution lines on the NNSS as well as other non-electric sources of mortality (e.g., vehicle collisions, habitat disturbance) (Section 13.3).
<u>The Bald and Golden Eagle Protection Act, 16 USC 668a-d, 703-712</u> **• FWS: 50 CFR 22 •NDOW: NRS 503.050**	
The Bald and Golden Eagle Protection Act prohibits any form of possession or taking of both bald and golden eagles. Eagles are also protected under Nevada wildlife laws.	Compliance with the act is documented under the EMAC Program. Eagles that are occasionally electrocuted on NNSS power lines are transferred to the FWS under an FWS special purpose possession permit. No eagle mortalities were observed (Section 13.3).
<u>Wild Free-Roaming Horses and Burros Act (Pub. L. 92–195)</u>	
This act makes it unlawful to harm wild horses and burros. It directs the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service to protect, manage, and control wild horses and burros on lands administered by BLM and the U.S. Forest Service, in a manner that is designed to achieve and maintain a thriving natural ecological balance.	The NNSS is not within a ***BLM active herd management area***. A Five-Party Cooperative Agreement exists, however, between NNSA/NFO, the Nevada Test and Training Range (NTTR), FWS, BLM, and the State of Nevada, which calls for cooperation in conducting resource inventories, developing resource management plans, and maintaining favorable habitat for wild horses and burros on federally withdrawn lands.

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
	NNSA/NFO consults with BLM on NNSS horse management, and NNSS biologists conduct opportunistic wild horse surveys for indications of abundance, recruitment (i.e., survival to reproductive age), and distribution (Section 13.3).
<u>Invasive Species</u> **• E.O. 13112** This E.O. directs federal agencies to act to prevent the introduction of, or to monitor and control, invasive (non-native) species; to provide for conservation of native species; and to exercise care in taking actions that could promote the introduction or spread of invasive species.	Land-disturbing activities on the NNSS have resulted in the spread of numerous invasive plant species. Habitat reclamation and other controls are evaluated and conducted, when feasible, to control such species and meet the purposes of this E.O. (Section 13.4).
Environmental Activities and Occurrence Reporting	
<u>Environment, Safety and Health Reporting</u> **• DOE O 231.1B** This order requires the timely collection, reporting, analysis, and dissemination of information on environment, safety, and health as required by law or regulations or as needed to ensure that DOE is kept fully informed on a timely basis about events that could adversely affect the health and safety of the public, workers, the environment, the intended purpose of DOE facilities, or the credibility of the DOE. It requires DOE and NNSA sites to prepare an annual calendar year report, referred to as the Annual Site Environmental Report.	NNSA/NFO prepares an Annual Site Environmental Report called the NNSS Environmental Report (NNSSER, i.e., this report) and provides data for DOE to prepare annual NEPA summaries and other Safety, Fire Protection, and Occupational Safety and Health Administration (OSHA) reports. The NNSSER demonstrates compliance with DOE internal standards and requirements, such as the radiation protection requirements of DOE O 458.1, and documents DOE's environmental performance to members of the public living near the NNSS and to other stakeholders.
<u>Occurrence Reporting and Processing of Operations Information</u> **• DOE O 232.2A** This order requires that DOE and NNSA be informed about events that could adversely affect the health and safety of the public, workers, environment, DOE missions, or the credibility of the DOE. It sets reporting criteria for unplanned environmental releases of pollutants, hazardous substances, petroleum products, and sulfur hexafluoride at DOE/NNSA sites and facilities. It also requires sites/facilities to report to DOE/NNSA any written notification received from an outside agency that the site/facility is non-compliant with a schedule or requirement.	NNSA/NFO contractors enter environmental occurrences, identified as reportable in accordance with this order, into DOE's Occurrence Reporting and Processing System. Reported information includes report level of the identified event, notifications, and if applicable, causal factors, and corrective actions based on the report level of the event. Reportable environmental events are discussed in Section 2.5.
Quality Assurance	
<u>Quality Assurance</u> **• 10 CFR 830 Subpart A and DOE O 414.1D Change 1** The objective of this order is to establish an effective management system using the performance requirements of the order, coupled with consensus standards, where appropriate, to ensure (1) products and services meet or exceed customers' expectations; (2) there is management support for planning, organization, resources, direction, and control; (3) performance and quality improvements occur by means of thorough, rigorous assessments and corrective actions; and (4) environmental, safety, and health risks and impacts associated with work processes are minimized, while maximizing reliability and performance of work products.	NNSA/NFO has quality assurance plans in place to implement quality management methodology in adherence to this DOE order. The quality assurance plans ensure that all environmental monitoring data meet ***quality assurance*** and ***quality control*** requirements. Samples are collected and analyzed using standard operating procedures to ensure representative samples are collected and reliable, defensible data are generated. Quality control in sub-contracted analytical laboratories is maintained through instrument calibration, efficiency and background checks, and testing for precision and accuracy. Data are verified and validated according to project-specific quality objectives before they are used to support decision-making (Chapters 14 and 15).

Table 2-1. Federal, state, and local environmental laws and regulations applicable to NNSA/NFO

Description of Law/Regulation [(a)(b)]	2020 Compliance Status
Using a graded approach, DOE/NNSA sites must develop a quality assurance plan to establish additional process-specific quality requirements and implement the approved quality assurance plan.	

(a) For federal laws, a reference to its implementing regulation, which was written by the identified federal regulatory agency, is given. The regulation is identified by its CFR title and part (e.g., 10 CFR 1021 means, "Title 10 Part 1021"). CFR references can be accessed at http://www.ecfr.gov/cgi-bin/ECFR?page=browse. If no implementing regulations have been written, then N/A (not applicable) is entered.
For Nevada State laws, either the Nevada Administrative Code (NAC) or the Nevada Revised Statute (NRS) reference is given. NACs can be accessed at http://search.leg.state.nv.us/NAC/NAC.html. NRSs can be accessed at http://search.leg.state.nv.us/NRS/NRS.html.

(b) For federal laws, the name of the law and its reference in the ***United States Code (USC)*** by title and section is given (e.g., 42 USC 4321 et seq. means, "Title 42 Section 4321 and the following"). USC references can be accessed at http://uscode.house.gov/. If there is not a USC reference, the public law (Pub. L.) number is given.

2.2 Environmental Permits

Table 2-2 presents the complete list of all federal and state permits active during 2020 for NNSS, NLVF, and RSL-Nellis operations. The table includes those pertaining to air quality monitoring, operation of drinking water and sewage systems, hazardous materials and HW management and disposal, and endangered species protection. Reports associated with permits are submitted to the appropriate designated state or federal office. Copies of reports may be obtained upon request.

Table 2-2. Environmental permits for NNSA/NFO operations at NNSS, NLVF, and RSL-Nellis

Permit Number	Permit Name or Description	Expiration Date	Report
	Air Quality		
	NNSS		
AP9711-2557.01	NNSS Class II Air Quality Operating Permit	June 25, 2019 (permit remains in effect until NDEP issues renewal)	Annual
18-32 and 19-06	NNSS Open Burn Authorization, Fire Extinguisher Training (Various Locations)	December 31, 2021	None
18-33 and 19-07	NNSS Open Burn Authorization, Simulated Vehicle Burns, A-23, Facility #23-T00200 (NNSS Fire & Rescue Training Center)	December 31, 2021	None
	UGTA Offsite		
AP9711-2659.01	NTTR Class II Air Quality Operating Permit, Surface Area Disturbance, Wells ER-EC-13 and ER-EC-15	Closed in April 2021	None
AP9711-2824.01	NTTR Class II Air Quality Operating Permit, Surface Area Disturbance, Well ER-EC-14	Closed in April 2021	None
	NLVF		
Source 657	Clark County Minor Source Permit	May 20, 2025	Annual
	RSL-Nellis		
Source 348	Clark County Minor Source Permit	June 28, 2022	Annual
	Drinking Water		
	NNSS		
NY-0360-NTNC	Areas 6 and 23	September 30, 2020/2021	None
NY-4098-NC	Area 25	September 30, 2020/2021	None
NY-4099-NC	Area 12	September 30, 2020/2021	None
NY-0835-NP	NNSS Water Hauler #84846	September 30, 2020/2021	None
NY-0836-NP	NNSS Water Hauler #84847	September 30, 2020/2021	None

Table 2-2. Environmental permits for NNSA/NFO operations at NNSS, NLVF, and RSL-Nellis

Permit Number	Permit Name or Description	Expiration Date	Report
	Septic Systems/Pumpers		
	NNSS		
NY-1054	Septic System, Area 3, Waste Management Offices – inactive	None	None
NY-1069	Septic System, Area 18 (Pahute Airstrip)[(a)]	None	None
NY-1077	Septic System, Area 27 (Baker Compound)[(a)]	None	None
NY-1079	Septic System, Area 12, U12g Tunnel – inactive	None	None
NY-1080	Septic System, Area 23 (Building 23-1103)[(a)]	None	None
NY-1081	Septic System, Area 6, Control Point-170 – inactive	None	None
NY-1082	Septic System, Area 22 (Building 22-1)[(a)]	None	None
NY-1083	Septic System, Area 5 (Area 5 RWMC)[(a)]	None	None
NY-1084	Septic System, Area 6, Device Assembly Facility – inactive	None	None
NY-1085	Septic System, Area 25 (Central Support Area)[(a)]	None	None
NY-1086	Septic System, Area 25 (Reactor Control Point)[(a)]	None	None
NY-1087	Septic System, Area 27 (Able Compound)[(a)]	None	None
NY-1089	Septic System, Area 12 (Area 12)[(a)]	None	None
NY-1090	Septic System, Area 6 (Los Alamos National Laboratory)[(a)]	None	None
NY-1091	Septic System, Area 23 (Gate 100)[(a)]	None	None
NY-1103	Septic System, Area 22 (Desert Rock Airstrip)[(a)]	None	None
NY-1106	Septic System, Area 5 (NPTEC)[(a)]	None	None
NY-1110-HAA-A	Individual Sewage Disposal System, A-12, Building 12-910 – inactive	None	None
NY-1112	Commercial Sewage Disposal System (U1a Complex)[(a)]	None	None
NY-1113	Commercial Sewage Disposal System, Area 1, Building 121 – inactive	None	None
NY-1124	Commercial Individual Sewage Disposal System (Radiological/Nuclear Countermeasures Test and Evaluation Complex)[(a)]	None	None
NY-1128	Commercial Individual Sewage Disposal System (Yucca Lake Airfield)[(a)]	None	None
NY-1130	Commercial Individual Sewage Disposal System (Building 06-950)[(a)]	None	None
NY-17-06839	Septic Tank Pumping Contractor (1 business/3 units)	July 31, 2020/2021	None
	Wastewater Discharge		
	NNSS		
GNEV93001 Rv XI	Water Pollution Control General Permit	August 5, 2020 (permit remains in effect until NDEP issues renewal)	Quarterly
NEV96021	Water Pollution Control for E Tunnel Waste Water Disposal System and Monitoring Well ER-12-1	October 1, 2018 (permit remains in effect until NDEP issues renewal)	Annual
	NLVF		
Class II ID# 036555-02	Authorization to Discharge	None	None
NV201000 Project ID DDP-42723	NPDES DeMinimis	None	Annual
	Wastewater Discharge		
Site Number: ISW-40564	Stormwater No Exposure Waiver	July 31, 2024	None
	RSL-Nellis		
Not applicable	Annual certification statement of zero discharge	None	January
	Underground Injection Control		
	NNSS		
UNEV2012203	NNSS Underground Injection Control Permit	July 6, 2022	Semi-annual

Table 2-2. Environmental permits for NNSA/NFO operations at NNSS, NLVF, and RSL-Nellis

Permit Number	Permit Name or Description	Expiration Date	Report
	Hazardous Materials		
	NNSS		
95604	NNSS Hazardous Materials Permit	February 28, 2022	Annual
	NLVF		
95585	NLVF Hazardous Materials Permit	February 28, 2022	Annual
	RSL-Nellis		
95579	RSL-Nellis Hazardous Materials Permit	February 28, 2022	Annual
	Hazardous Waste		
	NNSS		
NEV HW0101	RCRA Permit for NNSS Hazardous Waste Management (Area 5 Mixed Waste Disposal Unit, Area 5 Mixed Waste Storage Unit, Hazardous Waste Storage Unit, and Explosive Ordnance Disposal Unit)	December 10, 2020 (permit remains in effect until NDEP issues renewal)	Biennial and annual
	Waste Management		
	NNSS		
SW 532	Area 5 Solid Waste Disposal Site	Post-closure[(b)]	Annual
SW 13 097 02	Area 6 Hydrocarbon Disposal Site	Post-closure	Annual
SW 13 097 03	Area 9 U10c Solid Waste Disposal Site	Post-closure	Annual
SW 13 097 04	Area 23 Solid Waste Disposal Site	Post-closure	Biannual
Not Applicable	Approval to Establish a Solid Waste Incinerator – Area 25	None	None
	RSL-Nellis		
PR0064276	RSL-Nellis Waste Management Permit-Underground Storage Tank	December 31, 2021	None
	Endangered Species/Wildlife		
File Nos. 8ENVS00-2019-F-0073	FWS Desert Tortoise Incidental Take Authorization (Biological Opinion for Programmatic NNSS Activities)	2029	Annual
MB008695-2	FWS Migratory Bird Salvage and Collection	March 31, 2020 (permit remains in effect until FWS issues renewal)	Annual
MB60930C-1	FWS Migratory Bird Special Purpose Utility Permit – Electric	March 14, 2021	Annual
TE83414C-0	FWS Native Threatened Species Recovery – Juvenile Tortoise Study	August 22, 2023	Annual
TE84209B-0	FWS Native Threatened Species Recovery	August 22, 2021	Annual
261454	NDOW Scientific Collection of Wildlife Samples	December 31, 2021	Annual

(a) Name in parenthesis is name of the septic system shown on Figure 5-7 of Chapter 5.
(b) Permit expires 30 years after closure of the landfill.

2.3 National Environmental Policy Act Assessments

NEPA regulations require federal agencies to evaluate the environmental effects of proposed major federal activities. The prescribed evaluation process ensures that the proper level of environmental review is performed before an irreversible commitment of resources is made. NNSA/NFO performs environmental reviews with the aid of a NEPA Environmental Evaluation Checklist (Checklist), which is required for all proposed projects or activities on the NNSS. The Checklist is reviewed by the NNSA/NFO NEPA Compliance Officer to determine if the activity's environmental impacts have been addressed in a previous NEPA assessment. If a proposed project has not been covered under any previous NEPA analysis and it does not qualify for a "Categorical Exclusion" (per 10 CFR 1021), then a new NEPA analysis is initiated. The analysis may result in preparation of a new Environmental Assessment, Environmental Impact Statement, or supplemental document to the existing programmatic *Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-site Locations in the State of Nevada* (NNSS SWEIS) (U.S. Department of Energy, National Nuclear Security Administration Nevada

Site Office 2013). The NNSA/NFO NEPA Compliance Officer must approve each Checklist before a project proceeds. Table 2-3 presents a summary of how NNSA/NFO complied with NEPA in 2020.

Table 2-3. NNSS NEPA compliance activities

Results of NEPA Checklist Reviews/NEPA Compliance Activities
50 NEPA Checklists were reviewed (11 revisions, 39 new checklists).
- 13 projects were exempted from further NEPA analysis because they were of Categorical Exclusion[(a)] status.
- 37 projects were exempted from further NEPA analysis due to their inclusion under previous analysis in the NNSS SWEIS.

(a) "Categorical exclusion" means a category of actions which do not individually or cumulatively have a significant effect on the human environment and which have been found to have no such effect in procedures adopted by a Federal agency in implementation of these regulations (Sec. 1507.3) and for which, therefore, neither an environmental assessment nor an environmental impact statement is required.

2.4 Hazardous Materials Control and Management

2.4.1 Hazardous Substance Inventory

Hazardous materials used or stored on the NNSS are controlled and managed through the use of a chemical inventory module of an enterprise asset management software system called Maximo. Hazardous substances used or stored by contractors and subcontractors of NNSA/NFO are entered into this database. Contractors and subcontractors are required to comply with the operational and reporting requirements of the Toxic Substances Control Act; the Federal Insecticide, Fungicide, and Rodenticide Act; the Emergency Planning and Community Right-to-Know Act; and the Nevada Chemical Catastrophe Prevention Act. Chemicals to be purchased are subject to a requisition compliance review process. Hazardous substance purchases are reviewed to ensure that toxic chemicals and products are not purchased when less hazardous substitutes are commercially available. Requirements and responsibilities for the use and management of hazardous/toxic chemicals are provided in company documents.

The inventory management system allows the tracking of chemicals from the moment they arrive at NNSS, NLVF, or RSL-Nellis to when they are disposed, and provides an accurate account of chemicals on site. It provides chemical owners with additional information, including purchase dates, Safety Data Sheets, storage locations, and expiration dates. The system allows for chemical inventories to be utilized for emergency planning and planning for operational needs. The tracking system reduces the quantities of chemicals purchased and stored through the chemical custodians' awareness of the chemicals currently in inventory. Chemical compatibility and proper storage are routinely evaluated, which has improved NNSA/NFO's safety posture in regards to the control and management of chemicals. In 2020, the NNSS managed 5,014 chemicals in 60,292 containers.

2.4.2 Polychlorinated Biphenyls

The storage, handling, and use of PCBs are regulated under the TSCA. There are no known pieces of PCB-containing electrical equipment (transformers, capacitors, or regulators) at the NNSS, with the exception of PCB-containing light ballasts. The TSCA program consists mainly of properly characterizing, storing, and disposing of various PCB wastes generated on site through remediation activities at corrective action sites (Chapter 11) and maintenance of fluorescent lights. PCB bulk product waste (i.e., contaminated building materials) from onsite corrective action sites are disposed of in the Area 5 RWMS and light ballasts removed during normal maintenance are disposed of in the Area 9 U10c Solid Waste Disposal Site with prior State of Nevada approval. Soil and other remediation wastes contaminated with PCBs and large volumes of light ballasts are sent off site to an approved PCB disposal facility. Radioactive waste received from offsite waste generator facilities that contains regulated quantities of PCBs is disposed of at the Area 5 RWMS (Chapter 10) in accordance with the solid waste disposal permit SW 532, the RCRA hazardous waste management permit NEV HW0101, and/or TSCA regulations. Offsite waste generators bringing PCB wastes to the NNSS for disposal are issued a Certificate of Disposal for PCBs. Onsite PCB records are maintained as required by the EPA, and PCB management activities are documented herein annually. If any generated PCB wastes that are above threshold levels are released, they are also reported in the Toxic Release Inventory (TRI) Report (Section 2.4.4.1, Table 2-6). The EPA did not conduct any TSCA inspections at the NNSS in 2020.

In 2020, NNSS demolition activities generated one drum, 105 kilograms (kg) (232 pounds [lb]), of PCB light ballasts. Two drums, 146 kg (322 lb), were shipped off site from the Area 5 Hazardous Waste Storage Unit for treatment and disposal. These weights include the PCBs, the associated materials that are contaminated and/or cannot be separated from the PCBs, and the weight of the waste container.

2.4.3 Pesticides

The storage and application of pesticides (e.g., insecticides, rodenticides, and herbicides) are regulated under FIFRA and NAC 555.400-510. The NDA has oversight functions to ensure compliance with FIFRA and the NAC. Internal oversight activities include screening of all purchase requisitions, review of operating procedures for handling, storing, and applying pesticide products, and monthly inspections of stored pesticides. On the NNSS, pesticides are applied under the requirements of a Nevada Pest Control Government License. This service is provided by the MSTS Waste & Water Department. The application of restricted-use pesticides was discontinued on the NNSS in 2014. Only pesticides categorized as non-restricted-use (i.e., available for purchase and application by the general public) are used. In FY 2020, non-restricted use pesticides required the same level of record keeping as restricted use pesticides. Monthly inspections conducted in 2020 found that records were properly maintained, no restricted-use pesticides were used, and all pesticides were stored in accordance with their labeling. The State of Nevada did not conduct an inspection of restricted-use pesticide storage or use in 2020.

2.4.4 Release and Inventory Reporting

2.4.4.1 The Emergency Planning and Community Right-to-Know Act

EPCRA requires that facilities report inventories and releases of certain chemicals that exceed specific thresholds. Table 2-4 identifies the reporting requirements under EPCRA Sections 302, 304, 311, 312, and 313. Table 2-5 summarizes the applicability of the regulations to NNSA/NFO operations in 2020.

Table 2-4. Emergency Planning and Community Right-to-Know Act reporting criteria

Section	CFR Part	Reporting Criteria	Agencies Receiving Report
302	40 CFR 355: Emergency Planning Notifications	The presence of an extremely hazardous substance (EHS) in a quantity equal to or greater than the threshold planning quantity at any one time.	SERC[(a)], LEPC[(b)]
		Change occurring at a facility that is relevant to emergency planning.	LEPC
304	40 CFR 355: Emergency Release Notifications	Release of an EHS or a CERCLA hazardous substance[(c)] in a quantity equal to or greater than the reportable quantity.	SERC, LEPC
311	40 CFR 370: Safety Data Sheet Reporting	The presence at any one time at a facility of an OSHA hazardous chemical[(d)] in a quantity equal to or greater than 4,500 kg (10,000 lb) or an EHS in a quantity equal to or greater than the threshold planning quantity or 230 kg (500 lb), whichever is less.	SERC, LEPC, Local Fire Departments
312	40 CFR 370: Tier Two Report	Same as Section 311 reporting criteria above.	State Fire Marshal, SERC, LEPC, Local Fire Departments
313	40 CFR 372: Toxic Release Inventory (TRI) Report	Manufacture, process, or otherwise use at a facility, any listed TRI chemical in excess of its threshold amount during the course of a calendar year. Thresholds are 11,300 kg (25,000 lb) for manufactured or processed and 4,500 kg (10,000 lb) for otherwise used, except for persistent, bio-accumulative, toxic chemicals, which have thresholds of 45 kg (100 lb) or less.	EPA, NDEP

(a) SERC = State Emergency Response Commission
(b) LEPC = Local Emergency Planning Commission
(c) Hazardous substance as defined in CERCLA, 40 CFR 302.4
(d) Hazardous chemical as defined in the Occupational Safety and Health Act, 29 CFR 1910.1200

Table 2-5. Compliance with EPCRA reporting requirements

Section	Description of Reporting	2020 Status(a)
302	Emergency Planning Notification	Yes
304	EHS Release Notification	Not required
311–312	Safety Data Sheet/Chemical Inventory	Yes
313	TRI Reporting	Yes

(a) "Yes" indicates that NNSA/NFO reported under the requirements of the EPCRA section specified (Table 2-4).

NNSA/NFO produces the Nevada Combined Agency (NCA) Report, which satisfies EPCRA Section 302, 311, and 312 reporting requirements. The State Fire Marshal issues permits to store hazardous chemicals at the NNSS, NLVF, and RSL-Nellis based on the NCA Report. Due to reduction in chemicals stored at NPTEC, the facility no longer requires a separate permit, and will now be included in the NNSS report. The 2020 chemical inventory for NNSS facilities was updated and submitted to the State of Nevada in the NCA Report on February 25, 2021. No EPCRA Section 304 reporting was required in 2020 because no accidental or unplanned release of an extremely hazardous substance occurred at the NNSS, NLVF, or RSL-Nellis.

NNSA/NFO produces an annual TRI Report to comply with EPCRA Section 313 reporting. It identifies the reportable quantities of TRI chemicals released to the environment through air emissions, landfill disposal, and recycling. TRI chemicals that are recovered during NNSS remediation activities or become "excess" to operational needs (e.g., lead bricks, lead shielding) are sent off site for recycling, reuse, or proper disposal. Mixed wastes generated at other DOE facilities that contain TRI chemicals and are sent to the NNSS for disposal are included in the TRI Report. In 2020 at the NNSS, reportable quantities of lead, mercury, and PACs were released as a result of NNSS activities (Table 2-6). No accidental or intentional releases (e.g., proper waste disposal) of toxic chemicals at NLVF or RSL-Nellis exceeded the TRI reportable thresholds in 2020. No EPCRA inspections were performed by outside regulators in 2020.

Table 2-6. Summary of reported releases at the NNSS subject to EPCRA Section 313

	Quantity(a) (lb)		
2020 Reported Release	**Lead**	**Mercury**	**PACs**
Air Emissions(b)	2.522	0.04	5.17
Onsite Disposal(c)(d)	40,339.33	379	155
Onsite Release (e)	-----	-----	-----
Offsite Recycling(f)	29,331.8	0.0246	-----
Offsite Disposal(g)	25.94	1.389	-----
Totals	69,699.592	380.4536	160.17
EPCRA Reporting	**100**	**10**	**100**

(a) The weight of the chemical released, not the weight of the waste material containing the toxic chemical. Weights in the TRI Report vary from two to four decimal places.

(b) Fugitive airborne releases of lead include from weapons firing at the Mercury Firing Range, chemical releases and detonations, and from stack air emissions. All airborne releases of mercury were from stack air emissions. PACs, which are in asphalt, were released to the air as part of a road reconstruction project and resurfacing activities.

(c) MLLW or HW containing lead or mercury was received and disposed in Cells 18 and 25 at the Area 5 RWMS (Section 10.1.1).

(d) PACs, which are in asphalt, were released to the ground as part of paving and resurfacing activities.

(e) Lead from spent ammunition left on the ground during firing at the Mercury Firing Range. When the firing range is closed, ammunition will be collected for recycling.

(f) Lead was recycled from three waste streams: lead-acid batteries, miscellaneous lead items, and offsite waste treatment. Mercury was recycled from lamps and field test kits.

(g) Lead was from lead-contaminated debris and other routinely generated waste. Mercury was from lamps, test kits, and miscellaneous materials.

2.4.4.2 Nevada Chemical Catastrophe Prevention Act

This act directs NDEP to develop and implement a program called the Chemical Accident Prevention Program or CAPP. It requires registration of facilities storing or processing highly hazardous substances above listed thresholds. NPTEC in Area 5 of the NNSS is registered as a CAPP facility because of its use of the highly hazardous chemical oleum. On July 15, 2020, NDEP conducted an annual site inspection of NPTEC and did not identify any findings.

NNSA/NFO is required to submit an annual CAPP registration report to the State of Nevada for the NPTEC oleum release process. The CAPP reporting period is June 1 of the previous year through May 31 of the current year. The CAPP registration report for NPTEC operations for the reporting period of June 1, 2020, through May 31, 2021, was signed on June 14, 2021, and submitted to NDEP. The report states that no oleum was present during the reporting period.

2.4.4.3 Continuous Releases

Section 103(a) of CERCLA and EPA's implementing regulation (40 CFR 302.8) require that federal authorities be notified immediately whenever a reportable quantity of a hazardous substance is released into the environment, so that government response officials can evaluate the need for a response action. CERCLA Section 103(f) (2) provides relief from these immediate reporting requirements for releases of hazardous substances from facilities or vessels that are ***continuous*** and are predictable and regular in the amount and rate of emission. No continuous releases of hazardous substances are known to occur at the NNSS, NLVF, or RSL-Nellis.

2.5 Environmental Occurrences

On October 1, 2017, new Occurrence Reporting Criteria were established and implemented based on DOE O 232.2A, *Occurrence Reporting and Processing of Operations Information*. DOE defines an occurrence as "a documented evaluation of a reportable occurrence that is prepared in sufficient detail to enable the reader to assess its significance, consequences, or implications and to evaluate the actions being proposed or employed to correct the condition or to avoid recurrence."

In 2020, two environmental occurrences were reportable under the requirements of the order, and a 2019 occurrence was updated. Nineteen hazardous substance spills occurred in 2020: 17 at the NNSS, 1 at the NLVF and 1 at RSL-Nellis. One sewage overflow was reportable (Table 2-7), and the other spills were small-volume releases either to containment areas or to other surfaces. All spills were cleaned up.

One spill occurred in late 2019 that was not included in this report, and was reported to NDEP because it exceeded the 25-gallon threshold for petroleum products. Six cubic yards of contaminated soil were removed, but some contaminated soil remained, and a use restriction was recorded in the NNSS GIS application.

Table 2-7. Environmental occurrence in 2020 reportable under DOE O 232.2A

Description of Occurrence	Reporting Criteria[(a)]	Corrective Actions Taken
Report Number/Date of Occurrence: NA--NVSO-MSTS-NNSS-2020-0001, January 23, 2020 Occurrence Title: Sewage Overflow		
On January 23, 2020, a sewage overflow was discovered by Mission Support and Test Services, LLC, (MSTS). The release was 500 gallons of wastewater from a manhole cover outside of Building 23-460 in Mercury. Immediately upon discovery, the septic pumper truck was dispatched to the location and removed the wastewater from the manhole. A mechanical sewer line cleaning device "roto rooter" was deployed and cleared the plug. A dilute liquid bleach solution was applied to the affected area for disinfection and the area was cordoned off with safety barricades. The spilled wastewater evaporated and no sewage was evident after 24 hours, and the barricades were removed after 72 hours. Upon investigation, it was determined an obstruction of unknown origin (possibly sanitary wipes and feminine products) had plugged the line below the manhole. The impacted soil was limited to the roadside drainage ditch. MSTS Environmental Compliance Department notified MSTS line management and the National Nuclear Security Administration/Nevada Field Office, which made the notifications to the State of Nevada, Division of Environmental Protection Bureau of Federal Facilities.	5A(2) - Any release (onsite or offsite) of a pollutant from a DOE facility that is above levels or limits specified by outside agencies in a permit, license, or equivalent authorization, when reporting is required in a format other than routine periodic reports.	On January 23, 2020, upon discovery, the septic pumper truck was dispatched to the location immediately, and the septic pumper truck removed the wastewater from the manhole. A mechanical sewer line cleaning device "roto rooter" was deployed and cleared the plug. A dilute liquid bleach solution was applied to the affected area for disinfection, and the area was cordoned off with a safety barricade. The spilled wastewater evaporated and no sewage was evident after 24 hours, and the barricades were removed after 72 hours. Additional education information regarding accepted items considered flushable was provided to employees, and signs were installed in bathroom areas.
Report Number/Date of Occurrence: EM-NVSO-MSTS-NNSS-2019-0009, September 29, 2019, with June 25, 2020 update Occurrence Title: Y-12 NNSWAC Noncompliant Waste Violates NNSS TSRs		
On July 3, 2019, the NNSS Radioactive Waste Acceptance Program (RWAP) Manager was notified by the Y-12 Waste Certification Official that shipments of waste received at the 5 Radioactive Waste Management Complex (RWMC) during the 2013-2018 time frame were potentially non-compliant with the Nevada National Security Site (NNSS) Waste Acceptance Criteria (WAC). On July 11th the EM Nevada Program RWAP Manager formally declared a violation of the NNSS WAC. On July 17th a Technical Safety Requirement (TSR) violation was declared. On July 24, 2019, a positive Unreviewed Safety Question (USQ) Determination was declared for the Area 5 RWMC. UPDATE 6/25/20: On June 15, 2020, the NNSA/Nevada Field Office received a Finding of Alleged Violation (FOAV) and Order issued under the authority of the Administrator of the NDEP pursuant to Nevada Revised Statutes (NRS) 444.440 through NRS 444.620, specifically NRS 444.553, NRS 444.570, and NRS 444.592. The FOAV and Order relate to the alleged failure of the U.S. Department of Energy/National Nuclear Security Administration/Nevada Field Office to comply with provisions of a Solid Waste Permit issued by the Division under NRS 444.553.	3A(1) - Any violation or noncompliance of a TSR (or Operational Safety Requirement) Safety Limit, Hazard Category 1, 2, or 3 nuclear facility's TSR (or Operational Safety Requirement) Limiting Control Setting, Limiting Condition for Operation, Specific Administrative Control, or Surveillance Requirement. 3B(2) - Determination of a positive Unreviewed Safety Question (USQ) that reveals a currently existing inadequacy in the Documented Safety Analysis. 9(1) - Any written notification from an outside regulatory agency that a site/facility is considered to be in noncompliance with a schedule or requirement.	Following a series of collaborative conversations, on June 22, 2021, the DOE and the State of Nevada reached a mutually beneficial resolution to all regulatory actions resulting from the July 2019 waste issue. The final agreement[(b)] builds upon the Department's continued commitment to enhancing the rigor of its waste management activities for the protection of the DOE workforce, the public, and the environment.
Report Number/Date of Occurrence: NA-NVSO-MSTS-NNSS-2020-0002, April 23, 2020 Occurrence Title: US EPA Letter Received		
On April 13, 2020, the National Nuclear Security Administration Nevada Field Office (NNSA/NFO) received a letter from the United States Environmental Protection Agency (US EPA) Region 9. The letter provided the results of a Resource Conservation and	9(1) - Any written notification from an outside regulatory agency that a site/facility is considered to	Resolution of the CEI conducted by U.S. Environmental Protection Agency Region IX in August 2019 was referred to NDEP in April 2021. Following a series of collaborative conversations, on

Table 2-7. Environmental occurrence in 2020 reportable under DOE O 232.2A

Description of Occurrence	Reporting Criteria[a]	Corrective Actions Taken
Recovery Act (RCRA) Compliance Evaluation Inspection (CEI) and requested that the NNSA submit documentation to USEPA within 30 calendar days showing correction of each of the potential violations identified in the RCRA CEI report. The report detailed three items as areas of potential violations and one item as an area of concern. The potential violations are: 1) lack of historic data within a waste profile regarding the US Department of Transportation oxidizer/ignitable status of the waste, 2) groundwater monitoring data in past submittals of groundwater monitoring program data reports that may not have met applicable requirements, and 3) the possible disposal of hazardous wastes in class Ill solid waste disposal units. The area of concern addressed the location of a groundwater monitoring well and the constituents tested in the groundwater monitoring program.	be in noncompliance with a schedule or requirement.	June 22, 2021, the DOE and the State of Nevada reached a mutually beneficial resolution to all regulatory actions resulting from the July 2019 waste issue. The final agreement[b] builds upon the Department's continued commitment to enhancing the rigor of its waste management activities for the protection of the DOE workforce, the public, and the environment.

(a) Reporting requirements provided in DOE O 232.2A can be found at https://www.directives.doe.gov/directives-documents/200-series/0232.2-BOrder-a-chg1-minchg.
(b) The Settlement Agreement and Administrative Order can be found at https://ndep.nv.gov/uploads/land-doe-aip-docs/NDEPDOEJune22SASignedF.pdf

2.6 Environmental Reports Submitted to Regulators

Numerous reports were prepared to meet regulation requirements or to document compliance for NNSA/NFO activities. These reports and the federal or state regulators to whom they were submitted are listed in Table 2-8.

Table 2-8. List of environmental reports submitted to regulators for activities in 2020

Regulator(s)	Report
Air Quality	
EPA Region 9, NDEP	National Emission Standards for Hazardous Air Pollutants – Radionuclide Emissions, Calendar Year 2020
	Annual Asbestos Abatement Notification Form, submitted to NDEP and to EPA Region 9
NDEP	Calendar Year 2020 Actual Production/Emissions Reporting, State & Local Emissions Inventory System (SLEIS)
	Annual Summary Reports for Explosives Ordnance Disposal Unit (EODU) and Big Explosives Experimental Facility (BEEF)
CCDAQ	Clark County Division of Air Quality Annual Emission Inventory Reporting Form for North Las Vegas Facility
	Clark County Division of Air Quality Annual Emission Inventory Reporting Form for Remote Sensing Laboratory
Water Quality	
NDEP	Quarterly Monitoring Reports for Nevada National Security Site Sewage Lagoons
	Results of water quality analyses for PWSs, sent to the state throughout the year as they were obtained from the analytical laboratory
	Water Pollution Control Permit NEV 96021, Quarterly Monitoring Reports and Annual Summary Report for E Tunnel Wastewater Disposal System
Waste Management	
NDEP	Nevada National Security Area 5 Solid Waste Disposal Annual Report for CY 2020
	NNSS Quarterly Volume Reports (for all active LLW and MLLW disposal cells), April, July, and October 2020, and January 2021
	Fourth Quarter and Annual Transportation Report FY 2020, Waste Shipments to and from the Nevada National Security Site
	RCRA Permit for a Hazardous Waste Management Facility Permit Number NEV HW0101 – Annual Summary/Waste Minimization Report Calendar Year 2020
	Nevada National Security Site 2020 Data Report: Groundwater Monitoring Program Area 5 Radioactive Waste Management Site

Table 2-8. List of environmental reports submitted to regulators for activities in 2020

Regulator(s)	Report
	Nevada National Security Site 2020 Waste Management Monitoring Report, Area 3 and Area 5 Radioactive Waste Management Site
	Post-Closure Report for Closed Resource Conservation and Recovery Act Corrective Action Units, Nevada National Security Site, Nevada, for Fiscal Year 2020 (October 2019–September 2020)
	Annual Soil Moisture Monitoring Reports for the Nevada National Security Site, Nevada, Area 6 Hydrocarbon and Area 9 U10c Landfills
	Area 23 Semi-Annual Solid Waste Disposal Site (SWDS) Report for the Nevada National Security Site – January 1, 2020 Through June 30, 2020
	Area 23 Semi-Annual Solid Waste Disposal Site (SWDS) Report for the Nevada National Security Site – July 1, 2020 Through December 31, 2020
Environmental Corrective Actions	
NDEP	Calendar Year 2019 Underground Test Area Annual Sampling Report, Nevada National Security Site, Nevada, Rev. 1
	CY2019 Annual Closure Monitoring Report for Corrective Action Unit 98, Frenchman Flat, Underground Test Area, Nevada National Security Site, Nevada (January 2019–December 2019)
	Pahute Mesa-Oasis Valley Hydrostratigraphic Framework Model for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada. Rev. 1
	Post-Closure Inspection Letter Report for CAUs on the NNSS
	Post-Closure Inspection Report for the Tonopah Test Range and Nevada Test and Training Range, Nevada for Calendar Year 2019
	Post-Closure Report for Closed Resource Conservation and Recovery Act Corrective Action Units, Nevada National Security Site, Nevada for Calendar Year 2019
	Underground Test Area Calendar Year 2019 Quality Assurance Report Nevada National Security Site, Nevada
	Underground Test Area (UGTA) Closure Report for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nevada, Rev. 0
	Underground Test Area (UGTA) Closure Report for Corrective Action Unit 99: Rainier Mesa/Shoshone Mountain, Nevada National Security Site, Nevada, Rev. 1
	Underground Test Area (UGTA) Sampling Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada National Security Site, Nevada, Rev. 1
	Update to the Phase II Corrective Action Investigation Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada National Security Site, Nye County, Nevada, Rev. 1
Hazardous Materials Management	
EPA, NDEP	Toxic Release Inventory Report, Form Rs for CY 2020
NDEP	Chemical Accident Prevention Program 2021 Registration
State Fire Marshal, EPA	Nevada Combined Agency Hazmat Facility Report – Calendar Year (CY) 2020
Cultural and Natural Resources	
DOE	Preserve America: Nevada National Security Site in Response to Requirements of Executive Order 13287. Cultural Resources Report LR060220-1.
FWS	Annual Report of Actions Taken under Authorization of the Biological Opinion for NNSS Activities (File No. 8ENVS00-2019-F-0073) – January 1, 2020, through December 31, 2020
	Annual report for Migratory Bird Scientific Collecting Permit MB008695-2
	Annual report for Migratory Bird Special Purpose Utility Permit – Electric MB60930C-1
	Annual report for Native Threatened Species – Recovery Threatened Wildlife (Juvenile tortoise) permit TE83414C-0
NDOW	Annual report for Scientific Collection Permit 261454
NNSA/NFO[(a)]	Report on the Tribal Planning Committee's FY 2020 Second Quarterly Meeting, American Indian Consultation Program. Cultural Resources Report LR022520-1.
	Report on the Tribal Planning Committee's FY 2020 Third Quarterly Meeting, American Indian Consultation Program. Cultural Resources Report LR050520-1.
	Tribal Planning Committee's FY 2020 Fourth Quarterly Meeting Summary, American Indian Consultation Program. Cultural Resources Report LR081120-1.
	American Indian Consultation Program Annual Report Fiscal Year 2020. Cultural Resources Report LR090120-1.
	Tribal Planning Committee's FY 2021 First Quarterly Meeting Summary, American Indian Consultation Program. Cultural Resources Report LR121520-1.
	Tribal Planning Committee Field Assessment of Jailhouse Rockshelter (26NY3187), Area 1 Subdock, and the Area 6 Control Point, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report LR102820-1.
SHPO	Identification and Evaluation of Buildings 1-101 and 1-102 in the Area 1 Subdock, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report SR043020-1.
	Cultural Resources Letter Report on the Finding of Adverse Effect for the Removal of Ten Buildings and One Structure, Area 12, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report LR100418-1-FOE.

Table 2-8. List of environmental reports submitted to regulators for activities in 2020

Regulator(s)	Report
SHPO MHD PA[(b)]	A Cultural Resources Inventory of Off-Road Travel Areas and Parking Lot Expansion, Dense Plasma Focus Facility, Area 11, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report SR063020-1. A Section 110 Evaluation of Three Sites Associated with the Grable Test, Area 5, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report TR118. A Cultural Resources Inventory for the Proposed Expansion of the U1a Modernization Project, Area 1, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report SR020520-1. A Historic Context and Mitigation Documentation for a Portion of the U12n Tunnel Ventilation and Containment Systems, Area 12, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report SR100119- Fiscal Year 2020 Annual Historic Properties Monitoring Summary, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report LR102919-1. Curation Compliance Annual Report Fiscal Year 2020. Cultural Resources Report LR072020-1. Cultural Resource Monitoring and Condition Assessment Procedures for Historic Properties on the Nevada National Security Site. Cultural Resources Report SR120519-1. Assessment of Adverse Effects to the Control Point Historic District and Nearby Compounds from the Proposed 138-kV Transmission Line, Area 6, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report Finding of Adverse Effect for the Proposed 138-kilovolt Transmission Line, Areas 5, 6, and 23, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report LR052118-1-FOE. Finding of Adverse Effect and Mitigation Documentation for the Stormwater Drainage and Street Systems, Substation Foundations, and the Bus Parking Lot in Mercury, Area 23, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report LR040120-1. Finding of Adverse Effect and Mitigation Documentation for the Power and Communications System in Mercury, Area 23, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report LR052020-1. Annual Report on Progress in the Implementation of the Mercury Programmatic Agreement Covering FY 2020 Activities. Cultural Resources Report LR010121-1. Evaluation of the Craft Shops Building (23-710), Mercury, Area 23, Nevada National Security Site, Nye County, Nevada. Cultural Resources Report SR072220-1.
Public Notifications/Reports	
DOE	Nevada National Security Site Environmental Report 2019
Environmental Occurrences	
	See Section 2.5 for Occurrence Reporting and Processing System Reports

(a) Reports developed under the American Indian Consultation Program.
(b) MHD PA: Reporting in accordance with the *Programmatic Agreement between the National Nuclear Security Administration Nevada Field Office and the Nevada State Historic Preservation Officer Regarding Modernization and Operational Maintenance of the Nevada National Security Site, at Mercury in Nye County, Nevada.*

2.7 References

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, 2013. *Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada*. DOE/EIS-0426, Las Vegas, NV.

Chapter 3: Environmental Management System

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Mission Support and Test Services, LLC

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) conducts activities on the Nevada National Security Site (NNSS) while ensuring the protection of the environment, the worker, and the public. The NNSS Management and Operating (M&O) Contractor's policies and directives promote, guide, and regulate NNSS environmental aspects in order to protect the environment and public health. Mission Support and Test Services, LLC (MSTS), established an Environmental Management System (EMS) in accordance with International Organization for Standardization (ISO) Standard ISO-14001:2015 during the last quarter of 2019. A virtual EMS conformance audit is planned for 2021. A 2020 conformance audit that had been scheduled was canceled due to the COVID-19 pandemic.

This chapter describes the fiscal year (FY) 2020 progress made towards improving overall environmental performance and discusses the MSTS Sustainability Program. The Program has the specific mission to support and track DOE's complex-wide sustainability goals. Reported progress applies to operations on the NNSS as well as support activities conducted at the NNSA/NFO-managed North Las Vegas Facility (NLVF), Remote Sensing Laboratory–Nellis (RSL-Nellis), and additional outlying sites. NNSA/NFO uses this annual environmental report as the mechanism to communicate to the public the components and status of the EMS and the Sustainability Program.

3.1 Environmental Policy

MSTS's environmental commitments are incorporated into an Environmental Protection Policy approved by NNSA/NFO. The policy applies to all MSTS operations, projects, facilities, and personnel, including subcontractors. The EMS implements this policy and is incorporated into MSTS's Integrated Safety Management System. MSTS evaluates its operations, identifies aspects that can impact the environment, qualitatively assesses the potential impacts, and manages those aspects appropriately. In addition, the MSTS policy is designed to:

- Protect environmental quality and human welfare by implementing EMS practices that conform to the ISO 14001:2015 Standard.
- Minimize environmental impacts caused by MSTS activities and services by preventing pollution and protecting the natural environment.
- Use sustainable practices and purchase sustainable products to prevent degradation of resources.
- Continually improve the EMS by reviewing performance and making adjustments to achieve established objectives.
- Operate in compliance with applicable federal, state, and local regulations and contractual requirements related to environmental protection and performance.
- Rigourously review operations and correct non-compliance as discovered.

3.2 Significant Environmental Aspects

Six significant environmental aspects were identified for FY 2020 (October 1–September 30) based on company processes, missions, and activities, including potential emergency situations and abnormal conditions. Environmental aspects, such as energy use and sustainable acquisition, are addressed in Section 3.5.1.

Significant environmental aspects for FY 2020 were as follows:

1. Hazardous, radiological, and mixed waste generation and management
2. Industrial chemical storage and use

3. Air emissions
4. Cultural resources
5. Wastewater management (generation and disposal)
6. Energy use (fuel use, electricity, propane)

3.3 Environmental Objectives and Targets

Environmental objectives and targets were developed to address significant environmental aspects over which MSTS had the ability to effect a change (Table 3-1). Energy use is addressed separately in Section 3.5.1. Each objective and target is an opportunity to affect a significant environmental aspect by improving compliance, reducing impacts to operations, or enacting process improvements. Measurable milestones were developed for each target. Two objectives for cultural resources and wastewater systems were met. The third, improving air quality data, became a larger effort and has been extended through FY 2021.

Table 3-1. Environmental Objectives and Targets

FY 2020 Target	Objective	Significant Environmental Aspect
Improve MSTS Scope of Work for cultural resources	Improve the process and reduce time between National Environmental Policy Act requests and authorizations	Cultural Resources
Improve NNSS wastewater systems	Decrease the amount of wipes flushed into NNSS septic tanks and evaluate portable toilet maintenance for regulatory compliance	Wastewater Management
Improve air quality data recordkeeping practices at the NNSS	Improve equipment owner recordkeeping and reporting, including data quality assurances	Air Emissions

3.4 Legal and Other Requirements

MSTS environmental compliance requirements are documented in the M&O Prime Contract. Included is DEAR [U.S. Department of Energy Acquisition Regulation] Clause 970.5204-2, "Laws, Regulations, and DOE Directives," which requires compliance with all applicable laws and regulations (including DOE Order DOE O 436.1, "Departmental Sustainability," which contains DOE Sustainability Goals). These baseline directives are supplemented on an activity-specific basis as needed. M&O Contractor executive management and NNSA/NFO develop, update, and approve these standards through controlled processes. The M&O Contractor must also work to applicable Air Force Directives at RSL-Andrews and RSL-Nellis.

Environmental management performance-related needs and expectations of NNSA/NFO and M&O Contractor parent companies are identified in the M&O Contract, agreements, and the MSTS Board of Managers recommendations. These are considered when developing compliance obligations. The needs and expectations of interested parties include clean-up of contaminated sites, community air and groundwater monitoring, safe handling of hazardous and radioactive waste, compliance with environmental regulations, and host site environmental operating provisions.

MSTS has a process to review changes in federal, state, and local environmental regulations and to communicate those changes to affected staff and organizations.

DOE publishes updated sustainability goals and targets annually in a DOE Strategic Sustainability Performance Plan, and pursues and tracks goals under the MSTS Sustainability Program (Section 3.5.1). Implementing instructions for Executive Order (E.O.) 13834, "Efficient Federal Operations," listing goal targets for energy use intensity, water use intensity, and greenhouse gas (GHG) emission, were distributed in April 2019.

3.5 Environmental Management System Programs

NNSS 5- to 10-Year Major Initiatives

Mercury Modernization – create a modern, welcoming campus to support the goals and operations of the NNSS.

U1a Master Planning – plan for existing and future conditions of all buildings and infrastructure, personnel, space needs, and mission requirements.

DAF Master Planning – early planning for improved operations to support new capabilities and increased capacity for additional programs at the DAF [Device Assembly Facility].

Footprint Management – aggressive consolidation and modernization of facilities at the NNSS and NLVF to reduce the footprint and provide sustainable infrastructure to support mission needs.

NNSS Solar Project – early planning and viability assessment of a large solar Photo Voltaic (PV) project at the NNSS to cover power usage for the site.

Sustainability Strategies

- Provide sustainable facilities and equipment that meet requirements until at least the 2080s.
- Improve energy efficiency and strive to create some of the first net-zero energy buildings in the NNSA complex.
- Reduce the overall size of Mercury by consolidating operations.
- Complete utility/infrastructure upgrades and consolidations across the campus.
- Dispose of excess facilities.

3.5.1 Sustainability Program

The Sustainability Program has the specific mission to support and track DOE's complex-wide sustainability goals. The program strives to ensure continuous life cycle, cost-effective improvements to increase energy efficiency; increase the effective management of energy, water, and transportation fleets; and increase the use of clean energy sources for NNSA/NFO operations. NNSA/NFO currently uses electricity, fuel oil, and propane at the NNSS facility. At the NLVF and RSL-Nellis facilities, electricity and natural gas are used. NNSA/NFO vehicles and equipment are powered by unleaded gasoline, diesel, bio-diesel, E-85, and jet fuel. All water used at the NNSS is groundwater, and water used at the NLVF and RSL-Nellis is predominantly surface water from Lake Mead.

Each FY, the Sustainability Program produces an NNSA/NFO Site Sustainability Plan (SSP) (MSTS 2020). The SSP identifies how NNSA/NFO will meet DOE's sustainability goals, which were first published in the 2020 Sustainability Report and Implementation Plan (SRIP) (DOE 2020). The SSP describes the program, planning, and budget assumptions as well as NNSA/NFO's performance for the previous year for each DOE goal, and planned actions to meet each goal during the next year. To implement the SSP, an Energy Management Council meets bi-monthly to track requirements and progress and facilitate goal achievement. Table 3-2 includes a summary of the DOE goals and NNSA/NFO's FY 2020 performance.

Table 3-2. DOE sustainability goals and performance

DOE Goal[(a)]	NNSA/NFO FY 2020 Performance
Goals in green are met or exceeded	
GHG Reduction	
Year over year (YOY) Scope 1 and 2 GHG emissions [(b)] reduction from an FY 2008 baseline.	Goal met; Emissions were 31,212 metric tons of carbon dioxide equivalent ($MtCO_2e$), 52% below the baseline of 65,632 $MtCO_2e$[(c)].
YOY Scope 3 GHG emissions [(b)] reduction from an FY 2008 baseline.	Goal met; Emissions were 14,299 $MtCO_2e$, 71% below the baseline of 43,259 $MtCO_2e$[(c)].
Sustainable Buildings	
30% reduction of energy intensity (British Thermal Units per gross square feet [gsf]) in goal-subject buildings by FY 2015 from an FY 2003 baseline and 1.0% YOY thereafter.	Continuing to work toward goal: Energy intensity increased 4.51% from the FY 2015 baseline.
Energy and water assessments conducted for 25% of all facilities covered under Section 432 of the Energy Independence and Security Act to ensure 100% of covered facilities are assessed every 4 years.	Goal met; 42 energy audits/assessments were conducted, meeting this goal. They identified energy conservation measures for the facilities evaluated. Efficient Mobile Audit Technology was used in the field and allowed the successful upload of facility information, pictures, and notes.
Meter all individual buildings for electricity, natural gas, water, and steam where cost-effective and appropriate.	Continuing to work toward goal: two water meters were installed.
At least 15% (by count) of owned existing buildings to be compliant with the revised Guiding Principles for High Performance Sustainable Buildings (HPSBs) by FY 2020, with annual progress thereafter.	Goal met; There are 13 facilities of NNSS building inventory totaling 441,378 gsf that are HPSB certified.
Clean and Renewable Energy	
"Renewable Electric Energy" requires that renewable electric energy account for not less than 7.5% of a total agency electric consumption by FY 2013 and each year thereafter.	Current Status: 4%; Fire Station No. 1 Solar PV produced 856 megawatt hours (MWh); Renewable Energy Credits purchased 10,025 MWh; off-grid solar estimated at 253 MWh.
Water Use Efficiency and Management	
20% potable water intensity (gallons per gsf) reduction by FY 2015 from a FY 2007 baseline and 0.5% YOY thereafter.	Goal met; however there was a gradual increase in water usage due to site activities; a 35.47% reduction from the FY 2007 baseline; FY 2020 actual: 148,032,905 gallons (gal)/gsf.
Non-potable freshwater consumption (gal) reduction of industrial, landscaping, and agricultural (ILA). YOY reduction; no set target.	Goal met; ILA water production was 116,938,500 gal/gsf, a 112.95% increase from the FY 2010 baseline of 54,913,300 gal.
Fleet Management	
20% reduction in annual petroleum consumption by FY 2015 relative to an FY 2005 baseline and 2.0% YOY thereafter.	Goal met; petroleum consumption was 354,204 gal, 73% below the baseline of 1,328,957 gal.
10% increase in annual fleet alternative fuel consumption by FY 2015 from the FY 2005 baseline; maintain 10% increase thereafter.	Goal met; exceeds 10%; FY2020 actual is 323,439 gal.
75% of light duty vehicle acquisitions must consist of alternative fuel vehicles (AFVs).	Goal met; 96.64% of all light duty vehicle acquisitions (853) are AFVs, exceeding this goal.
Sustainable Acquisition	
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring biopreferred and biobased provisions and clauses are included in all applicable contracts.	Goal met; relevant sustainable acquisition clauses included in applicable subcontracts.
Waste Management	
Reduce at least 50% of non-hazardous ***solid waste***,[1] excluding construction and demolition debris sent to treatment and disposal facilities.	Diverted 33% of non-hazardous solid waste.
Reduce construction and demolition materials and debris sent to treatment and disposal facilities. YOY reduction; no set target.	Diverted 5% of construction waste from disposal. Several construction projects occurred throughout the year, but additional education on company procedures is necessary; a draft of a new company procedure was prepared in 2020 and is under review.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

Table 3-2. DOE sustainability goals and performance

DOE Goal[a]	NNSA/NFO FY 2020 Performance
Goals in green are met or exceeded	
Energy Performance Contracts	
Annual targets for sustainability investment with appropriated funds and/or financed contracts to be implemented in FY 2019 and annually thereafter.	A draft Notice of Opportunity was completed in 2019; conducted an Energy Savings Performance Contract (ESPC) overview briefing for new Field Office point of contact and began repairs on the WSI Solar lighting from ESPC Delivery Order 2.
Electronic Stewardship	
End of Life – 100% of used electronics are reused or recycled using environmentally sound disposition options each year.	Goal met; all electronic equipment that passed excess screening in 2020 was sold for reuse for their original intended use or e-recycled.
Data center efficiency: establish a power usage effectiveness (PUE) [d] target for new and existing data centers.	Continue to work toward goal; the data center PUE goal of less than 1.5 for existing data centers was not met.
Resilience	
Discuss overall integration of climate resilience in emergency response, workforce, and operations procedures and protocols.	Established a Technical Resilience Navigator account. Information Technology added more remote workstations as well as virtual desktops and cloud computing to support increased need for alternative work arrangements. Continued Risk Analysis for extreme weather and other natural phenonmena events.

(a) The DOE goals listed are identified in the FY 2020 DOE Site Sustainability Plan Guidance Document (DOE 2019) which is based on DOE's SRIP (DOE 2020) and E.O. 13834.
(b) The GHGs targeted for emission reductions are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Scope 1 GHG emissions include direct emissions from sources that are owned or controlled by a federal agency. Scope 2 includes direct emissions resulting from the generation of electricity, heat, or steam purchased by a federal agency. Scope 3 includes emissions from sources not owned or directly controlled by a federal agency but related to agency activities, such as vendor supply chains, delivery services, employee business air and ground travel, employee commuting, contracted solid waste disposal, contracted waste water discharge, and transmission and distribution losses related to purchased electricity. Fugitive GHG emissions are uncontrolled or unintentional releases from equipment leaks, storage tanks, loading, and unloading.
(c) The FY 2008 baselines for Scope 1 and 2 GHGs and for Scope 3 GHGs were revised in 2018 to meet the current DOE reporting requirements.
(d) PUE is determined by dividing the amount of power entering a data center by the power used to run the computer infrastructure within it. PUE is expressed as a ratio; efficiency improves as the quotient approaches 1.

3.5.2 Pollution Prevention and Waste Minimization (P2/WM)

The P2/WM Program has initiatives to eliminate or reduce the generation of waste and the release of pollutants to the environment. These initiatives are pursued through source reduction, reuse, segregation, and recycling, and by procuring recycled-content materials and sustainable products and services. The initiatives also ensure that proposed methods of treatment, storage, and waste disposal minimize potential threats to human health and the environment. These initiatives address the goals and the requirements of the DOE SRIP, DOE orders, and federal and state regulations applicable to operations at the NNSS, NLVF, and RSL-Nellis (Table 2-1). Strategies to meet P2/WM goals include:

Source Reduction – The preferred method of waste minimization is source reduction, i.e., to minimize or eliminate waste before it is generated by a project or operation. NNSA/NFO's Integrated Safety Management System requires every project/operation to identify waste minimization opportunities during the planning phase and allocate adequate funds for waste minimization activities.

Recycling/Reuse – NNSA/NFO maintains a recycling program for some recyclable waste streams. Items routinely recycled include cardboard; mixed paper (office paper, shredded paper, newspaper, magazine, color print, glossy paper); plastic bottles; plastic grocery bags; elastic/plastic stretch pack; milk jugs; Styrofoam; tin and aluminum cans; glass containers; toner cartridges; cafeteria food waste; computers; software; scrap metal; rechargeable batteries; lead-acid batteries; used oil, antifreeze, and tires.

An Excess Property Program also exists to provide excess property to NNSA/NFO employees or subcontractors, laboratories, other DOE sites, other federal agencies, state and local government agencies, universities, and local schools. If new users are not found, excess property is made available to the public for recycle/reuse through periodic Internet sales.

Sustainable Acquisition – The Resource Conservation and Recovery Act, as amended, requires federal agencies to develop and implement an affirmative procurement program. NNSA/NFO's affirmative procurement program stimulates a market for recycled-content products and closes the loop on recycling. The U.S. Environmental Protection Agency (EPA) maintains a list of items containing recycled materials and what the minimum content of recycled material should be for each item. Federal facilities are required to ensure, where possible, that 100% of purchases of items on the EPA-designated list contain recycled materials at the specified minimum content. The U.S. Department of Agriculture designates types of materials that have a required minimum amount of bio-based chemicals. Products that meet this requirement are identified by requestors and tracked in the procurement system.

3.6 EMS Competence, Training, and Awareness

EMS awareness is included in the orientation training for all new MSTS employees. Ongoing EMS awareness is accomplished by publishing environmental articles in electronic employee newsletters. Focused environmental briefings are given at tailgate meetings in the field prior to work with high or non-routine environmental risk. Facility specific environmental aspect briefings were provided to personnel at RSL-Nellis and the NLVF.

3.7 Audits and Operational Assessments

MSTS conducts internal management assessments and compliance evaluations. These assessments and evaluations determine the extent of compliance with environmental regulations, DOE sustainability goals, and identify areas for overall improvement. In FY 2020, MSTS conducted 7 internal environmental protection management assessments and 113 environmental inspections. Seven Surveillances were peformed by Quality Assurance on the MSTS EMS for compliance to ISO 14001:2015 elements: Context of the Organization, Leadership, Planning, Support, Operation, Performance Evaluation, and Improvement. No non-conformances were identified; two opportunities for improvement were noted.

3.8 EMS Effectiveness and Reporting

The FY 2020 Facility EMS Annual Report Data for the NNSS was entered into the DOE Headquarters EMS database during January 2021. This database, which is accessed through the FedCenter.gov website, (http://www.fedcenter.gov/programs/ems/) gathers information in several EMS areas from all DOE sites to produce a combined report reflecting DOE's overall performance compared to other federal agencies. The report includes a scorecard section, which is a series of questions regarding a site's EMS effectiveness in meeting the objectives of federal EMS directives. The NNSS scored an "A" in FY 2020 for all 5 criteria: Environmental Aspects, Environmental Objectives, Operational Controls, Compliance with Regulatory Requirements/Corrective Actions, and EMS/E.O. Goals Integration.

3.9 Awards, Recognition, and Outreach

The NNSS received two awards in 2020:

1. The NNSS Asset and Material Management (AMM) Team received the 2020 Department of Energy Sustainability Award for Strategic Partnership in the Sustainability category for their e-recycling efforts with the Blind Center of Nevada. One hundred percent of used electronic equipment was either sold for reuse for their original intended use or recycled with Blind Center of Nevada or other services and was diverted from Las Vegas landfills. In addition, approximately 270 items valued at $830,000 were transferred to other groups or directorates instead of purchasing new materials or products.
2. The Mercury Modernization Building 1 Team received an NNSA Excellence Award in June 2020. The team "exemplified teamwork and collaboration to overcome obastacles…and delivered the first new construction net-zero energy facility within the NNSA complex." Building 23-460 also achieved both green building goals of Leadership in Energy and Environmental Design Gold certification in April 2020

and HPSB certification through the Green Business Certification, Inc. third party process in November 2020 (Figure 3-2).

Figure 3-1. Mercury Modernization Building 1, 23-460

Earth Day events in 2020 included a major milestone celebration with its 50th year Anniversary. Due to the COVID-19 pandemic, the NNSS Sustainability Program, Health and Productivity, and DOE Headquarters collaborated to offer employees the opportunity to celebrate the 2020 50th Earth Day virtual activities from home. The Earth Day activities included a month-long Earth Day Mile challenge where employees joined with other participants from across the world to collectively walk or run 24,901 miles, which is equivalent to the distance of the equator; by the end of the challenge, participants logged a total of 51,023 miles. Other Earth Day activities included a Zero Waste Countdown podcast, a Sustainability Treasure Hunt, along with attending the Smithsonian Garden virtual tours.

Activities for Energy Action Month in October included a Lunch and Learn event on recycling co-hosted by a speaker from the local recycling company, Republic Services, an e-waste recycling event and a water bottle challenge between NLVF Buildings B-3 and C-01. Through these annual employee outreach events, along with the site's quarterly participation with Safe Nest, site employees managed to divert a total of 2,290 pounds of clothing items and 175 pounds of e-waste from the landfill. These two major outreach activities continued the efforts to provide NNSS employees with educational opportunities on how to embrace and integrate sustainability into their day-to-day activities while still working from home.

3.10 References

DOE, see U.S. Department of Energy.

MSTS, see Mission Support and Test Services, LLC.

Mission Support and Test Services, LLC, 2020. *FY2021 NNSA/NFO Site Sustainability Plan*. Las Vegas, NV, December 2020.

U.S. Department of Energy, 2019. *Fiscal Year 2020 Site Sustainability Plan Guidance Document*, U.S. Department of Energy Sustainability Performance Office, September 2019. Available at: https://sustainabilitydashboard.doe.gov/PDF/Resources/FY%202020%20SSP%20Guidance-1-2.pdf.

———, 2020. *2020 Sustainability Report and Implementation Plan*. Report to the White House Council on Environmental Quality and Office of Management and Budget, August 2020. Available at: https://www.sustainability.gov/pdfs/doe-2020-sustainability-plan.pdf.

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Chapter 4: Air Monitoring

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This chapter is divided into two major sections that address different categories of air monitoring. Section 4.1 presents the results of radiological air monitoring conducted on the Nevada National Security Site (NNSS) by the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) to verify compliance with radioactive air emission standards. Measurements of ***radioactivity***[1] in air are also used to assess the radiological ***dose*** to the general public from inhalation. The assessed dose to the public from all ***exposure*** pathways is presented in Chapter 9. Section 4.2 presents the results of nonradiological air quality assessments that are conducted to ensure compliance with NNSS air quality permits.

NNSA/NFO has also established an independent Community Environmental Monitoring Program (CEMP) to monitor ***radionuclides*** in air in communities adjacent to the NNSS. It is managed by the Desert Research Institute (DRI) of the Nevada System of Higher Education. DRI's offsite air monitoring results are presented in Chapter 7.

4.1 Radiological Air Monitoring and Assessment

Radiological Air Monitoring Goals

Monitor air at or near historical or current operation sites to (1) detect and identify local and site-wide trends, (2) quantify radionuclides emitted to air, and (3) detect accidental and unplanned releases.

Conduct point-source operational monitoring required under National Emission Standards for Hazardous Air Pollutants (NESHAP) for any facility with the potential to emit radionuclides to the air and cause a dose greater than 0.1 millirem per year (mrem/yr) (0.001 millisievert per year [mSv/yr]) to any member of the public. Determine if the air pathway dose to the public from past or current NNSS activities complies with the Clean Air Act (CAA) NESHAP standard of 10 mrem/yr (0.1 mSv/yr). Determine if the total radiation dose to the public from all pathways (air, water, and food) complies with the 100 mrem/yr standard set by DOE Order DOE O 458.1, "Radiation Protection of the Public and the Environment."

The sources of radioactive air emissions on the NNSS include the following: (1) tritium (^{3}H) in water (tritiated water) evaporated from containment ponds; (2) tritiated water vapor diffusing from soil at the Area 3 Radioactive Waste Management Site (RWMS), the Area 5 Radioactive Waste Management Complex (RWMC), and historical surface or near-surface nuclear device test locations (particularly Sedan and Schooner craters); (3) resuspension of contaminated soil at historical surface or near-surface nuclear device test locations; and, (4) radionuclides from current operations. Figure 4-1 shows locations of known radiological air emission sources in 2020 and areas of soil contamination related to historical nuclear explosive tests. The NNSS air monitoring network consists of samplers near sites of soil contamination, at facilities that may produce radioactive air emissions, and along the NNSS boundaries. The objectives and design of the network are described in the *Routine Radiological Environmental Monitoring Plan* (Bechtel Nevada 2003).

Analytes Monitored
Americium-241 (^{241}Am)
Gamma ray emitters (includes Cesium-137 [^{137}Cs])
Tritium (^{3}H)
Plutonium-238 (^{238}Pu)
Plutonium-239+240 ($^{239+240}$Pu)
Uranium-233+234 ($^{233+234}$U)
Uranium-235+236 ($^{235+236}$U)
Uranium-238 (^{238}U)
Gross alpha radioactivity
Gross beta radioactivity

Monitored ***analytes*** include radionuclides most likely to be present in air as a result of past or current NNSS operations, based on inventories of radionuclides in surface soil (McArthur 1991) and the volatility and availability of radionuclides for resuspension (Table 1-5 lists the ***half-lives*** of these radionuclides). Uranium is included because uranium (primarily ***depleted uranium [DU]***) has been used during exercises in specific areas of

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

the NNSS. Samples from locations near these areas are analyzed for uranium. ***Gross alpha*** and ***beta*** readings are used in air monitoring as a relatively rapid screening measure.

4.1.1 Monitoring System Design

Air samplers operated at a total of 19 environmental monitoring locations on the NNSS in 2020 (Figure 4-2). Of these, 16 have both air particulate and atmospheric moisture samplers, one has only an air particulate sampler (Able Site), and two have only an atmospheric moisture sampler (North Schooner and Buggy). The Buggy sampler was temporary, operating from January 13–December 2, 2020, to determine tritium concentrations in air near the Buggy test (Plowshare experiment conducted in 1967). Air samplers are positioned in predominantly downwind directions from sources of radionuclide air emissions and/or are positioned between NNSS contaminated locations and potential offsite receptors. Wind rose data, showing predominant wind directions on the NNSS, are presented in Section A.3 of *Attachment A: Site Description*.[2] Most radionuclide air emission sources are ***diffuse sources*** that include areas with (1) radioactivity in surface soil that can be resuspended by the wind, (2) tritiated water transpiring or evaporating from plants and soil at the sites of past nuclear tests, and (3) tritiated water evaporating from ponds receiving water either from contaminated wells or from tunnels that cannot be sealed. Sampling and analysis of air particulates and atmospheric moisture are performed at these locations (Section 4.1.2). Radionuclide concentrations measured at these samplers are used for trending, determining ambient ***background*** concentrations in the environment, and monitoring for unplanned releases of radioactivity.

Critical Receptor Samplers – Six of the sampling locations with both air particulate and atmospheric moisture samplers have been proposed and formally submitted to the U.S. Environmental Protection Agency (EPA) Region 9 as ***critical receptor samplers*** (EPA 2001). They are located near the boundaries and in the center of the NNSS (Figure 4-2). Radionuclide concentrations measured at these locations are used to assess compliance with the NESHAP public dose limit of 10 mrem/yr (0.1 mSv/yr). The annual average concentrations from each location are compared with the NESHAP Concentration Levels for Environmental Compliance (***concentration levels [CLs]***) listed in Table 4-1. Compliance with NESHAP is demonstrated when the sum of the fractions, determined by dividing each radionuclide's concentration by its CL and then adding the fractions together, is less than 1.0 at all samplers.

Table 4-1. Concentration limits for radionuclides in air

Radionuclide	Concentration (× 10^{-15} microcuries/milliliter [µCi/mL]) NESHAP Concentration Level for Environmental Compliance [(a)]	10% of Derived Concentration Standard [(b)]
^{241}Am	1.9	4.1
^{137}Cs	19	9,800
^{3}H	1,500,000	1,400,000
^{238}Pu	2.1	3.7
^{239}Pu	2	3.4
^{233}U	7.1	39
^{234}U	7.7	40
^{235}U	7.1	45
^{236}U	7.7	44
^{238}U	8.3	47

(a) From Table 2, Appendix E of Title 40 ***Code of Federal Regulations (CFR)*** Part 61 (2010).

(b) From DOE Standard DOE-STD-1196-2011, "Derived Concentration Technical Standard."

[2] Attachment A, *Site Description*, is a separate file on the compact disc version of this report and is also accessible on the NNSA/NFO web page at http://www.nnss.gov/pages/resources/library/NNSSER.html.

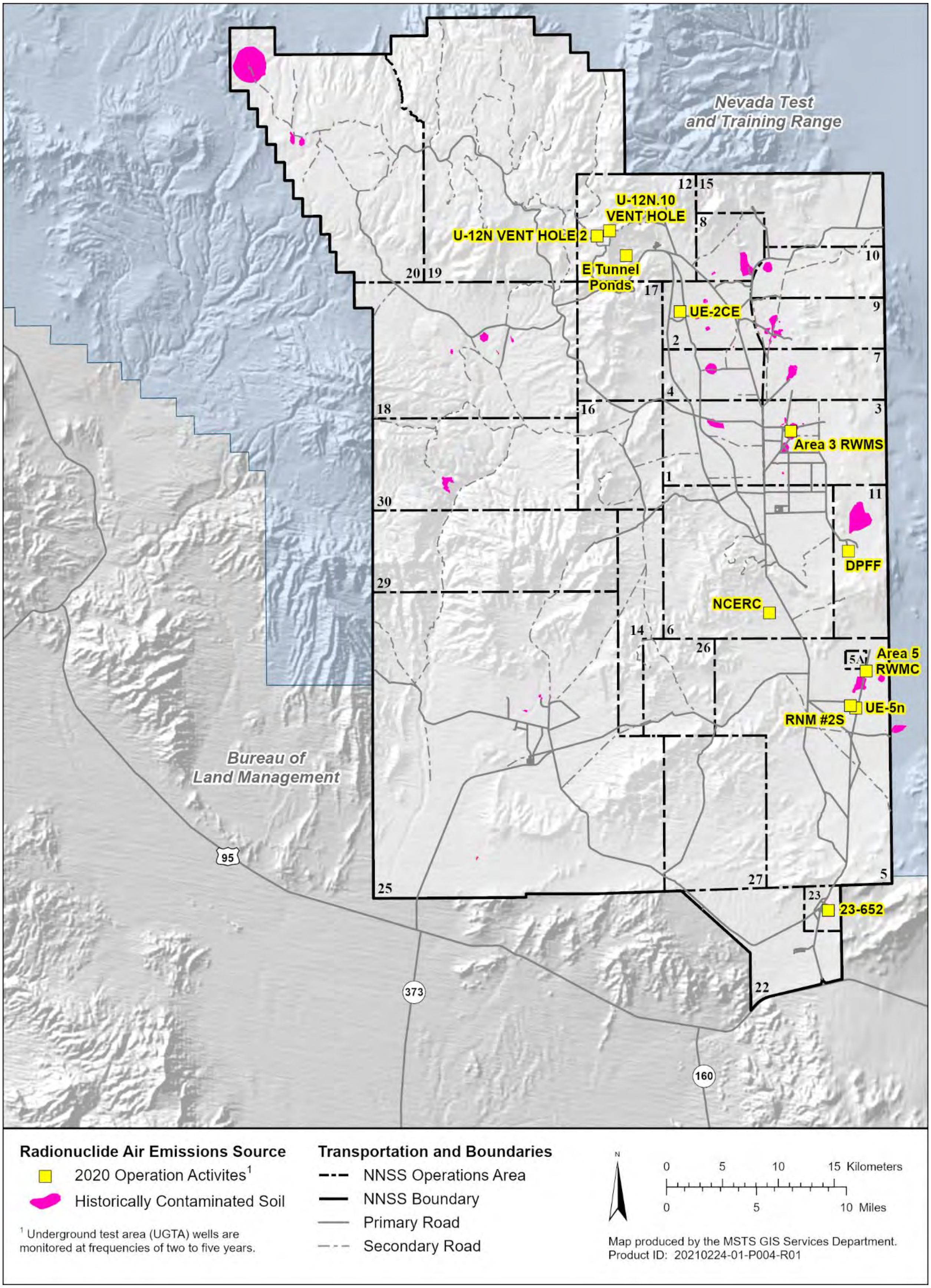

Figure 4-1. Sources of radiological air emissions on the NNSS in 2020

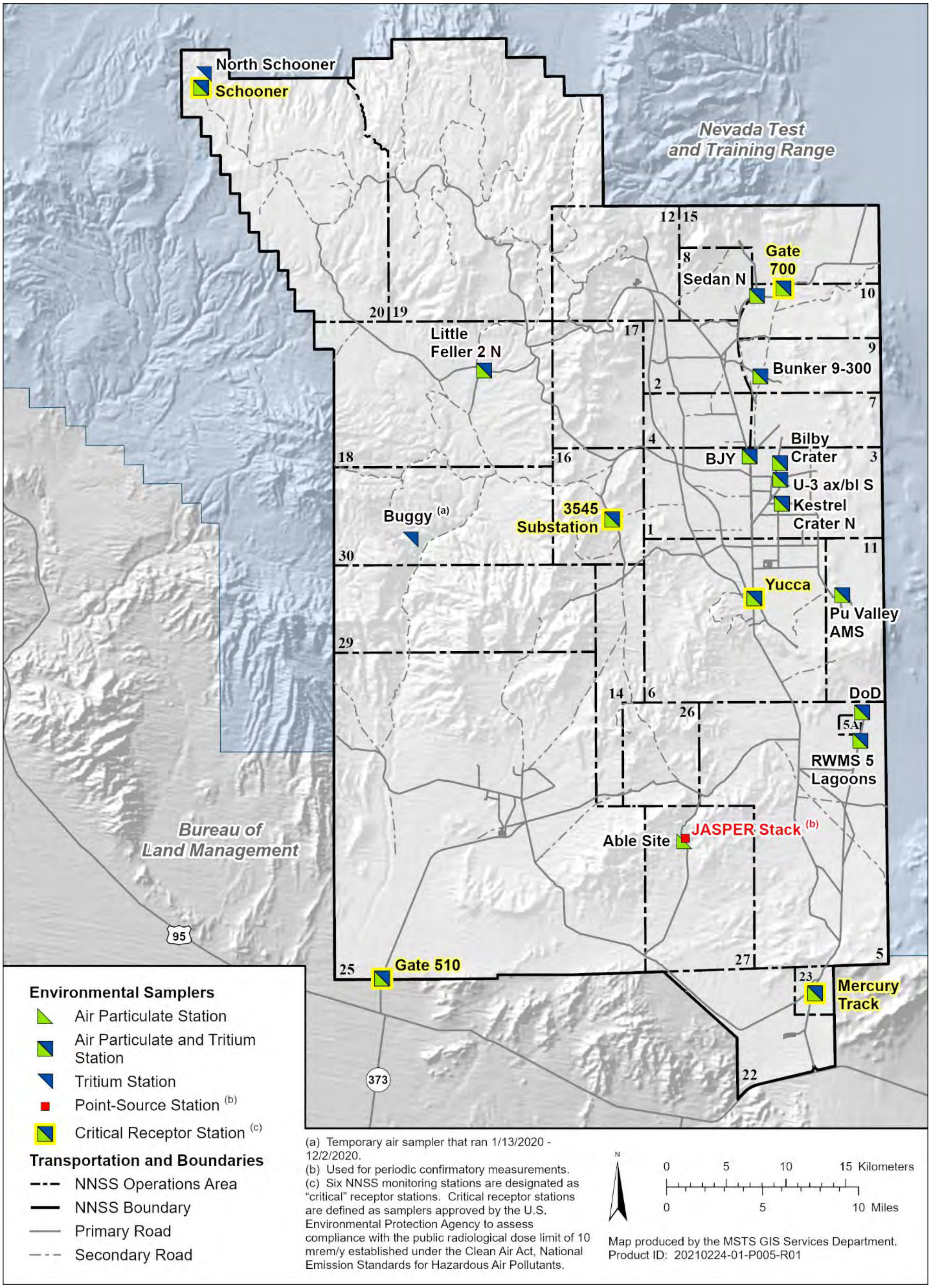

Figure 4-2. Radiological air sampling network on the NNSS in 2020

In addition to CLs, air concentrations may also be compared with ***Derived Concentration Standard (DCS)*** values. They represent the annual average air concentrations that would result in a ***total effective dose equivalent*** of 100 mrem/yr (the federal dose limit to the public from all radiological exposure pathways). Ten percent of the DCS (third column of Table 4-1) represents a 10 mrem/yr dose and is analogous to the CLs (second column). Differences between the CLs and 10% of the DCS are because the DCS values are based only on inhalation of radionuclides in air, while the CLs consider external dose and ingestion of radionuclides deposited from air.

Because of this, and the fact the CLs are regulatory values, the CLs are generally the more conservative of the two and are used to demonstrate compliance. Air concentrations approaching 10% of the CLs are investigated for causes that may be mitigated in order to ensure that regulatory dose limits are not exceeded.

Point-Source (Stack) Sampler – Stack sampling is only conducted at one facility on the NNSS, the Joint Actinide Shock Physics Experimental Research facility in Area 27 (Figure 4-2). In 2013, the potential air emissions from the facility were re-evaluated and determined to result in a potential offsite dose that is much less than the 0.1 mrem/yr threshold at which continuous stack monitoring is required under NESHAP. Therefore, only periodic sampling is recommended to verify low emissions. In 2020, one sample was taken from January 27–28 for this purpose. No man-made radionuclides were detected in the sample, which confirms continued low emissions.

4.1.2 Air Particulate and Tritium Sampling Methods

A sample is collected from each air particulate sampler by drawing air through a 10-centimeter (4-inch) diameter glass-fiber filter at a flow rate of about 85 liters (3 cubic feet [ft^3]) per minute. The particulate filter is mounted in a filter holder that faces downward at a height of about 1.5 meters (m) (5 feet [ft]) above ground. A timer measures the operating time. The run time multiplied by the flow rate yields the volume of air sampled, which is about 1,720 cubic meters (m^3) (60,000 ft^3) during a typical 14-day sampling period. The air sampling rates are measured using mass-flow meters. The filters are collected every 2 weeks.

Filters are analyzed for gross alpha and gross beta radioactivity after an approximate 5-day holding time to allow for the decay of naturally occurring ***radon progeny***. They are then composited quarterly for each sampler. The composite samples are analyzed for gamma-emitting radionuclides (which includes ^{137}Cs) by gamma ***spectroscopy*** and for ^{238}Pu, $^{239+240}Pu$, and ^{241}Am by alpha spectroscopy after chemical separation. Samples from nine locations relatively near potential sources of uranium emissions are also analyzed for uranium isotopes by alpha spectroscopy. These sampling locations are: BJY (Area 1), RWMS 5 Lagoons (Area 5), Yucca (Area 6), Bunker 9-300 (Area 9), Sedan Crater N (Area 10), Gate 700 S (Area 10), 3545 Substation (Area 16), Gate 510 (Area 25), and Able Site (Area 27).

Atmospheric moisture samples, for measuring tritium in air, are collected by continuously drawing air through molecular sieve desiccant at a flow rate of about 566 cubic centimeters per minute (1.2 ft^3 per hour). The air intake is about 1.5 m (5 ft) above ground. A timer measures the operating time. The run time multiplied by the flow rate yields the volume of air sampled, which is about 11 m^3 (388 ft^3) over a 2-week sampling period. The molecular sieve desiccant is exchanged every 2 weeks. Water is extracted from the desiccant and analyzed for ^3H by liquid scintillation counting.

Measured radioactivity in each sample is converted to units per volume of air prior to the reporting described in the following sections.

Quality control air samples (e.g., duplicates, blanks, and spikes) are also routinely incorporated into the analytical suites. Chapter 14 contains a discussion of ***quality assurance/quality control*** protocols and procedures.

4.1.3 Presentation of Air Sampling Data

The 2020 annual average radionuclide concentrations at each air sampling location are presented in the following sections. The annual average (mean) concentration for each radionuclide is estimated from uncensored analytical results for individual samples; i.e., values less than their analysis-specific ***minimum detectable concentrations (MDCs)*** are included in the calculation. $^{239+240}Pu$, $^{233+234}U$, and $^{235+236}U$ are reported as the sum of isotope concentrations because the analytical method cannot readily distinguish the individual ***isotopes***. Where field duplicate measurements are available, plots and summaries use the average of the regular and field duplicate measurements.

In graphs of concentration data in the following figures, the CL (second column of Table 4-1) or a fraction of the CL is included as a dashed green horizontal line. For graphs displaying individual measurements, the CL or fraction thereof is shown for reference only; assessment of NESHAP compliance is based on annual average concentrations rather than individual measurements.

4.1.4 Air Sampling Results

Radionuclide concentrations in the air samples shown in the following tables and graphs are attributed to the resuspension of legacy contamination in surface soils, the upward flux of ^{3}H from the soil at sites of past nuclear tests, buried low-level radioactive waste, or NNSS operations. Tables 4-2 through 4-7 and Figures 4-3 through 4-7 include data for all environmental locations that collect air particulate samples (i.e., the North Schooner Station is excluded from these data sets because only atmospheric moisture is sampled at that location). Table 4.8 and Figure 4-10 include data for all environmental locations that collect samples to measure ^{3}H in atmospheric moisture (Able Site is excluded from this data set because only air particulates are sampled at that location).

4.1.4.1 Gross Alpha and Gross Beta

Gross alpha and gross beta radioactivity measurements in air samples collected in 2020 are summarized in Tables 4-2 and 4-3. CL values do not exist for gross alpha and gross beta concentrations in air because these radioactivity measurements include naturally occurring radionuclides (such as ^{40}K, ^{7}Be, uranium, thorium, and the ***daughter isotopes*** of uranium and thorium) in uncertain proportions. However, these analyses are useful in that results can be economically obtained just 5 days after sample collection to identify any increases requiring investigation.

Overall, the mean gross alpha and gross beta results across the network are comparable with those of the past few years.

Table 4-2. Gross Alpha radioactivity in air samples collected in 2020

			Gross Alpha (x 10^{-16} µCi/mL)			
Area	**Station**	**Number of Samples**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
1	BJY	27	29.39	17.10	0.80	68.29
3	Bilby Crater	27	30.30	17.53	3.27	65.98
3	Kestrel Crater N	27	26.36	17.20	-3.36	50.87
3	U-3ax/bl S	27	29.86	16.17	-7.06	60.70
5	DoD	27	27.31	15.86	1.37	52.08
5	RWMS 5 Lagoons	27	30.00	14.04	9.50	53.68
6	Yucca*	27	25.46	15.22	4.11	54.98
9	Bunker 9-300	27	30.60	18.50	4.01	71.65
10	Gate 700 S*	27	28.64	13.06	9.43	60.60
10	Sedan N	27	27.11	15.29	-3.15	61.07
11	Pu Valley AMS	27	37.26	24.25	0.00	108.74
16	3545 Substation*	27	26.00	15.39	-4.67	57.14
18	Little Feller 2 N	27	27.85	16.45	4.51	58.19
20	Schooner*	27	27.26	15.21	0.00	55.39
23	Mercury Track*	27	26.36	14.02	-0.68	54.81
25	Gate 510*	27	29.44	16.79	3.52	70.87
27	ABLE Site	27	28.39	15.79	1.52	53.67
All Environmental Locations		459	28.68	16.44	-7.06	108.74

* Critical Receptor Station

Table 4-3. Gross Beta radioactivity in air samples collected in 2020

Area	Station	Number of Samples	Gross Beta (x 10^{-15} µCi/mL)			
			Mean	Standard Deviation	Minimum	Maximum
1	BJY	27	23.76	7.11	11.22	37.31
3	Bilby Crater	27	24.29	6.12	14.92	37.40
3	Kestrel Crater N	27	24.48	7.01	10.99	38.52
3	U-3ax/bl S	27	24.74	6.17	13.09	36.29
5	DoD	27	25.68	6.86	11.48	41.28
5	RWMS 5 Lagoons	27	26.47	7.25	15.50	40.52
6	Yucca*	27	25.04	7.04	13.32	37.58
9	Bunker 9-300	27	24.06	6.90	13.39	40.16
10	Gate 700 S*	27	24.41	6.62	14.04	37.59
10	Sedan N	27	23.90	6.11	14.24	34.78
11	Pu Valley AMS	27	24.16	6.98	12.42	37.64
16	3545 Substation*	27	23.23	6.86	11.94	40.37
18	Little Feller 2 N	27	22.89	6.66	11.31	37.34
20	Schooner*	27	24.36	7.24	13.81	39.90
23	Mercury Track*	27	24.51	6.27	13.10	38.03
25	Gate 510*	27	25.53	6.87	12.04	38.92
27	ABLE Site	27	24.55	6.56	12.91	36.92
All Environmental Locations		459	24.47	6.69	10.99	41.28

* Critical Receptor Station

4.1.4.2 Americium-241

The mean ^{241}Am concentration for environmental sampler locations was 7.55 × 10^{-18} µCi/mL in 2020. This is lower than most recent years; the annual means were 1.36, 15.13, 14.87, 11.67, 8.55, 10.09, 12.74, 15.99, 6.99, and 6.33 × 10^{-18} µCi/mL in 2019 through 2009, respectively. The 2020 average concentration is 0.4% of the CL (shown at the bottom of Table 4-4). In the plots for ^{241}Am and other actinides (^{238}Pu and $^{239+240}$Pu), values for Pu Valley AMS, Bunker 9-300, and Sedan N (Areas 11, 9, and 10, respectively) are shown individually, as these stations tend to have higher measurements. Area 1 and Area 3 stations are grouped together, with a green vertical bar extending from the lowest to highest values in the quarter and lines connecting the quarterly mean values. One second quarter value in Area 3 (U-3ax/bl S) was relatively higher than the others in Area 3 for both ^{241}Am and $^{239+249}$Pu but not out of its historical range. The other stations are grouped similarly, using black vertical bars and lines.

Table 4-4. Concentrations of ^{241}Am in air samples collected in 2020

Area	Station	Number of Samples	^{241}Am (x 10^{-18} µCi/mL) Mean	Standard Deviation	Minimum	Maximum
1	BJY	4	2.23	2.53	-1.10	4.95
3	Bilby Crater	4	3.12	5.94	-3.90	9.91
3	Kestrel Crater N	4	5.27	4.91	0.00	10.25
3	U-3ax/bl S	4	15.55	18.46	1.46	42.57
5	DoD	4	1.93	3.19	-0.67	6.29
5	RWMS 5 Lagoons	4	-0.05	5.02	-6.53	5.72
6	Yucca*	4	2.86	2.65	0.44	6.56
9	Bunker 9-300	4	16.13	11.79	4.30	30.45
10	Gate 700 S*	4	3.03	2.81	0.85	7.16
10	Sedan N	4	11.44	6.93	1.76	16.48
11	Pu Valley AMS	4	56.84	73.54	-0.61	164.35
16	3545 Substation*	4	1.23	1.58	-0.41	2.60
18	Little Feller 2 N	4	5.28	7.19	-0.51	15.79
20	Schooner*	4	0.69	2.15	-2.05	2.92
23	Mercury Track*	4	1.07	2.67	-0.70	5.03
25	Gate 510*	4	0.92	2.27	-1.64	3.89
27	ABLE Site	4	0.75	1.64	-0.48	3.13
All Environmental Locations		68	7.55	21.28	-6.53	164.35

CL = 1900 x 10^{-18} µCi/mL

* Critical Receptor Station

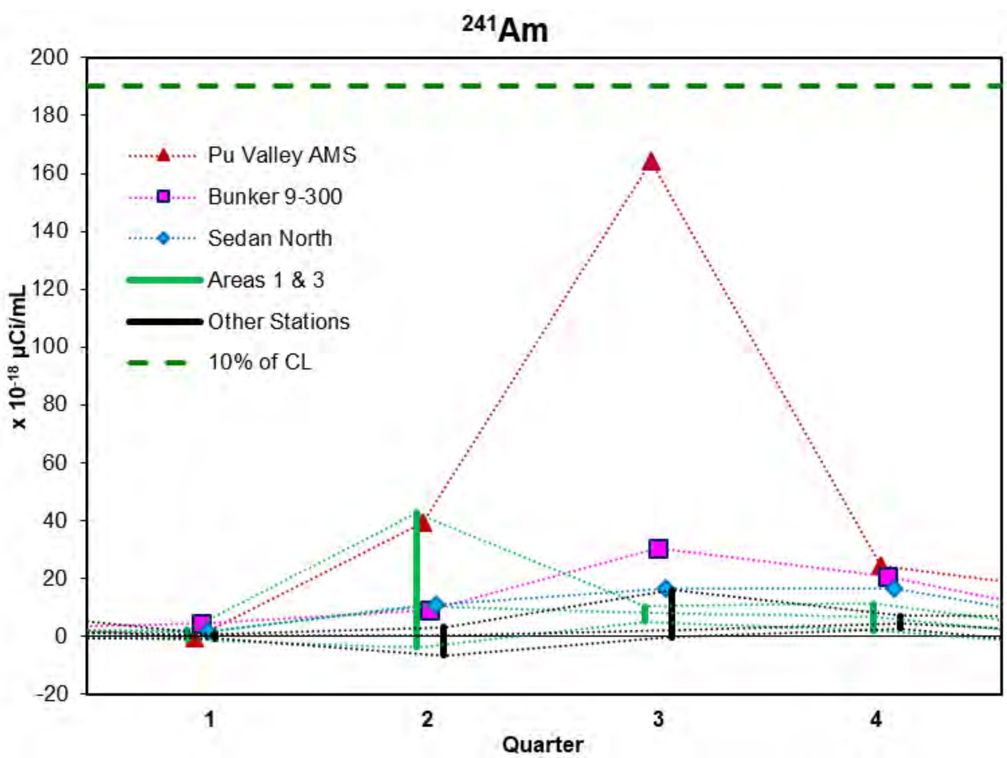

Figure 4-3. Concentrations of ^{241}Am in air samples collected in 2020

4.1.4.3 Plutonium Isotopes

The overall mean concentration for ^{238}Pu at environmental samplers in 2020 (1.09 × 10^{-18} µCi/mL) (Table 4-5) is near the low end of the range of values (0.98 to 5.54 × 10^{-18} µCi/mL) observed from 2009 through 2019. The highest 2020 mean (3.83 × 10^{-18} µCi/mL) was at DoD in Area 5; this is 0.2% of the CL (Figure 4-4).

The $^{239+240}$Pu isotopes are of greater abundance and hence greater interest. The overall mean of 43.45 × 10^{-18} µCi/mL in 2020 is in the lower part of the range of values measured during 2009–2019 (33.47 to 96.46 × 10^{-18} µCi/mL). The locations with the highest means are Pu Valley AMS (308.63 × 10^{-18} µCi/mL, 15.4% of the CL), Bunker 9-300 (121.73 × 10^{-18} µCi/mL, 6.1% of the CL), U-3ax/bl S (112.73 × 10^{-18} µCi/mL, 5.6% of the CL), and Sedan N (56.77 × 10^{-18} µCi/mL, 2.8% of the CL); see Table 4-6 and Figure 4-5.

The concentrations of ^{241}Am, $^{239+240}$Pu, and to some extent ^{238}Pu, often show similar patterns through time at Bunker 9-300 and other areas of known contamination from past nuclear tests. This is because ^{241}Am is the long-lived ***daughter product*** obtained when ^{241}Pu (a short-lived isotope created along with the more common Pu isotopes) decays by beta emission. Hence $^{239+240}$Pu and ^{241}Am (and also ^{238}Pu) tend to be found together in particles of Pu remaining from past tests. The half-life of ^{241}Pu is 14.4 years, whereas that of ^{241}Am is 432 years. Consequently, the amount of ^{241}Am will gradually increase temporarily as ^{241}Pu decays, and then it will decrease.

Figure 4-6 shows long-term trends in $^{239+240}$Pu annual mean concentrations at locations with at least 15-year data histories since 1971. Rather than showing the time histories for all 50 such locations, Figure 4-6 shows the average (geometric mean) trend lines for Areas 1 and 3; Area 5; Areas 7, 9, 10, and 15; and other areas. Areas 1, 3, 7, 9, 10, and 15 in the northeast portion of the NNSS have a legacy of soil contamination from surface and atmospheric nuclear tests and safety shots. The average annual rates of decline for these groups range from 2.2% (Areas 1 and 3) and 2.6% (Areas 7, 9, 10, and 15) to 10.2% and 10.7% (the Area 5 and other areas groups). This equates to a reduction in $^{239+240}$Pu concentration by half every 30.7 years for Areas 1 and 3; 26.2 years for Areas 7, 9, 10, and 15; 6.4 years for Area 5; and 6.1 years for the other areas. Declining rates are not attributable to ***radioactive decay*** alone, as the physical half-lives of ^{239}Pu and ^{240}Pu are 24,110 and 6,537 years, respectively. The decreases are due primarily to immobilization and dilution of Pu particles in surface soil, resulting in reduced concentrations re-suspended in air. The half-life of the less abundant ^{238}Pu is 88 years.

Table 4-5. Concentrations of ^{238}Pu in air samples collected in 2020

			^{238}Pu (x 10^{-18} µCi/mL)			
Area	**Station**	**Number of Samples**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
1	BJY	4	1.89	1.34	0.00	2.96
3	Bilby Crater	4	-3.19	5.08	-8.10	1.49
3	Kestrel Crater N	4	-0.44	4.84	-7.51	3.49
3	U-3ax/bl S	4	1.41	1.44	0.00	2.67
5	DoD	4	3.83	5.54	0.50	12.10
5	RWMS 5 Lagoons	4	0.63	2.46	-2.86	2.92
6	Yucca*	4	-0.29	1.77	-2.04	1.25
9	Bunker 9-300	4	3.39	3.58	0.00	8.07
10	Gate 700 S*	4	1.53	3.23	-2.69	5.07
10	Sedan N	4	1.90	2.70	-2.02	4.02
11	Pu Valley AMS	4	3.61	8.37	-4.74	15.10
16	3545 Substation*	4	1.14	0.93	0.38	2.49
18	Little Feller 2 N	4	0.44	3.28	-3.66	4.29
20	Schooner*	4	0.09	2.59	-3.03	2.72
23	Mercury Track*	4	1.97	2.74	-0.52	5.87
25	Gate 510*	4	0.07	1.84	-2.57	1.72
27	ABLE Site	4	0.52	1.12	-0.81	1.46
All Environmental Locations		68	1.09	3.58	-8.10	15.10

CL = 2100 x 10^{-18} µCi/mL

* Critical Receptor Station

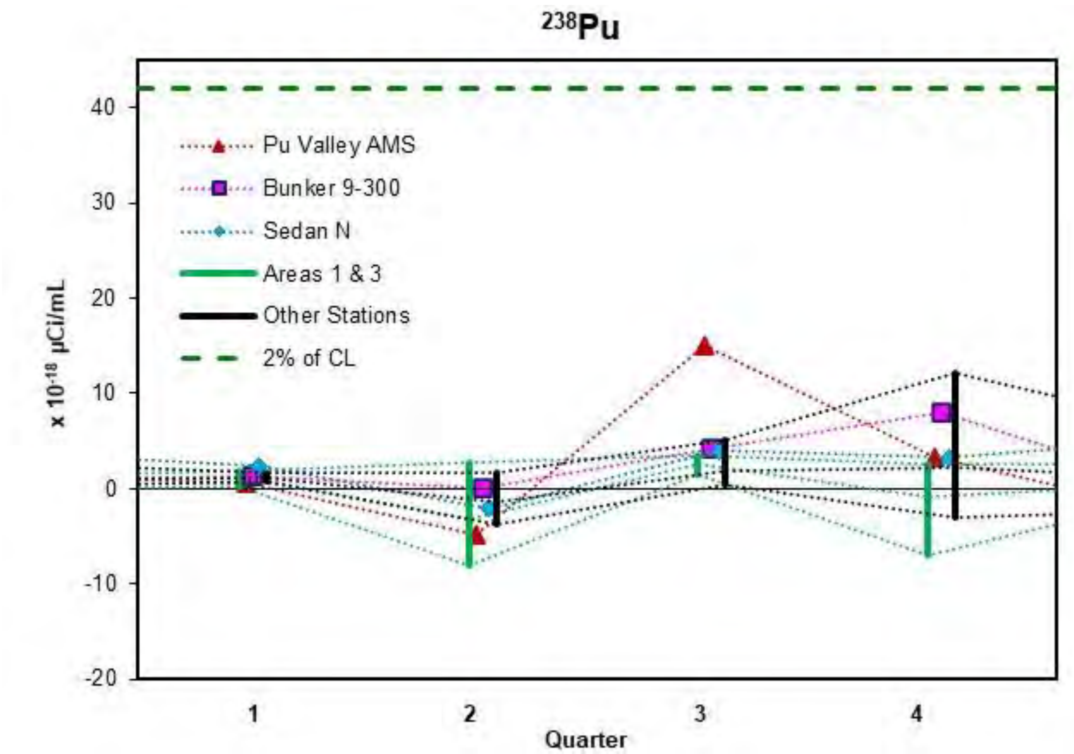

Figure 4-4. Concentrations of ^{238}Pu in air samples collected in 2020

Table 4-6. Concentrations of $^{239+240}$Pu in air samples collected in 2020

Area	Station	Number of Samples	$^{239+240}$Pu (x 10^{-18} µCi/mL) Mean	Standard Deviation	Minimum	Maximum
1	BJY	4	18.52	17.17	8.69	44.16
3	Bilby Crater	4	30.68	28.05	14.08	72.39
3	Kestrel Crater N	4	24.60	16.89	3.59	44.49
3	U-3ax/bl S	4	112.73	144.09	16.77	327.17
5	DoD	4	9.50	15.03	1.15	31.98
5	RWMS 5 Lagoons	4	2.10	0.93	0.97	2.86
6	Yucca*	4	10.82	9.81	2.09	24.84
9	Bunker 9-300	4	121.73	91.27	33.00	238.19
10	Gate 700 S*	4	8.79	13.61	0.11	29.04
10	Sedan N	4	56.77	42.03	10.02	109.56
11	Pu Valley AMS	4	308.63	407.71	3.93	909.35
16	3545 Substation*	4	2.57	4.11	0.00	8.70
18	Little Feller 2 N	4	21.34	39.61	-0.91	80.69
20	Schooner*	4	5.80	7.83	0.00	17.20
23	Mercury Track*	4	1.86	3.50	-2.58	5.87
25	Gate 510*	4	0.13	2.87	-3.42	3.04
27	ABLE Site	4	2.00	0.65	1.39	2.85
All Environmental Locations		68	43.45	121.45	-3.42	909.35

CL = 2000 x 10^{-18} µCi/mL

* Critical Receptor Station

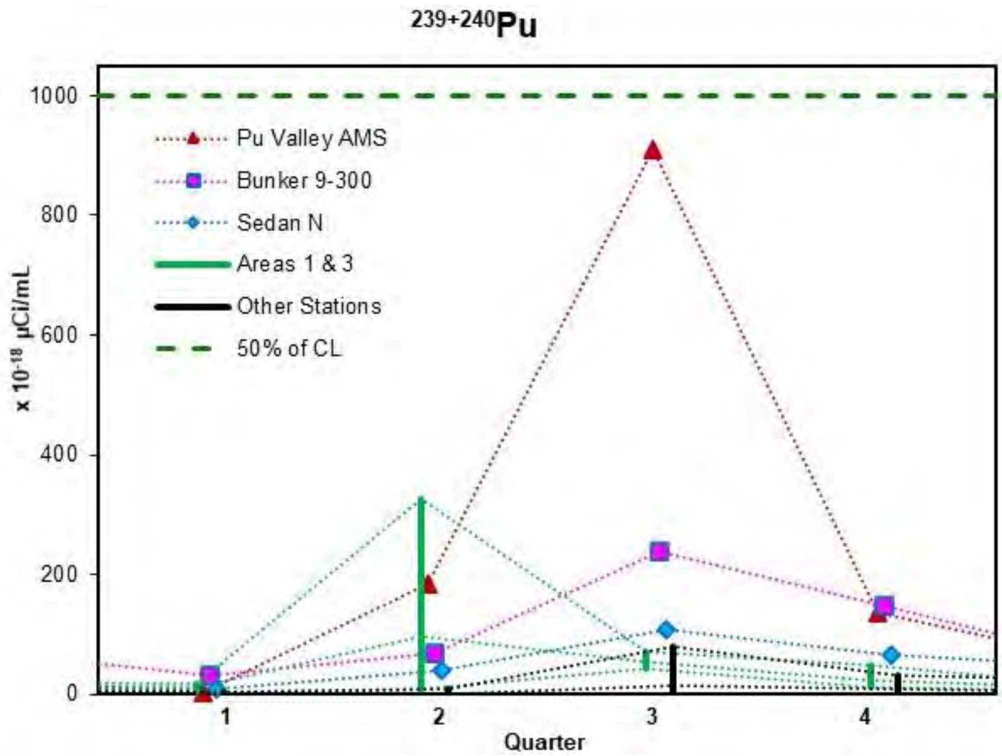

Figure 4-5. Concentrations of $^{239+240}Pu$ in air samples collected in 2020

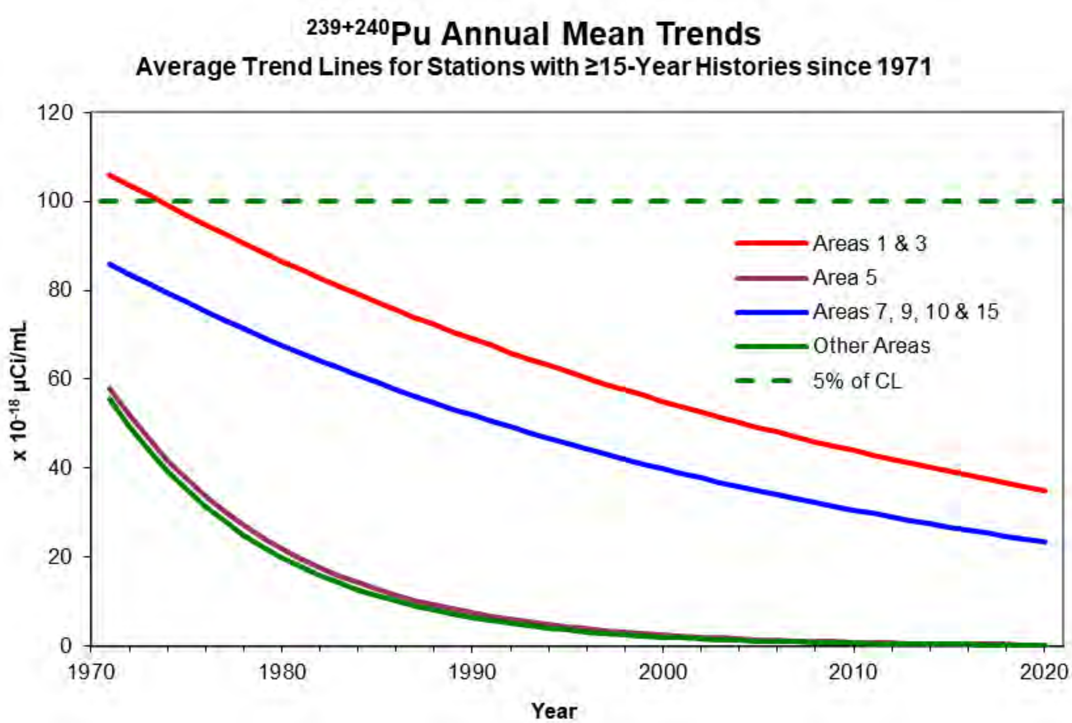

Figure 4-6. Average trends in $^{239+240}Pu$ in air annual means, 1971-2020

4.1.4.4 Cesium-137

Cesium-137 was detected in three samples during the second quarter of 2020. The value at BJY was 20.8% higher than its MDC and that at Gate 510 was 33.6% higher than its MDC. The field duplicate at Mercury Track was high, but the regular value was slightly negative; the average of these was 14.7% higher than the average of their MDCs. The mean, standard deviation, minimum, and maximum for all sample locations are listed in Table 4-7. The annual average concentration was less than 0.3% of the CL at all locations. Figure 4-7 shows all stations grouped together with a vertical bar extending from the lowest to the highest value for the quarter; the overall means are connected.

Table 4-7. Concentrations of ^{137}Cs in air samples collected in 2020

			^{137}Cs (x 10^{-17} µCi/mL)			
Area	**Station**	**Number of Samples**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
1	BJY	4	4.81	12.63	-5.81	20.30
3	Bilby Crater	4	1.19	5.53	-6.93	5.48
3	Kestrel Crater N	4	2.22	10.90	-10.27	13.35
3	U-3ax/bl S	4	-0.41	4.69	-5.88	5.08
5	DoD	4	-1.14	3.73	-6.09	2.53
5	RWMS 5 Lagoons	4	-0.94	9.09	-12.98	8.69
6	Yucca*	4	-3.74	5.40	-10.29	1.35
9	Bunker 9-300	4	-3.33	4.89	-8.67	1.73
10	Gate 700 S*	4	0.95	4.69	-5.09	5.60
10	Sedan N	4	1.59	8.92	-10.89	8.12
11	Pu Valley AMS	4	2.67	10.54	-8.50	16.94
16	3545 Substation*	4	-0.65	6.37	-7.90	7.63
18	Little Feller 2 N	4	-1.89	11.23	-15.90	9.57
20	Schooner*	4	-3.00	5.63	-10.55	1.81
23	Mercury Track*	4	2.91	11.01	-6.85	18.42
25	Gate 510*	4	2.49	12.53	-7.92	19.04
27	ABLE Site	4	-2.57	7.90	-11.20	7.45
All Environmental Locations		68	0.07	7.83	-15.90	20.30

CL = 1900 x 10^{-17} µCi/mL

* Critical Receptor Station

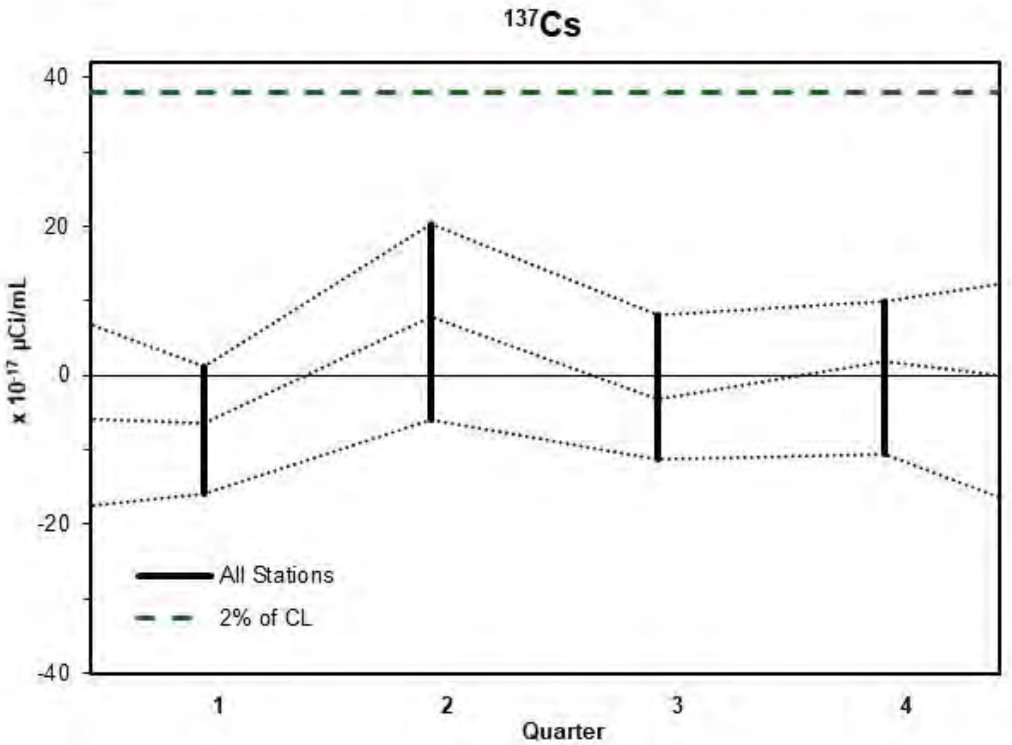

Figure 4-7. Concentrations of ^{137}Cs in air samples collected in 2020

4.1.4.5 Uranium Isotopes

Uranium analyses were performed in 2020 for samples collected near sites where exercises using uranium (predominately DU) have been conducted. Quarterly samples from nine samplers were analyzed. Uranium is also a naturally occurring radionuclide so tests were conducted to determine if man-made uranium is present. Ratios of the U isotopes ($^{233+234}$U / ^{238}U and $^{235+236}$U / ^{238}U) were compared among the samplers and compared with ratios found in blank filters. No evidence of elevated uranium or presence of DU in air was observed in these comparisons.

4.1.4.6 Tritium

Tritium concentrations in air vary widely across the NNSS (Table 4-8). As seen in previous years, the sample location with the highest annual mean concentration is at the Schooner sampler (57.8 × 10^{-6} picocuries per milliliter [pCi/mL]). The next highest is 9.1 × 10^{-6} pCi/mL at Pu Valley AMS. Figure 4-8 shows these data with Schooner results plotted at one-tenth of their actual values to allow the variation at other locations to be visible. The Schooner and Pu Valley AMS annual means are 3.9% and 0.6% of the CL, respectively; mean concentrations at other locations are less than 0.1% of the CL. Only one sample from the Buggy sampler had a result slightly above the MDC. It was concluded that tritium concentrations at this location are negligible and the sampler was removed on December 2, 2020.

Tritium released to the environment quickly oxidizes into tritiated water. Tritium from past nuclear tests or buried waste diffuses into the surrounding soil and rubble until it moves to the surface and is emitted either through evaporation or plant transpiration. Because of this, higher ^{3}H concentrations in air are generally observed in the summer months. Increased ^{3}H emissions are likely due to the movement of relatively deep soil moisture (> 2 m) containing relatively high concentrations of ^{3}H to the surface when temperatures are the highest and when shallow (< 2 m) soil moisture is the lowest. During the summer months, rainfall can temporarily suppress these emissions by diluting ^{3}H in the atmosphere and in the shallow soil moisture. Figure 4-8 shows the relationship between ^{3}H and average daily temperature at Schooner Crater. Figure 4-9 shows the amount of precipitation occurring during monitoring periods at the Schooner sample location. In 2020, the summer rise in ^{3}H air concentrations was a bit delayed following the rains of early June. The points plotted in these figures show the average ^{3}H concentrations in air for the 2-week periods. The average temperature and total precipitation are from the Schooner Crater meteorological station for those periods.

Figure 4-10 shows average (geometric mean) long-term trends for the annual mean ^{3}H levels at locations with at least 7-year histories since 1999, by Area groups. Tritium measurements have been decreasing fairly rapidly at most locations; the overall average decline rate for samplers other than Schooner is around 9.8% per year. The decline rate for Schooner has been about 11.7% per year since 2002. These correspond to half-lives in the environment of approximately 6.7 and 5.6 years, respectively.

4.1.4.6.1 Tritium Monitoring at the North Las Vegas Facility

In 1995, a container of tritium-aluminum foils was opened in Building A-01 at the North Las Vegas Facility (NLVF) and emitted at least 1 curie (Ci) of tritium into a basement area used as a fixed radiation source range (U.S. Department of Energy 1996). Constant sampling of tritium in air began immediately and continued through 1998. During the years 1999 through 2020, air sampling for tritium in the basement was conducted intermittently. For Calendar Year (CY) 2020, the results of two atmospheric moisture samples were 203 picocuries per cubic meter (pCi/m^3) for the sample collected May 19–26, 2020, and 240 pCi/m^3 for the sample collected September 1–8, 2020. The average of these sample results (222 pCi/m^3) was multiplied by the room ventilation rate to estimate the total annual emission (2.22 mCi/yr). Tritium concentrations continue to decrease at a rate of about 50% every 5.5 years.

Table 4-8. Concentrations of ^{3}H in air samples collected in 2020

			^{3}H Concentration ($\times 10^{-6}$ pCi/mL)			
Area	**Station**	**Number of Samples**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
1	BJY	27	0.21	0.33	-0.37	0.75
3	Bilby Crater	27	0.05	0.36	-1.26	0.58
3	Kestrel Crater N	27	0.19	0.24	-0.49	0.58
3	U-3ax/bl S	27	0.17	0.35	-0.67	0.62
5	DoD	27	0.93	0.73	-0.18	2.73
5	RWMS 5 Lagoons	27	1.28	1.56	-0.17	5.54
6	Yucca*	27	0.07	0.32	-0.55	0.73
9	Bunker 9-300	27	0.25	0.31	-0.16	1.20
10	Gate 700 S*	27	0.05	0.31	-0.69	1.15
10	Sedan N	27	0.80	0.87	-0.37	2.80
11	Pu Valley AMS	27	9.14	9.96	1.24	55.03
16	3545 Substation*	27	0.05	0.22	-0.38	0.66
18	Little Feller 2 N	27	0.05	0.36	-1.02	0.49
20	North Schooner	27	1.21	1.08	-0.01	3.73
20	Schooner*	27	57.76	63.07	2.18	189.28
23	Mercury Track*	27	-0.06	0.45	-1.60	1.08
25	Gate 510*	27	0.04	0.36	-1.31	0.61
30	Buggy	10	0.24	0.25	-0.16	0.63
All Environmental Locations		469	4.16	20.18	-1.60	189.28

CL = 1500×10^{-6} pCi/mL

* Critical Receptor Station

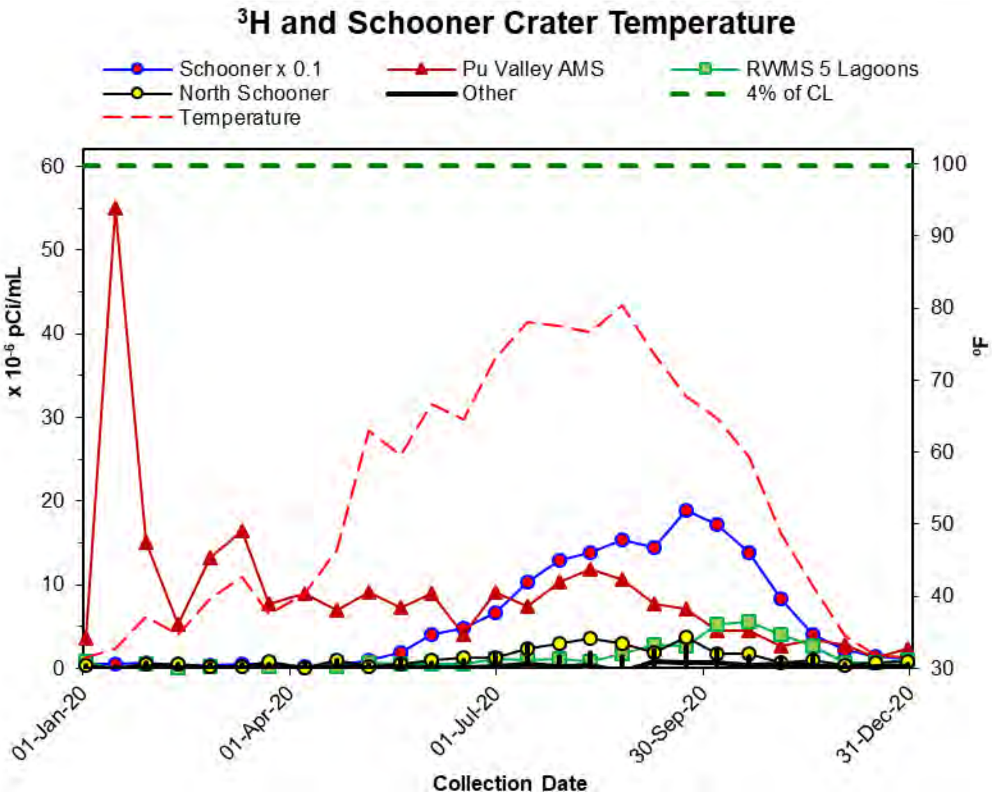

Figure 4-8. Concentrations of ^{3}H in air samples collected in 2020 with the average air temperature near the Schooner sampler during the collection period

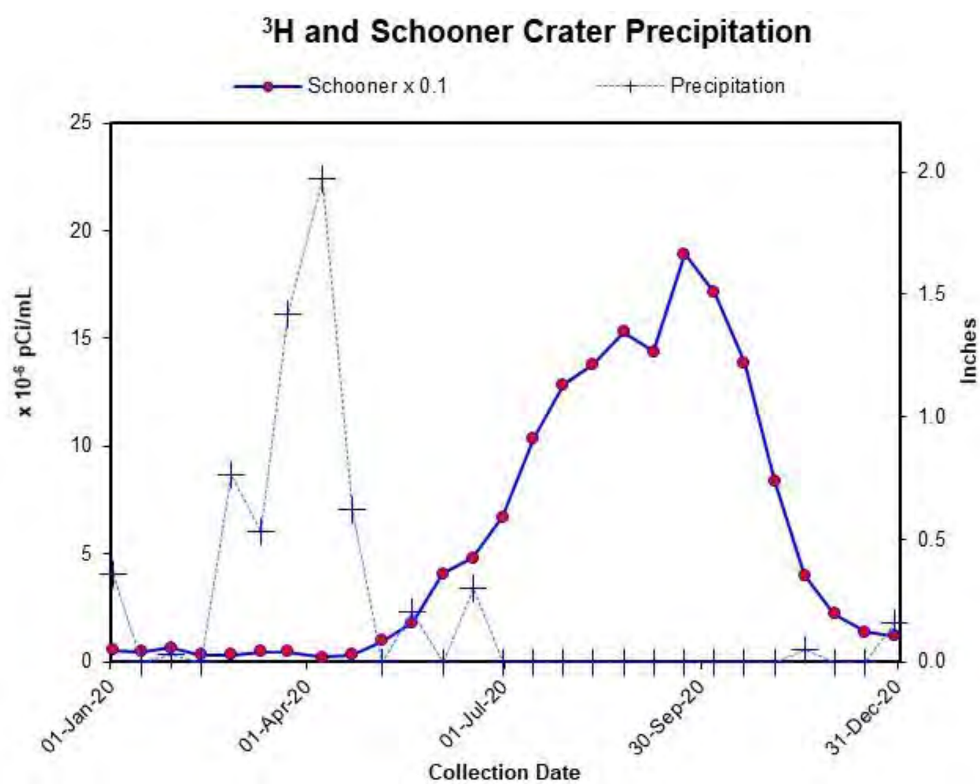

Figure 4-9. Concentrations of ^{3}H in air and precipitation during the sample collection period at Schooner

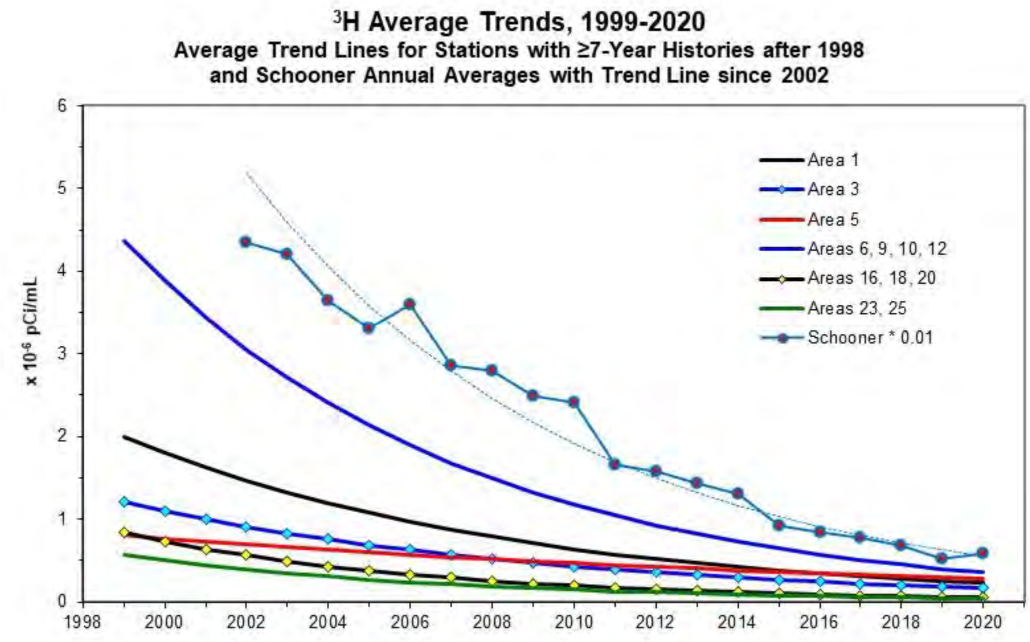

Figure 4-10. Average trend lines for annual mean ^{3}H air concentrations for Area groups, 1999-2020

4.1.5 Emission Evaluations for Planned Projects

In 2020, three NESHAP evaluations for radionuclide emissions were conducted. Two were for research activities and one for plans to cover a contaminated location with clean soil. These evaluations were to determine if activities had the potential to release airborne radionuclides that would expose the public to a dose equal to or greater than 0.1 mrem/yr. For any project or facility with this potential, the EPA requires monitoring of the emissions and possibly the submittal of an application for EPA approval prior to active operations. The predicted dose at the nearest offsite receptor for each activity evaluated in 2020 was much less than the 0.1 mrem/yr level specified under NESHAP regulations. Therefore, it is concluded that these activities constituted minor sources that do not require point-source operational monitoring. A summary of these dose evaluations is reported in the NESHAP annual report for 2020 (Mission Support and Test Services, LLC [MSTS], 2021).

4.1.6 Unplanned Releases

There were no known unplanned radionuclide releases in 2020. Five wildland fires were reported on the NNSS in 2020. The largest of these, named the Area 16 Fire, started in late July, from a lightning strike. It burned about 3,149 acres in Area 16 and Area 1. It took NNSS Fire and Rescue and some additional assets, including fire retardant drops from aircraft, several days to put the fire out. The other four fires were caused by lightning (one), electrocuted raptor (one), and manmade activities (two) but were all small, <0.25 acres in size. These fires were extinguished by NNSS Fire and Rescue personnel or carefully monitored until they burned out.

4.1.7 Estimate of Total NNSS Radiological Atmospheric Releases

Each year, existing operations that have the potential for airborne emissions of radioactive materials are reviewed. Quantities of radionuclides released during these operations and from legacy contamination sites are measured or calculated to obtain the total annual quantity of radiological atmospheric releases from the NNSS. The methods are described in detail in the NESHAP annual report for 2020 (MSTS 2021).

Total emissions in 2020, by radionuclide, are shown in Table 4-9. Radionuclide emissions by source are shown in Table 4-10. Their locations in relation to critical receptor air monitoring locations are shown in Figure 4-1.

In 2020, an estimated 193 Ci of radionuclides were released as air emissions. Of this amount, about 44.9% (86.6 Ci) was from the very short-lived (15.3 minute) metastable xenon-135 (Table 4-9 lists radionuclide name, half-life, and amount emitted). Short-lived radionuclides decay very quickly and are essentially not available to contribute dose to the public at the 31 to 62-kilometer (19 to 38 mile) distances over which they have to travel. Of the total emission, noble gases make up about 55.1%, tritium makes up about 31.5%, and the radionuclides in the "Other" category (Table 4-9) make up about 13.2%.

Table 4-9. Total estimated NNSS radionuclide emissions for 2020

Radionuclide	Symbol	Half-life[(a)]	Total Quantity (Ci)
Primary Radionuclides			
Tritium	^{3}H	12.32 years (yr)	60.82
Plutonium-238	^{238}Pu	87.7 yr	0.039
Plutonium-239+240	$^{239+240}Pu$	24,110 yr	0.29
Americium-241	^{241}Am	432 yr	0.070
Noble Gases			
Argon-41	^{41}Ar	109.61 minutes (min)	0.28
metastable Krypton-85	^{85m}Kr	4.48 hours (h)	5.29
Xenon-133	^{133}Xe	5.24 days (d)	0.95
Xenon-135	^{135}Xe	9.14 h	13.10
metastable Xenon-135	^{135m}Xe	15.29 min	86.60
Other			
Cobalt-60	^{60}Co	5.27 yr	0.000205
Strontium-90	^{90}Sr	28.79 yr	0.0504
Tellurium-132	^{132}Te	3.2 d	1.1
Iodine-131	^{131}I	8.02 d	0.317
Iodine-133	^{133}I	20.8 h	5.77
Iodine-135	^{135}I	6.57 h	17.7
Cesium-137	^{137}Cs	30.17 yr	0.0494
Barium-140	^{140}Ba	12.75 d	0.38
Lanthanum-140	^{140}La	1.68 d	0.000000029
Europium-152	^{152}Eu	13.54 yr	0.0088
Europium-154	^{154}Eu	8.59 yr	0.000078

(a) Source: International Commission on Radiological Protection (2008).

Table 4-10. Radiological atmospheric releases from the NNSS for 2020

Emission Source[a]	Emission Control	Radionuclide	Quantity (Ci/y)
Historical Contamination Sites			
Grouped Area Sources–All NNSS Areas	None	^{3}H	13.45
		^{60}Co	0.000206
		^{90}Sr	0.050
		^{137}Cs	0.049
		^{152}Eu	0.0088
		^{154}Eu	0.000078
		^{238}Pu	0.039
		$^{239+240}Pu$	0.29
		^{241}Am	0.070
Building A-01, basement ventilation, North Las Vegas Facility	None	^{3}H	0.0022
2020 Operations			
DPF[b]	None	^{3}H	39
		^{41}Ar	0.00000026
E-Tunnel Ponds	None	^{3}H	4.21
UGTA Wells[c]	None	^{3}H	0.036
Area 3 RWMS	Soil cover over waste	^{3}H	1.35
Area 5 RWMC	Soil cover over waste	^{3}H	2.77
Building 23-652	None	^{3}H	0.0000090
NCERC[d]	HEPA filter[e]	^{3}H	0.0000018
		^{41}Ar	0.28
		^{85m}Kr	5.29
		^{90}Sr	0.00041
		^{132}Te	1.10
		^{131}I	0.32
		^{133}I	5.77
		^{135}I	17.70
		^{133}Xe	0.95
		^{135m}Xe	86.60
		^{135}Xe	13.10
		^{137}Cs	0.00043
		^{140}Ba	0.38
		^{140}La	0.000000029

(a) All locations are on the NNSS except for Building A-01.
(b) Dense Plasma Focus (Facility).
(c) Underground Test Area (UGTA) wells.
(d) National Criticality Experimental Research Center.
(e) ***High-efficiency particulate air (HEPA) filter***.

4.1.8 Radiological Emissions Compliance

The NNSS demonstrates compliance with air pathway dose limits using environmental measurements of radionuclide air concentrations near the NNSS borders and near the center of the NNSS. This critical receptor method [40 CFR 61.93(g)] was proposed and formally submitted to EPA Region 9 for use on the NNSS in 2001 (EPA 2001) and has been used to demonstrate compliance with the 40 CFR 61.92 dose standard since 2002. The six critical receptor locations are listed in Table 4-11 and displayed in Figure 4-2.

The following radionuclides from NNSS-related activities were detected at one or more of the critical receptor samplers: ^{3}H, ^{238}Pu, $^{239+240}$Pu, ^{241}Am, and ^{137}Cs. All of the measured concentrations were well below their CLs. No man-made uranium was detected above levels found in blank filters (Section 4.1.4.5). The annual average concentration of each measured man-made radionuclide at each of the six critical receptor samplers is divided by its respective CL (Table 4-1) to obtain a "fraction of CL." If the average value is negative due to background measurements being higher than the low result, the negative value is set to zero to ensure the ratio to the CL is not negative. These are then summed for each sampler. The sum of these fractions at each critical receptor sampler is far less than 1; the highest sum was 0.042 at Schooner Crater. This demonstrates that the NESHAP dose limit of 10 mrem/yr at these critical receptor locations was not exceeded (Table 4-11).

Table 4-11. Sums of fractions of concentration levels for man-made radionuclides at critical receptor samplers in 2020

Radionuclides Included in Sum of Fractions	NNSS Area	Station	Sum of Fractions of Concentration Levels
^{241}Am, ^{238}Pu, $^{239+240}$Pu, ^{137}Cs, and ^{3}H	6	Yucca	0.0070
	10	Gate 700 S	0.0073
	16	3545 Substation	0.0025
	20	Schooner	0.0418
	23	Mercury Track	0.0040
	25	Gate 510	0.0019

As a secondary measure of NNSS compliance with air pathway dose limits, the radioactive air emissions from each NNSS sample location in Table 4-10 were modeled using the ***Clean Air Package, 1988***, model (CAP88-PC, Version 4.0; EPA 2014). Wind files containing frequency distributions of wind speed, direction, and stability class from CY 2020 meteorological stations on the NNSS were provided by the National Oceanic and Atmospheric Administration, Air Resources Laboratory, Special Operations and Research Division. CAP88-PC predicted annual dose (mrem/yr) from each emission source to each receptor was calculated. The highest value (***maximally exposed individual***) is predicted to be 0.063 mrem/yr for a person residing in Amargosa Valley (Chapter 9 has a discussion of dose to the public from all pathways).

Nearly all radionuclides detected by environmental air samplers in 2020 appear to be from two sources: (1) legacy deposits of radioactivity on and in the soil from past nuclear tests, and (2) the upward flux of ^{3}H from the soil at sites of past nuclear tests and low-level radioactive waste burial. Long-term trends of $^{239+240}$Pu and ^{3}H in air continue to show a decline with time. Radionuclide concentrations in plants and animals on the NNSS and their potential impact are discussed in Chapter 8.

4.2 Nonradiological Air Quality Monitoring and Assessment

Air Quality Assessment Program Goals

Ensure NNSS operations comply with all requirements of the current air quality permit issued by the State of Nevada. Ensure emissions of criteria air pollutants (sulfur dioxide [SO_2], nitrogen oxides [NO_X], carbon monoxide [CO], volatile organic compounds [VOCs], and particulate matter) and emissions of hazardous air pollutants do not exceed limits established under National Ambient Air Quality Standards (NAAQS) and NESHAP, respectively. Ensure emissions of permitted NNSS equipment comply with the opacity criteria set by NAAQS and New Source Performance Standards (NSPS). Ensure NNSS operations comply with asbestos abatement reporting requirements under NESHAP. Document usage of ozone-depleting substances (ODS) to comply with Title VI of the CAA.

NNSS operations that are potential sources of air pollution include aggregate production, surface disturbance (e.g., construction), release of fugitive dust from driving on unpaved roads, use of fuel-burning equipment, open burning, venting from bulk fuel storage facilities, explosives detonations, and releases of various chemicals during testing. Air quality assessments are conducted to document compliance with the current State of Nevada air quality permit that regulates specific operations or facilities on the NNSS. The assessments mainly address nonradiological air pollutants. The State of Nevada has adopted the CAA standards, which include NESHAP, NAAQS, and NSPS. NESHAP compliance with radionuclide emissions monitoring and with air pathway public dose limits are presented in Section 4.1. Compliance with all other CAA air quality standards is addressed in this section. Data collection, opacity readings, recordkeeping, and reporting activities on the NNSS are conducted to meet the specific program goals.

4.2.1 Permitted NNSS Facilities

NNSA/NFO maintains a Class II Air Quality Operating Permit (AP9711-2557.01) for NNSS activities. State of Nevada Class II permits are issued for sources of air pollutants considered "minor," i.e., where annual emissions do not exceed 100 tons of any one ***criteria pollutant***, 10 tons of any one ***hazardous air pollutant (HAP)***, or 25 tons of any combination of HAPs. The NNSS facilities regulated by permit AP9711-2557.01 include the following:

- Approximately 14 facilities/131 pieces of equipment in Areas 1, 2, 5, 6, 12, 18, 19, 20, 23, 25, 26, 27, and 29
- Chemical releases at the Nonproliferation Test and Evaluation Complex (NPTEC) in Area 5 and in Port Gaston in Area 26
- Site-wide chemical releases (conducted throughout the NNSS)
- The Big Explosives Experimental Facility (BEEF) in Area 4
- Explosives Ordnance Disposal Unit (EODU) in Area 11
- Explosives activities sites at NPTEC in Area 5; High Explosives Simulation Test (HEST) in Area 14; Test Cell C, Calico Hills, and Army Research Laboratory (ARL) in Area 25; Port Gaston in Area 26; and Baker in Area 27

4.2.2 Permit Maintenance Activities

An application to renew the NNSS air permit (AP9711-2557) was submitted to the Nevada Division of Environmental Protection (NDEP) in April 2014 prior to the permit's expiration. The air permit was issued in January 2019. Operations at the NNSS continued under a permit application "shield" until the permit was renewed. Nevada Administrative Code Chapter 445B, "Air Controls," allows for the continued operation of a stationary source until the permit is renewed or denied. The permit issued in January 2019 expired in June 2019, and an application for permit renewal was submitted to the state in April 2019. It is anticipated that the renewal of the NNSS air permit will be issued by NDEP in 2021. Until a renewed operating permit is issued by NDEP, operations at the NNSS will continue under conditions of the existing permit issued in January 2019.

New operational allowances in the 2019 permit include:

- Modification of the EODU reporting requirement to coincide with the submittal of other facility annual reports.
- Reduction of the site-wide HAP emissions cap for a single pollutant from 8 tons/yr down to 7 tons/yr. Actual emissions are typically < 1 ton/yr.

Requested permit modifications for the next permit include:

- Addition of three aggregate hoppers and three conveyors to the Erie Strayer Batch Plant (Systems 115-122).
- Relocation of the Erie Strayer Batch Plant from NNSS Area 1 to Area 6.
- Removal of Emission Units PF1.138 and PF1.139 from System 115 to add them to Area 1 Batch Plant (Systems 16–18).
- Revision to the List of Insignificant Activities to include two infrared heaters.

4.2.3 Emissions of Criteria Air Pollutants and Hazardous Air Pollutants

A source's regulatory status is determined by ***potential to emit (PTE)***, the maximum number of tons of criteria air pollutants and nonradiological HAPs it may emit in a 12-month period if the source were operated for the maximum number of hours and at the maximum production amounts specified in the source's air permit. The PTE is specified in an Air Emissions Inventory of all emission units. In past years, NNSA/NFO has submitted Actual Production/Emissions Reporting Forms to NDEP, as required by the NNSS air permit. In 2019, NDEP changed annual emissions reporting to an electronic system, the State and Local Emissions Inventory System (SLEIS). Information reported electronically includes the actual annual operational information and the calculated emissions of the criteria air pollutants and HAPs for all permitted emission units used within the calendar year. The state uses the information to determine permit fees and to verify that emissions do not exceed the PTEs. Based on operational data and corresponding SLEIS calculations of emissions for CY 2020, PTEs for permitted facilities and equipment were not exceeded.

In April 2019, NDEP determined that measuring meteorological data and monitoring of particulate matter equal to or less than 10 microns in diameter (PM10) were no longer applicable for permitted explosives activities at the NNSS. As such, for the applicable permitted facilities, this data and information is no longer collected nor reportable to NDEP.

Unless specifically exempted, the open burning of any combustible refuse, waste, garbage, or oil is prohibited. Open burning for other purposes is allowed if approved in advance by the state issuance of an Open Burn Authorization. For the NNSS, two Open Burn Authorizations are maintained and renewed annually. These authorizations are issued for fire extinguisher training and for support-vehicle live-fire training activities. In 2020, 24 fire extinguisher training sessions and 3 live vehicle burns were conducted at the NNSS. The fire extinguisher training sessions used a new system that burns propane rather than diesel fuel, resulting in greatly reduced hydrocarbon emissions. Quantities of criteria air pollutants produced by open burns are not required to be calculated or reported.

Table 4-12. Criteria air pollutants and HAPs released (in tons) on the NNSS over the past 5 years

Pollutant	2016	2017	2018	2019	2020
Particulate Matter (PM10)(b)	1.1	0.54	0.45	0.71	0.20
Carbon Monoxide (CO)	1.81	0.51	0.61	1.48	0.10
Nitrogen Oxides (NO_X)	7.47	1.21	2.8	3.27	0.34
Sulfur Dioxide (SO_2)	0.31	0.01	0.18	0.36	0.02
Volatile Organic Compounds (VOCs)	1.45	1.14	1.83	5.25	4.26
Hazardous Air Pollutants (HAPs)(c)	0.02	0.02	0.01	0.01	0.01

(a) For metric tons, multiply tons by 0.9072.
(b) Particulate matter equal to or less than 10 microns in diameter.
(c) The site-wide PTE for HAPs is 7 tons per individual HAP and 18 tons for all.

4.2.4 Performance Emission Testing and State Inspection

No performance emission testing was required or performed for any of the emission units in 2020. It is anticipated that once the renewed NNSS air permit is issued (Section 4.2.2), none of the equipment will require performance testing. In addition, no state air inspections were conducted in 2020. In August 2020, NDEP conducted a partial compliance inspection consisting of a records review.

4.2.5 Opacity Readings

Visual opacity readings are conducted in accordance with permit and regulatory requirements. Personnel who take opacity readings are certified semiannually. In 2020, five employees on the NNSS were certified. No visible emission/opacity readings were conducted during CY 2020.

4.2.6 Chemical Releases and Detonations Reporting

The NNSS air permit regulates the release of chemicals at specific locations under three separate “systems”: NPTEC in Area 5 (System 29), site-wide releases throughout the NNSS (System 81), and Port Gaston in Area 26 (System 95). The types and amounts of chemicals that may be released vary depending on the system. In 2020, no activities were conducted at these facilities.

Near-surface explosives detonations can take place at nine locations on the NNSS (BEEF in Area 4; EODU in Area 11; NPTEC in Area 5; Port Gaston in Area 26; HEST in Area 14; Test Cell C, Calico Hills, and ARL in Area 25; and Baker in Area 27). BEEF is permitted to detonate large quantities of explosives (up to 41.5 tons per detonation with a limit of 50.0 tons per 12-month period), while the other locations are limited to much smaller quantities (1 ton per detonation with a limit of 10 tons per 12-month period). Permitted limits exist also for the amounts of criteria air pollutant and HAP emissions generated by the detonations. In 2020, explosives were detonated at BEEF and EODU, and no permit limits were exceeded. Annual summary reports for activities at BEEF and EODU were completed for activities conducted in 2020. These reports were submitted to NDEP in February 2021, as required. No detonations took place at any of the other detonation permitted explosives facilities.

4.2.7 Ozone-depleting Substances Recordkeeping

At the NNSS, refrigerants containing ODS are mainly in air conditioning units in vehicles, buildings, refrigerators, drinking water fountains, vending machines, and laboratory equipment. Halon 1211 and 1301, classified as ODS, have been used in the past in fire extinguishers and deluge systems, but all known occurrences of these halons have been removed from the NNSS. ODS recordkeeping requirements applicable to NNSS operations include maintaining evidence of technician certification at all times and for 3 years, recycling/recovery equipment approval, servicing records for appliances containing 22.7 kilograms (50 pounds) or more of refrigerant, and the amount and type of refrigerant sent off site for reclamation.

4.2.8 Asbestos Abatement

A Notification of Demolition and Renovation Form is submitted to the EPA at least 10 working days prior to the start of a demolition or renovation project if the quantities of asbestos-containing material (ACM) to be removed are estimated to equal or exceed 260 linear ft, 160 square ft, or 35 ft^3. Small asbestos abatement projects are conducted during the year with the removal of lesser quantities of ACM and a Notification of Demolition and Renovation Form is not required.

Three Notification of Demolition and Renovation Forms were submitted in 2020. One notification was for demolition of a facility. Two notifications were for renovation activities at the NNSS regarding underground utility upgrades. ACM was buried in the Area 10 or Area 23 ***solid waste*** disposal site as per each project’s work plan. Friable materials are segregated in a defined section of the landfill.

The recordkeeping requirements for asbestos abatement activities include maintaining air and bulk sampling data records, abatement plans, and operations and maintenance activity records for up to 75 years; and maintaining location-specific records of ACM for a minimum of 75 years. Compliance is verified through periodic internal management assessments. Asbestos abatement records continue to be maintained as required.

4.2.9 Fugitive Dust Control

The NNSS Class II Air Quality Operating Permit states that the best practical methods should be used to prevent particulate matter from becoming airborne prior to the construction, repair, demolition, or use of unpaved or untreated areas. At the NNSS, the main method of dust control is the use of water sprays. In 2020, field personnel observed operations throughout the NNSS for the occurrence of excessive fugitive dust, and water sprays were used to control dust at sites where trenching and digging activities occurred in Areas 1, 2, 5, 6, 12, and 23.

Off the NNSS, all NNSA/NFO surface-disturbing activities that cover 5 or more acres are regulated by stand-alone Class II Surface Area Disturbance (SAD) permits issued by the state. Current SAD permits exist for the operation of three UGTA wells on the Nevada Test and Training Range: ER-EC-13, ER-EC-14, and ER-EC-15. No activities occurred at these wells in 2020, and all reporting requirements of the SAD permits were met.

4.2.10 Environmental Impact of Nonradiological Emissions

In 2020, NNSS activities produced a total of 5.50 tons of criteria air pollutants and 0.01 tons of HAPs. These small quantities had little, if any, impact on air quality on or around the NNSS. NNSS air pollutant emissions are very low compared to the estimated daily releases from point sources in Clark County, Nevada. For example, the average annual projected emissions of NO_X in Clark County for base year 2002 through projected year 2020 is 37,549 tons per year (Pollack 2007), whereas the estimated annual release from the NNSS in 2020 of 2.8 tons of NO_X represents less than 0.01% of Clark County's projected annual emissions of this criteria pollutant.

Impacts of the chemical release tests at the NNSS are minimized by controlling the amount and duration of each release. Biological monitoring at NPTEC is performed if there is a risk of significant exposure to downwind plants and animals from the planned tests. To date, chemical releases at NPTEC and other locations are such small quantities (when dispersed into the air) that downwind test-specific monitoring has not been warranted. No measurable impacts to downwind plants or animals have been observed.

4.3 References

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Chapter 5: Water Monitoring

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This chapter presents the recent results of water monitoring conducted on and near the Nevada National Security Site (NNSS) by the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) and the Environmental Management (EM) Nevada Program. NNSA/NFO and the EM Nevada Program monitor groundwater to provide safe drinking water for NNSS workers and visitors, avoid NNSS groundwater contamination from current activities, and protect the public and environment from areas of known underground contamination as a result of historical nuclear testing. Water is monitored to comply with applicable state and federal water quality and water protection regulations, DOE directives, and the Federal Facility Agreement and Consent Order (FFACO), a legally binding agreement between the DOE, the U.S. Department of Defense, and the State of Nevada. Laws and regulations applicable to water monitoring are listed in Table 2-1.

The Community Environmental Monitoring Program (CEMP) and the Nye County Tritium Sampling and Monitoring Program (TSaMP) perform annual, independent radiological monitoring of water supply systems in communities surrounding the NNSS and encourage community involvement in these efforts. The TSaMP is funded through a grant from EM Nevada Program and the CEMP is funded by NNSA/NFO. Sections 7.2 and 7.3 describe CEMP's and Nye County's groundwater monitoring activities in 2020.

5.1 Radiological Monitoring

Radiological Water Monitoring Objectives

Provide data to complete corrective actions prescribed under the FFACO to protect the public from groundwater contaminated by historical underground nuclear testing. Monitor water supply wells on the NNSS to demonstrate safety of the drinking water. Determine compliance with the dose limits to the general public via the water pathway as set by DOE Order DOE O 458.1, "Radiation Protection of the Public and the Environment" (see Chapter 9 for estimates of public dose). Monitor, operate, and maintain wells downgradient of the NNSS radioactive waste disposal unit in accordance with a Resource Conservation and Recovery Act (RCRA) permit to ensure wastes do not impact groundwater.

Radionuclides[1] have been detected in the groundwater in some areas of the NNSS and Nevada Test and Training Range (NTTR) that are a result of historical underground nuclear tests (UGTs). Between 1951 and 1992, 828 UGTs were conducted, and approximately one-third were detonated near or in the ***saturated zone*** (NNSA/NFO 2015). These UGTs are geographically grouped into underground test area (UGTA) corrective action units (CAUs), which are in various stages of corrective action (see Section 11). A complete description of the hydrogeological environment in which UGTs were conducted is in *Attachment A: Site Description*.[2]

The NNSS Integrated Groundwater Sampling Plan (EM Nevada Program 2018), referred to hereafter as the Plan, describes the approach for collecting and analyzing groundwater samples near and downgradient of historical underground nuclear test locations. The Plan applies only to sampling in UGTA CAUs that have not yet reached the closure stage (see Section 11.2); sampling requirements for CAUs in the closure stage are described in Closure Reports. In November 2020, the Plan was updated to focus on the Central and Western Pahute Mesa CAUs (CAUs 101/102) (EM Nevada Program 2020d), which are the only UGTA CAUs that have yet to enter the closure stage. While sampling in support of UGTA CAU evaluations is described in the Plan and Closure Reports, sampling requirements for compliance and NNSS ***public water system [PWS]*** wells are described within permits.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.
[2] *Attachment A: Site Description* is included on the compact disc of this report and on the NNSA/NFO web site at http://www.nnss.gov/pages/resources/library/NNSSER.html.

5.1.1 NNSA/NFO and EM Nevada Program Groundwater Sampling Design

The radiological water sampling network consists of 69 sample locations (Figure 5-1), categorized into eight different well types (Table 5-1), with some locations monitored to meet multiple objectives. The first five sample source types listed below (Characterization, Source/Plume, Early Detection, Distal, and Community) are described by the Plan and the other three are either described in a permit or a UGTA CAU Closure Report. Risks associated with groundwater contaminated by UGTs remain low due to slow groundwater movement, the immobility of some contaminants, radioactive decay, and long distances to publicly accessible groundwater supplies.

Table 5-1. Definitions and objectives for radiological water sample types

Sample Source Type	Purpose	Frequency
Characterization	Used for system characterization or model evaluation	2–3 years, as needed
Source/Plume	Located within the plume of a UGT (i.e., confirmed presence of radionuclides from test)	4 years
Early Detection	Located downgradient of, or near, a UGT and no radionuclides detected above 1,000 picocuries per liter (pCi/L)	2–5 years
Distal	Downgradient of the Early Detection area	5 years
Community	Located on Bureau of Land Management (BLM) or private land; used as a water supply source or is near one	5 years
Closure	Monitoring location supporting closure of an UGTA CAU	As specified by Closure Report
NNSS PWS	Permitted water supply well that is part of a state-designated non-community PWS on the NNSS	Quarterly
Compliance	Sampled to comply with specific federal/state regulations or permits	As specified by permit

5.1.1.1 Analytes

Most radionuclides produced by NNSS UGTs are relatively immobile in groundwater because they are bound within the melt glass produced during nuclear detonation or have chemical properties that cause them to bind strongly to the aquifer rock materials. Analysis of ***tritium (^3H)*** is required for all sampling locations as it is the radionuclide with the greatest potential for impacting groundwater quality because it is one of the most mobile in groundwater and is produced in highest abundance during nuclear testing. In addition, ^{3}H is the only radionuclide produced by NNSS UGTs known to have exceeded its U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act (SDWA) ***maximum contaminant level (MCL)*** of 20,000 pCi/L in sampling locations away from the nuclear test location or outside of tunnels used for conducting UGTs. Though ^{3}H is one of the most mobile in groundwater, it decays rapidly (half-life of 12.3 years) and is not expected to be detectable when groundwater reaches publicly accessible wells.

Tritium (^{3}H) is a radioactive form of hydrogen with a half-life of 12.3 years. The Safe Drinking Water Act limit for ^{3}H in drinking water is 20,000 pCi/L. If an individual drank water with this amount of ^{3}H for an entire year, it would amount to the same dose of radiation as a single commercial flight between Los Angeles and New York City.

pCi/L is a unit used to express the amount of radioactivity in one liter of a gas or a liquid. A picocurie is one-trillionth of a ***Curie***, and 1 pCi/L is the amount of radioactive material in 1 liter of a gas or liquid that will produce 0.037 disintegrations per second. In the case of ^{3}H, a disintegration is the emission of a beta particle.

Additional radionuclides from NNSS UGTs are analyzed in samples collected at Characterization and Source Plume locations (Table 5-2). These radionuclides, if present, are at insignificant levels (i.e., less than 0.1% of their MCL) unless ^{3}H is present at concentrations above the 20,000 pCi/L SDWA safety standard. Therefore, these radionuclides are not required to be analyzed for Early Detection, Distal, and Community sampling locations. Trends in these data will be evaluated to determine whether any additional radionuclides should be monitored in Early Detection wells in the future. ***Gross alpha*** and ***gross beta*** are analyzed along with ^{3}H for PWS and Compliance.

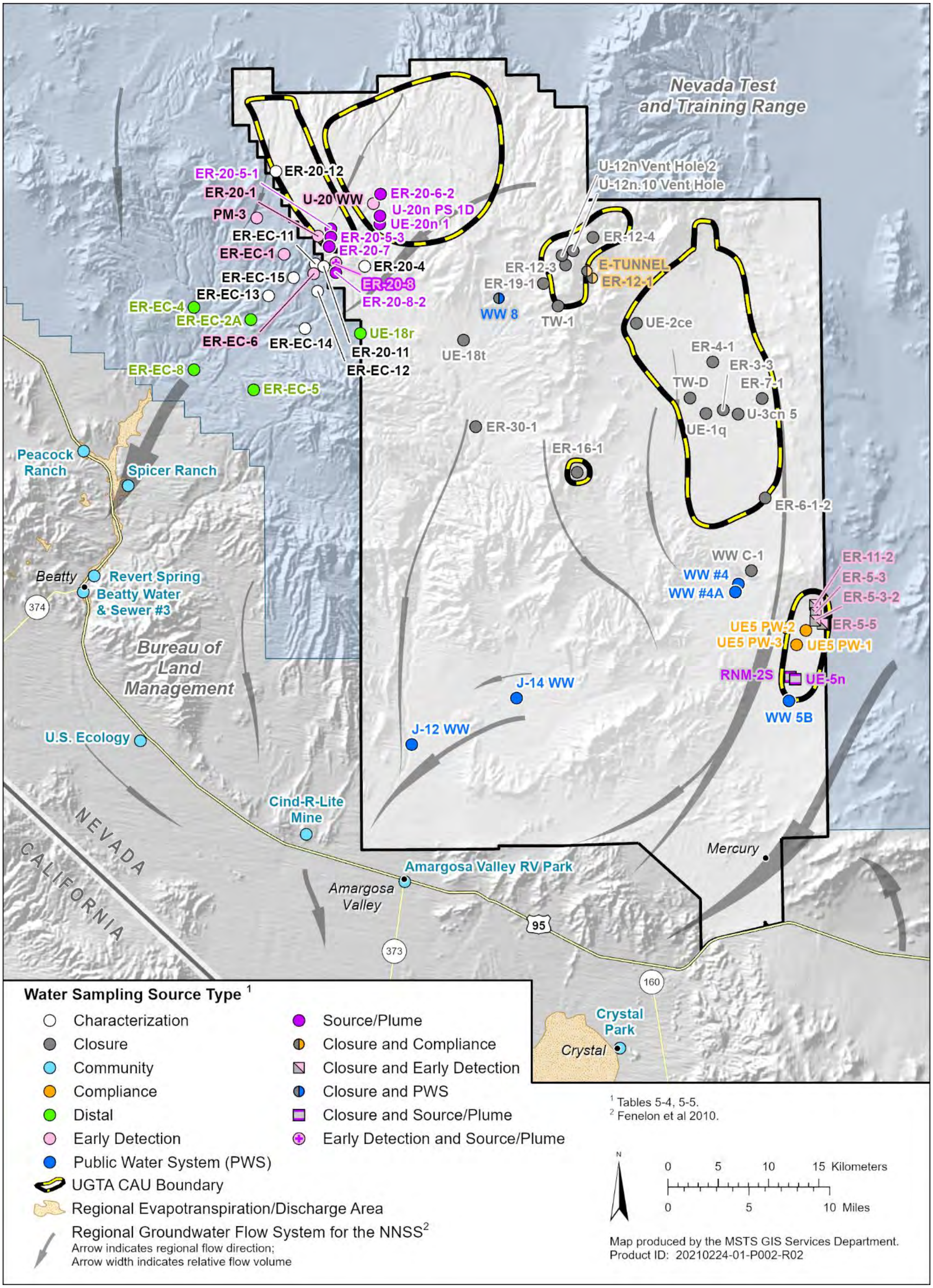

Figure 5-1. NNSA/NFO and EM Nevada Program water sampling network

Table 5-2. Radionuclides analyzed for each sample source type

Type	Radionuclide[1]
Characterization	Gross alpha, gross beta, ^{3}H, ^{14}C, ^{36}Cl, ^{90}Sr, ^{99}Tc, ^{129}I, U, Pu Gamma emitters (^{26}Al, ^{94}Nb, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{235}U, ^{241}Am, ^{243}Am)
Source Plume	^{3}H, ^{14}C, and ^{129}I (Pahute Mesa CAUs) and ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, and ^{129}I (Frenchman Flat)
UGTA Closure, Early Detection, Distal, and Community	^{3}H (additional analyses are performed for select Closure wells as described in Section 5.1.3.1)
NNSS PWS and Compliance	Gross alpha, gross beta, and ^{3}H

[1] See Table 1-5 of Chapter 1 for a listing of full names and half-lives of radionuclide abbreviations listed.

5.1.1.2 *Sample Collection Methods*

Water sampling methods are based, in part, on the characteristics and configurations of sample locations. For example, wells with dedicated pumps may be sampled from the associated plumbing (e.g., spigots) at the wellhead, while wells without pumps may be sampled using a wireline bailer or a portable pumping system. Most wells in the sample network are single-zone completion wells, meaning that the wells were constructed to collect groundwater samples from a single depth interval. Some wells, however, are multiple-completion wells constructed to allow for collecting groundwater samples at different depth intervals that access multiple formations that may or may not be connected (e.g., wells ER-EC-11, -12, -13, -14, -15, ER-20-8, and ER-20-12).

Water samples are collected following the sampling methods described in standard operating procedures. Wells that are sampled using pumps are purged until the stability of certain water quality parameters (e.g., pH, temperature, and electrical conductivity) is achieved. Stabilization of these water quality parameters indicates that formation water is being sampled instead of stagnant water from within and surrounding the wellbore. Other wells are sampled using a depth-discrete bailer to obtain representative groundwater for certain sampling objectives (e.g., demonstrate early detection of ^{3}H at levels well below the 20,000 pCi/L MCL and to evaluate trends over time).

5.1.1.3 *Detection Limits*

Standard methods for radionuclide analysis are performed by commercial laboratories that are certified by the Nevada Division of Environmental Protection (NDEP) Bureau of Safe Drinking Water. The ***minimum detectable concentration (MDC)*** using these methods must be at or below the EPA SDWA MCL. The MDC for ^{3}H analyses using a standard method (approximately 300 pCi/L) is well below the EPA SDWA-required detection limit of 1,000 pCi/L and the MCL of 20,000 pCi/L. For gross alpha and beta ***radioactivity***, the MDCs are 2 and 4 pCi/L, respectively, and satisfy their EPA SDWA-required detection limits of 3 and 4 pCi/L, respectively. Samples collected from some wells that are expected to have ^{3}H levels below 300 pCi/L (Early Detection and some Characterization wells) are enriched before ^{3}H analysis. The enrichment process (DOE 1997), referred to throughout this report as low-level ^{3}H analysis, concentrates ^{3}H in a sample to provide a lower MDC, of approximately 2 to 40 pCi/L depending on the laboratory performing the enrichment process.

Analysis routinely includes quality control samples such as duplicates, blanks, and spikes. Chapter 14 describes ***quality assurance*** and ***quality control*** procedures for groundwater samples and analyses.

- The standard ^{3}H analysis method can detect ^{3}H at levels of approximately 300 pCi/L.
- The low-level ^{3}H analysis method, which concentrates ^{3}H in a sample through an enrichment process, can detect ^{3}H at levels of 2–40 pCi/L.
- Groundwater samples collected at all Early Detection and some Characterization wells are analyzed using the low-level ^{3}H analysis method.

5.1.2 Presentation of Water Sampling Data

NNSA/NFO and the EM Nevada Program classify each well in the sample network into one of four ^{3}H concentration levels (Table 5-3). The four categories are based on the percent of SDWA MCL (20,000 pCi/L) for ^{3}H concentrations measured in the most recent sampling event (Tables 5-4 and 5-5, and Figure 5-2). Thirteen locations currently exceed the SDWA MCL; all are located on the NNSS.

Table 5-3. Tritium concentration categories

^{3}H Concentration in pCi/L	Percent of SDWA MCL	# of locations in each category
Less than 1,000	Less than 5[(a)]	53
Greater than 1,000 but less than 10,000	5–50	2
Greater than 10,000 but less than 20,000	50–100	1
Greater than 20,000	Greater than 100 (Exceeds SDWA)	13

(a) Includes samples in which ^{3}H is undetectable.

Table 5-4 shows ^{3}H concentrations for the most recent sampling events at wells in the sampling network. For wells with the same classification that were sampled at multiple depths during a single sampling event, the depth with the highest concentration is listed. For example, the Plan requires that three ***piezometers*** and the main completion of Well ER-20-12 be sampled as Characterization wells; Figure 5-2 and Table 5-4 only report the results of the shallowest piezometer for ER-20-12 because the greatest concentration of ^{3}H is associated with this sample location. Data in Table 5-4 are grouped by CAU and then by sample location type. When ^{3}H was not detected, the value is reported as less than the sample's MDC (i.e., <1.5 or <270 when the sample's MDC is 1.5 or 270 pCi/L, respectively). Results from the analyses for radionuclides other than ^{3}H (Table 5-2) are not presented in this report but can be acquired upon request from NNSA/NFO. The ^{3}H, gross alpha, and gross beta levels for water samples in 2020 for the NNSS PWS and Compliance sampling locations are listed in Table 5-5.

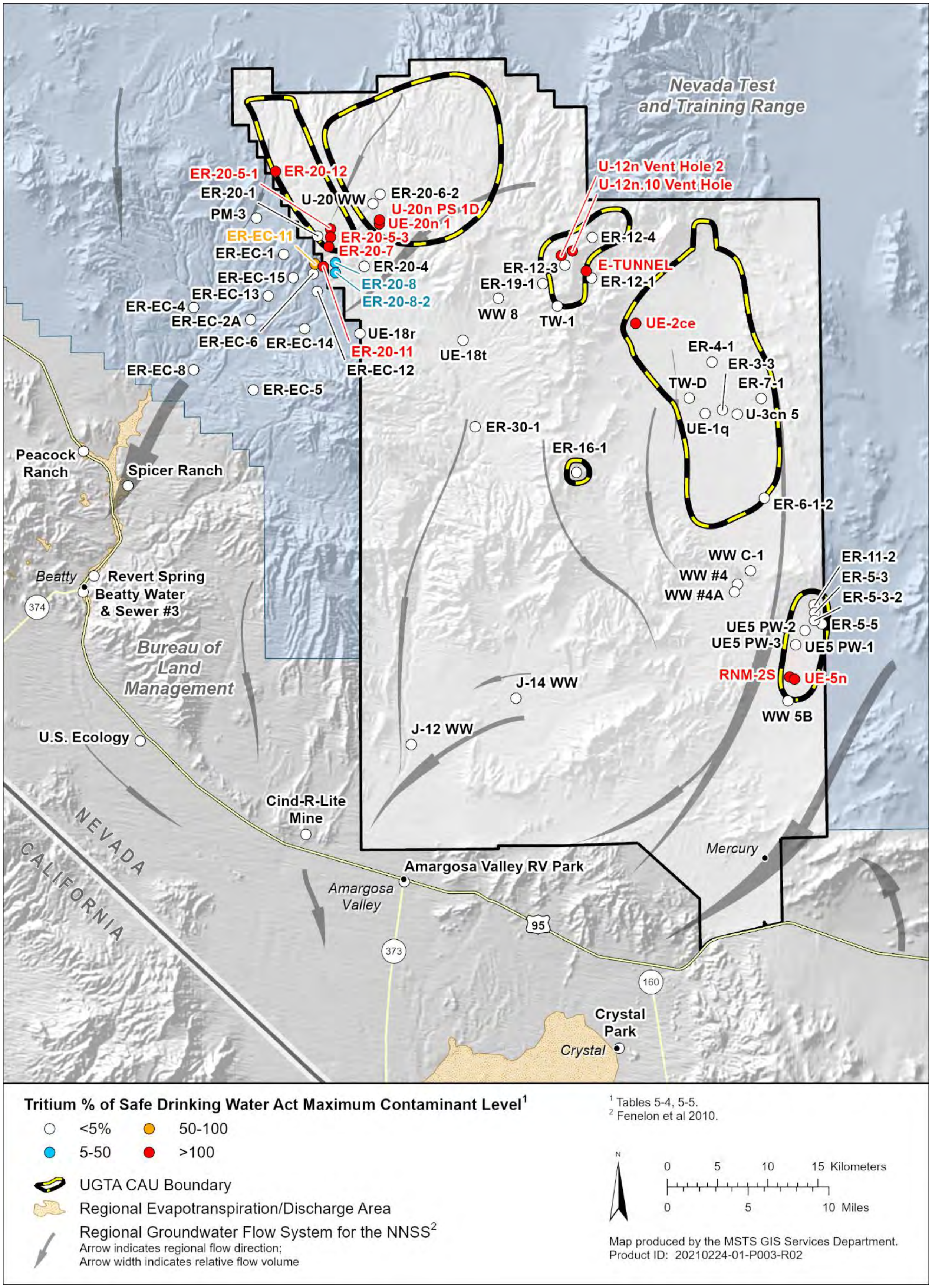

Figure 5-2. Tritium concentration categories at NNSA/NFO and EM Nevada Program sampling locations

Table 5-4. Tritium concentrations for the most recent sample at wells near and down gradient of historical underground nuclear test locations

Sample Location[(a)]	Land Management or NNSS Area	Sample Year	Maximum ^{3}H Concentration (pCi/L)[(b)]
Yellow highlight indicates ^{3}H levels above the SDWA MCL of 20,000 pCi/L			
Frenchman Flat			
Closure Wells			
ER-5-3[(c)]	Area 5	2020	<2.5
ER-5-3-2[(c,d)]	Area 5	2020	<3.0
ER-5-5[(c)]	Area 5	2020	<3.3
ER-11-2[(c)]	Area 5	2020	<2.9
RNM-2S[(e)]	Area 5	2020	65,100
UE-5n[(e)]	Area 5	2020	116,000
Rainier Mesa/Shoshone Mountain			
Closure Wells			
E Tunnel[(f)]	Area 12	2020	281,000
ER-12-1[(f)]	Area 12	2020	<296
ER-12-3[(g)]	Area 12	2020	<300
ER-12-4	Area 12	2020	<300
ER-16-1	Area 16	2020	<142
ER-19-1[(g)]	Area 19	2020	<142
ER-30-1	Area 30	2020	<143
TW-1	Area 17	2020	<142
U-12n.10 Vent Hole	Area 12	2020	4,410,000
U-12n Vent Hole 2	Area 12	2020	666,000
UE-18t	Area 18	2020	<143
WW-8[(h)]	Area 18	2020	<248
Yucca Flat/Climax Mine			
Closure Wells			
ER-3-3	Area 3	2020	<310
ER-4-1	Area 4	2020	<310
ER-5-3-2[(d)]	Area 5	2020	<3.0
ER-6-1-2	Area 6	2020	<263
ER-7-1	Area 7	2020	<300
TW-D	Area 4	2020	<273
U-3cn 5	Area 3	2020	<280
UE-1q	Area 1	2020	<276
UE-2ce	Area 2	2020	89,900
WW C-1	Area 6	2020	9.9
Pahute Mesa (Central and Western)			
Characterization Wells			
ER-20-4	Area 20	2018	<3.0
ER-20-11	Area 20	2017	202,000
ER-20-12[(g)]	Area 20	2017	58,100
ER-EC-11[(g)]	NTTR	2017	18,400
ER-EC-12[(g)]	NTTR	2018	U 3.2[(i)]
ER-EC-13[(g)]	NTTR	2019	<2.7
ER-EC-14[(g)]	NTTR	2019	<3.0[(j)]
ER-EC-15[(g)]	NTTR	2019	<2.8
Source/Plume Wells			
ER-20-5-1	Area 20	2019	20,000,000
ER-20-5-3	Area 20	2019	64,900
ER-20-6-2	Area 20	2017	U 390[(i)]
ER-20-7	Area 20	2017	13,600,000
ER-20-8_m2[(k)]	Area 20	2017	6,400
ER-20-8-2	Area 20	2017	3,670
U-20n PS 1D	Area 20	2019	13,100,000
UE-20n 1	Area 20	2019	32,600,000

Table 5-4. Tritium concentrations for the most recent sample at wells near and down gradient of historical underground nuclear test locations

Sample Location[a]	Land Management or NNSS Area	Sample Year	Maximum ^3H Concentration (pCi/L)[b]
Yellow highlight indicates ^3H levels above the SDWA MCL of 20,000 pCi/L			
Early Detection Wells			
ER-20-1	Area 20	2019	<3.2
ER-20-8_p1[k]	Area 20	2017	191
ER-EC-1	NTTR	2016	<2.9
ER-EC-6	NTTR	2018	U 4.1[i]
PM-3[g]	NTTR	2018	574
U-20 WW	Area 20	2018	<3.2
Distal Wells			
ER-EC-2A	NTTR	2019	<310
ER-EC-4	NTTR	2018	<2.7
ER-EC-5	NTTR	2019	<3.1[j]
ER-EC-8	NTTR	2016	<4.5
UE-18r	Area 18	2017	<188
Community Wells/Springs			
Amargosa Valley RV Park	BLM	2017	<211
Beatty Water & Sewer #3	Beatty	2017	<201
Cind-R-Lite Mine	BLM	2017	<205
Crystal Park	Private land	2020	<223
Peacock Ranch	Private land	2017	<209
Revert Spring	Private land	2019	<247
Spicer Ranch	Private land	2017	<205
U.S. Ecology	BLM	2017	<207

(a) Only the sample result, not the field duplicate, is reported.
(b) Concentrations presented as less than (<) a number indicate that ^3H levels are less than its sample-specific MDC shown. When the results of multiple samples are below the MDC, the lowest MDC is reported.
(c) Closure well is also an Early Detection well.
(d) Closure well for Frenchman Flat and Yucca Flat/Climax Mine CAUs.
(e) Closure well is also a Source Plume well.
(f) ER-12-1 and E Tunnel are also Compliance locations (Table 5-5).
(g) Multiple depths are sampled at this location. The highest value is presented when multiple depths are sampled within the same year.
(h) WW-8 is also an NNSS PWS well (Table 5-5).
(i) U qualifier indicates that the reported result is less than the MDC plus measurement uncertainty and is considered a nondetect.
(j) Value is qualified as an estimate because a quality control measure was outside its acceptable limit (see Chapter 14).
(k) ER-20-8_m2 accesses the shallow interval and ER-20-8_p1 access the deeper intervals of Well ER-20-8.

Table 5-5. Sample analysis results from NNSS PWS wells and Compliance wells/surface waters

Sample Location	NNSS Area	Sample Date	Concentration (pCi/L)[(a)]		
			^3H	α[(b)]	β[(b)]
NNSS PWS Wells					
J-12 WW	Area 25	1/28/2020	<249	3.6	3.1
		1/28/2020 FD[(c)]	<246	<2.2	3.3
		6/9/2020	<249	<1.8	4.9
		8/25/2020	<180	<1.4	3.0
		4th Quarter – NA[(d)]	--	--	--
J-14 WW	Area 25	NA all 2020	--	--	--
WW-4	Area 6	1/28/2020	<247	6.3	4.8
		6/9/2020	<247	7.2	3.3
		8/25/2020	<174	5.5	4.0
		8/25/2020 FD	<177	5.9	4.2
		10/27/2020	<201	8.5	5.2
WW-4A	Area 6	1/28/2020	<244	7.6	4.8
		6/9/2020	<215	7.0	4.8
		6/9/2020 FD	<230	5.6	5.6
		8/25/2020	<177	10.4	3.8
		10/27/2020	<195	5.6	4.2
WW-5B	Area 5	1/28/2020	<255	6.9	9.1
		6/9/2020	<250	4.6	8.4
		8/25/2020	<173	6.4	8.4
		10/27/2020	<201	3.2	6.1
		10/27/2020 FD	<192	3.5	8.4
WW-8	Area 18	1/28/2020	<248	<2.3	2.4
		6/9/2020	<218	1.5	3.6
		8/25/2020	<173	1.8	2.4
		10/27/2020	<188	<2.0	2.2
Compliance Wells/Surface Waters					
UE-5 PW-1	Area 5	3/24/2020	<186	5.2	6.0
		3/24/2020 FD	<181	NA	NA
		3/24/2020 FD	<188	NA	NA
		8/11/2020	<276	6.2	6.8
		8/11/2020 FD	<243	7.7	5.4
		8/11/2020 FD	<275	NA	NA
UE-5 PW-2	Area 5	3/24/2020	<180	4.1	2.6
		3/24/2020 FD	<188	NA	NA
		3/24/2020 FD	<180	NA	NA
		8/11/2020	<266	6.5	5.6
		8/11/2020 FD	<283	NA	NA
		8/11/2020 FD	<290	NA	NA
UE-5 PW-3	Area 5	3/24/2020	<185	5.9	4.5
		3/24/2020 FD	<185	NA	NA
		3/24/2020 FD	<184	7.8	3.8
		8/11/2020	<268	7.3	4.2
		8/11/2020 FD	<270	NA	NA
		8/11/2020 FD	<267	NA	NA
ER-12-1[(e)]	Area 12	8/18/2020	< 296	-24	7.3
		8/18/2020 FD	< 297	6.0[(f)]	4.4
E Tunnel Waste Water Disposal System[(e)]	Area 12	10/14/2020	281,000	5.8	25.7
		10/14/2020 FD	296,000	6.9	26.9

(a) Concentrations given as less than (<) a number indicate ^3H levels are less than its sample-specific MDC shown.
(b) α = gross alpha and β = gross beta.
(c) FD = field duplicate sample.
(d) NA = not applicable, either because the well was not operational, or the analysis was not performed.
(e) α in Well ER 12-1 and E Tunnel Waste Water Disposal System is reported as adjusted α.
(f) This value was calculated from the reanalysis of the sample, and is not the FD sample value.

5.1.3 Discussion of 2020 Sample Results

The following sections discuss results for the eight sample source types that comprise the radiological water-sampling network (Table 5-1). As illustrated in Figure 5-1, Community wells or springs are on lands managed by BLM or on private land and all other water-sampling network wells are on properties managed by the government. As reflected in Table 5-4 and discussed in the sections below, no test-related radionuclides have been detected in the Distal or Community wells. Consistent with the definition of Early Detection wells (^{3}H levels are less than 1,000 pCi/L), low concentrations of ^{3}H have been detected at a few locations. As reflected in Table 5-5, sampling results from NNSS PWS wells indicate that water sources used by NNSS personnel are not affected by past UGTs. In addition, all regulatory requirements associated with Compliance samples were satisfied.

5.1.3.1 Closure Wells

Characterization activities have been completed and advancement to the closure stage has been achieved for three UGTA CAUs: Frenchman Flat (CAU 98), Rainier Mesa/Shoshone Mountain (CAU 99), and Yucca Flat/Climax Mine (CAU 97). Closure Reports that describe the required post-closure monitoring program have been developed and approved by NDEP (NNSA/NFO 2016; NNSA/NFO 2019; EM Nevada Program 2020a,b,c). Post-closure monitoring results for these CAUs are summarized below and are further discussed in Section 11.2.1.

Frenchman Flat Post-Closure Monitoring: The Closure Report for the Frenchman Flat CAU, approved by NDEP in 2016 (NNSA/NFO 2016), specifies the monitoring program for the first 5 years post-closure (2016 to 2020). The Frenchman Flat monitoring network consists of six Closure wells (Table 5-4). Four of these wells (ER-5-3, ER-5-5, ER-5-3-2, and ER-11-2) are also categorized as Early Detection wells and analyzed for low-level ^{3}H. No ^{3}H was detected in samples collected from these wells in 2020 (Table 5-4). Two Closure wells (RNM-2S and UE-5n) are also categorized as Source/Plume wells and analyzed for ^{3}H, ^{14}C, ^{36}Cl, ^{99}Tc, and ^{129}I. Groundwater of these wells is impacted by a radionuclide migration experiment at the CAMBRIC UGT. Pumping at RNM-2S pulled groundwater containing radionuclides from the CAMBRIC UGT. UE-5n groundwater was impacted from infiltration of water from the unlined ditch used to transport water pumped during the experiment (Rose et al. 2003). Pumping and discharge occurred from 1975 to 1991, with two additional short periods of pumping in 1999 and 2003. Tritium concentrations in these wells over this time period are presented in Figure 5-3 (Navarro 2021).

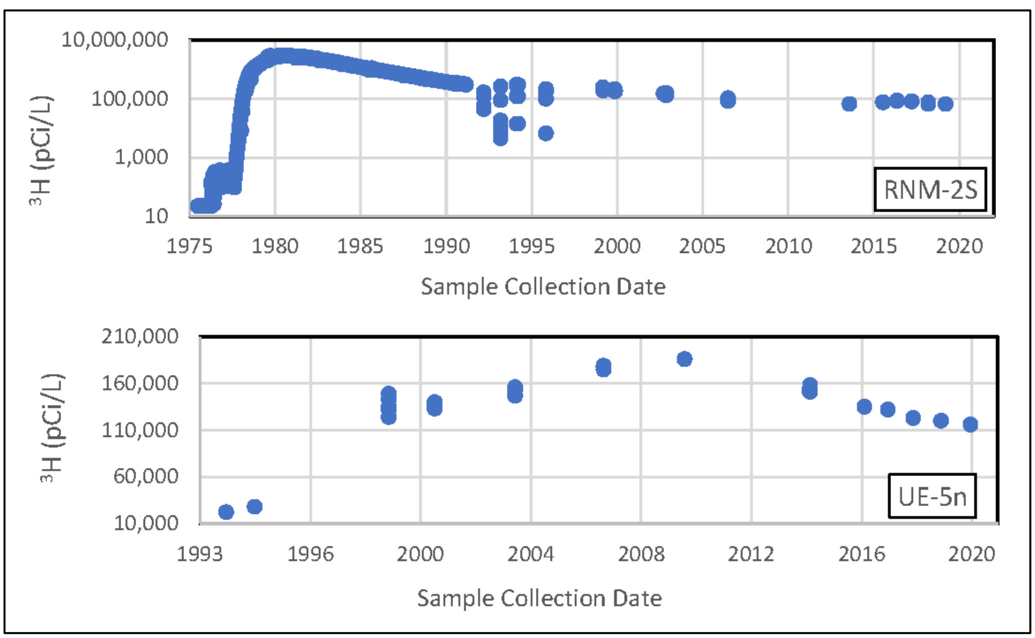

Figure 5-3. ^{3}H trends in Two Frenchman Flat wells

In 2019, the ^{3}H concentrations of a sample and a duplicate from RNM-2S were 65,000 pCi/L and 74,800 pCi/L, respectively. In 2020, the ^{3}H concentrations for the RNM-2S sample and its duplicate were 65,100 pCi/L and 65,000 pCi/L, respectively (an average of 7% decrease from 2019). This is consistent with the slowly decreasing trend observed over the last decade after peak breakthrough occurred in 1980 (Figure 5-3). The ^{3}H in UE-5n decreased from 120,000 pCi/L in 2019 to 116,000 pCi/L in 2020, which is consistent with the decreasing trend following peak breakthrough in 2009 (Figure 5-3). No other radionuclides were detected in the 2020 samples.

Rainier Mesa/Shoshone Mountain Post-Closure Monitoring: The Closure Report for the Rainier Mesa / Shoshone Mountain CAU, establishing the post-closure monitoring network, was approved by NDEP in 2020 (EM Nevada Program 2020c). The monitoring network includes 12 locations; two locations, ER-12-3 and ER-19-1, are sampled at two separate depths. Sampling for ^{3}H is required every 6 years. Additional radionuclides (^{3}H, ^{14}C, ^{36}Cl, ^{90}Sr, ^{99}Tc, ^{129}I, and $^{238/239/240}$Pu) are analyzed at three locations that sample water from tunnels where nuclear testing occurred (E Tunnel, U-12n.10 Vent Hole, and U-12n Vent Hole 2). E Tunnel, as well as ER-12-1, are also compliance locations and are discussed further in Section 5.1.3.8. These locations were sampled in 2020 and the ^{3}H results are presented in Table 5-4. Tritium at a concentration above SDWA MCL is present in the three locations accessing the tunnels. A decrease in ^{3}H concentration from 5,550,000 pCi/L (2017) to 4,410,000 pCi/L (2020) was observed at U-12n.10 Venthole and from 930,000 pCi/L (2017) to 666,000 pCi/L (2020) at U-12n10 Venthole 2. The trends in ^{3}H concentration for the vent holes are presented in Figure 5-4. No ^{3}H is observed in monitoring locations downgradient of the tunnels.

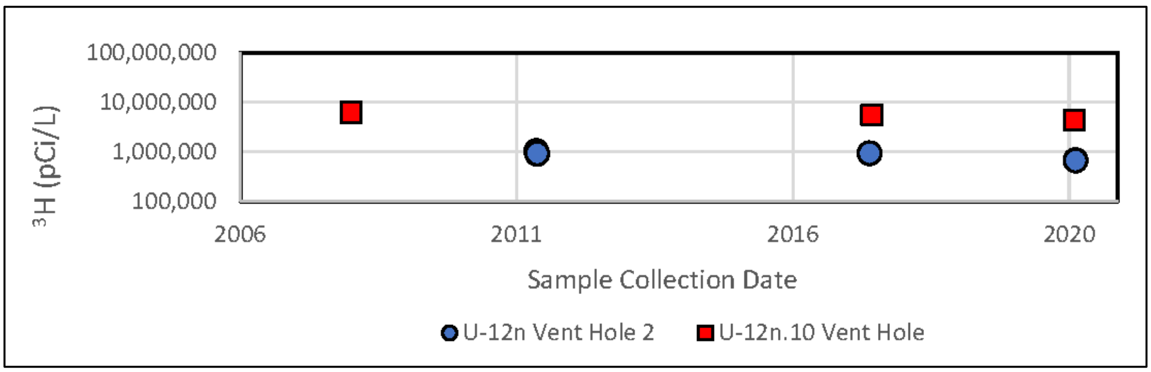

Figure 5-4. ^{3}H trend in vent holes within Rainier Mesa N Tunnel

Yucca Flat/Climax Mine Post-Closure Monitoring: The Closure Report for the Yucca Flat/Climax Mine CAU, establishing the post-closure monitoring network, was approved by NDEP in 2020 (EM Nevada Program 2020a,b). The monitoring network includes 10 Closure Wells, all of which are sampled for ^{3}H. Eight wells in Yucca Flat and one well in Frenchman Flat are sampled every 6 years and one well in Yucca Flat, WW C-1, is sampled annually for the next 6 years. Note that ER-5-3-2 is also a monitoring well for the Frenchman Flat CAU. These wells access the lower carbonate aquifer (LCA), which is a regional aquifer and the only pathway out of Yucca Flat (Navarro 2019). Sampling the LCA in Yucca Flat and in Frenchman Flat supports the regulatory boundary objective to verify that radionuclide contamination from this CAU is contained within the Yucca Flat basin, thus not impacting the Frenchman Flat LCA or downgradient receptors (EM Nevada Program 2020a,b). These wells were sampled in 2020 and the analytical results for ^{3}H are presented in Table 5-4. With the exception of UE-2ce and WW C-1, no ^{3}H was detected in the 2020 samples. Well UE-2ce is located 183 meters (600 feet [ft]) south of the Nash UGT, which was detonated within the carbonate aquifer near the water table. UE-2ce was used to support a radionuclide migration experiment where approximately 11 million gallons of groundwater were pumped between 1977 and 1984 (Buddemeier and Isherwood 1985). The ^{3}H concentration in Well UE-2ce is on average 38% lower than the concentration reported in 2016 (144,000 pCi/L) and 99.9% lower than the maximum concentration (65,000,000 pCi/L) reported in 1978 (Figure 5-5). The ^{3}H concentration in WW C-1 was similar in 2020 (9.9 pCi/L) when compared to 2019 (12.2 pCi/L). These values are less than 0.1 percent of the 20,000 pCi/L SDWA MCL.

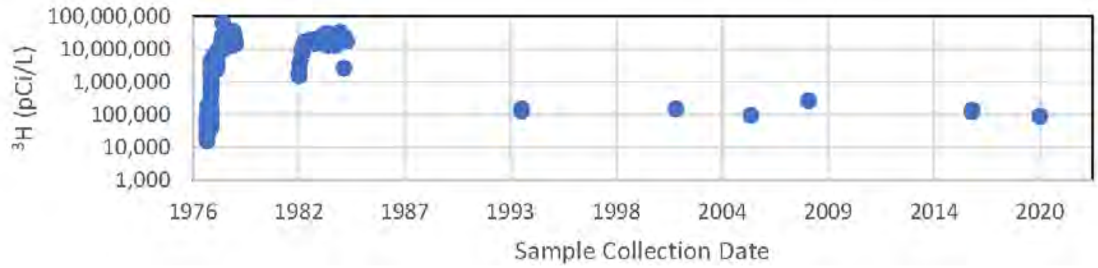

Figure 5-5. ^{3}H trends in Yucca Flat Well UE-2ce

5.1.3.2 Characterization Wells

^{3}H was detected in Well ER-EC-11, a Characterization well in the Pahute Mesa CAUs, in 2009 at 10,600 pCi/L. This was the first time that a radionuclide from NNSS UGTs had been detected in groundwater beyond NNSS boundaries. In 2017, it was detected at 18,400 pCi/L. This concentration is below the allowable drinking water limit of 20,000 pCi/L set by the EPA.

Characterization wells are either new wells or wells that require additional radionuclide data to establish a baseline and/or to ensure the current list of radionuclides is accurate for monitoring the CAU. A large suite of radionuclides are analyzed in samples collected from Characterization wells (Table 5-2). Once a baseline has been developed, each Characterization well will be reclassified and sampled according to its new type (Source/Plume, Early Detection, or Distal). Characterization wells in the Yucca Flat/Climax Mine and Rainier Mesa/Shoshone Mountain CAUs were reclassified as Closure wells. Also, two wells (ER-EC-4 and ER-EC-5) were reclassified from Characterization to Distal wells in the revised Plan (EM Nevada Program 2020d). A total of eight Characterization wells, six accessing multiple (2–4) depths, are located within the Pahute Mesa CAUs (Figure 5-1). Results for these Characterization locations are presented in Table 5-4; only the depth with the greatest ^{3}H concentrations is reported for each location. As shown in Table 5-4, ^{3}H in the Characterization wells ranges from below the 2.7 pCi/L MDC in well ER-EC-13 located on the NTTR to more than 200,000 pCi/L in well ER-20-11 located on the NNSS (Figure 5-1). While ^{3}H is not present in most wells on the NTTR, it has been detected at ER-EC-11. ER-EC-11 along with the other "ER-EC" wells monitors a contaminant plume believed to originate from the TYBO and BENHAM UGTs, which were detonated in 1975 and 1968, repectively. ER-EC-11 is the first location where a radionuclide from NNSS UGTs had been detected in groundwater beyond NNSS boundaries. In 2017, ^{3}H was detected at 18,400 pCi/L at ER-EC-11 (Table 5-4). No Characterization wells were sampled in 2020.

5.1.3.3 Source/Plume Wells

Source/Plume wells are located within the plume from a UGT where ^{3}H is present at or exceeds (or has exceeded) 1,000 pCi/L. These locations are sampled to support flow and transport model development, identify potential radionuclides of concern to be monitored by downgradient wells, and to monitor contaminant migration (EM Nevada Program 2020d). Source/Plume wells are analyzed for ^{3}H and additional CAU-specific radionuclides (Table 5-2). Eight Source/Plume wells are located in Pahute Mesa and two are located in Frenchman Flat. Locations in Pahute Mesa range from those accessing the nuclear test cavity (U-20n PS 1D) to those downgradient of a UGT (e.g., ER-20-8-2) where lower concentrations are observed (Table 5-4). A ^{3}H concentration near the 320 pCi/L-MDC is observed at one Source/Plume well (ER-20-6-2) (Table 5-4). This well was used for a pumping experiment in 1997 to evaluate radionuclide movement away from the Bullion UGT within the Central Pahute Mesa CAU. The ^{3}H concentration decreased from 70,800 to 7,000 pCi/L during the pumping experiment (Lawrence Livermore National Laboratory [LLNL] 1998). The ^{3}H concentration in 2017 is a significant decrease from the concentration reported 20 years ago. Although the ^{3}H is less than 1,000 pCi/L in this well, it is still considered a Source/Plume well because of the previously high ^{3}H observed. No Source/Plume wells in Pahute Mesa were sampled in 2020. Results of 2020 sampling of Source/Plume wells in Frenchmna Flat, also classified as Closure wells, are presented in Section 5.1.3.1.

5.1.3.4 *Early Detection Wells*

Early Detection wells are the next wells downgradient of a UGT or Source/Plume well and are monitored to detect the presence of a plume well before concentrations reach levels near the 20,000-pCi/L SDWA MCL. Early Detecion wells are recategorized as Source Plume wells if ^{3}H levels reach 1,000 pCi/L. The new Plan (EM Nevada Program 2020d) revised this from the previous 300-pCi/L criterion. In the absence of ^{3}H, no other test-related radionuclides are present in historically sampled groundwater; therefore, Early Detection wells are monitored solely for ^{3}H. The low-level ^{3}H method is used for the analyses when concentrations are less than 300 pCi/L and the standard ^{3}H method is used when levels exceed 300 pCi/L.

Six Early Detection wells are located in Pahute Mesa and are sampled once every 5 years (EM Nevada Program 2020d). The ^{3}H in PM-3 ranged from 192 pCi/L (deep *piezometer*) to 574 pCi/L (shallow *piezometer)* in samples collected in 2018. Both piezometers are now classified as Early Detection wells (EM Nevada Program 2020d). PM-3, located downgradient of the HANDLEY UGT, is the second location where a radionuclide from NNSS UGTs had been detected in groundwater beyond NNSS boundaries. The ^{3}H level is less than 3% of the SDWA MCL. No Early Detection wells in Pahute Mesa were sampled in 2020. Results of 2020 samples collected from Early Detection wells in Frenchman Flat, also classified as Closure wells, are presented in Section 5.1.3.1.

5.1.3.5 *Distal Wells*

Distal wells are sampled to demonstrate that ^{3}H is not present downgradient of UGTs at levels exceeding the SDWA-required minimum detection limit of 1,000 pCi/L. Data from these wells also support the development and evaluation of the groundwater flow and contaminant transport models. Distal well samples, collected at a 5-year frequency, are analyzed for ^{3}H using the standard EPA method. Five Distal wells are located in the Pahute Mesa CAUs. No ^{3}H was detected at these locations (Table 5-4). No Distal wells were sampled in 2020.

5.1.3.6 *Community Wells/Springs*

The community sampling network comprises nine locations that are associated with the Pahute Mesa CAUs (Table 5-4). These wells and springs are used as private, business, or community water supply sources or are near such sources, and they are sampled for ^{3}H every 5 years. Sampling at a 5-year frequency is sufficient because of the long flow paths to these locations, the slow groundwater velocities, and the monitoring of Early Detection wells upgradient from the community wells and springs. Early Detection well samples will detect the arrival of a contaminant plume at very low concentrations (i.e., measuring ^{3}H at 0.01% of its MCL) long before such a plume could be detected in these more distant private, business, or community water supply sources. Samples are analyzed using a standard EPA method. The objective is to demonstrate that ^{3}H is not present at levels exceeding the SDWA-required minimum detection limit of 1,000 pCi/L. Crystal Park was sampled in 2020 and ^{3}H was not detected. No ^{3}H has been detected at any community location (Table 5-4 and Chapter 7).

5.1.3.7 *NNSS Public Water System Wells*

Results from the NNSS PWS water wells sampled quarterly in 2020 continue to indicate that historical underground nuclear testing has not impacted the NNSS water supply network. No ^{3}H measurements exceeded MDCs using the EPA standard analysis method (Table 5-5). Gross alpha and gross beta radioactivity were found at concentrations slightly greater than MDCs in most 2020 samples and are believed to represent the presence of naturally occurring radionuclides. However, no water supply samples had gross alpha measurements that exceeded the EPA MCL (15 pCi/L) or gross beta measurements that exceeded the EPA level of concern (50 pCi/L).

5.1.3.8 *Compliance Wells/Groundwater Discharges*

5.1.3.8.1 *RCRA Permitted Wells for the Area 5 Mixed Waste Disposal Unit*

Wells UE-5 PW-1, UE-5 PW-2, and UE-5 PW-3 are sampled semi-annually for ^{3}H. They are monitored for ^{3}H and nonradiological parameters (Section 10.1.1) to verify the performance of the Area 5 Mixed Waste Disposal Unit (Cells 18 and 25), which is operated under a RCRA permit. In 2020, standard ^{3}H analyses of water samples from these wells were performed; all samples had non-detectable levels of ^{3}H (Table 5-5), and MDCs were less than the permit-established investigation level (IL) of 2,000 pCi/L. Further groundwater analysis is required if the IL is exceeded. Results continue to indicate that Cell 18 and Cell 25 radioactive wastes have not contaminated local groundwater. Table 10-4 presents the 2020 sampling results for four additional indicators of groundwater contamination, and all 2020 sample analysis results for these three wells are presented by the NNSS Management and Operating (M&O) Contractor, Mission Support and Test Services, LLC (MSTS), in MSTS (2021).

Drilling of a fourth monitoring well (UE5 MW-4) began in December 2019 and was completed in February 2020. A pump with a pump rate compatible with the well production rate was installed in April 2021, and after purging 4,380 gallons, samples were collected to evaluate the well condition. The results indicated that more purging would be needed to ensure no drilling contaminants are included in future samples. Prior to collecting samples in August 2021, an attempt will be made to purge approximately 12,000 gallons.

5.1.3.8.2 NDEP Permitted E Tunnel Waste Water Disposal System

NNSA/NFO manages and operates the NNSS Area 12 E Tunnel Waste Water Disposal System (ETDS) in accordance with the NDEP Bureau of Federal Facilities water pollution control permit (NEV 96021), Revision 1. The permit governs the management of radionuclide-contaminated wastewater that discharges from the E Tunnel portal into a series of conveyance pipes and earthen holding/infiltration ponds.

The permit requires chemical and radiological constituents monitoring of the ETDS effluent and groundwater associated with nearby Well ER-12-1. Tritium, adjusted gross alpha, and gross beta activities are measured in ETDS effluent annually. Groundwater ^{3}H, adjusted gross alpha, and gross beta activities are required to be measured biennially at Well ER-12-1. Negotiations between NDEP, NNSA/NFO, and the EM Nevada Program resulted in sampling Well ER-12-1 in 2020, in advance of the permit-required 24-month interval. This was negotiated so that the UGTA 6-year sampling interval aligned with the permit's 24-month interval, and both requirements would be satisified with one sampling event in 2020 and subsequent 6-year intervals. The permissible limits of ^{3}H, adjusted gross alpha, and gross beta in the ETDS effluent are 1,000,000 pCi/L, 35.1 pCi/L, and 101 pCi/L, respectively. The permissible limits for ^{3}H, adjusted gross alpha, and gross beta in groundwater of Well ER-12-1 are 20,000 pCi/L, 15 pCi/L, and 50 pCi/L, respectively.

Monitoring personnel sampled the ETDS effluent on October 14, 2020, and sampled Well ER-12-1 on August 18, 2020 (Table 5.5). All radiological parameters were within their permissible and threshold limits. The initial calculated adjusted gross alpha result for Well ER-12-1 yielded a concentration of -24 pCi/L. The same sample was later reanalyzed and the concentration was calculated to be 6.0 pCi/L. Non-radiological results and associated threshold limits are provided in Section 5.2.4.

5.1.3.8.3 UGTA Well Discharged Groundwater and Fluids

UGTA wells are regulated through an agreement between DOE and NDEP called the Fluid Management Plan for the UGTA Project (Attachment 1 of NNSA/NFO 2009). The Fluid Management Plan is used in lieu of an NDEP-approved water pollution control permit for management of fluids produced during the drilling, construction, development, testing, experimentation, and/or sampling of wells by the UGTA Activity. The plan provides criteria by which fluids may be discharged on site and applies to groundwater purged (pumped) from the well during sampling. Groundwater ^{3}H concentrations are measured daily during sampling activities. Groundwater with ^{3}H greater than or equal to 400,000 pCi/L is discharged to lined sumps to evaporate. Groundwater with ^{3}H activity less than 400,000 pCi/L may be discharged to either lined/unlined sumps or infiltration areas. Fluid Management Plan samples are collected to analyze for metals, gross alpha, gross beta, and ^{3}H, unless previously demonstrated that these analyses have satisfied criteria established by the plan.

All requirements of the UGTA Fluid Management Plan were satisfied in 2020. No wells with ^{3}H greater than or equal to 400,000 pCi/L were pumped for sample collection in 2020. Although ^{3}H exceeded 400,000 pCi/L at two locations, u-12n.10 vent hole and u-12n vent hole 2, these locations were sampled in 2020 with a bailer and no groundwater was discharged to the ground surface. Groundwater from pumped wells with ^{3}H less than 400,000 pCi/L was discharged to either lined/unlined sumps or infiltration areas. Criteria for all Fluid Management Plan samples were within threshold levels established in the plan.

5.2 Nonradiological Drinking Water and Wastewater Monitoring

Nonradiological Water Monitoring Goals

Ensure that the operation of NNSS PWSs and private water systems provides high-quality drinking water to workers and visitors at the NNSS. Determine if NNSS PWSs are operated in accordance with the requirements in Nevada Administrative Code NAC 445A, "Water Controls," under permits issued by the state. Determine if the operation of commercial septic systems that process domestic wastewater on the NNSS meets operational standards in accordance with the requirements of NAC 445A under permits issued by the state. Determine if the operation of industrial wastewater systems on the NNSS meets operational standards of federal and state regulations as prescribed under the GNEV93001 state permit.

Federal and state laws regulate the quality of drinking water and wastewater on the NNSS. The design, construction, operation, and maintenance of many of the drinking water and wastewater systems are regulated under state permits. NNSA/NFO ensures systems meet applicable water quality standards and permit requirements. The NNSS nonradiological water monitoring goals are shown below. They are met by analyzing water samples, performing assessments, and maintaining documentation. This section describes the results of 2020 activities. Results from radiological monitoring of drinking water on and off the NNSS and of wastewater on the NNSS are discussed in Section 5.1.3.

5.2.1 Drinking Water Monitoring

Six wells on the NNSS are permitted to supply the potable water needs of NNSS operations. These are grouped into three PWSs (Figure 5-6). The largest system (NNSS Main) is classified under its permit as a non-transient non-community PWS and serves the main work areas of the NNSS. The other two systems (NNSS Area 12 and Area 25) are classified as transient non-community PWSs. The PWSs are designed, operated, and maintained in accordance with the requirements in NAC 445A under permits issued by the NDEP Bureau of Safe Drinking Water (BSDW). PWS permits are renewed annually.

The three PWSs must meet National Primary Drinking Water Standards and Secondary Standards (set by the state) for water quality. They are sampled according to a 9-year monitoring cycle, which identifies the specific classes of contaminants to monitor at each drinking water source, and the frequency (Table 5-6). At sample locations in buildings, the sampling point for coliform bacteria is a sink within the building. Samples for chemical contaminants are collected at the points of entry to the PWS. Although not required by regulation or by any permit, NNSA/NFO collects samples inside service connections for coliform bacteria to further ensure safe drinking water.

In addition to the monitoring required under the PWS permits, NNSA/NFO has been actively evaluating the potential for per- and polyfluoroalkyl substances (PFAS) contamination in the drinking water supply, an emerging concern across the nation. While the NNSS is generally considered a low risk for PFAS contamination of the groundwater, the six permitted wells and PWS points of entry were monitored in 2020, with the samples analyzed by a Nevada certified laboratory. All results were non-detect at less than 1 nanogram per liter (part per trillion). A regulatory MCL has not been established for PFAS compounds, as the EPA and others continue to research this issue. More information can be found at https://www.epa.gov/pfas.

For work locations at the NNSS not connected to a PWS, NNSA/NFO hauls potable water in two water tanker trucks. The trucks are permitted by the BSDW, and the water they carry is subject to water quality standards for coliform bacteria (Table 5-6). Normal water delivery is to remote service connections and hand-washing stations at construction sites, which are activities not subject to permitting. NNSA/NFO renews the permits for the trucks annually.

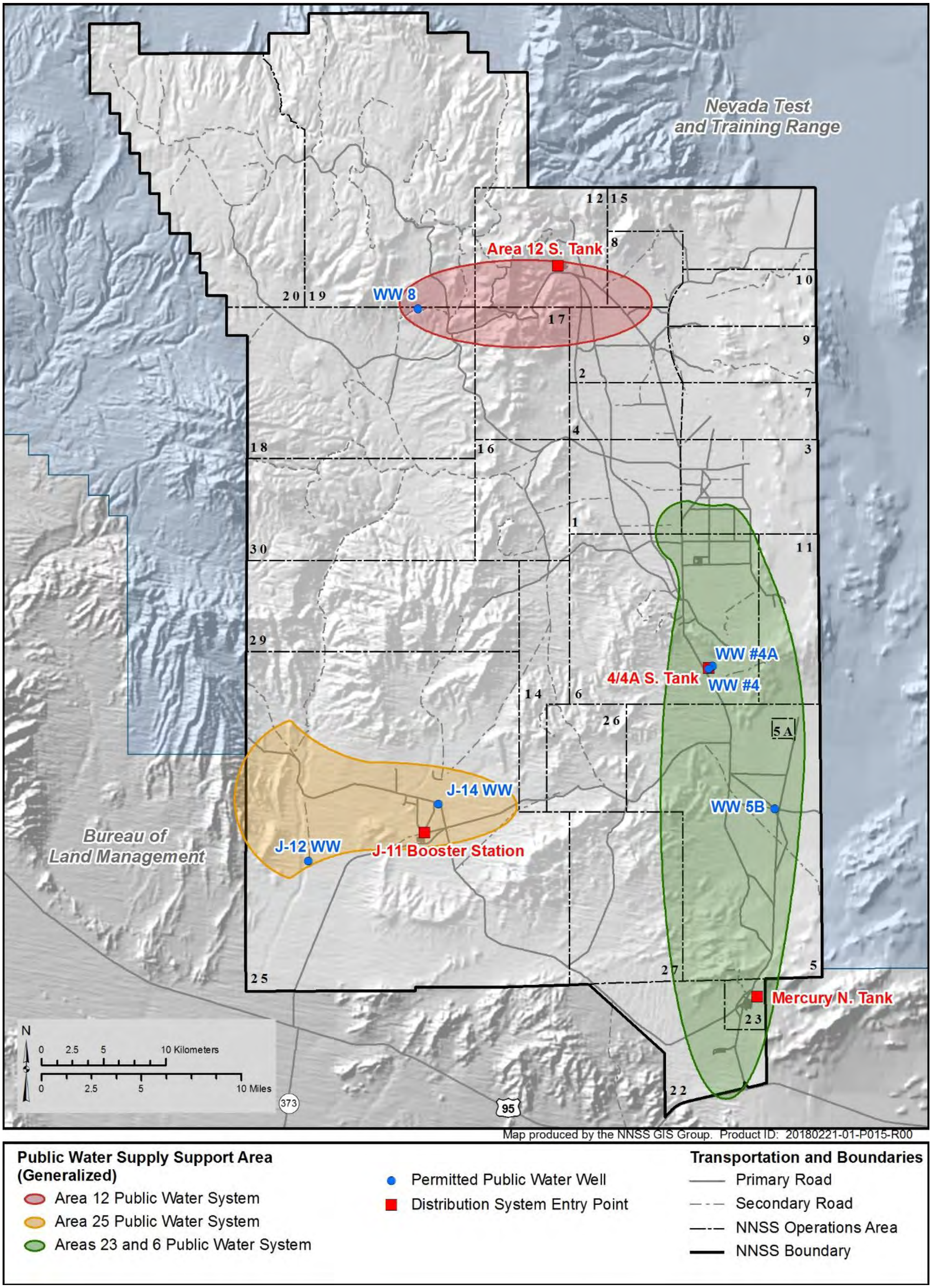

Figure 5-6. Water supply wells and drinking water systems on the NNSS

Table 5-6. Current sampling requirements for permitted NNSS PWSs and water-hauling trucks

System/ Truck	Contaminant or Contaminant Category	Sample Location	Sampling Cycle	Number of Samples
NNSS Main	**National Primary Standards**			
	Coliform	WDP-23/6[a]	monthly	2
	Disinfectant residual	WDP-23/6	monthly	2
	Asbestos	WDP-23/6	9 year	1
	Disinfection by-products	WDP-23/6	1 year	1
	Lead and copper	WDP-23/6	3 year	10
	Arsenic	POE-23/6[b]	3 year	1
	IOCs[c] - Phase 2 and 5[d]	POE-23/6	9 year	1
	Nitrate	POE-23/6	1 year	1
	Nitrite	POE-23/6	3 year	1
	SOCs[e] - Phase 2 and 5	POE-23/6	6 year	1
	VOCs[f] - Phase 2 and 5	POE-23/6	3 year	1
	Secondary Standards			
	Secondary IOCs	POE-23/6	3 year	1
Area 12 and Area 25	**National Primary Standards**			
	Coliform	WDP-12/25[g]	quarterly	1
	Nitrate	POE-12/25[h]	1 year	1
	Nitrite	POE-12/25	3 year	1
	Secondary Standards			
	Secondary IOCs	POE-12/25	3 year	1
Water-hauling Trucks				
Trucks 84846 and 84847	Coliform Bacteria	Truck valve	monthly	1

(a) WDP–23/6 = Water delivery points for the NNSS Main PWS: taps within Buildings 5-7, 6-609, 6-900, 22-1, 23-180, 23-701, 23-777, 23-1103, and the U1H restroom.
(b) POE–23/6 = Points of entry for the Area 23 and 6 PWS: Mercury N. Tank and 4/4A S. Tank (Figure 5-6).
(c) IOCs = Inorganic chemicals.
(d) Refers to sets of chemical contaminants in drinking water for which the EPA established MCLs through a series of rules known as the Chemical Phase Rules issued from1987 (Phase 1) through 1992 (Phase 5); http://water.epa.gov/lawsregs/rulesregs/sdwa/chemicalcontaminantrules/basicinformation.cfm.
(e) SOCs = Synthetic organic chemicals.
(f) VOCs = Volatile organic compounds.
(g) WDP-12/25 = Water delivery points for the Area 12 and Area 25 PWSs: Buildings 12-909 and 25-3123 or 25-4222.
(h) POE-12/25 = Points of entry for the Area 12 and Area 25 PWSs: Area 12 S. Tank, J-11 Booster Station, and J-14 WW (Figure 5-6).

5.2.1.1 Results of Public Water System and Water-Hauling Truck Monitoring

Water samples are collected in accordance with accepted practices, analyses are conducted by state-certified laboratories, and analytical methods are approved as listed in NAC 445A and Title 40 ***Code of Federal Regulations (CFR)*** Part 141, "National Primary Drinking Water Standards." The 2020 monitoring results indicated all of the PWSs complied with applicable National Primary Drinking Water Quality Standards (Table 5-7). In addition, water samples from the water-hauling trucks were negative for coliform bacteria.

5.2.1.2 State Inspections

Approximately every 3 years, NDEP conducts a sanitary survey of the permitted PWSs that includes an inspection of wells, tanks, and other visible portions of each PWS. The last NDEP survey was in 2017; no sanitary surveys were conducted in 2020. Water-hauling trucks are inspected annually for compliance with NAC 445A; truck inspections were in June 2020, and NDEP renewed both permits.

Table 5-7. Water quality analysis results for NNSS PWSs

Contaminant	Maximum Contaminant Level (mg/L)[a]	2020 Results (mg/L)		
		Area 23 and 6 PWS	Area 12 PWS	Area 25 PWS
Coliform Bacteria	Absent in all samples	Absent in all samples	Absent in all samples	Absent in all samples
Secondary Standards				
Aluminum	0.2	NA[b]	0.068 U[c]	NA
Chloride	400.0	NA	8.85	NA
Color	15 color units	NA	7.5	NA
Copper	1.0	NA	0.003 U	NA
Fluoride	2.0	NA	0.79	NA
Iron	0.6	NA	0.38	NA
Magnesium	150.0	NA	0.034	NA
Manganese	0.1	NA	0.034	NA
Odor	3.0 threshold odor number	NA	0	NA
pH	6.5-8.5	NA	7.71	NA
Silver	0.1	NA	0.001 U	NA
Sulfate	500.0	NA	15.4	NA
Surfactant (MBAS)	0.10	NA	<0.10	NA
Total Dissolved Solids	1000.00	NA	150	NA
Zinc	5.0	NA	0.005 U	NA
Inorganic Chemicals				
Nitrate	10 (as nitrogen)	4.0	1.1	1.9
Disinfection By-products				
Total Trihalomethanes	0.080	0.030	NA	NA
Haloacetic Acids	0.060	0.004	NA	NA

(a) mg/L = milligrams per liter.
(b) NA = Not applicable, no requirement to sample in 2020.
(c) U = Flagged by the analytical laboratory as below detection limits.

5.2.2 Domestic Wastewater Monitoring

A total of 17 active and permitted domestic wastewater septic systems are being used on the NNSS (Figure 5-7). The septic systems are permitted to process/store up to 5,000 gallons of wastewater per day. They are inspected periodically for sediment loading and pumped as required. The NNSS M&O Contractor maintains a septic pumping contractor permit, issued by the NDEP and the Nevada Division of Public and Behavioral Health. State representatives conduct onsite inspections of septic pump trucks and contractor operations. NNSA/NFO performs management assessments and maintenance for domestic wastewater septic systems to document compliance with permit conditions. Management assessments are performed according to existing directives and procedures.

In February 2020, the state conducted an inspection of NNSS septic pump trucks and both trucks were found to be compliant with permit conditions.

A septic tank pumping contractor permit for three septic tank pump trucks (NY-17-06839) was renewed in July 2020.

5.2.3 Industrial Wastewater Monitoring

Industrial discharges on the NNSS are limited to three sewage lagoon systems: Area 6 Yucca Lake, Area 6 DAF [Device Assembly Facility], and Area 23 Mercury (lagoon systems also receive domestic wastewater) (Figure 5-7). The Yucca Lake system includes two primary lagoons and two secondary lagoons. The DAF system comprises one primary and one secondary lagoon. Both the Yucca Lake and DAF lagoons are lined with compacted native soils and meet state requirements for transmissivity (10^{-7} centimeters per second).

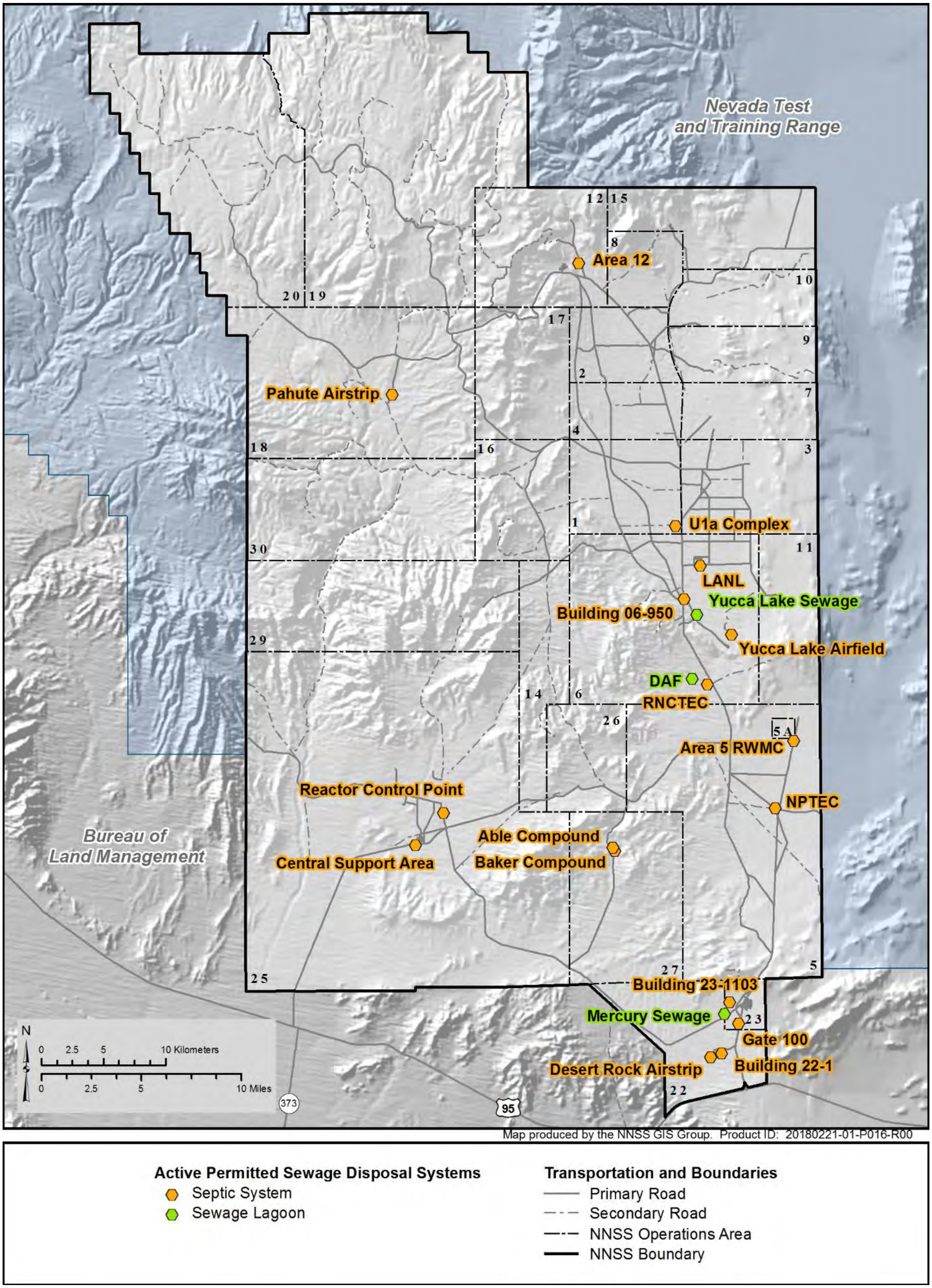

Figure 5-7. Active permitted sewage disposal systems on the NNSS

The Area 23 Mercury system includes one primary lagoon and one secondary lagoon. The primary and secondary lagoons are lined with geosynthetic clay and high-density polyethylene. The lining of the ponds allows these systems to operate as fully contained, evaporative, non-discharging systems. The sewage lagoons operate in compliance with Water Pollution Control General Permit GNEV93001 Revision (Rv) XI.

5.2.3.1 *Quarterly and Annual Influent Monitoring*

Sewage systems are monitored quarterly for influent quality. Composite samples from each system are collected over a period of 6 hours and analyzed by state-certified laboratories. Methods for sample collection and analyses are in accordance with NAC 445A and 40 CFR 141. Composite samples are analyzed for three parameters: ***5-day biochemical oxygen demand (BOD_5)***, total suspended solids (TSS), and pH. In 2020, sample analyses results for influent waters were within permitted limits (GNEV93001 Rv XI) (Table 5-8).

Toxicity monitoring of influent waters of the lagoons was not conducted in 2020. Permit GNEV93001 Rv XI requires lagoons to be sampled and analyzed for the 29 contaminants listed in Table 4-10 of the *Nevada Test Site Environmental Report 2008* (NSTec 2009) only in the event of specific or accidental discharges of potential contaminants. No specific or accidental discharges occurred in 2020.

Table 5-8. Water quality and flow monitoring results for NNSS sewage lagoon influent waters

Parameter	Units	Minimum and Maximum Values from Quarterly Samples: Area 6 Yucca Lake	Area 23 Mercury	Area 6 DAF
BOD_5	mg/L	19-141	54-171	22-151
Permit Limit		None	None	None
BOD_5 Mean Daily Load[(a)]	kg/d	0.11-0.37	4.29-11.20	0.58-3.30
Permit Limit		34.43	124.31	15.29
TSS	mg/L	7.8-110	82-203	2-183
Permit Limit		None	None	None
pH	S.U.[(b)]	7.71-8.17	7.76-8.18	8.07-8.59
Permit Limit		6.0–9.0	6.0–9.0	6.0–9.0
Quarterly Average Flow Rate	GPD[(c)]	405-4,058	6,733-42,100	3,056-11,591
Permit Limit		10,850	73,407	3,080[(d)]

(a) BOD_5 Mean Daily Load in kilograms per day (kg/d) = (mg/L BOD × liters per day (L/d) average flow × 3.785)/10^6.
(b) Standard units of pH.
(c) Gallons per day.
(d) Average flow rate exceeded reported limit; NDEP granted a waiver for flow rate at the Area 6 DAF (included in GNEV93001 Rv XI). The limit was initially too low due to the use of a standard water balance calculation in lieu of a metering device.

5.2.3.2 *Sewage System Inspections*

NNSA/NFO personnel inspect active systems bi-weekly; no notable observations were made in 2020. NDEP inspects both active and inactive NNSS lagoon systems annually; there were no findings of deficiency in 2020. Inspections evaluate all infrastructure (i.e., field maintenance programs, lagoons, sites, and access roads) for abnormal conditions, weeds, algae blooms, pond color, abnormal odors, dike erosion, burrowing animals, discharge, depth of staff gauge, crest level, excess insect population, maintenance/repairs, and general conditions.

5.2.4 *E Tunnel Waste Water Disposal System Monitoring*

NNSA/NFO manages and operates the ETDS in Area 12 under a separate water pollution control permit (NEV 96021) issued by the NDEP Bureau of Federal Facilities. The permit regulates the management of radionuclide-contaminated wastewater that drains from the E Tunnel portal into a series of holding ponds. The permit requires ETDS discharge waters to be monitored every 12 months for radiological parameters (Adjusted Gross Alpha, Gross Beta, ^3H) and nonradiological parameters (Table 5-9). It also requires nearby Well ER-12-1 to be sampled for the same parameters once every 24 months. ETDS discharge water is also monitored monthly for flow rate, pH, temperature, and specific conductance, and for the volume and structural integrity of the holding ponds. Monitoring data are reported to the NDEP Bureau of Federal Facilities in quarterly and annual reports.

Monitoring personnel sampled the ETDS effluent on October 14, 2020, and sampled well ER-12-1 on August 18, 2020. All nonradiological parameters, with the exception of the ER-12-1 Manganese result, were within the threshold limits. It is suspected that by allowing the well's water column to settle overnight, instead of sampling immediately following purging of the well, the higher volume of total suspended solids may have contributed to the slightly elevated Manganese result. The exceedance was reported as required by the permit. Nonradiological results and thresholds are provided in Table 5-9.

Table 5-9. Nonradiological results for Well ER-12-1 groundwater and E Tunnel Waste Water Disposal System discharge samples

Nonradiological Parameter	ETDS Discharge Water Sampled Every 12 Months (October 2020)		Well ER-12-1 Groundwater Sampled Every 24 Months (August 2020)	
	Threshold (mg/L)	Concentration (mg/L)	Threshold (mg/L)	Concentration (mg/L)
Cadmium	0.045	0.0002[(a)]	0.005	0.00015[(a)]
Chloride	360	8.4	250	14
Chromium	0.09	0.006[(a)]	0.09	0.0062[(a)]
Copper	1.2	0.003[(a)]	1.2	0.0082[(b)]
Fluoride	3.6	0.19	3.6	0.25
Iron	5.0	1.4	5.0	3.3
Lead	0.014	0.0009	0.014	0.0066
Magnesium	135	0.7	135	57
Manganese	0.25	0.016	0.25	0.29
Mercury	0.0018	0.0001[(a)]	0.0018	0.00006[(a)]
Nitrate Nitrogen	9	0.29	9	0.2[(a)]
Selenium	0.045	0.0007[(a)]	0.045	0.00067[(a)]
Sulfate	450	14	450	340
Zinc	4.5	0.015[(b)]	4.5	0.33
Flow Rate (liters/minute)	MR[(c)]	29.1[(d)]	NA	NA
pH (S.U.)[(e)]	6.0–9.0	7.1 [(d)]	6.0–9.0	7.40
Specific conductance (µS/cm)[(f)]	<1,500	370[(d)]	<1,500	992

(a) Analyte not detected.
(b) Reported result is an estimate.
(c) Permit requires NNSA/NFO to monitor and report (MR); there are no threshold limits.
(d) Average of 12 monthly measures.
(e) S.U. = standard unit(s) (for measuring pH).
(f) µS/cm = microsiemens per centimeter.

5.3 Water-level and Usage Monitoring

The U.S. Geological Survey (USGS) Nevada Water Science Center collects, compiles, stores, and reports hydrologic data used in determining the local and regional hydrogeological conditions in and around the NNSS. Hydrologic data are collected quarterly or semi-annually from wells on and off the NNSS. The USGS also has developed models for the Death Valley Regional Groundwater Flow System (Belcher and Sweetkind 2010, Belcher et al. 2017, Halford and Jackson 2020), and manages other NNSS hydrologic and geologic information databases (for example, https://waterdata.usgs.gov/nv/nwis and https://pubs.usgs.gov/ds/2007/297/).

In 2020, the USGS monitored water levels in 233 wells on and near the NNSS; these included 132 wells on the NNSS and 101 off the NNSS. Water levels are monitored to identify where water occurs in the subsurface, changes in the quantity of water in aquifers, the direction of groundwater movement, and groundwater velocity (derived from knowledge of groundwater movement and formation properties). Along with radiological groundwater data presented in Section 5.1, water-level data contribute to the development of UGTA CAU-specific models of groundwater flow and radionuclide transport (Section 11.2.1). A map showing the locations of monitored wells and all water level data are available on the USGS-U.S. Department of Energy Cooperative Studies in Nevada project website at https://nevada.usgs.gov/doe_nv/.

Groundwater-use data are collected from water supply wells on the NNSS using flow meters, and are reported monthly. The principal NNSS water supply wells monitored included J-12 WW, J-14 WW (no production during 2020), WW #4, WW #4A, WW 5B, WW 8 (Figure 5-1), and UE-16d WW. The USGS compiles the water-use data and reports annual withdrawals in millions of gallons. Withdrawal data from these wells for 2020 have been compiled and processed, and are available from the Water Withdrawals page on the USGS-U.S. Department of Energy Cooperative Studies in Nevada project website at https://nevada.usgs.gov/doe_nv/water_withdrawals.html. Total groundwater withdrawals from these wells in 2020 was about 136 million gallons (Figure 5-8).

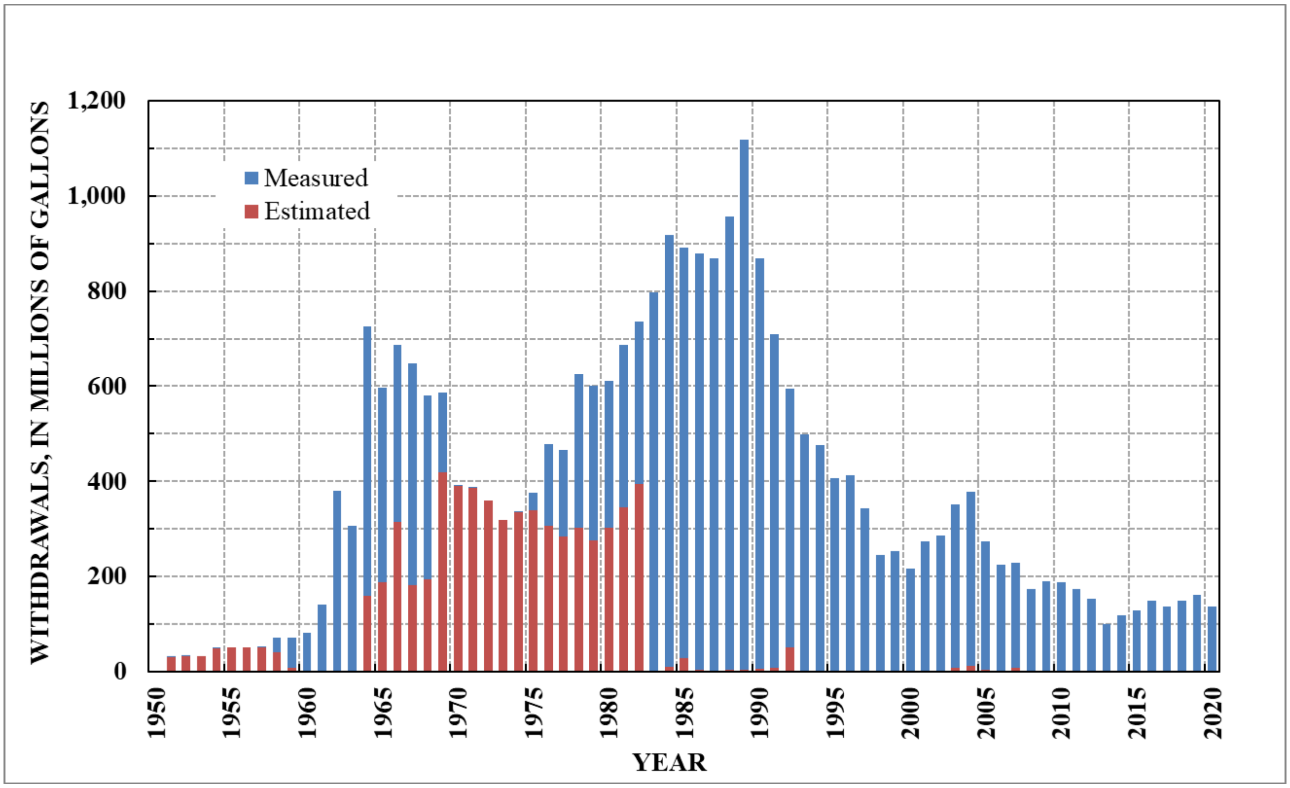

Figure 5-8. Annual withdrawals from the NNSS, 1951 to 2020

5.4 Water Monitoring Conclusions

Groundwater contaminated by historical UGTs does not impact the public or NNSS workers who consume water from wells located off or on the NNSS. Although the potential radiological impact to water resources from past activities on the NNSS is from migration of radionuclides in the groundwater downgradient from the UGTA CAUs, only testing within the Pahute Mesa CAUs has impacted groundwater off the NNSS boundary, while remaining on the NTTR. Furthermore, the detection of ^{3}H above its standard analysis method MDC of 300 pCi/L has only been observed in two wells on the NTTR (ER-EC-11 and PM-3). Seven wells (including ER-EC-11) monitor a contaminant plume of ^{3}H believed to originate from the TYBO and BENHAM UGTs. These seven wells are within 900 ft to 17,000 ft (0.2 to 3.2 miles) of these two UGTs. Similarly, two wells (including PM-3) monitor a contaminant plume of ^{3}H believed to originate from the HANDLEY UGT. Eight other UGTA wells on the NTTR (i.e., "ER-EC" wells) have not shown the presence of man-made radionuclides downgradient of Pahute Mesa. Because of the slow migration of groundwater and the relatively rapid decay of ^{3}H, ^{3}H is not expected to be observed off the NTTR boundary at levels exceeding the SDWA MCL. In fact, ongoing scientific studies indicate that contaminated groundwater at levels exceeding the SDWA MCLs for all radionuclides is not expected to reach publicly accessible areas. Samples from community wells, including samples collected by CEMP and TSaMP (Sections 7.2 and 7.3), farther downgradient of Pahute Mesa, also contain no detectable man-made radionuclides.

NNSS wildlife can be exposed to ^3H in their drinking water or in their aquatic habitats whenever contaminated waters are retained for evaporation in state-approved ponds or sumps. Examples are the E Tunnel ponds and UGTA groundwater sumps used by wildlife as drinking water and by plants, insects, and amphibians as aquatic habitats. The potential dose to NNSS biota from these water sources is routinely assessed and reported annually in this report (Section 9.2). Each year, results have demonstrated that the doses to biota are less than the limits established to protect plant and animal populations.

Potential nonradiological parameters concerning drinking water and wastewater monitored on the NNSS in 2020 were all less than permit limits, with the following exception: the DAF sewage lagoon exceeded the daily flow limit. The DAF sewage lagoon flow exceedance had no impact, as there was no loss of containment. If present, nonradiological contamination of groundwater from NNSS operations would likely be co-located with the radiological contamination from historical UGTs within UGTA CAUs. It is expected to be minor, however, in comparison to the radiological contamination. For nuclear tests detonated above the water table, potential nonradiological contaminants are not likely to reach groundwater because of their negligible advective and dispersive transport rates through the thick ***vadose zone***. Water samples from UGTA investigation wells, which include highly contaminated wells, have not had elevated levels of nonradiological man-made contaminants.

Well drilling, waste burial, chemical storage, and wastewater management are the only current NNSS activities that have the potential to contaminate groundwater with nonradiological contaminants. This potential is very low, however, due to engineered and operational deterrents and natural environmental factors. Current drilling operations procedures include the containment of drilling muds and well effluents in sumps (Section 5.1.3.8.3). Well effluents are monitored for nonradiological contaminants (predominantly lead) to ensure lined sumps are used when necessary. The Area 3 and Area 5 Radioactive Waste Management Sites are monitored to ensure that contaminants do not reach groundwater (Chapter 10). In addition, the potential for mobilization of contaminants from all these sources to groundwater is negligible due to the arid climate, the great depth to groundwater (thickness of the vadose zone), and the proven behavior of liquid and vapor fluxes in the vadose zone (primarily upward liquid movement towards the ground surface due to evapotranspiration).

The EM Nevada Program is responsible for completing environmental corrective actions at sites where surface and shallow subsurface contamination historically occurred. Some of these sites also have nonradiological contaminants such as metals, petroleum hydrocarbons, hazardous organic and inorganic chemicals, and unexploded ordinance (Sections 11.2.2 and 11.3.2). The potential for mobilization of these contaminants to groundwater is negligible due to the same regional climatic, soil, and hydrogeological factors mentioned above.

Water level monitoring continues to be used to develop and refine CAU-specific models of groundwater flow and contaminant transport. Section 11.2.1 of this report describes the status of these models.

Current water usage, monitored annually, has dropped to levels that have not been seen since the early 1960s, due mainly to changes in site operations, and to some extent, recent conservation actions. Within the past several years, NNSA/NFO has taken actions to conserve groundwater by addressing DOE's water efficiency and water management goals, which include reducing both potable and non-potable water use (Chapter 3).

5.5 References

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Chapter 6: Direct Radiation Monitoring

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Direct Radiation Monitoring Program Goals

Assess the proportion of external dose from background radiation versus that from operations at the Nevada National Security Site (NNSS). Measure external radiation to assess the potential external dose to a member of the public from operations at the NNSS (Chapter 9 gives estimates for public dose). Measure external radiation to assess the potential external dose to a member of the public from operations at the Area 3 and 5 Radioactive Waste Management Sites (RWMSs). Monitor operational activities involving radioactive material, radiation-generating devices, and accidental releases of radioactive material to ensure exposure to members of the public are kept as low as is reasonably achievable (ALARA). Measure external radiation to assess the potential external and absorbed radiation doses to NNSS plants and animals (Section 9.2 gives biota dose assessments). Determine the patterns of exposure rates through time at various soil contamination areas to characterize releases in the environment.

U.S. Department of Energy (DOE) Orders DOE O 458.1, "Radiation Protection of the Public and the Environment," and DOE O 435.1, "Radioactive Waste Management," have requirements to protect the public and environment from radiation ***exposure***;[1] see descriptions of these orders in Table 2-1. Energy absorbed from radioactive materials outside the body results in an external ***dose***. On the NNSS, external dose comes from direct ***ionizing radiation*** including natural ***radioactivity*** from cosmic and terrestrial sources as well as man-made radioactive sources. This chapter presents data obtained to assess external dose for 2020. Chapters 4, 5, and 8 present monitoring results for radioactivity from NNSS activities in air, water, and biota, respectively. Those results help estimate potential internal radiation dose to the public via inhalation and ingestion. The total estimated dose, both internal and external, from NNSS activities is presented in Chapter 9.

Direct radiation monitoring is conducted to assess the external radiation environment, detect changes in that environment, respond to releases from U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) activities, and measure ***gamma radiation*** levels near potential exposure sites. In addition, DOE O 458.1 states that "it is also an objective that potential exposures to members of the public be ***as low as is reasonably achievable (ALARA)***."

An offsite monitoring program implemented by NNSA/NFO monitors direct radiation in communities adjacent to the NNSS. The Desert Research Institute (DRI) conducts this monitoring as part of its Community Environmental Monitoring Program (CEMP). DRI's 2020 direct radiation monitoring results are in Sections 7.1.4 and 7.1.5; DRI ***thermoluminescent dosimeter (TLD)*** data are compared with onsite TLD data in this chapter (Figures 6-2 and 6-3).

6.1 Measurement of Direct Radiation

Direct (or external) radiation exposure can occur when ***alpha particles***, ***beta particles***, or electromagnetic (gamma and X-ray) radiation interact with living tissue. Electromagnetic radiation can travel long distances through air and penetrate living tissue, causing ionization within the body tissues. For this reason, electromagnetic radiation is one of the greater concerns of direct radiation exposure. By contrast, alpha and beta particles do not travel far in air (a few centimeters for alpha, and about 10 meters [m] or 33 feet [ft] for beta particles). Alpha particles deposit only negligible energy to living tissue as they rarely penetrate the outer dead layer of skin and cannot penetrate thin plastic. Beta particles are generally absorbed in the layers of skin immediately below the outer layer.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

Direct radiation exposure is usually reported in the unit milliroentgen (mR), which is a measure of exposure in terms of numbers of ionizations in air. The dose in human tissue resulting from an exposure from one of the most common ***radionuclides*** (cesium-137) is approximated by equating a 1-mR exposure with a dose of 1 millirem (mrem) (or 0.01 millisievert [mSv]).

6.2 Thermoluminescent Dosimetry Surveillance Network Design

A surveillance network of TLD sample locations (Figure 6-1) monitors NNSS areas with elevated radiation levels from historical nuclear weapons testing, current and past radioactive waste management activities, and/or current operations involving radioactive material or radiation-generating devices. The objectives and design of the network are described in detail in the *Routine Radiological Environmental Monitoring Plan* (RREMP) (Bechtel Nevada 2003).

TLDs have the capability to measure exposure from all sources of ionizing radiation, but with normal use, the TLD will detect only electromagnetic radiation, high-energy beta particles, and in some special cases, neutrons. This is due to the penetrative abilities of the radiation. The TLD used for environmental sampling is the Panasonic UD-814AS, which has three calcium sulfate elements housed in an air-tight, water-tight, ultra-violet light-protected case. Measurements from the three calcium sulfate elements are averaged to assess penetrating gamma radiation.

A pair of TLDs is placed at 1.0 ± 0.3 m (28 to 51 inches) above the ground at each monitoring location. TLD analysis is performed quarterly using automated TLD readers calibrated and maintained by the Radiological Control Department. Reference TLDs are exposed to a 100 mR cesium-137 source under tightly controlled conditions. These are read along with TLDs collected from the network to calibrate their responses.

There were 105 active environmental TLD locations on the NNSS in 2020 (Figure 6-1), along with six control locations. They include the following:

- Background (B) – 10 locations where radiation effects from NNSS operations are negligible.
- Environmental 1 (E1) – 41 locations where there is no measurable radioactivity from past operations, but which are locations of interest due to the presence of people in the area and/or the potential for increased radiation exposure from a current operation.
- Environmental 2 (E2) – 35 locations where there is or has been measurable added radioactivity from past operations; these locations are of interest for monitoring direct radiation trends in the area. Some locations fitting this description are grouped with the Waste Operations category below.
- Waste Operations (WO) – 19 locations in and around the Area 3 and 5 RWMSs.
- Control (C) – Five locations in Building 652 and one in Building 650 (both in Area 23). Control TLDs are kept in stable environments. Those in Building 652 are shielded inside a lead cabinet, and those in Building 650 are shielded by just the building itself. These TLDs are used as a quality check on the TLDs and the analysis process.

This network of TLD stations, along with the analysis of their data, serve to monitor operational activities throughout the NNSS for changes in external radiation measures over time and any accidental releases of radioactive material. TLD data are reviewed annually to identify any patterns of exposure rates through time at various soil contamination areas.

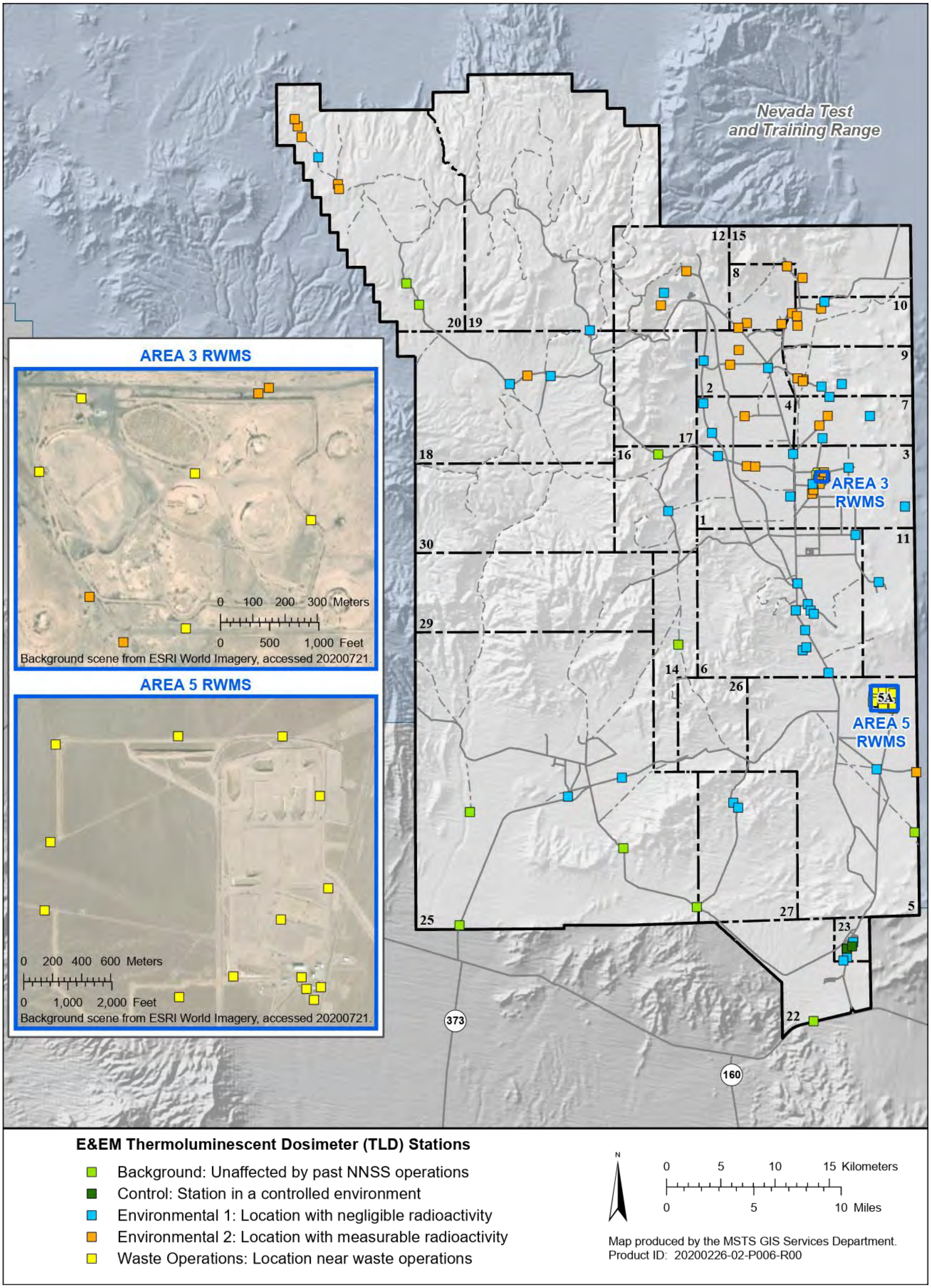

Figure 6-1. Locations of TLDs on the NNSS

6.2.1 Data Quality

Quality assurance (QA) procedures for direct radiation monitoring involve: (1) comparison of readings among the three TLD elements in individual TLDs, (2) comparison of data from the paired TLDs at each location to estimate the measurement and its precision, (3) comparison of current and past data measurements at each TLD location, and (4) review of data from the TLDs in the control locations. The TLDs in control locations allow the detection and estimation of any systematic variations that might be introduced by the measurement process itself.

As specified by the RREMP, QA and ***quality control (QC)*** protocols (including Data Quality Objectives) are maintained as essential elements of direct radiation monitoring. QA/QC requirements include the use of sample packages to thoroughly document each sampling event, rigorous management of databases, and completion of essential training (Chapter 14). The Radiological Control Department maintains certification through the DOE Laboratory Accreditation Program for ***dosimetry***.

Four steps comprise the monitoring process for each environmental TLD: the TLD is (1) annealed (i.e., heated and then cooled) to reset its original unexposed condition, then stored in a shielded location; (2) deployed to the field at the beginning of each quarter; (3) collected from the field at the end of each quarter; and (4) again stored in a shielded location until it is read. To control for variations related to holding times, an estimate of the additional dose due to holding prior to deployment and following collection in the shielded location is subtracted from the measured quarterly dose before computing annual exposure estimates. This adjustment has been applied retroactively to data from 2003 on. This adjustment resulted in a decrease of estimated dose between 0.21% and 3.50%, averaging 1.37% for stations that were in the field at the beginning of 2020.

6.2.2 Data Reporting

Direct radiation is recorded as exposure per unit time in milliroentgens per day (mR/d), calculated by dividing the measured exposure per quarter for each TLD by the number of days the TLD was exposed at its measurement location. These are multiplied by 365.25 to obtain annualized values. The estimated annual exposure is the average of the quarterly annualized values; this is the metric used to determine compliance with federal annual dose limits.

6.3 Results

Estimated annual exposures for all TLD locations are listed in Table 6-1. Summary statistics for the five location types are listed in Table 6-2. Data were successfully obtained from nearly all of the TLDs during all quarters in 2020; four measurements were rejected due to inadequate inter-element agreement. Otherwise, agreement between the results provided by the paired TLDs was quite good, with an average relative percent difference between measurements of 2.5%. The quarter-to-quarter coefficient of variation (CV) (i.e., the relative standard deviation) ranged from 0.5% to 6.3% (mean = 3.0%) over all locations, excluding Gate 100 Truck Parking 1 (discussed in Section 6.3.2).

6.3.1 Background Exposure

In 2020, the average of the estimated annual exposures among the 10 background locations was 121 mR, ranging from 80 to 163 mR (Table 6-2). A 95% prediction interval (PI) for annual exposures based on the 2020 estimated annual exposures at the background locations (denoted "95% PI from B" in the plots, Figures 6-2, 6-4, and 6-5) is 48.3 to 193.6 mR. This interval predicts mean annual background exposures at locations where radiation effects from NNSS operations are negligible.

For comparison, the CEMP's estimated annual exposure in Las Vegas, Nevada (at 622 m [2,040 ft] elevation), was 110 mR in 2020 (Table 7-3). Estimated mean annual exposures at CEMP locations ranged from 85 mR at Pahrump, Nevada (777 m [2,550 ft] elevation), to 146 mR at Beatty, Nevada (980 m [3,216 ft] elevation). There is a general increasing relationship between natural background exposure and elevation due to cosmic radiation (Figure 6-3). The NNSS background locations with lowest and highest exposures are at elevations 1,064 m (3,490 ft) at Old Indian Springs Road in Area 5 and 1,737 m (5,700 ft) at Stake A-112 in Area 20, respectively.

Exposure estimates at all locations include contributions from natural sources of radiation (i.e., cosmic, terrestrial), legacy sources (i.e., contaminated soils from NNSS historical nuclear testing), and current NNSS operational sources. It is important to note that all DOE dose limits to the public are for dose over and above background. In order to study whether the NNSS TLD system is able to measure very small dose changes in environment above the background radiation, statistical analyses of historical data from the 10 current background locations was performed, and is summarized in Table 6.3. The estimated annual exposure was consistent over time at each background location from 2003 to 2019. The average annual exposures of the background locations varied from 80 mR to 163 mR, and the year-to-year CVs ranged from 0.8% to 2.4% (mean = 1.9%). The relative differences between the 2020 mean exposures and their corresponding average annual exposures of the background locations are very small, ranging from 0.1% to 3.6%, averaging 1.9%. These results showed that the TLDs are sensitive enough to measure a very low radiation level above background, and no man-made radiation from NNSS operations was detected at the background locations in 2020. These data are shown in Figure 6-7.

Table 6-1. Annual direct radiation exposures measured at TLD locations on the NNSS

NNSS Area	Station	Number of Quarters	Estimated Annual Exposure (mR)[a] Mean[b]	Minimum[b]	Maximum[b]
		Background			
5	Old Indian Springs Road	4	80	74	85
14	Mid-Valley	4	148	144	152
16	Stake P-3	4	118	115	122
20	Stake A-112	4	163	160	168
20	Stake A-118	4	157	152	166
22	Army #1 Water Well	4	86	84	87
25	Gate 25-4-P	4	131	126	134
25	Gate 510	4	131	129	134
25	Jackass Flats & A-27 Roads	4	84	82	86
25	Skull Mtn Pass	4	111	108	114
		Control			
23	Building 650 Dosimetry	4	60	59	61
23	Lead Cabinet, 1	4	26	26	27
23	Lead Cabinet, 2	4	26	25	27
23	Lead Cabinet, 3	4	26	25	26
23	Lead Cabinet, 4	4	26	24	27
23	Lead Cabinet, 5	4	27	25	27
		Environmental 1[c]			
1	BJY	4	121	117	126
1	Sandbag Storage Hut	4	118	114	121
1	Stake C-2	4	122	116	129
2	Stake M-140	4	139	134	143
2	Stake TH-58	4	93	89	95
3	LANL Trailers	4	123	118	128
3	Stake OB-20	4	91	88	93
3	Well ER 3-1	4	128	126	130
4	Stake TH-41	4	110	106	112
4	Stake TH-48	4	117	114	121
5	Water Well 5b	4	113	109	119
6	CP-6	4	72	71	75
6	DAF East	4	102	98	106
6	DAF North	4	106	103	111
6	DAF South	4	141	137	147
6	DAF West	4	87	81	91
6	Decon Facility NW	4	134	130	139
6	Decon Facility SE	4	139	134	142
6	Stake OB-11.5	4	134	131	137
6	Yucca Compliance	4	94	92	97
6	Yucca Oil Storage	4	105	101	110
7	Reitmann Seep	4	128	124	131
7	Stake H-8	4	128	123	133

Table 6-1. Annual direct radiation exposures measured at TLD locations on the NNSS

NNSS Area	Station	Number of Quarters	Estimated Annual Exposure (mR)[a] Mean[b]	Minimum[b]	Maximum[b]
9	Papoose Lake Road	4	88	86	88
9	U-9cw South	4	103	101	104
9	V & G Road Junction	4	111	109	113
10	Gate 700 South	4	129	126	133
11	Stake A-21	4	137	132	143
12	Upper N Pond	4	130	127	135
16	3545 Substation	4	140	135	145
18	Stake A-83	4	146	141	149
18	Stake F-11	4	148	139	156
19	Stake P-41	4	164	159	175
20	Stake J-41	4	142	133	150
23	Gate 100 Truck Parking 1	4	65	55	74
23	Gate 100 Truck Parking 2	4	56	55	56
23	Mercury Fitness Track	4	59	58	60
25	HENRE	4	125	123	128
25	NRDS Warehouse	4	127	124	129
27	Cafeteria	4	114	112	116
27	JASPER-1	4	115	110	118
		Environmental 2[c]			
1	Bunker 1-300	4	113	106	118
1	T1	4	202	200	203
2	Stake L-9	4	158	152	163
2	Stake N-8	4	350	340	369
3	Stake A-6.5	4	136	131	142
3	T3	4	268	261	279
3	T3 West	4	246	240	252
3	T3a	4	263	256	272
3	T3b	4	354	350	359
3	U-3co North	4	167	161	171
3	U-3co South	4	138	134	143
4	Stake A-9	4	349	329	363
5	Frenchman Lake	4	225	218	238
7	Bunker 7-300	4	182	176	190
7	T7	4	113	110	119
8	Baneberry 1	4	303	297	317
8	Road 8-02	4	123	118	128
8	Stake K-25	4	112	110	114
8	Stake M-152	4	156	148	164
9	B9a	4	128	124	137
9	Bunker 9-300	4	123	118	127
9	T9b	4	389	380	408
10	Circle & L Roads	4	117	114	120
10	Sedan East Visitor Box	4	131	126	135
10	Sedan West	4	199	197	202
10	T10	4	217	213	221
12	T-Tunnel #2 Pond	4	223	218	232
12	Upper Haines Lake	4	105	103	109
15	EPA Farm	4	110	109	114
18	Johnnie Boy North	4	148	145	153
20	Palanquin	4	202	200	205
20	Schooner-1	4	431	402	467
20	Schooner-2	4	204	202	209
20	Schooner-3	4	147	138	159
20	Stake J-31	4	160	155	168
		Waste Operations[c]			
3	RWMS Center	4	133	129	137
3	RWMS East	4	133	128	141
3	RWMS North	4	125	121	130

Table 6-1. Annual direct radiation exposures measured at TLD locations on the NNSS

NNSS Area	Station	Number of Quarters	Estimated Annual Exposure (mR)[a] Mean[b]	Minimum[b]	Maximum[b]
3	RWMS South	4	256	248	265
3	RWMS West	4	128	123	133
5	CAU-111	4	129	122	134
5	Lysimeter	4	133	130	139
5	Pilot Well 3	4	149	145	155
5	Powerline Rd	4	142	137	149
5	RWMS East Gate	4	103	98	106
5	RWMS Expansion NE	4	160	152	166
5	RWMS NE Corner	4	131	127	135
5	RWMS North	4	146	139	151
5	RWMS SW Corner	4	128	125	131
5	Vefa	4	146	141	151
5	Waterline Rd	4	136	132	140
5	WEF North	4	115	111	121
5	WEF South	4	126	122	131
5	WEF West	4	124	119	129

(a) To obtain the estimated daily exposure rates, divide the annual exposure estimates by 365.25.
(b) Mean, minimum, and maximum values from the adjusted quarterly estimates. Each quarterly estimate is the average of two TLD readings per location in all but four instances.
(c) Location types: Environmental 1 = Environmental locations with exposure rates near background, but monitored for potential for increased exposures due to NNSS operations; Environmental 2 = Environmental locations with measurable radioactivity from past operations, excluding those designated WO; Waste Operations = Locations in or near waste operations.

Table 6-2. Summary statistics for mean annual direct radiation exposure by TLD location type

Location Type	Number of Locations	Estimated Annual Exposure (mR) Mean	Minimum	Maximum
Background (B)	10	121	80	163
Environmental 1 (E1)	41	116	56	164
Environmental 2 (E2)	35	200	105	431
Waste Operations (WO)	19	139	103	256
Control, Shielded (C)	5	26	26	27
Control, Unshielded (C)	1	60	60	60

Table 6-3. Summary statistics for exposure history of background TLD stations

Area	Station	Historical Average Annual Exposure(mR)[a]	CV(%)[b]	Estimated Exposure in 2020 (mR)	Difference(%)[c]
5	Old Indian Springs Road	79.4	0.8	80.0	0.8
14	Mid-Valley	144.7	2.2	147.7	2.1
16	Stake P-3	117.3	2.0	117.7	0.3
20	Stake A-112	161.6	1.9	163.4	1.1
20	Stake A-118	153.9	2.4	157.0	2.0
22	Army #1 Water Well	83.9	1.9	85.7	2.1
25	Gate 25-4-P	131.3	1.8	131.5	0.1
25	Gate 510	127.0	1.8	131.5	3.5
25	Jackass Flats & A-27 Roads	80.9	2.4	83.8	3.6
25	Skull Mtn Pass	107.7	1.5	111.1	3.1

(a) Average annual exposure was calculated from all available TLD data from 2003 to 2019.
(b) Coefficient of variation = the relative standard deviation.
(c) Relative difference between the 2020 exposure and the average of 2003–2019 estimates.

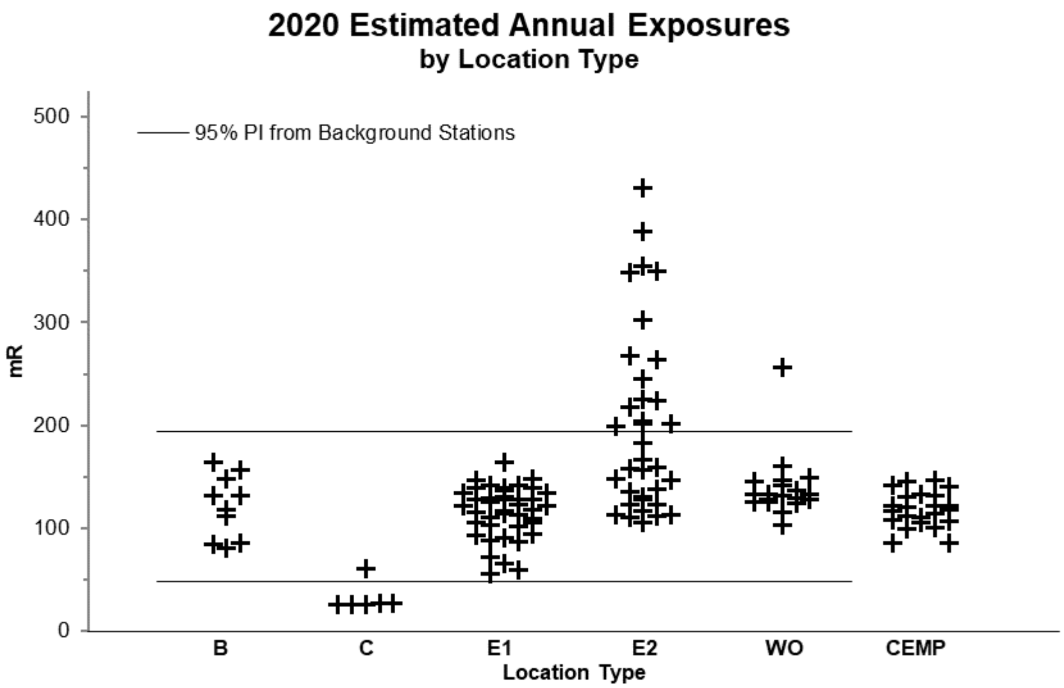

Figure 6-2. Estimated exposures on the NNSS, by location type, and off the NNSS at CEMP stations

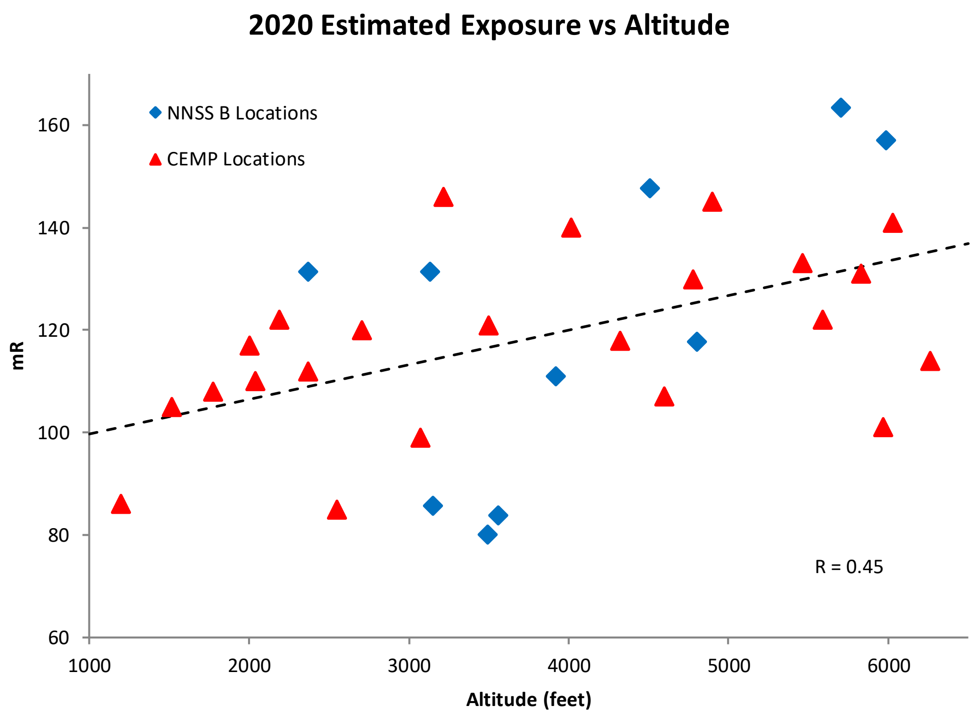

Figure 6-3. Correlation between exposures at NNSS Background and CEMP TLD locations and altitude

6.3.2 Potential Exposure to the Public along the NNSS Boundary

Most of the NNSS is not accessible to the public; the public has limited access only at the southern portion of the NNSS, where Gate 100 is the primary entrance point to the NNSS. The outer parking areas are accessible to the public. Trucks hauling radioactive materials, primarily ***low-level waste (LLW)*** destined for disposal in the RWMSs, often park outside Gate 100 while waiting to enter the NNSS. Two TLD locations were established in October 2003 to monitor this truck parking area.

The TLDs at the north end of the parking area (Gate 100 Truck Parking 2) had an estimated annual exposure of 56 mR in 2020, with quarterly estimates of 55, 55, 56, and 56 mR, a bit lower than in past years. The TLD location about 64 m (210 ft) away, on the west side of the parking area (Gate 100 Truck Parking 1), has had elevated exposure levels at various times in its history, likely from waste shipments. Its average value for 2020 was 65 mR, with quarterly estimates of 61, 55, 72, and 74 mR. All results for both locations are within the range of background variation.

While the public has limited access to the NNSS at Gate 100 along its southern border, others may have access to other boundaries of the NNSS. Most of the NNSS is bounded by the Nevada Test and Training Range (NTTR). Military or other personnel on the NTTR who are not classified as radiation workers would also be subject to the DOE public dose limit of 100 millirem per year (mrem/yr [1 mSv/yr]). Nuclear tests on the NTTR (Double Tracks and Project 57) consisted of experiments (called safety experiments) where weapons were exploded conventionally without going critical (i.e., starting a nuclear chain reaction). These areas, therefore, have primarily alpha-emitting radionuclides that do not contribute significantly to external dose. Historical nuclear testing activities also occurred on the Tonopah Test Range (TTR) (Clean Slate I, II, and III) in the northwest portion of the NTTR. Radiation exposure rates are measured on and around the TTR, and the results are reported by Sandia National Laboratories in the TTR annual environmental report posted at https://www.sandia.gov/news/publications/.

A radioactive material area boundary extends beyond the NNSS in the Frenchman Lake region of Area 5 along the southeast boundary of the NNSS. This region was a location of atmospheric weapons testing in the 1950s and is inaccessible to the public. A TLD location was established there in July 2003 to characterize direct radiation levels from this legacy contaminated-soil area and to assess the external dose to personnel not classified as radiation workers who may visit the area. The estimated annual exposure to a hypothetical person at the Frenchman Lake TLD location in 2020 was 225 mR. This has been consistently declining over time, down from 420 mR in 2003. The estimated above-background dose in 2020 would be approximately 62 to 145 mrem, depending on which background value is subtracted. This may exceed the 100 mrem dose limit to a person residing full time, year-round, at this location, but there are no living quarters or full-time non-radiation workers in this vicinity. Workers specially trained and classified as radiation workers, although they do not work in the vicinity, have a higher allowable dose limit of 5,000 mrem/yr, which would not be exceeded in the vicinity of the Frenchman Lake TLD.

Based on these results, the potential external dose to a member of the public due to past or present operations at the NNSS does not exceed 100 mrem/yr (1 mSv/yr) and exposures are kept ALARA, as required by DOE O 458.1.

6.3.3 Exposures from NNSS Operational Activities

Forty-one TLDs are placed in locations where either workers and/or the public have the potential to receive radiation exposure from current operations (E1 locations). E1 locations have negligible radioactivity from past operations. The mean estimated annual exposure at these locations was 116 mR in 2020, a little lower than the mean estimated annual exposure at background locations (see Table 6-2). Overall, annual exposures were not different between B and E1 locations (Figure 6-2); the estimated annual exposures at all E1 locations are well within the 95% PI calculated from B locations. E1 location exposures were also comparable with the offsite exposures reported by the CEMP stations, as shown in Figure 6-2.

6.3.4 Exposures from Radioactive Waste Management Sites

DOE Manual DOE M 435.1-1, "Radioactive Waste Management Manual," states that LLW disposal facilities shall be operated, maintained, and closed so that a reasonable expectation exists that the annual dose to members of the public shall not exceed 25 mrem from all exposure pathways combined. The RWMSs are located well within the NNSS boundaries, which are patrolled by security personnel; no member of the public can access these areas for significant periods of time. TLDs placed at the RWMSs show the potential dose from external radiation to a hypothetical person residing year-round at each RWMS.

Between 1952 and 1972, 60 nuclear weapons tests were conducted in Yucca Flat within 400 m (1,312 ft) of the current Area 3 RWMS boundary. Fourteen of these tests were atmospheric tests that left radionuclide-contaminated surface soil and, therefore, elevated radiation exposures across the area. Waste pits in the Area 3 RWMS are ***subsidence craters*** from seven subsurface tests, which have been filled with LLW and then covered with clean soil. As a result, exposures inside the Area 3 RWMS are low when compared with those at or outside the fence line.

Annual exposures measured inside the Area 3 RWMS and at three of four locations at the boundary were within the range of NNSS background exposures in 2020 (Figure 6-4). The boundary location A3 RWMS South has an estimated exposure above the range of NNSS background; it is 160 m (525 ft) from the site of two atmospheric nuclear weapons tests. The three E2 TLD locations outside the RWMS that are also above the range of NNSS background (Figure 6-4) are a similar distance from the same atmospheric tests, but on the other side, farther from the RWMS boundary. Based on these measurements, it does not appear that waste buried at the Area 3 RWMS would have contributed external exposure to a hypothetical person residing at its boundary during 2020.

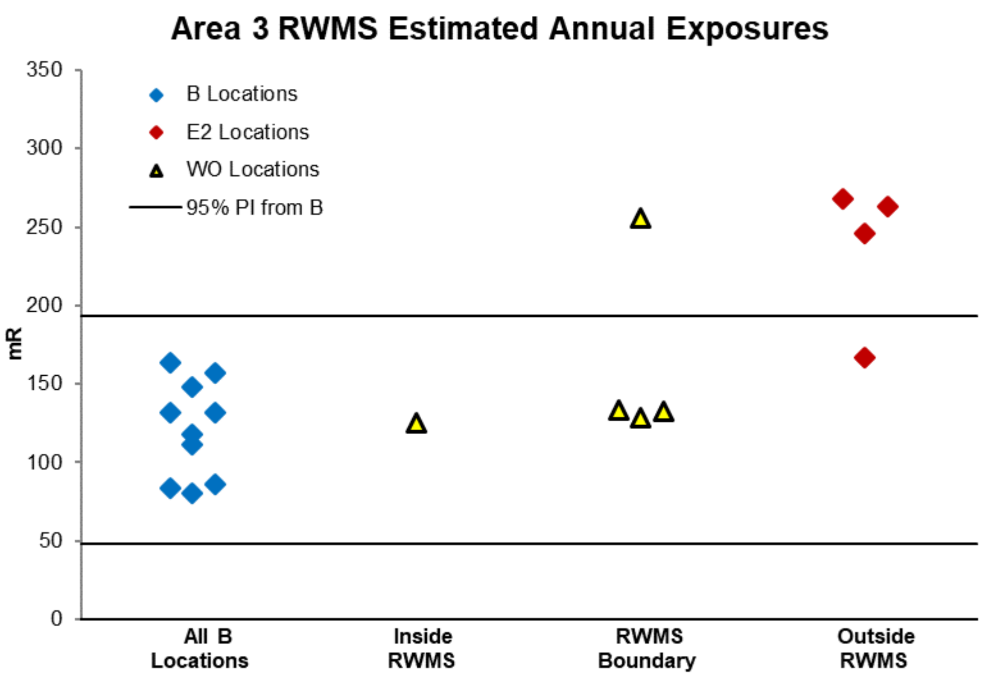

Figure 6-4. 2020 annual exposures in and around the Area 3 RWMS and at background locations

The Area 5 RWMS is located in the northern portion of Frenchman Flat. Between 1951 and 1971, 25 nuclear weapons tests were conducted within 6.3 kilometers (km) (3.9 miles [mi]) of the Area 5 RWMS. Fifteen of these were atmospheric tests and, of the remaining ten, nine released radioactivity to the surface, which contributes to exposures in the area. No nuclear weapons testing occurred within the boundaries of the Area 5 RWMS.

In 2020, estimated annual exposures at Area 5 RWMS TLD locations were within the range of exposures measured at NNSS ***background*** locations (Figure 6-5). The one location outside the Area 5 RWMS that has an estimated exposure above background levels (the Frenchman Lake TLD station) is within 0.5 km (0.3 mi) of six atmospheric tests in the Frenchman Lake Playa.

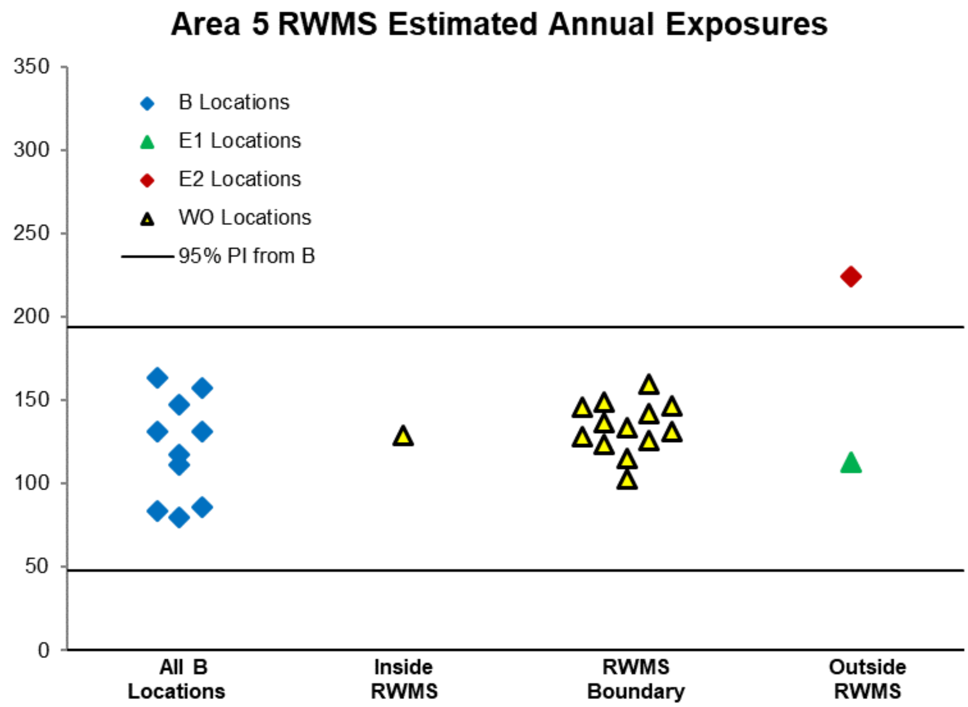

Figure 6-5. 2020 annual exposures around the Area 5 RWMS and at background locations

Based on these results, the potential external dose to a member of the public from operations at the Area 3 and Area 5 RWMSs does not exceed the 25 mrem/yr (0.25 mSv/yr) dose limit specified in DOE M 435.1-1. See Section 9.1.2 of this report for a summary of the potential dose to the public from the RWMSs from all exposure pathways.

6.3.5 Exposures to NNSS Plants and Animals

The highest exposure rate measured at any TLD location in 2020 was 467 mR/yr (1.28 mR/d) at the Schooner-1 location during the second quarter (Table 6-1). Given such a large area source, there is very little difference between the exposure measured at a height of 1 m (3.3 ft) and that measured near the ground (e.g., 3 centimeters, or 1.2 inches) where small plants and animals reside. The daily exposure rate near the ground surface would be less than 2% of the total dose rate limit to terrestrial animals and less than 1% of the limit to terrestrial plants. Hence, doses to plants and animals from external radiation exposure at NNSS monitoring locations are much lower than the dose limits. Doses to biota from both internal and external radionuclides are presented in Section 9.2.

6.3.6 Exposure Patterns in the Environment over Time

Direct radiation monitoring is conducted to help characterize releases from NNSA/NFO activities. Continued monitoring of exposures at locations of past releases on the NNSS helps to accomplish this. Small quarter-to-quarter changes are normally seen in exposure rates from all locations. In 2020, the median CV for measurements between quarters was 3.0%. Gate 100 Truck Parking 1 showed the highest variation with a CV of 13.6%. No other environmental stations had CVs over 10%. In the past 8 years (2012–2019) the median CV has ranged from 2.8% to 4.8%, so the quarter-to-quarter variability in 2020 is consistent with those of the past 5 years.

Long-term trends are displayed in Figure 6-6 by location type for locations that have been monitored for at least 10 years. The average annual ***decay*** rates by location group are 0.14% (B), 0.07% (C), 0.20% (E1), 1.77% (E2), and 0.62% (WO). Annual exposures decreased 2.95% per year on average at those locations with significant added man-made radiation, those being the E2 and WO locations with 2020 estimated exposures higher than the 95% PI calculated from B locations. These average rates of decay are very similar to those measured from 2008 through 2019. The observed decreases are due to a combination of natural radioactive decay, dispersal, and dilution in the environment.

The stations with the six highest estimated annual exposures in 2020 are Schooner-1 (Area 20), T9B (Area 9), T3B (Area 3), Stake N-8 (Area 2), Stake A-9 (Area 4), and Baneberry 1 (Area 8). Their annual exposures have been decreasing at an estimated rate of 50% every 15, 26, 33, 16, 16, and 32 years, respectively.

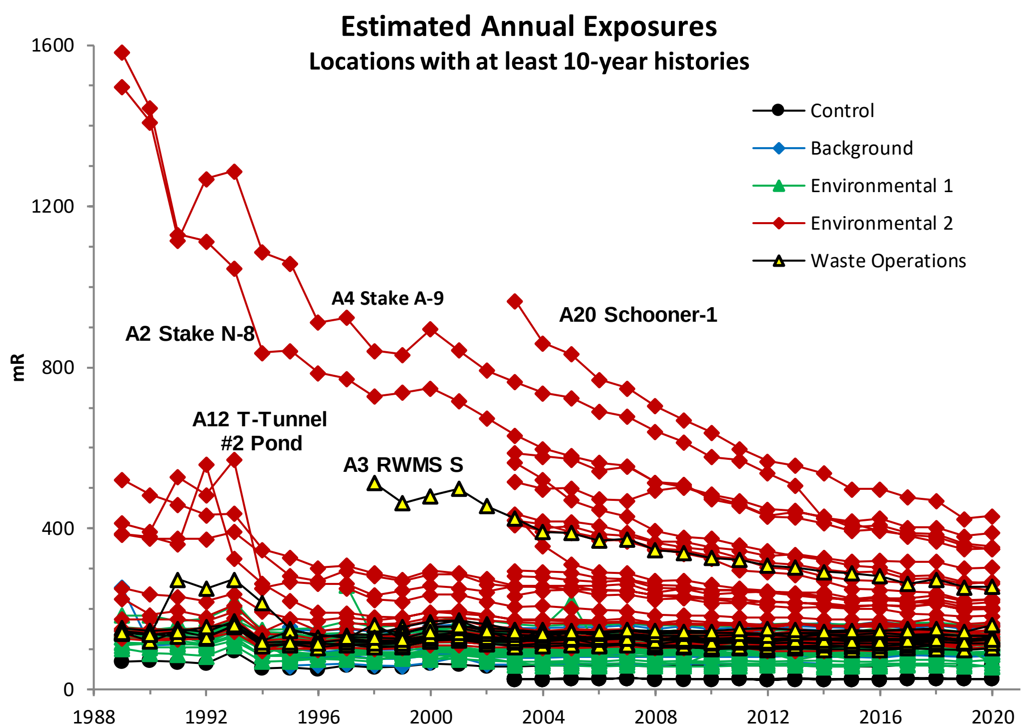

Figure 6-6. Trends in direct radiation exposure measured at TLD locations

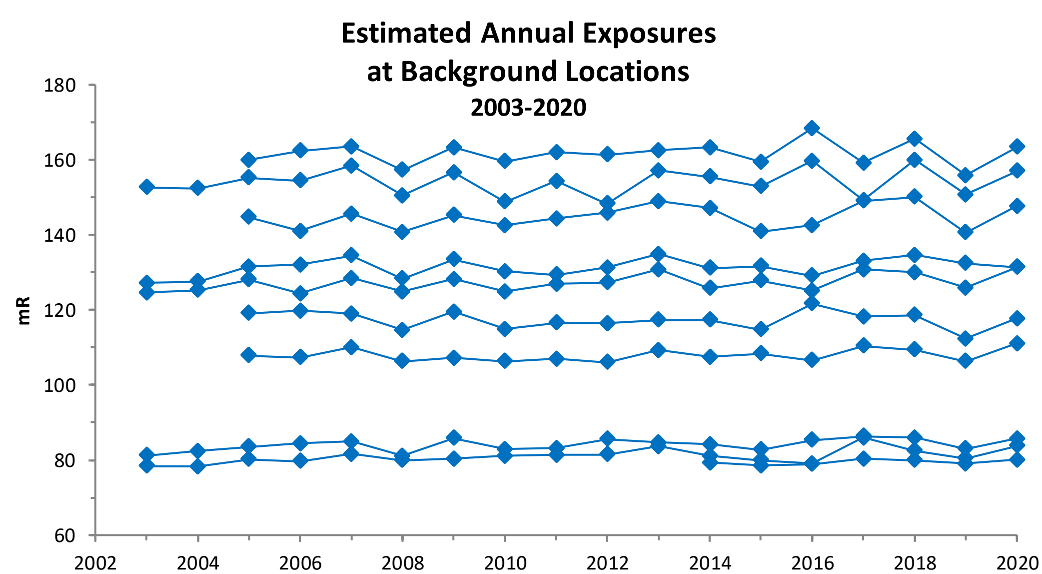

Figure 6-7. Trends in direct radiation exposure at 2020 background locations

6.4 Environmental Impact

Direct radiation exposure to the public from NNSS operations during 2020 was negligible. Radionuclides historically released to the environment on the NNSS have resulted in localized elevated exposures. The areas of elevated exposure are not open to the public, nor do personnel work in these areas full-time. Overall exposures at the RWMSs appear to be generally lower inside and at the boundary than those outside the RWMSs. This is due to the presence of radionuclides released from historical testing distributed throughout the area around the RWMSs compared with the clean soil used inside the RWMSs to cover the waste. The external dose to plants and animals at the location with the highest measured exposure was a small fraction of the dose limit to biota; hence, no detrimental effects to biota from external radiation exposure are expected at the NNSS.

6.5 References

Bechtel Nevada, 2003. *Routine Radiological Environmental Monitoring Plan*. DOE/NV/11718--804, Las Vegas, NV.

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Chapter 7: Community-Based Offsite Monitoring

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Community Environmental Monitoring Program Goals

Provide independent monitoring at offsite locations and communicate environmental data relevant to past and continuing activities at the Nevada National Security Site (NNSS). Engage the public through hands-on monitoring of environmental conditions in their communities as they might relate to activities at the NNSS. Communicate environmental monitoring data to the public in a transparent and accessible manner. Provide an educated, trusted, local resource for public inquiries regarding past and present activities at the NNSS.

Two community-based radiological monitoring programs are conducted off the NNSS. They provide independent results for the presence of man-made ***radionuclides***[1] in air and groundwater samples from communities surrounding the NNSS.

The Community Environmental Monitoring Program (CEMP) was initiated in 1981 and is conducted by the Desert Research Institute (DRI) of the Nevada System of Higher Education. CEMP's mission is to provide data to the public regarding the presence of man-made radionuclides in air and groundwater off of the NNSS that could be the result of current operations or past nuclear testing on the NNSS. Initially, the CEMP network functioned as a first line of offsite detection of potential radiation releases from underground nuclear tests at the NNSS. It currently exists as a non-regulatory public informational and outreach program. Monitored and collected data include, but are not necessarily limited to, ***background*** and airborne radiation data, meteorological data, and ***tritium (^3H)*** concentrations in downgradient community drinking water. Network air monitoring stations, located in Nevada, Utah, and California, are managed by local citizens, many of them high school science teachers, whose routine tasks are to ensure equipment is operating normally and to collect air filters and route them to DRI for analysis. These Community Environmental Monitors (CEMs) are also available to discuss the monitoring results with the public and to speak to community and school groups. DRI's responsibilities include maintaining the physical monitoring network through monthly visits by environmental radiation monitoring specialists, who also participate in training and interfacing with CEMs and interacting with local community members and organizations to provide information related to the monitoring data. DRI also provides public access to the monitoring data through maintenance of a project website at http://www.cemp.dri.edu/. A detailed informational background narrative about the CEMP can be found at http://www.cemp.dri.edu/cemp/moreinfo.html along with more detailed descriptions of the various types of sensors found at the stations and on outreach activities conducted by the CEMP.

The Nye County Tritium Sampling and Monitoring Program (TSaMP) was initiated in 2015 when the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) and the Environmental Management (EM) Nevada Program issued a 5-year grant to Nye County to monitor ^3H in wells downgradient of the NNSS. The grant supports the annual sampling of 10 core wells (i.e., the same wells year to year) and 10 additional wells (selected locations change from year to year). The program also supports Nye County's involvement in technical reviews of the Underground Test Area (UGTA) corrective action program (Chapter 11). Nye County coordinates with DRI, CEMs, and Nye County citizens to determine the sample well locations. Due to CEMP's success at involving and educating local communities, the grant directs that data administration and communication to the public of Nye County's program be conducted through the CEMP. DRI provides a link to Nye County's TSaMP data from the CEMP website at http://www.cemp.dri.edu/.

Sections 7.1 and 7.2 of this chapter present the 2020 CEMP air and water monitoring results. Section 7.3 presents the 2020 TSaMP monitoring results. Results from radiological monitoring of air, groundwater, direct radiation,

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

and biota conducted on the NNSS and the Nevada Test and Training Range (NTTR) by NNSA/NFO are presented in Chapters 4, 5, 6, and 8.

7.1 CEMP Air Monitoring

In 2020, DRI managed 24 CEMP stations, which compose the Air Surveillance Network (ASN) (Figure 7-1). The ASN stations include various types of equipment to monitor airborne radiation and meteorological conditions. Descriptions of the various types of sensors at the stations can be found at http://www.cemp.dri.edu/cemp/moreinfo.html. The air monitoring equipment described in Section 7.1.1 is shown in Figure 7-2.

7.1.1 Air Monitoring Equipment

CEMP Low-Volume Air Sampler Network – In 2020, the CEMP ASN included 23 continuously operating low-volume particulate air samplers. Warm Springs Summit, Nevada, is the only ASN station with no low-volume air sampler. Duplicate continuously operating air samplers are co-located at two randomly selected full-time stations for 3 months (one calendar quarter) before being moved to a new location. Glass-fiber filters from the low-volume particulate samplers are collected every 2 weeks by the CEMs and mailed to DRI. Each quarter, one complete set of filters are selected, prepared, and forwarded to an independent laboratory to be analyzed for ***gross alpha*** and ***beta radioactivity***, as well as gamma ***spectroscopy***. Samples are held for a minimum of 7 days after collection to allow for the decay of naturally occurring ***radon progeny***. Filters not selected for laboratory analysis are archived at DRI.

CEMP Thermoluminescent Dosimetry Network – Thermoluminescent ***dosimetry*** is used to measure both individual and population external ***exposure*** to ambient radiation from natural and man-made sources. In 2020, this network consisted of fixed environmental ***thermoluminescent dosimeters (TLDs)*** at 23 of the 24 CEMP stations. A TLD is not currently deployed at Warm Springs Summit due to limited access during the winter months. The TLD utilized for the CEMP is a Panasonic UD-814AS. Within the TLD, a slightly shielded lithium borate element is used to check low-energy radiation levels, and three calcium sulfate elements are used to measure penetrating ***gamma radiation***. For quality assurance purposes, duplicate TLDs are deployed at three randomly selected stations. An average daily exposure rate is calculated for each quarterly exposure period. The average of the quarterly daily values is multiplied by 365.25 days to obtain the total annual exposure for each station.

CEMP Pressurized Ion Chamber (PIC) Network – The PIC detector measures gamma radiation exposure rates and, because of its sensitivity, may detect low-level exposures that go undetected by other monitoring methods. PICs are in place at all 24 stations in the CEMP ASN. The primary function of the PIC network is to detect changes in ambient gamma radiation due to human activities. In the absence of such activities, ambient gamma radiation rates vary naturally among locations, reflecting differences in altitude (cosmic radiation), ***radioactivity*** in the soil (terrestrial radiation), and slight variations at a single location due to weather patterns. Because a full suite of meteorological data is recorded at each CEMP station (see next paragraph), variations in PIC readings caused by weather events such as precipitation or changes in barometric pressure are more readily identified. Variations are easily viewed by selecting a station location on the Graph link from the CEMP home page, http://www.cemp.dri.edu/, then selecting the desired variables.

CEMP Meteorological (MET) Network – Changing weather conditions can have an effect on measurable levels of background radiation; therefore, meteorological instrumentation is in place at each of the 24 CEMP stations and at the four ranch MET stations that do not monitor airborne radiation: Stone Cabin, Twin Springs, Nyala Ranch, and Medlin's Ranch. The MET network includes sensors that measure air temperature, humidity, wind speed and direction, solar radiation, barometric pressure, precipitation, and soil temperature and moisture. All of these data can be observed real-time at the onsite station display and archived data are available by accessing the CEMP home page at http://www.cemp.dri.edu/.

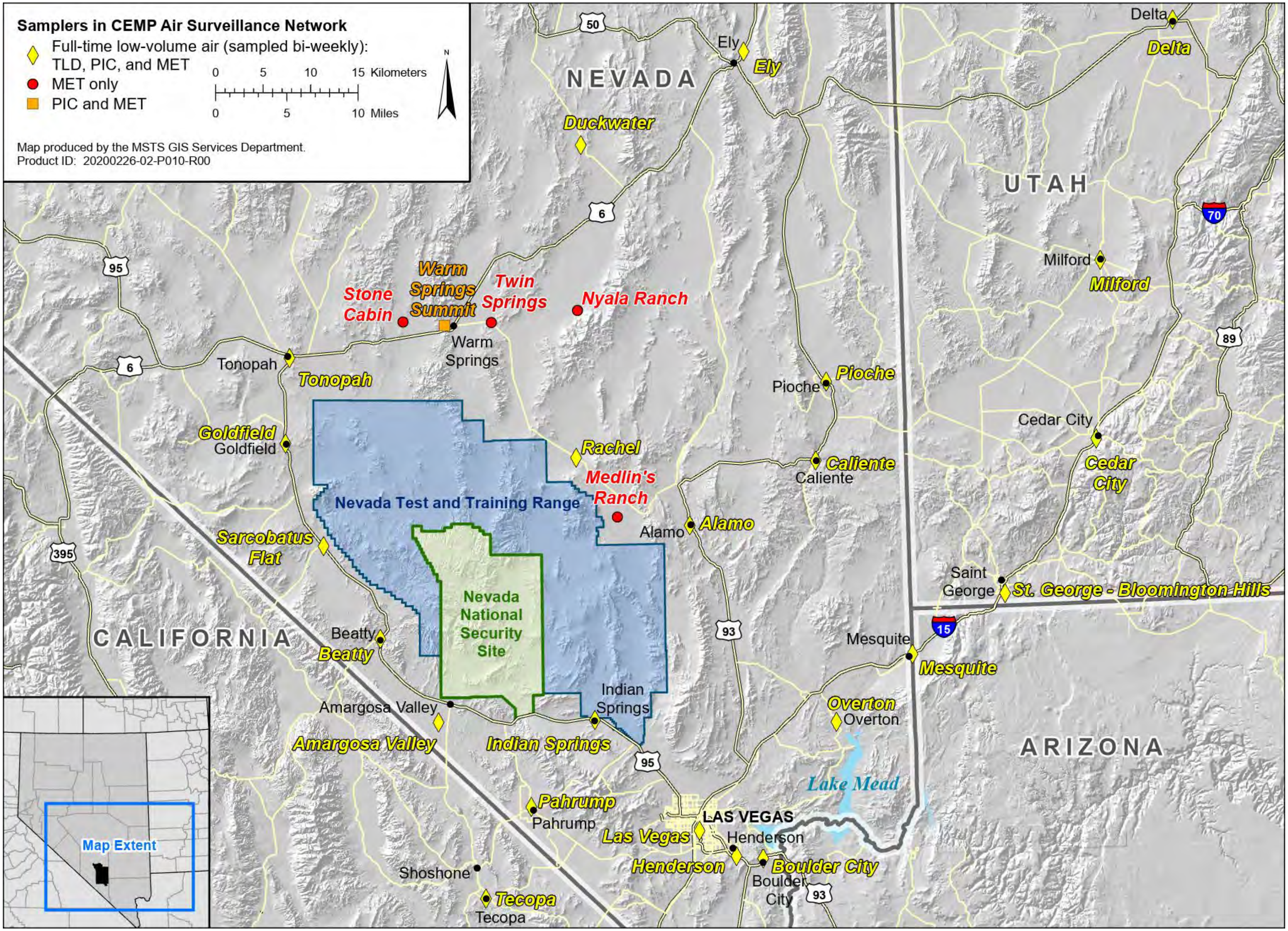

Figure 7-1. 2020 CEMP Air Surveillance Network

7.1.2 Air Sampling Methods

Samples of airborne particulates from CEMP ASN stations were collected by drawing air through a 5-centimeter (2-inch) diameter glass-fiber filter at a constant flow rate of 49.5 liters (1.75 cubic feet [ft^3]) per minute at standard temperature and pressure. The actual flow rate and total volume were measured with an in-line air-flow calibrator. The filter is mounted in a holder that faces downward at a height of approximately 1.5 meters (m) (5 feet [ft]) above the ground. The total volume of air collected ranged from approximately 1,030 to 1,290 cubic meters (m^3) (36,000 to 45,000 ft^3), depending on the elevation of the station and changes in air temperature and/or pressure.

Air sampling occurs full-time year-round at all stations, but only one sample per quarter from each station is selected for routine analysis.

Figure 7-2. CEMP station in Cedar City, Utah

7.1.3 Air Sampling Results

7.1.3.1 Gross Alpha and Gross Beta

Analyses of gross alpha and beta in airborne particulate samples are used to screen for long-lived radionuclides in the air. During 2020, the mean annual gross alpha activity across all CEMP sample locations was $2.45 \pm 1.09 \times 10^{-15}$ microcuries per milliliter (μCi/mL) ($9.07 \pm 4.03 \times 10^{-5}$ ***becquerels*** [Bq]/m^3) (Table 7-1). As expected, gross alpha was detectable in all 2020 air particulate samples. Figure 7-3 shows the long-term maximum, mean, and minimum alpha trend for all CEMP stations combined.

Although the cumulative gross alpha results for 2020 show an apparent increase over recent years, all individual measurements are within the range of historical values observed for the stations from which samples were obtained. To rule out laboratory processing and analytical error as a potential source of the increase, the decision was made to analyze samples from four additional sampling intervals during 2020 per station across the network. Results of that analysis are pending and will be available through the CEMP web site at https://cemp.dri.edu/2020_report.html as soon as they become available.

Table 7-1. Gross alpha results for the CEMP offsite ASN in 2020

Sampling Location	Number of Samples	Concentration (× 10^{-15} µCi/mL [3.7 × 10^{-5} Bq/m^3]) Mean	Standard Deviation	Minimum	Maximum
Alamo	4	2.88	1.51	1.35	4.48
Amargosa Valley	5	3.10	1.60	1.83	5.11
Beatty	5	2.03	0.71	1.44	3.01
Boulder City	4	2.64	0.49	2.18	3.15
Caliente	4	2.93	1.63	1.50	5.24
Cedar City	4	2.34	1.51	1.26	4.55
Delta	4	1.94	0.76	1.44	3.05
Duckwater	4	2.54	1.75	1.07	4.91
Ely	4	1.93	0.73	1.12	2.79
Goldfield	5	2.45	1.22	1.34	4.44
Henderson	4	2.99	0.79	2.24	3.77
Indian Springs	5	2.71	0.97	1.63	4.06
Las Vegas	4	2.26	1.14	1.03	3.79
Mesquite	4	3.33	1.82	1.44	5.68
Milford	4	1.98	0.50	1.43	2.64
Overton	4	3.11	1.67	1.69	5.21
Pahrump	4	2.76	1.17	1.04	3.60
Pioche	4	2.10	0.94	1.51	3.49
Rachel	4	1.94	0.82	1.10	2.93
Sarcobatus Flats	5	2.08	0.75	1.51	3.37
St. George, Bloomington Hills (BH)	4	2.29	0.40	1.89	2.84
Tecopa	4	2.34	0.66	1.55	3.11
Tonopah	5	1.75	0.58	1.26	2.71

Network Mean = 2.45 ± 1.09 × 10^{-15} µCi/mL.
Mean ***Minimum Detectable Concentration (MDC)*** = 0.31 × 10^{-15} µCi/mL.
Standard Error of Mean MDC = 0.01 × 10^{-15} µCi/mL.

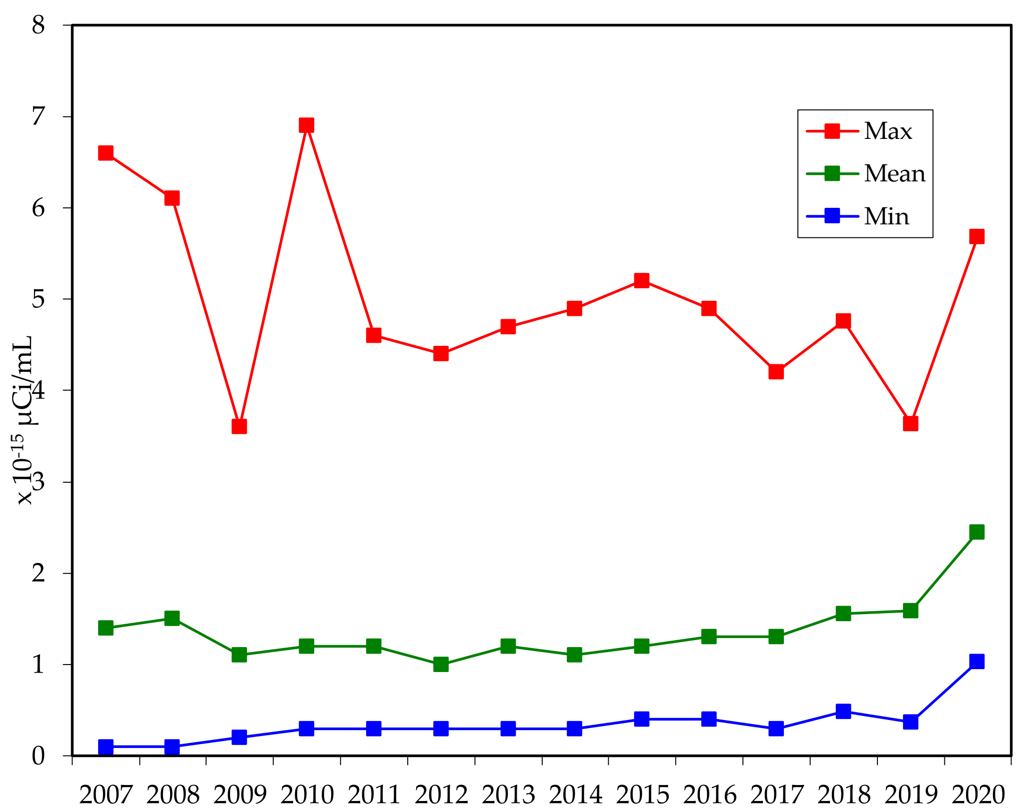

Figure 7-3. Historical trend for gross alpha analysis for all CEMP stations

The mean annual gross beta activity across all sample locations (Table 7-2) was 2.30± 0.55× 10^{-14} µCi/mL (8.51 ± 2.04 × 10^{-4} Bq/m^3). Gross beta activity was detected in all air samples and, overall, was similar to previous years' levels. Figure 7-4 shows the long-term maximum, mean, and minimum beta trend for all stations combined. The 2011 peak in the maximum data, observed across all stations in the network, was due to the tsunami-damaged Fukushima Nuclear Power Plant accident in Japan. Except for 2011, mean gross beta results have been essentially level from 2007 to 2020. This trend is also reflected by most of the stations on an individual basis.

Table 7-2. Gross beta results for the CEMP offsite ASN in 2020

Sampling Location	Number of Samples	Concentration (× 10^{-14} µCi/mL [3.7 × 10^{-4} Bq/m^3])			
		Mean	Standard Deviation	Minimum	Maximum
Alamo	4	2.19	0.35	1.74	2.59
Amargosa Valley	5	2.52	0.59	1.53	3.01
Beatty	5	2.01	0.47	1.49	2.57
Boulder City	4	2.56	0.52	2.14	3.31
Caliente	4	2.62	0.72	1.64	3.35
Cedar City	4	2.05	0.54	1.36	2.68
Delta	4	2.02	0.39	1.46	2.35
Duckwater	4	1.96	0.60	1.18	2.54
Ely	4	1.73	0.48	1.04	2.15
Goldfield	5	1.89	0.50	1.18	2.42
Henderson	4	2.53	0.41	2.13	2.91
Indian Springs	5	2.52	0.50	1.72	3.01
Las Vegas	4	2.29	0.18	2.07	2.44
Mesquite	4	2.62	0.25	2.37	2.91
Milford	4	2.23	0.62	1.36	2.80
Overton	4	2.73	0.15	2.55	2.89
Pahrump	4	2.21	0.51	1.54	2.66
Pioche	4	2.07	0.54	1.27	2.38
Rachel	4	2.11	0.62	1.56	2.70
Sarcobatus Flats	5	2.44	0.58	1.46	2.98
St. George (BH)	4	2.80	0.69	2.21	3.72
Tecopa	4	2.81	0.49	2.15	3.34
Tonopah	4	2.09	0.74	1.02	2.77

Network Mean = 2.30 ± 0.55 × 10^{-14} µCi/mL.
Mean MDC = 0.06 × 10^{-14} µCi/mL.
Standard Error of Mean MDC = 0.002 × 10^{-14} µCi/mL.

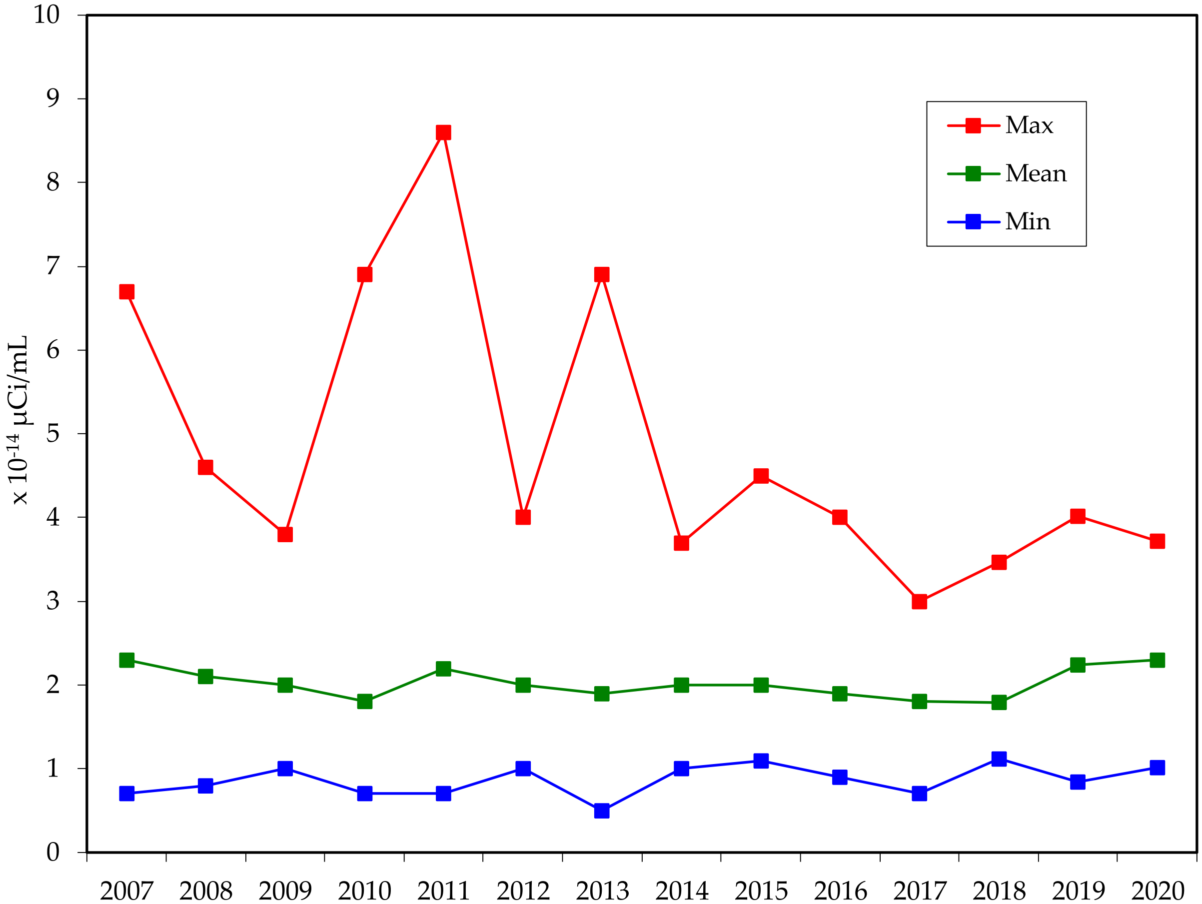

Figure 7-4. Historical trend for gross beta analysis for all CEMP stations

7.1.3.2 Gamma Spectroscopy

As with gross alpha and beta, gamma spectroscopy analysis was performed on one set of samples from the low-volume air sampling network each quarter. As in previous years, man-made gamma-emitting radionuclides were not detected in any samples. In most of the samples, naturally occurring beryllium-7 (^{7}Be) was detectable. This radionuclide is produced by cosmic ray interaction with nitrogen in the atmosphere. The mean annual activity for ^{7}Be for the sampling network was $1.03 \pm 0.28 \times 10^{-13}$ μCi/mL.

7.1.4 Thermoluminescent Dosimetry Results

TLDs measure ***ionizing radiation*** from all sources, including natural radioactivity from cosmic or terrestrial sources and from man-made radioactive sources. The TLDs are mounted in a Plexiglas holder approximately 1 m (3.3 ft) above the ground and are exchanged quarterly. TLD results are not presented for the Warm Springs Summit station because access is limited in the winter, which does not allow for the required quarterly change of the TLD. The total mean annual exposure for 2020 ranged from 73 milliroentgens (mR) (0.73 millisieverts [mSv]) at Pahrump, Nevada, to 164 mR (1.64 mSv) at Duckwater, Nevada, with a mean annual exposure of 118 mR (1.18 mSv) for all operating locations. Results are presented in Table 7-3 and are consistent with previous years' data. Figure 7-5 shows the long-term data trend for the CEMP stations as a whole.

Table 7-3. TLD monitoring results for the CEMP offsite ASN in 2020

		Estimated Annual Exposure (mR)[(a)]		
Sampling Location	**Number of Quarters**	**Mean[(b)]**	**Minimum[(b)]**	**Maximum[(b)]**
Alamo	4	121	110	134
Amargosa Valley	4	117	99	130
Beatty	4	146	130	161
Boulder City	4	112	108	120
Caliente	4	118	103	149
Cedar City	4	101	85	111
Delta	4	107	96	120
Duckwater	4	133	99	164
Ely	4	114	87	143
Goldfield	4	122	105	138
Henderson	4	122	115	130
Indian Springs	4	99	91	112
Las Vegas	3	110	91	112
Mesquite	4	108	100	120
Milford	4	145	128	153
Overton	4	86	75	96
Pahrump	4	85	73	96
Pioche	4	131	107	149
Rachel	4	130	114	145
Sarcobatus Flats	4	140	126	159
St. George (BH)	4	120	100	133
Tecopa	4	105	92	124
Tonopah	4	141	126	156

(a) To obtain daily exposure rates, divide annual exposure rates by 365.25.
(b) Mean, minimum, and maximum values are from quarterly estimates.

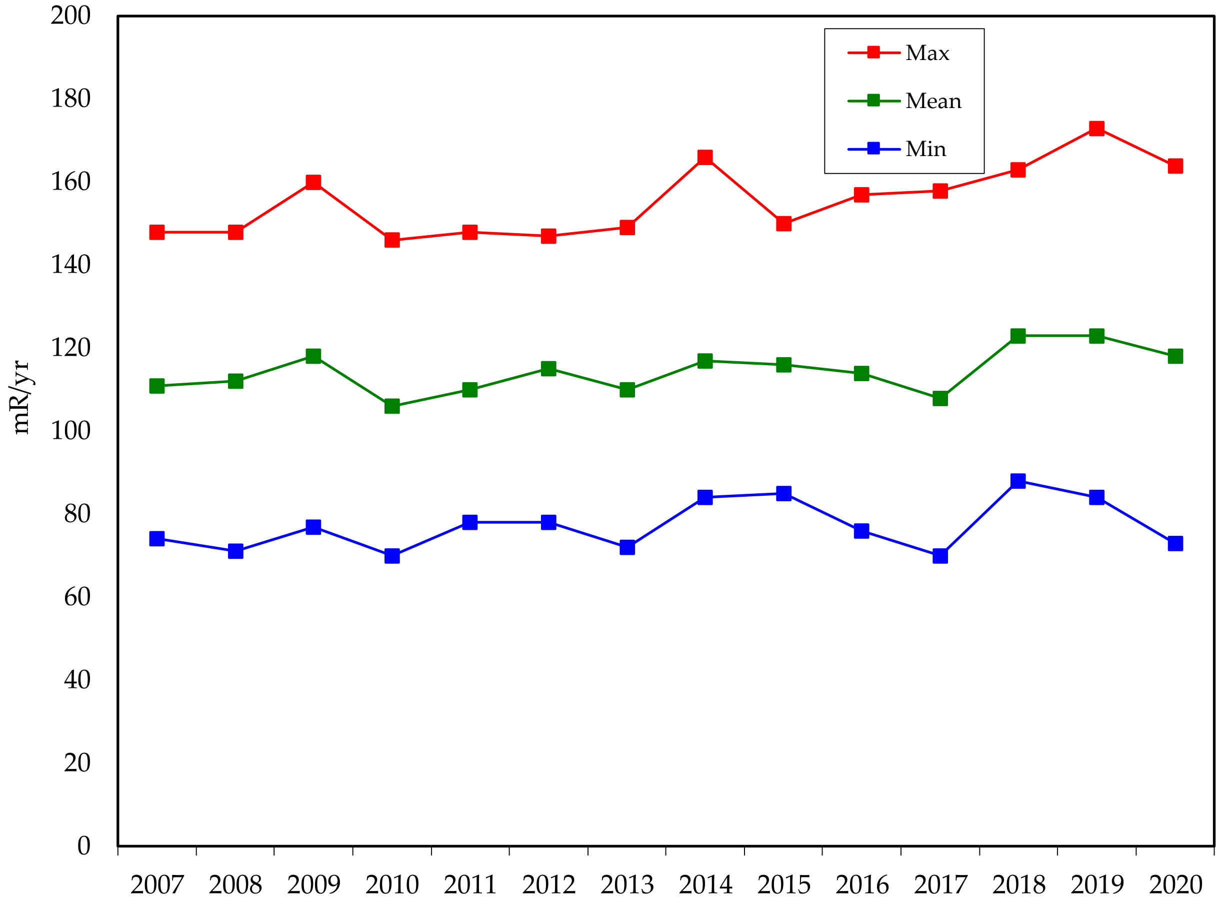

Figure 7-5. Historical trend for TLD analysis for all CEMP stations

7.1.5 Pressurized Ion Chamber Results

The PIC data presented in this section are based on daily averages of gamma exposure rates from each station. Table 7-4 lists the maximum, minimum, and standard deviation of daily averages (in microroentgens per hour [µR/hr]) for periods in 2020 when data were available. It also shows the average gamma exposure rate for each station during the year (in µR/hr) as well as the total annual exposure (in milliroentgens per year [mR/yr]). The exposure rate ranged from 75.34 mR/yr (0.75 mSv/yr) in Pahrump, Nevada, to 173.45 mR/yr (1.73 mSv/yr) at Warm Springs Summit, Nevada. Background levels of environmental gamma exposure rates in the United States (from combined effects of terrestrial and cosmic sources) vary between 49 and 247 mR/yr (Committee on the Biological Effects of Ionizing Radiation III 1980). Averages for selected regions of the United States were compiled by the U.S. Environmental Protection Agency (EPA) and are shown in Table 7-5. The annual exposure levels observed at the CEMP stations in 2020 are well within these United States background levels, and are consistent with previous years' exposure rates.

Table 7-4. PIC monitoring results for the CEMP offsite ASN in 2020

	Daily Average Gamma Exposure Rate (µR/hr)				
Sample Location	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Annual Exposure (mR/yr)**
Alamo	13.40	0.35	12.4	14.4	117.38
Amargosa Valley	11.65	0.15	11.1	12.2	102.05
Beatty	17.00	0.36	15.9	18.1	148.92
Boulder City	15.20	0.13	14.7	15.7	133.15
Caliente	16.40	0.25	15.3	17.5	143.66
Cedar City	13.20	0.23	12.3	14.1	115.63
Delta	13.05	0.19	12.4	13.7	114.32
Duckwater	15.60	0.26	14.8	16.4	136.66
Ely	12.45	0.29	11.4	13.5	109.06
Goldfield	16.05	0.35	14.8	17.3	140.60
Henderson	13.50	0.28	12.8	14.2	118.26
Indian Springs	11.65	0.21	10.9	12.4	102.05
Las Vegas	10.55	0.17	10.1	11.0	92.42
Mesquite	11.90	0.17	11.1	12.7	104.24
Milford	18.55	0.54	17.0	20.1	162.50
Overton	11.05	0.21	10.4	11.7	96.80
Pahrump	8.60	0.18	8.0	9.2	75.34
Pioche	16.40	0.21	15.6	17.2	143.66
Rachel	15.65	0.48	14.4	16.9	137.09
Sarcobatus Flats	16.90	0.31	15.9	17.9	148.04
St. George (BH)	14.25	0.18	13.5	15.0	124.83
Tecopa	13.30	0.25	12.5	14.1	116.51
Tonopah	16.65	0.35	15.6	17.7	145.85
Warm Springs Summit	19.80	0.40	18.4	21.2	173.45

Table 7-5. Average natural background radiation (excluding radon) for selected U.S. cities

City	Annual Exposure (mR/yr)
Denver, CO	164.6
Fort Worth, TX	68.7
Las Vegas, NV	69.5
Los Angeles, CA	73.6
New Orleans, LA	63.7
Portland, OR	86.7
Richmond, VA	64.1
Rochester, NY	88.1
St. Louis, MO	87.9
Tampa, FL	63.7
Wheeling, WV	111.9

Source: https://cemp.dri.edu/cemp/Radiation.html. "Radiation in Perspective," August 1990 (Access Date: 8/5/2021)

7.1.6 Environmental Impact

Results of analyses conducted on data obtained from the CEMP network of low-volume particulate air samplers, TLDs, and PICs showed no measurable evidence at CEMP stations of offsite impacts from radionuclides from NNSA/NFO activities. Activity observed in gross alpha and beta analyses of low-volume air sampler filters was consistent with previous years' results, and is within the range of activity found in other communities of the United States not adjacent to man-made radiation sources. Likewise, no man-made gamma-emitting radionuclides were detected. TLD and PIC results remained consistent with previous years' background levels and are well within average background levels observed in other parts of the United States (Table 7-5).

Occasional elevated gamma readings (10%–50% above normal average background) detected by the PICs in 2020 were associated with precipitation events and/or low barometric pressure. Low barometric pressure can result in the release of naturally occurring radon and its progeny from the surrounding soil and rock. Precipitation events can result in the "rainout" of globally distributed radionuclides occurring as airborne particulates in the upper atmosphere. Figure 7-6, generated from the CEMP website, illustrates an example of this phenomenon.

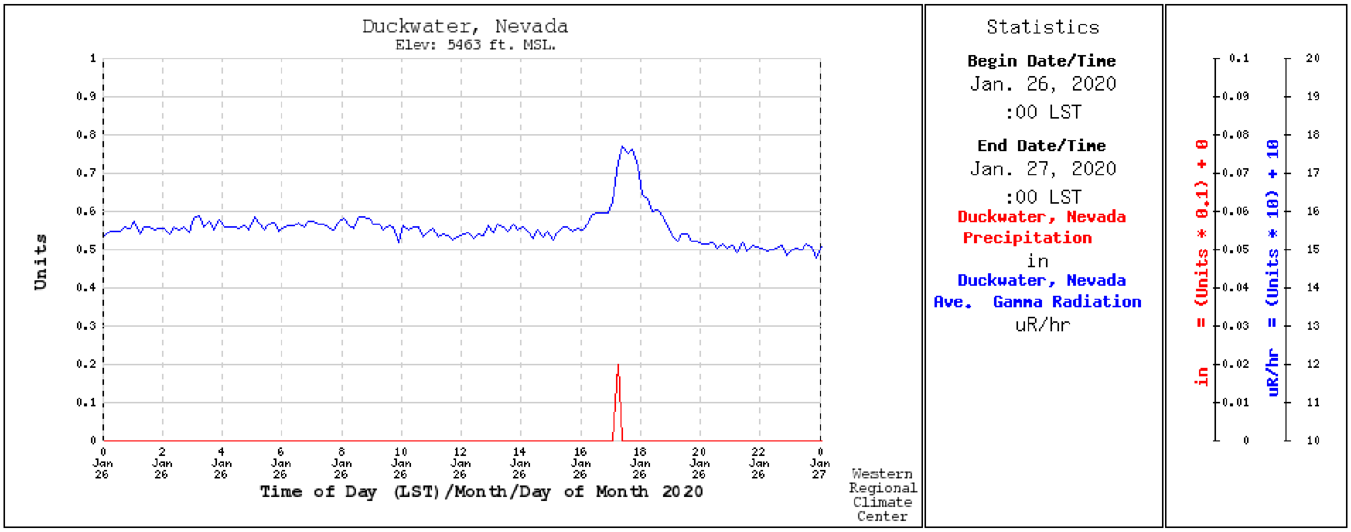

Figure 7-6. An example of the effect of meteorological phenomena on background gamma readings at the Duckwater, Nevada, CEMP station

7.2 CEMP Groundwater Monitoring

The CEMP for water is a non-regulatory program; its purpose is outreach and information to the public. Water samples are collected and analyzed for the presence of man-made radionuclides that could be the result of past nuclear testing on the NNSS. The CEMP monitors four groundwater wells downgradient of the NNSS (Figure 7-7). Water samples are collected by DRI personnel and analyzed for ^3H. Tritium is one of the most abundant radionuclides generated by an underground nuclear test, and because it is a constituent of the water molecule itself, it is also one of the most mobile. DRI provides public access to water monitoring data through CEMP's website at http://www.cemp.dri.edu/.

7.2.1 Sample Locations and Methods

In August 2020, DRI sampled four wells. Sample locations (Figure 7-7) were selected based upon input from participating CEMs in communities located downgradient of the NNSS. All wells were sampled at a water delivery point (i.e., faucet). Each sample originated from water distribution lines connected to submersible pumps that sampled the local groundwater system. Water was allowed to flow from each water delivery point for 5 to 15 minutes prior to obtaining a sample in order to purge stagnant water from the distribution lines. This process ensured the resultant sample was representative of local groundwater. Table 7-6 lists sample locations, date sampled, and sampling method.

Table 7-6. CEMP water monitoring locations sampled in 2020

Monitoring Location Description	Latitude[(a)]	Longitude[(a)]	Date Sampled	Sample Collection Method
Amargosa Valley school well	36°34.18'	−116°27.50'	8/28/2020	By hand from line off well head
Beatty Water and Sewer municipal water distribution system	36°57.09'	−116°48.26'	8/24/2020	By hand from well head
Sarcobatus Flats well	37°16.76'	−117°01.06'	8/24/2020	By hand at residential source
Tecopa residential well	35°50.89'	−116°13.63'	8/21/2020	By hand at residential source

(a) Coordinate datum is WGS84 and was obtained using a GPS [global positioning system].

Samples were sent to ARS Aleut Analytical Laboratory in Port Allen, Louisiana, for ^{3}H analysis using an EPA-approved method consisting of unenriched scintillation counting. The ***decision level (L_C)*** for this counting process was less than 239 picocuries per liter (pCi/L). The L_C is based on the variability of multiple measures of samples which establish laboratory background. If a sample exceeds the L_C, it is considered distinguishable from background. The MDC considers both the variability associated with multiple measures of the background and the variability associated with multiple measures of a laboratory control sample containing trace quantities of ^{3}H. In 2020, the MDC for ^{3}H was approximately 486 pCi/L; this is a more rigorous threshold than the L_C, dictating that the sample be distinguishable from background at a confidence of 95%. The L_C and the MDC are approximately 1% and 2% of the EPA limit for ^{3}H in drinking water (respectively); the EPA limit is 20,000 pCi/L. ***Quality assurance*** and ***control*** procedures are described in Chapter 15.

7.2.2 Results of Groundwater Monitoring

Tritium analyses from ARS Aleut Analytical for the four groundwater samples yielded results that were all quantifiably below background (≤ the MDC of approximately 486 pCi/L). Public access to monitoring data is available on the DRI CEMP website at http://www.cemp.dri.edu/.

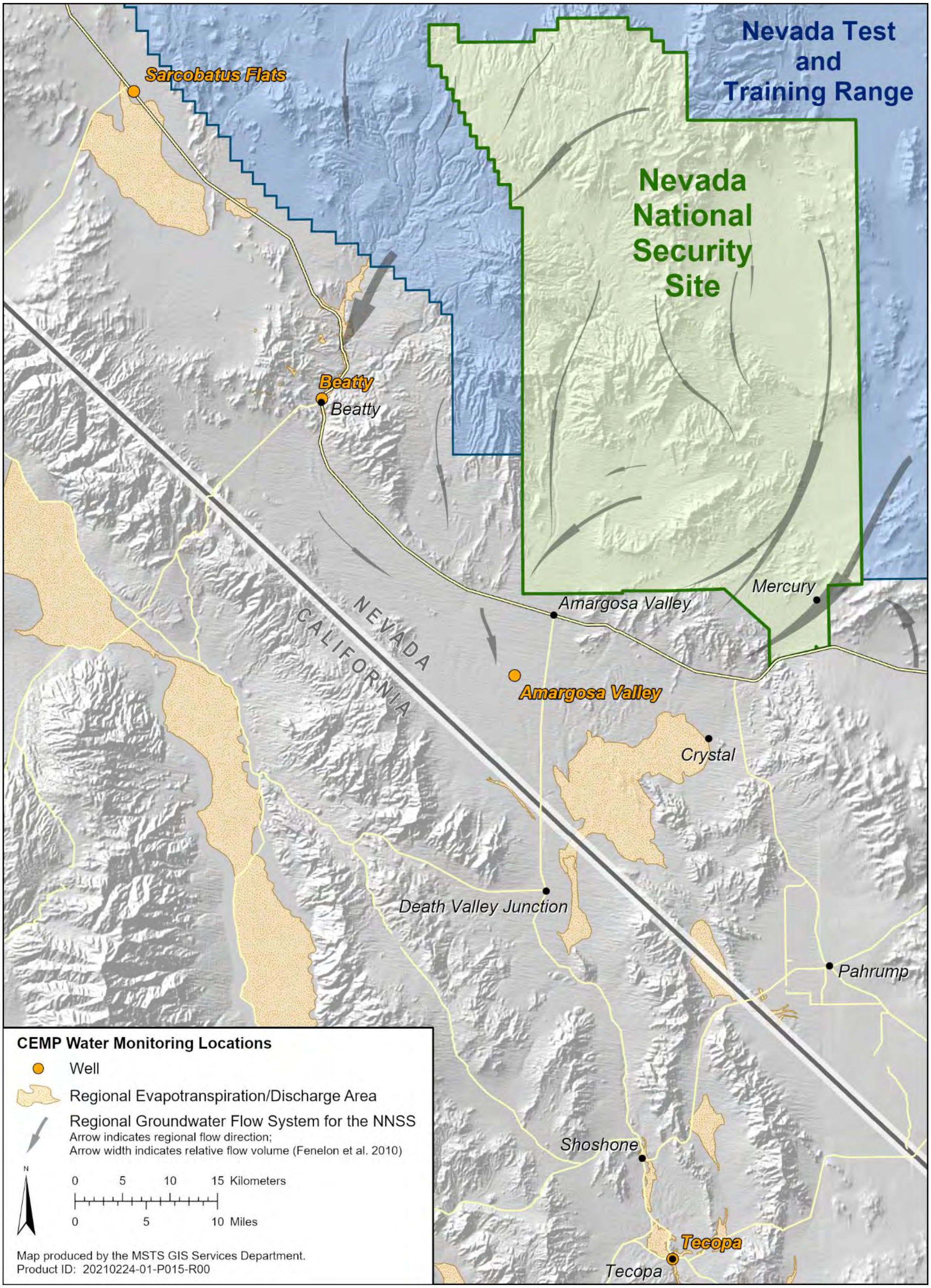

Figure 7-7. 2020 CEMP water monitoring locations

7.3 Nye County Tritium Sampling and Monitoring Program

The Nye County TSaMP was initiated in 2015 in response to the county's request to expand its support of offsite community-based monitoring of wells for ^{3}H. A 7-year grant from the EM Nevada Program supports the county's annual sampling of 20 locations downgradient of the NNSS: 10 core locations (i.e., the same locations year to year) and 10 additional locations (selected locations change from year to year). The grant also supports Nye County's involvement in technical reviews of the UGTA corrective action program (Chapter 11). To help determine sample locations, Nye County coordinates with DRI, who conducts the CEMP, with the CEMP's CEMs, and Nye County citizens. Nye County communicates their TSaMP activities and results to the public through poster presentations at annual DOE EM-funded Groundwater Open House meetings (Section 11.6), presentations at annual CEMP meetings, articles published in the Pahrump Valley Times, and this annually published report.

In 2020, in addition to the 10 core locations (9 wells and 1 spring), Nye County sampled 9 wells and 1 spring. (Table 7-7 and Figure 7-8). Selected locations for 2020 were in the same general areas as 2015–2019, and were chosen for their position within the projected groundwater flow path from the NNSS, proximity to downgradient communities, and recommendations provided by CEMs or Nye County citizens. Wells managed by Nye County and being sampled for ^{3}H under the TSaMP were initially drilled as part of the Early Warning Drill Program ("EWDP" labeled wells) or as Nye County Groundwater Evaluation Wells ("NC-GWE" labeled wells). Nye County also takes water levels in these wells on a quarterly basis through funding from the Nye County Water District's Water Level Measurement Program. Some locations selected for sampling under the TSaMP may include NNSA/NFO wells or locations that are also sampled under the NNSS Integrated Groundwater Sampling Plan (Section 5.1) or under the CEMP.

All wells without integrated pumps were sampled using either an air-powered submersible positive displacement pump or a 3-inch submersible electric pump. A minimum of three well volumes was pumped from each well prior to sampling in order to purge water from the pump tubing and well annulus and ensure samples are representative of local groundwater conditions. Community wells, which include domestic or municipal wells, were sampled from the dedicated pump discharge. Two private domestic wells were sampled in 2020, with the samples also being collected from the dedicated pump discharge. Sampling of private domestic wells was incorporated into the TSaMP program in 2018 to expand the spatial distribution of sampling sites and to provide a means to increase community involvement. Two springs were sampled in 2020, with samples being collected directly from the spring discharge.

All samples were analyzed for ^{3}H by Radiation Safety Engineering, Inc., in Chandler, Arizona, using an EPA-approved, unenriched scintillation counting method. The sample MDCs for this method were either 292 or 296 pCi/L, which is less than 2% of the EPA limit for ^{3}H in drinking water (20,000 pCi/L). Analytical methods included the use of quality control samples such as duplicates, blanks, and spikes. Nye County's quality assurance procedures for ^{3}H sampling are documented in Test Plan TPN-11.8 (2019), "Groundwater Sampling and Analysis for the Nye County Tritium Sampling and Monitoring Program," and Work Plan WP-11, "Groundwater Chemistry Sampling and Analysis" (2019) (available on the Nye County website at http://www.co.nye.nv.us/index.aspx?NID=901).

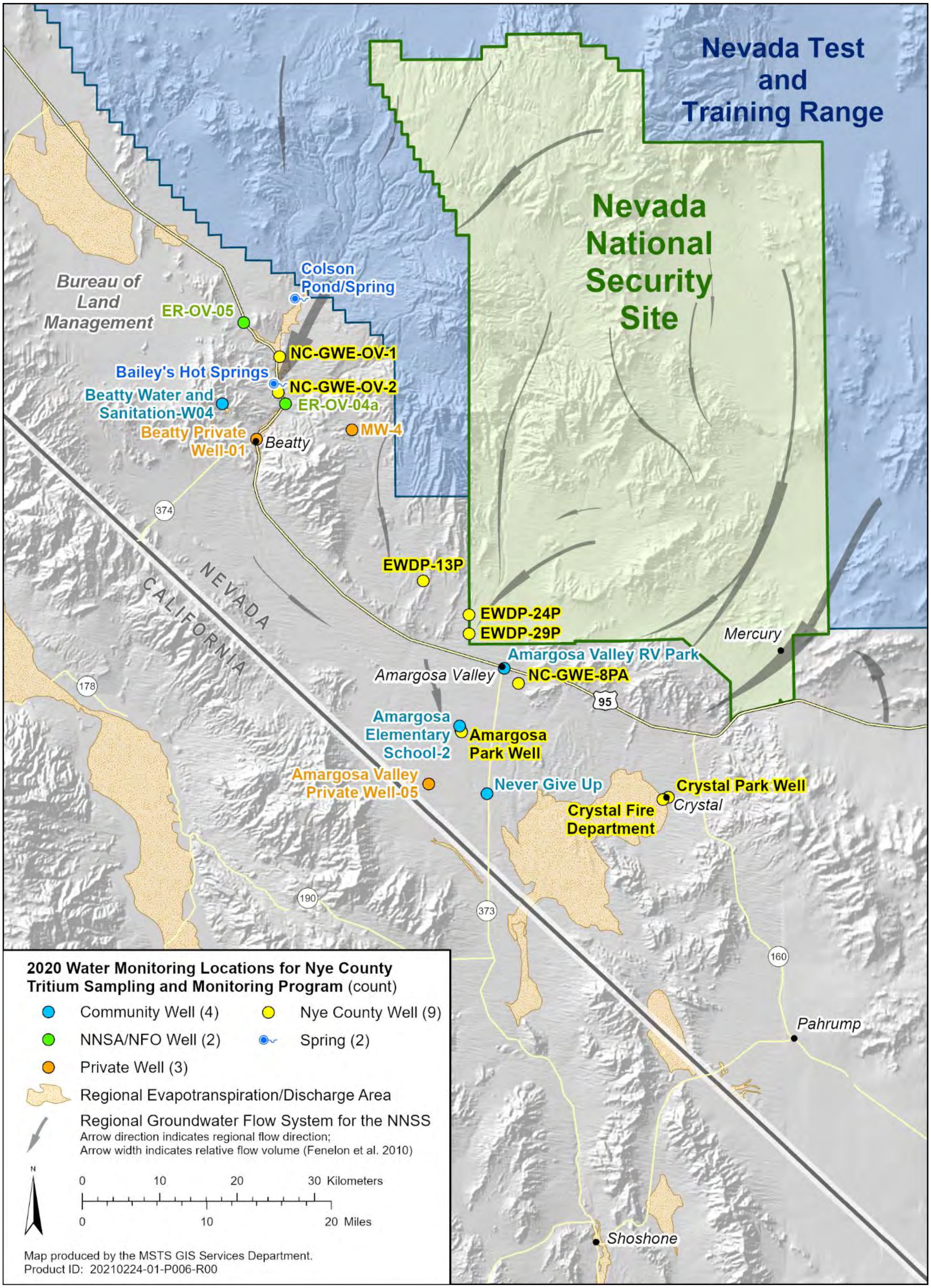

Figure 7-8. 2020 Nye County TSaMP water monitoring locations

Table 7-7. Nye County TSaMP water monitoring locations, results, and dates sampled

Sample Locations	Latitude[(a)]	Longitude[(a)]	Date Sampled	H^3 Activity Minimum Detectable Concentration (pCi/L)
		Nye County Wells		
Amargosa Park well	36.56829	−116.45969	11/9/2020	<296
Crystal Park Well	36.49045	−116.16179	11/9/2020	<296
Crystal Fire Department	36.48785	−116.16985	11/9/2020	<296
EWDP-13P*	36.74441	−116.51395	10/22/2020	<292
EWDP-24P*	36.70466	−116.44799	10/21/2020	<292
EWDP-29P	36.68258	−116.44802	10/27/2020	<292
NC-GWE-8PA*	36.62442	−116.37708	10/20/2020	<292
NC-GWE-OV-1*	37.00618	−116.72076	10/28/2020	<292
NC-GWE-OV-2*	36.96455	−116.72298	10/28/2020	<292
		NNSA/NFO Wells		
ER-OV-04a	36.95133	−116.71256	12/2/2020	<296
ER-OV-05	37.04605	−116.77284	12/1/2020	<296
		Community Wells		
Amargosa Elementary School-2*	36.56988	−116.46063	11/4/2020	<292
Amargosa Valley RV Park*	36.64205	−116.39751	11/4/2020	<292
Beatty Water and Sanitation W04*	36.95155	−116.80433	11/5/2020	<292
Never Give Up*[(b)]	36.49617	−116.42356	11/2/2020	<292
		Private Wells		
Amargosa Valley Private Well-05	36.50785	−116.50753	11/10/2020	<292
Beatty Private Well-01	36.91020	−116.75464	11/10/2020	<292
MW-4	36.92076	−116.61625	11/16/2020	<296
		Springs		
Baileys Hot Springs*	36.97472	−116.72250	11/5/2020	<292
Colson Pond -Spring	37.07390	−116.69120	11/5/2020	<296

*Core locations are sampled each year.

(a) Coordinates are North American Datum 1983.

(b) Formerly Northwest Academy.

All ^3H analysis results were below background, i.e., ≤ the MDC. Similar to the CEMP water sampling results (Section 7.2) and those of the community wells within NNSA/NFO's water sampling network (Section 5.1.3.6), Nye County's monitoring confirms that ^3H from past underground nuclear testing on the NNSS is not present in these wells.

The wells and water supply systems within the CEMP and Nye County monitored network downgradient of the NNSS continue to show no evidence of ^3H contamination from past underground nuclear testing on the NNSS. To date, the maximum concentration of ^3H observed off site is at ER-EC-11 on the NTTR. Tritium at ER-EC-11 was reported as 18,400 pCi/L in 2017 (NNSS Environmental Report 2017, Table 5-4 [MSTS 2018]). Well ER-EC-11 is approximately 0.72 kilometers (km) (0.45 mile [mi]) west of the NNSS boundary (Figure 5-2). Additional sampling and analyses will continue as part of the Phase II investigation for the Central and Western Pahute Mesa, and groundwater characterization and modeling activities are ongoing to forecast the extent of offsite contamination over the next 1,000 years (Section 11.2.1). The nearest CEMP water monitoring locations downgradient of the NNSS are Amargosa Valley and Beatty, approximately 70 km (43 mi) and 40 km (25 mi), respectively, southwest of Well ER-EC-11.

7.4 References

Committee on the Biological Effects of Ionizing Radiation III, 1980. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980*. National Academy Press, Washington, D.C.

Mission Support and Test Services LLC, 2018. *Nevada National Security Site Environmental Report 2017*. DOE/NV/03624--0270, Las Vegas, Nevada.

MSTS, see Mission Support and Test Services, LLC.

TPN-11.8, 2019. *Groundwater Sampling and Analysis for the Nye County Tritium Sampling and Monitoring Program*. Test Plan: Nye County Nuclear Waste Repository Project Office, Pahrump, Nevada.

WP-11, 2019. *Groundwater Chemistry Sampling and Analysis for the Nye County Tritium Sampling and Monitoring Program*. Work Plan: Nye County Nuclear Waste Repository Project Office, Pahrump, Nevada.

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Chapter 8: Radiological Biota Monitoring

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Radiological Biota Monitoring Goals

*Collect and analyze biota samples for radionuclides to estimate the potential dose to humans who may consume plants or game animals from the Nevada National Security Site (NNSS) (see Chapter 9 for the estimates of dose to humans). Collect and analyze biota samples for radionuclides to estimate the **absorbed radiation dose**[1] to NNSS biota (see Chapter 9 for the estimates of dose to NNSS plants and animals). Collect and analyze soil samples at the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) to provide evidence that the burrowing activities of fossorial animals have or have not compromised the integrity of the soil-covered waste disposal units.*

Historical atmospheric nuclear explosive testing, releases from underground nuclear tests, and radioactive waste disposal sites provide potential sources of radiation contamination and ***exposure*** to NNSS plants and animals (biota). U.S. Department of Energy (DOE) Order DOE O 458.1, "Radiation Protection of the Public and the Environment," requires DOE sites to monitor ***radioactivity*** in the environment to ensure the public does not receive a radiological ***dose*** greater than 100 millirems per year from all pathways of exposure, including the ingestion of contaminated plants and animals. DOE O 458.1 also requires monitoring to ensure aquatic and terrestrial plant and animal populations are protected from excessive radiological dose.

The U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) land-use practices on the NNSS discourage the harvesting of plants or plant parts (e.g., pine nuts and wolfberries) for direct consumption by humans. Some edible plant material might be taken off site and consumed, but this is generally not allowed and, if it does occur, is very limited. Game animals on the NNSS might travel off the site and become available through hunting for consumption by the public, which makes the ingestion of game animals the primary potential biotic pathway for dose to the public.

Plants and game animals are monitored under the Routine Radiological Environmental Monitoring Plan (RREMP) (Bechtel Nevada 2003). They are sampled annually from contaminated NNSS sites to estimate doses to persons hypothetically consuming them, to measure the potential for ***radionuclide*** transfer through the food chain, and to determine if NNSS biota are exposed to radiation levels harmful to their own populations. Biota and soil samples from the RWMSs are also periodically collected to assess the integrity of waste disposal cells. This chapter describes the biota-monitoring program designed to meet public and environmental radiation protection regulations (Section 2.4) and presents the field sampling and analysis results from 2020. The estimated dose to humans potentially consuming NNSS plants and animals and the dose to biota from these radionuclides are presented in Chapter 9.

8.1 Species Selection

The goal for vegetation monitoring is to sample the plants most likely to have the highest contamination within the NNSS environment. They are generally found inside demarcated radiological areas near the "ground zero" locations of historical aboveground or near-surface nuclear tests. The species selected for sampling represent the most dominant life forms (e.g., trees, shrubs, herbs, or grasses) at these sites. Woody vegetation (i.e., shrubs versus forbs or grasses) is sampled because it is reported to have deeper penetrating roots and potentially higher concentrations of ***tritium (^{3}H)*** (Hunter and Kinnison 1998). Woody vegetation also is a major source of browse for game animals that might potentially migrate off site. Grasses and forbs are sampled when present because they are also a source of food for wildlife. Plant parts collected for analysis represent new growth over the past year. Pine nuts from singleleaf pinyon pine trees, which may be consumed by humans, are also sampled periodically.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

When determining the potential dose to animals, the goal of sampling is to select species that are most exposed and most sensitive to the effects of radiation. In general, mammals and birds are more sensitive to radiation than fish, amphibians, reptiles, or invertebrates (DOE Standard DOE-STD-1153-2019, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota"). The list of species used to assess the potential dose to animals in Table 8-1 reflects this graded approach and the fact that no native fish or amphibians are found on the NNSS.

The game animals monitored to assess the potential dose to the public meet three criteria: (1) they are a species consumed by humans; (2) they have a home range that overlaps a contaminated site and, as a result, have the potential for relatively high radionuclide body burdens from exposure to contaminated soil, air, water, or plants at the contaminated site; and, (3) they are sufficiently abundant at a site that an adequate tissue sample can be acquired for laboratory analysis. These criteria limit the candidate game animals to those listed in Table 8-1. Mule deer, pronghorn antelope, bighorn sheep, and predatory game animals such as mountain lions or bobcat are only collected as the opportunity arises, that is, if they are found dead on the NNSS (e.g., killed by a predator or accidentally hit by a vehicle). Tissues from species analogous to big game, such as feral horses or burros, may be collected opportunistically as well. If game animals are not sufficiently abundant at a particular site or at a particular time, non-game small mammals may be used as an ***analog*** (Table 8-1).

A habitat-use study of mule deer and pronghorn antelope was initiated in November 2019. A total of 23 mule deer and 20 pronghorn antelope were captured. GPS [global positioning system] collars were put on all the 23 mule deer and on 18 of the pronghorn antelope. Part of this study is to learn of how these animals use the NNSS, how much time they may spend in radiologically contaminated areas, and what the potential dose is to the animals and to someone who may consume them. Samples were collected from study animals that died during 2020 where possible.

The sampling strategy to assess the integrity of radioactive waste containment includes sampling plants, animals, and soil excavated by ants or small mammals on top of waste covers. Plants are generally selected by size, with preference for larger shrubs, under the assumption that they have deeper roots and therefore would be more likely to penetrate buried waste. Small mammals selected for sampling meet three criteria: (1) they are fossorial (i.e., they burrow and live predominantly underground), (2) they have a home range small enough to ensure that they reside most of the time on the waste disposal site, and (3) they are sufficiently abundant at a site to acquire an adequate tissue sample for laboratory analysis. These criteria limit the animals to those listed in Table 8-1. Soils excavated by ants or small mammals are also selected for sampling based on size, with preference for larger ant mounds and animal burrow sites, under the assumption that these burrows are deeper and have a higher potential for penetrating waste.

Table 8-1. NNSS animals monitored for radionuclides

Small Mammals	Large Mammals	Birds	Reptiles
Game Animals Monitored for Dose Assessments			
Cottontail rabbit *(Sylvilagus audubonii)* Jackrabbit *(Lepus californicus)*	Mule deer *(Odocoileus hemionus)* Pronghorn antelope *(Antilocapra americana)* Mountain lion *(Puma concolor)* Desert bighorn sheep *(Ovis canadensis nelsoni)* Bobcat *(Lynx rufus)*	Mourning dove *(Zenaida macroura)* Chukar *(Alectoris chukar)* Gambel's quail *(Callipepla gambelii)*	Desert tortoise (*Gopherus agassizii*)
Animals Monitored for Integrity of Radioactive Waste Containment or as Game Animal Analogs			
Kangaroo rats *(Dipodomys spp.)*			
Mice *(Peromyscus spp.)*			
Antelope ground squirrel *(Ammospermophilus leucurus)*			
Desert woodrat *(Neotoma lepida)*			

8.2 Site Selection

The monitoring program design focuses on sampling sites with the highest concentrations of radionuclides in natural media (e.g., soil and surface water) and relatively high densities of candidate animals. The RREMP identifies five contaminated sites and their associated control sites. Each year, biota from one or two of these sites is sampled, and each of the sites is sampled once every 5 years. They are E Tunnel Ponds, Palanquin/Schooner Craters, Sedan Crater, T2, and Plutonium Valley (Figure 8-1), and each is associated with one type of legacy contamination area (see list below). The control site selected for each contaminated site has similar biological and physical features. Control sites are sampled to document the radionuclide levels representative of ***background***.

- **Runoff areas or containment ponds associated with underground or tunnel test areas.** Contaminated water draining from test areas can form surface water sources that are important, given the limited availability of surface water on the NNSS. Therefore, they have a high potential for transferring radionuclides to plants and to wildlife seeking surface water. The associated monitoring site is E Tunnel Ponds below Rainier Mesa. This contaminated site, along with its control site, was last sampled in 2017.
- **Plowshare sites in alluvial fill at lower elevations with high surface contamination.** The historical ***Plowshare Program***, conducted throughout the NNSS, explored the potential use of nuclear explosives for peaceful purposes. Surface and shallow subsurface nuclear detonations at these alluvial, low elevation sites have distributed contaminants over a wide area, usually in the lowest precipitation areas of the NNSS. The associated monitoring site is Sedan Crater in Yucca Flat. It was sampled in 2020.
- **Plowshare sites in bedrock or rocky fill at higher elevations with high surface contamination.** Surface and shallow subsurface nuclear detonations at these Plowshare Program sites distributed contaminants over a wide area, usually in the highest precipitation areas of the NNSS. Two monitored sites are in this category: Palanquin Crater and Schooner Crater. Both sites were last sampled in 2018.
- **Atmospheric test areas.** These sites have highly disturbed soils due to the removal of topsoil during historical cleanup efforts and due to the sterilization of soils from heat and radiation during testing. The same areas were often used for multiple nuclear tests. The associated monitoring site is T2 in Yucca Flat. It was last sampled in 2016.
- **Aboveground safety experiment sites.** These areas are typified by current radioactive soil contamination, primarily in the form of plutonium and uranium. The associated monitoring site is Plutonium Valley in Area 11. It was last sampled in 2019.

Soil sampling is also conducted periodically at radioactive waste disposal locations on the NNSS to assess whether fossorial small mammals are being exposed to buried wastes and, therefore, whether the integrity of waste containment is compromised. Two radioactive waste disposal facilities are sampled:

- **Area 3 RWMS.** Waste disposal cells within the Area 3 RWMS were created within subsidence craters resulting from underground nuclear testing. Two closed cells containing bulk ***low-level radioactive waste*** are craters U-3ax and U-3bl, which were combined to form the U-3ax/bl disposal unit (Corrective Action Unit 110). U-3ax/bl is covered with a vegetated, native alluvium closure cover that is at least 2.4 meters (m) (8 feet [ft]) thick. It was sampled in 2020.
- **Area 5 RWMS.** Waste disposal has occurred at the Area 5 RWMS since the early 1960s. There are 11 closed disposal cells containing bulk low-level radioactive waste. The cells are unlined pits and trenches that range in depth from 4.6 to 15 m (15 to 48 ft). Efforts are currently being made to establish native vegetation on the cover cap of the 92-Acre Area, which caps multiple waste cells. The cover cap is approximately 2.4 m (8 ft) thick. It was sampled in 2020.

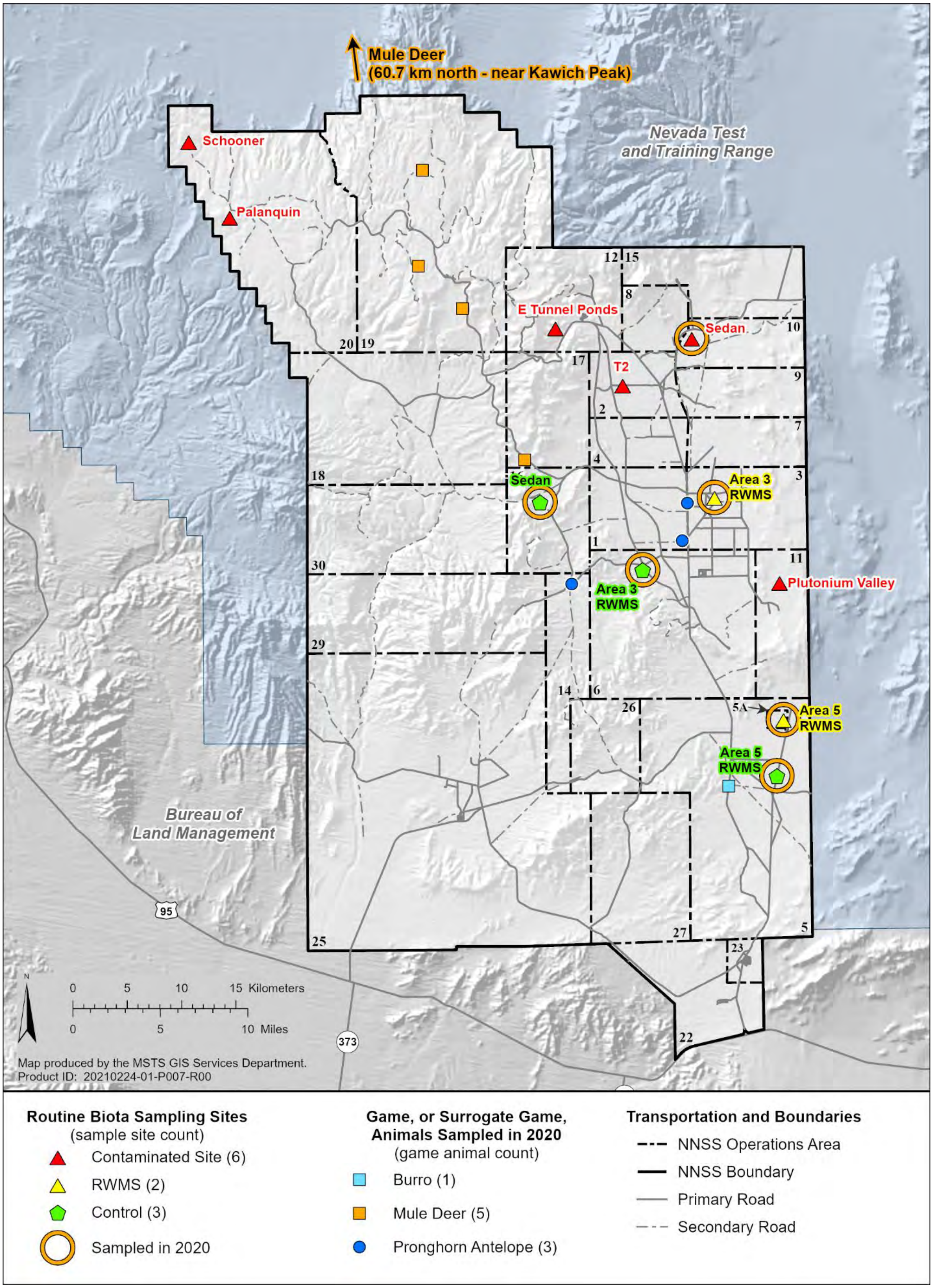

Figure 8-1. Radiological biota monitoring sites on the NNSS

8.3 Sampling and Analysis

In 2020, the Sedan site and its control were sampled for plants and animals (Figure 8-1). The Sedan test was conducted July 6, 1962, in the northern portion of Area 10. This cratering experiment displaced 12 million tons of earth and formed a 390 m (1,280 ft) diameter by 97 m (320 ft) deep depression in the desert floor. The purpose of the test was to determine if nuclear devices could be used as cratering or earth-moving mechanisms. Contaminants resulting from this test were primarily ^{3}H, strontium-90 (^{90}Sr), cesium-137 (^{137}Cs), plutonium-239+240 ($^{239+240}$Pu), and americium-241 (^{241}Am). A control area for Sedan is located about 20 kilometers (km) (12.6 miles [mi]) southwest of the sample site near a spring in Area 16. Any of the candidate game species is likely to be present at the Sedan Control site.

Measurements of gamma-emitting radionuclides in soil were made at the Sedan location on November 23, 2015, and at its control location on July 6, 2020. In September 1982, the Radionuclide Inventory and Distribution Program (RIDP) took measurements at Sedan at two locations (called points 35 and 36) (McArthur and Mead 1987). In 2015 and 2020, measurements were made at these same two locations and are compared with those made in 1982 (see Section 8.3.3). As in 2015, all 2020 measurements were made using an uncollimated Canberra Model GX5520 germanium detector mounted downward looking on a tripod 1 m above ground level. The spectra were analyzed using Canberra Genie 2000 (version 3.4) and ISOCS (version 4.4) software with a 10 m circular plane geometry to a depth of 30 centimeters (cm) for the efficiency calibration. For natural radionuclides in the soil, a uniform depth distribution was used in the efficiency calibration. However, the abundance of man-made radionuclides in NNSS soil decreases with depth (McArthur and Mead 1987). The following percentages of radioactivity per 5 cm depth increment were used by McArthur and Mead (1987) for their geometry calibrations of sample measurements for the RIDP: 24.2% in 0-5 cm, 21.2% in 5-10 cm, 20.0% in 10-15 cm, 14.7% in 15-20 cm, 11.3% in 20-25 cm, and 8.6% in 25-30 cm.

The Area 3 and Area 5 RWMSs and their associated control sites were also sampled in 2020 (Figure 8-1). The Area 3 RWMS is in Yucca Flat at an elevation of 1,223 m (4,012 ft). Yucca Flat was one of several primary nuclear test areas. Between 1952 and 1972, 60 nuclear weapons tests were conducted within 400 m (1,312 ft) of the Area 3 RWMS boundary (NNSA/NFO 2015). Fourteen of these tests were atmospheric, which left primarily ^{3}H, ^{90}Sr, ^{137}Cs, europium-152 (^{152}Eu), $^{239+240}$Pu, and ^{241}Am in the surface soil across the area. Sampling in 2020 was conducted on the U-3ax/bl cover (Figure 8-2). The Area 3 RWMS control site is located about 9.5 km (5.9 mi) southwest of the U-3 ax/bl cover.

The Area 5 RWMS is in northern Frenchman Flat at an elevation of 962 m (3,156 ft) and consists of numerous landfill cells. Buried radioactive materials at the Area 5 RWMS consist primarily of ^{3}H, ^{90}Sr, ^{137}Cs, uranium (various ***isotopes***), plutonium (various isotopes), and ^{241}Am. No nuclear weapons testing occurred within the boundaries of the Area 5 RWMS, but there were 10 underground tests within 4.3 km (2.7 mi) and 14 atmospheric tests within 7 km (4.3 mi). Sampling was conducted on the 92-Acre Area cover, specifically the North, South, South, and West portions of the 92-Acre Area cover (Figure 8-2). The Area 5 RWMS Control site is located about 4.5 km (2.8 mi) south of the 92-Acre Area cover.

8.3.1 Plants

On June 23, 2020, three composite plant samples were collected from each of the Sedan and control locations (Figure 8-1). Sampled species represented common vegetation at each site (Table 8-2). One composite plant sample was collected from each of the Area 5 RWMS 92-Acre Area North, South, and West covers and the Area 5 RWMS control site as well as the Area 3 RWMS U-3ax/bl cover and the Area 3 RWMS control site on June 29, 2020.

All samples consisted of about 150 to 500 grams (5.3 to 17.6 ounces) of fresh-weight plant material and were composites of material from 5 to 21 plants of the same species. The species sampled (Table 8-2) represent the dominant vegetation at each site.

Plant leaves and stems were handpicked and stored in airtight Mylar bags. Rubber gloves were used by samplers and changed between each composite sample. Samples were labeled and stored in an ice chest. Within 4 hours of collection, the samples were delivered to the laboratory for processing. Water was separated from the samples by distillation and the dry plant material homogenized. The water and dried plant tissues were submitted for analysis of ^{241}Am, ^{90}Sr, plutonium-238 (^{238}Pu), $^{239+240}$Pu, and gamma emitting radionuclides (including cobalt-60 [^{60}Co], europium isotopes, and ^{137}Ce).

Table 8-2. Plant samples

Common Name	Scientific Name	Name Code	Sedan	Sedan Control	Area 3 RWMS	Area 3 Control	Area 5 RWMS	Area 5 Control
Indian ricegrass	*Achnatherum hymenoides*	ACHY	X					
Shadscale saltbush	*Atriplex confertifolia*	ATCO			X		X	X
Flatcrown buckwheat	*Eriogonum deflexum*	ERDE	X	X				
Rubber rabbitbrush	*Ericameria nauseosa*	ERNA	X	X		X		
Saltlover	*Halogeton glomeratus*	HAGL					X	
Basin wildrye	*Leymus cinereus*	LECI		X				
Russian thistle	*Salsola sp.*	Salsola					X	

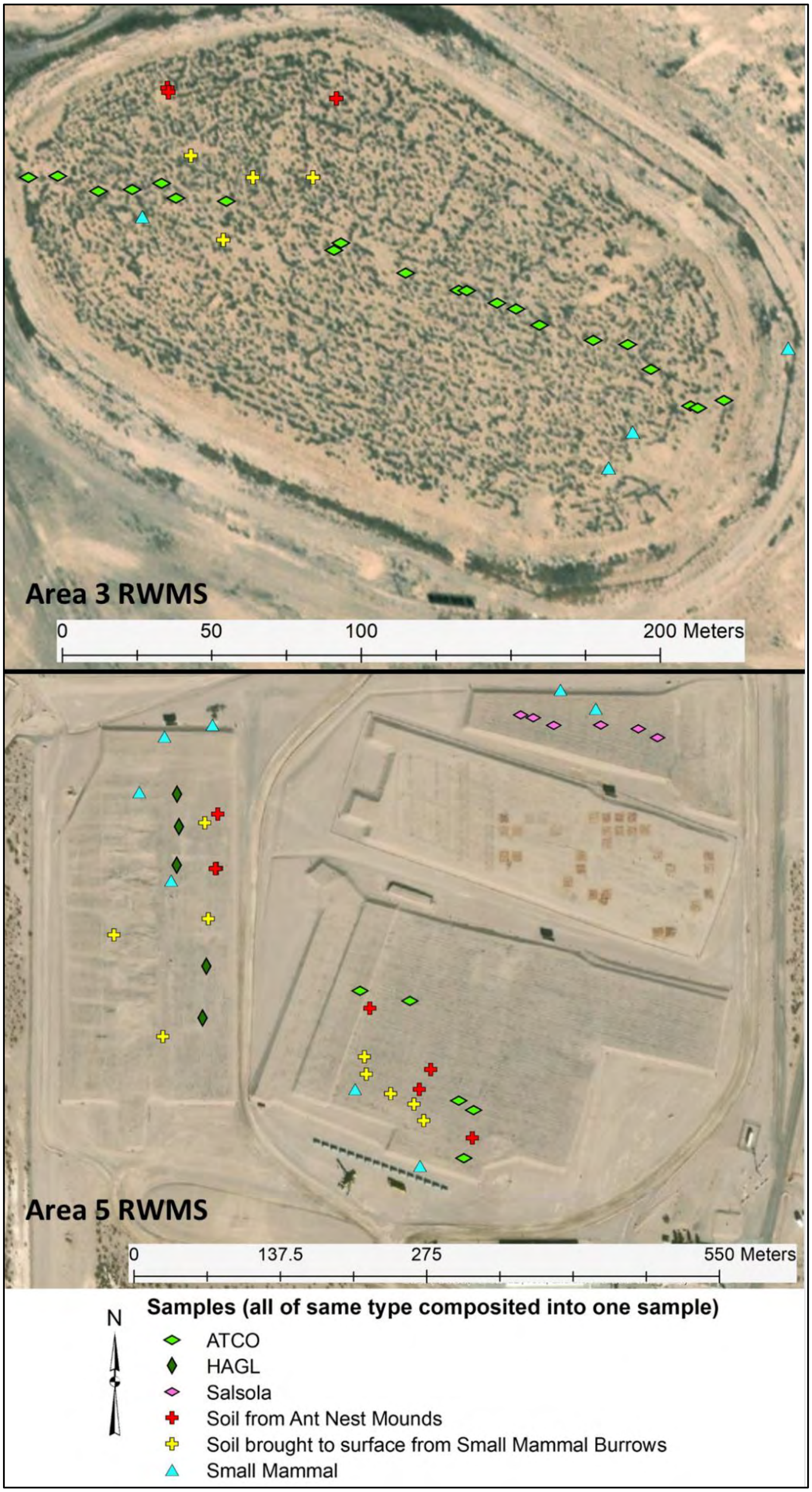

Figure 8-2. Biota and soil sample locations at the Area 3 and Area 5 RWMS

Results of radiological analyses are shown in Table 8-3. All detected man-made radionuclides at Sedan (^{3}H, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239+240}$Pu, and ^{241}Am) were higher than at the control site, which is expected due to Sedan being a near surface test that distributed radionuclides across the soil surface. Concentrations at Sedan were generally unchanged from previous years (Figure 8-3). The only man-made radionuclides detected at the Area 3 and Area 5 RWMSs were ^{3}H (both sites) and $^{239+240}$Pu (Area 3 RWMS). No man-made radionuclides were detected at the RWMS control sites. Radionuclide concentrations at the Area 3 and Area 5 RWMSs were generally unchanged from those observed in recent years (Figure 8-4).

Table 8-3. Concentrations of man-made radionuclides in plants

Sample	Radionuclide Concentrations ± Uncertainty[(a)]				
	^{3}H (pCi/L)[(b)]	^{90}Sr (pCi/g)[(c)]	^{238}Pu (pCi/g)[(c)]	$^{239+240}$Pu (pCi/g)[(c)]	^{241}Am (pCi/g)[(c)]
Sedan					
ACHY	66700 ± 5,960	0.665 ± 0.161	0.0375 ± 0.0121	0.2460 ± 0.0479	0.0646 ± 0.0160
ERDE	80,500 ± 7,190	2.300 ± 0.542	0.0721 ± 0.0183	0.4820 ± 0.0856	0.1250 ± 0.0248
ERNA #1	360,000 ± 32,200	0.287 ± 0.073	0.0034 ± 0.0030	0.0187 ± 0.0070	0.0039 ± 0.0043
ERNA #2	396,000 ± 35,300	0.312 ± 0.078	0.0043 ± 0.0035	0.0238 ± 0.0085	0.0010 ± 0.0035
Average	225,800	0.891	0.0293	0.1926	0.0486
Average MDC[(d)]	287	0.040	0.0028	0.0037	0.0072
Sedan Control					
ERDE	930 ± 173	0.024 ± 0.023	0.0013 ± 0.0025	0.0009 ± 0.0025	-0.0017 ± 0.0031
ERNA	28 ± 102	0.005 ± 0.023	0.0016 ± 0.0029	0.0039 ± 0.0042	-0.0005 ± 0.0029
LECI	51 ± 103	0.032 ± 0.027	0.0031 ± 0.0028	0.0019 ± 0.0027	-0.0007 ± 0.0029
Average	336	0.020	0.0020	0.0022	-0.0010
Average MDC[(d)]	174	0.039	0.0036	0.0044	0.0072
RWMS 3 U-3 ax/bl					
ATCO	3,820 ± 411	0.025 ± 0.026	0.0040 ± 0.0036	0.0622 ± 0.0161	0.0066 ± 0.0049
MDC[(d)]	166	0.042	0.0043	0.0017	0.0071
RWMS 3 Control					
ERNA	22.9 ± 106	0.010 ± 0.021	0.0004 ± 0.0034	0.0020 ± 0.0035	0.0040 ± 0.0043
MDC[(d)]	181	0.035	0.0065	0.0065	0.0072
RWMS 5 92 Acre Cover					
North Salsola sp.	459,000 ± 41,000	0.009 ± 0.023	0.0021 ± 0.0027	0.0004 ± 0.0027	0.0003 ± 0.0031
South ATCO	43,500,000 ± 3,880,000	0.018 ± 0.023	0.0019 ± 0.0027	0.0034 ± 0.0033	-0.0019 ± 0.0024
West HAGL	38,300 ± 3,450	-0.001 ± 0.033	0.0039 ± 0.0035	0.0013 ± 0.0027	-0.0022 ± 0.0022
Average	14,665,767	0.008	0.0026	0.0017	-0.0012
Average MDC[(d)]	3,353	0.044	0.0034	0.0037	0.0066
RWMS 5 Control					
ATCO	124 ± 111	0.006 ± 0.024	0.0006 ± 0.0025	0.0025 ± 0.0028	-0.0010 ± 0.0030
MDC[(d)]	179	0.039	0.0016	0.0039	0.0076

(a) ***Uncertainty*** is ± 2 standard deviations.

(b) Picocuries per liter water from sample.

(c) Picocuries per gram dry weight of sample.

(d) Average sample-specific ***minimum detectable concentration (MDC)***.

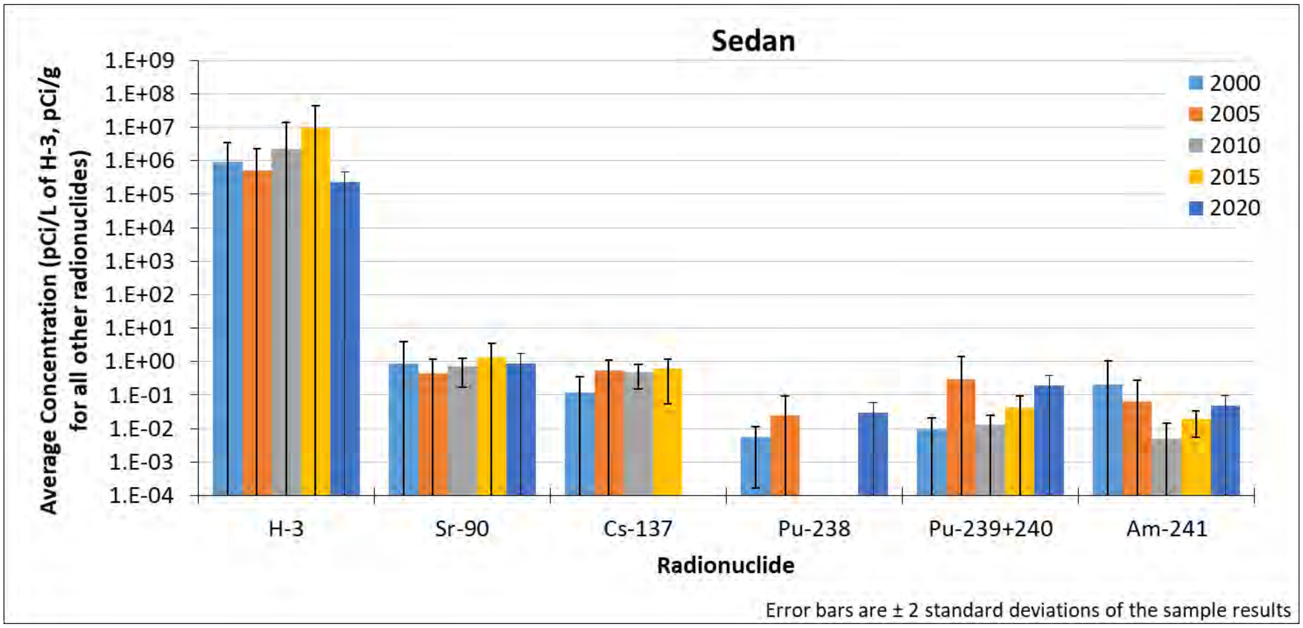

Figure 8-3. Concentrations in vegetation sampled near Sedan Crater, 2000–2020

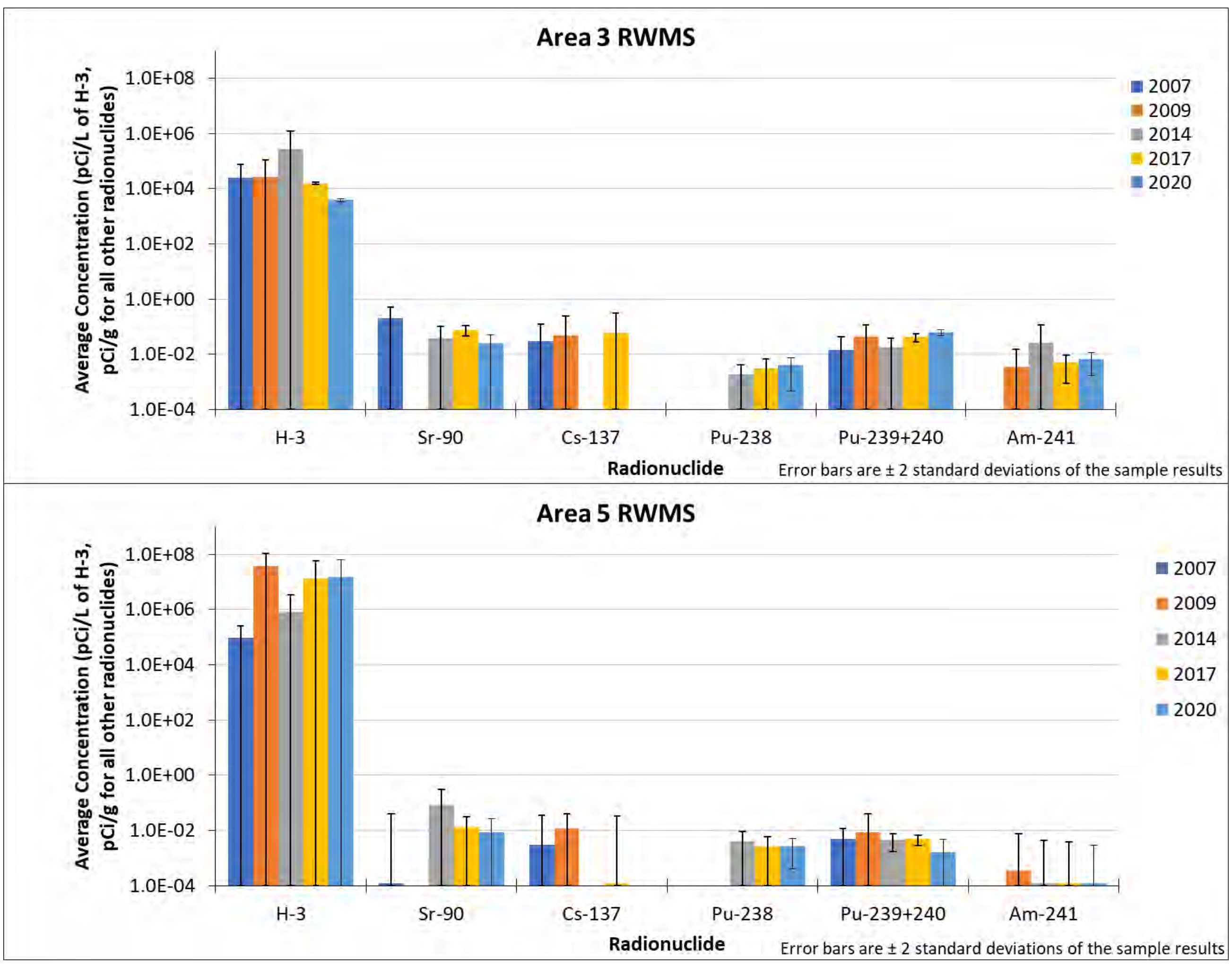

Figure 8-4. Concentrations in vegetation sampled at the Area 3 and Area 5 RWMSs, 2007–2020

8.3.2 Animals

State and federal permits were secured to trap specific small mammals and birds in 2020 and opportunistically sample large mammal mortalities on the NNSS. Small mammal trapping occurred June 29 through July 21, 2020. Three jackrabbits were captured from the Sedan site and two cottontail rabbits were sampled from the control site (Table 8-4). Small mammals captured from the Area 3 and Area 5 RWMSs, and their control sites, were composited by area (Table 8-4). One feral burro, five mule deer, and three pronghorn antelope were sampled during 2020. Two of these (the burro and one pronghorn antelope) were killed by vehicles on the NNSS. The five mule deer and two of the pronghorn antelope were study animals captured and affixed with GPS collars in November 2019. All but one of these died on the NNSS, mostly due to predation. One mule deer (GPS collar ID 705960) was legally hunted approximately 61 km north of the NNSS. The hunter willingly agreed to supply a sample.

The entire bodies of small mammals were taken as samples. Muscle tissue was collected from all but one large mammal. Only bone and hide were found at the kill site of the mule deer from Area 17. Blood and liver tissue were also collected from the pronghorn sampled in Area 14 because it was a study animal and had the availability of tissue (very fresh kill that had not been scavenged by wildlife). All samples were homogenized and water distilled for ^{3}H analysis. The tissue samples and the blood sample were submitted for ^{90}Sr, ^{238}Pu, $^{239+240}$Pu, ^{241}Am, and gamma spectroscopy analysis.

Table 8-4. Animal samples

Location	Sample	Collection Date	Sample Description
Routine Monitoring Samples			
Sedan			
	Jackrabbit #1	7/3/2020	Whole body
	Jackrabbit #2	7/3/2020	Whole body
	Jackrabbit #3	7/8/2020	Whole body
Sedan Control			
	Cottontail rabbit #1	6/30/2020	Whole body
	Cottontail rabbit #2	7/2/2020	Approximately half of a cottontail rabbit. Trap moved about 5 m with rabbit dead and partially eaten inside
Area 3 RWMS ax/bl Cover			
	Small Mammal Composite	7/21/2020	Composite of 6 kangaroo rats (*Dipodomys merriami*)
Area 3 RWMS Control			
	Small Mammal Composite	7/21/2020	Composite of 6 small mammals: 4 kangaroo rats (*Dipodomys merriami*), 1 mouse (*Peromyscus sp*.), and 1 antelope ground squirrel (*Ammospermophilius leurcurus*)
Area 5 RWMS 92 Acre Cover			
	Small Mammal Composite	7/20/2020	Composite of 8 small mammals: 7 kangaroo rats (*Dipodomys merriami*) and 1 mouse (*Peromyscus sp*.)
Area 5 RWMS Control			
	Small Mammal Composite	7/21/2020	Composite of 3 small mammals: 2 antelope ground squirrels (*Ammospermophilius leurcurus*) and 1 kangaroo rat (*Dipodomys merriami*)
Opportunistic Samples			
Location	**Sample**	**Collection Date**	**Sample Description**
Area 5	Burro	1/22/2020	Muscle from ~1-year-old burro killed by a vehicle on Mercury Highway
Area 19	Mule Deer #1	6/22/2020	Muscle from adult female mule deer (GPS collar ID 705935) that died of unknown natural causes
Area 19	Mule Deer #2	11/28/2020	Muscle from adult male mule deer (GPS collar ID 705958) killed by a mountain lion
Area 19	Mule Deer #3	11/30/2020	Muscle from adult female mule deer (GPS collar ID 705937) possibly killed by predator
Area 17	Mule Deer	12/28/2020	Water distilled from bone and marrow of lower leg from adult female mule deer (GPS collar ID 705936) that died (likely predation). Only lower leg and some hide found
Off-site	Mule Deer	10/10/2020	Muscle from adult male mule deer (GPS collar ID 705960) hunted near Kawich Peak
Area 14	Pronghorn	5/4/2020	Muscle, liver, and blood sampled from adult male pronghorn (GPS collar ID 705961) that apparently died from injuries sustained from a predation attack (likely mountain lion)
Area 1	Pronghorn	7/20/2020	Muscle from 4-year-old male pronghorn antelope (GPS collar ID 705962) who died of unknown causes near roadway in U1a Complex
Area 3	Pronghorn	10/21/2020	Muscle from young (<1-year-old) male pronghorn killed by a vehicle on Mercury Highway

Radionuclide concentration results are listed in Table 8-5. Elevated concentrations of man-made radionuclides were measured in rabbits from Sedan as expected and at levels within the range measured in the past. Only low levels of ^{238}Pu and $^{239+240}$Pu were detected in animals from the control sites. Elevated tritium was detected in animals from the Area 5 RWMS, like past measurements, but tritium was not detected in animals sampled from the Area 3 RWMS. This is a change from the past as tritium has normally been detected in animals from this location.

Table 8-5. Concentrations of man-made radionuclides in animals

	Radionuclide Concentrations ± Uncertainty[a]					
Sample	**^{3}H (pCi/L)[b]**	**^{90}Sr (pCi/g)[c]**	**^{137}Cs (pCi/g)[c]**	**^{238}Pu (pCi/g)[c]**	**$^{239+240}$Pu (pCi/g)[c]**	**^{241}Am (pCi/g)[c]**
Sedan						
Jackrabbit #1	12,000 ± 1,140	0.380 ± 0.102	0.1650 ± 0.1120	0.0104 ± 0.0055	0.0894 ± 0.0210	0.0279 ± 0.0076
Jackrabbit #2	20,400 ± 1,870	0.263 ± 0.077	0.1490 ± 0.0806	0.0007 ± 0.0036	0.0000 ± 0.0036	0.0111 ± 0.0043
Jackrabbit #3	29,800 ± 2,690	0.198 ± 0.064	0.1230 ± 0.0822	0.0112 ± 0.0053	0.0886 ± 0.0201	0.0180 ± 0.0057
Average	20,733	0.280	0.1457	0.0074	0.0593	0.0190
Average MDC[d]	181	0.076	0.1277	0.0033	0.0049	0.0040
Sedan control						
Cottontail #1	79 ± 111	-0.039 ± 0.036	-0.0278 ± 0.0965	0.0012 ± 0.0021	0.0026 ± 0.0023	-0.0001 ± 0.0019
Cottontail #2	-20 ± 99	-0.001 ± 0.035	-0.0140 ± 0.0552	0.0021 ± 0.0027	0.0012 ± 0.0021	-0.0010 ± 0.0017
Average	29.4	-0.020	-0.0209	0.0017	0.0019	-0.0005
Average MDC[d]	178.5	0.079	0.1455	0.0039	0.0023	0.0038
RWMS 3 U-3 ax/bl Cover						
Small Mammal Composite	-28 ± 98	0.036 ± 0.041	-0.0689 ± 0.0870	0.0004 ± 0.0021	0.0301 ± 0.0094	0.0049 ± 0.0031
MDC[d]	169	0.084	0.1810	0.0040	0.0033	0.0039
RWMS 3 Control						
Small Mammal Composite	-32 ± 101	0.016 ± 0.036	-0.0049 ± 0.0989	-0.0005 ± 0.0023	0.0016 ± 0.0025	0.0007 ± 0.0026
MDC[d]	178	0.078	0.1860	0.0052	0.0045	0.0051
RWMS 5 92 Acre Cover						
Small Mammal Composite	185,000 ± 16,500	0.014 ± 0.037	-0.0198 ± 0.0658	0.0002 ± 0.0023	0.0354 ± 0.0109	0.0029 ± 0.0025
MDC[d]	276	0.080	0.1260	0.0036	0.0051	0.0036
RWMS 5 Control						
Small Mammal Composite	-7 ± 100	0.016 ± 0.036	0.0166 ± 0.0726	0.0037 ± 0.0029	0.0027 ± 0.0024	0.0006 ± 0.0020
MDC[d]	171	0.078	0.1300	0.0014	0.0014	0.0038
Opportunistic Sampling						
Area 5 Burro	352 ± 122	0.036 ± 0.041	-0.0125 ± 0.0339	0.0038 ± 0.0071	0.0047 ± 0.0059	0.0002 ± 0.0030
MDC[d]	170	0.068	0.0560	0.0123	0.0084	0.0058
Area 19 Mule Deer #1	25 ± 91	-0.009 ± 0.031	-0.0987 ± 0.1010	-0.0040 ± 0.0043	0.0040 ± 0.0036	0.0000 ± 0.0037
Area 19 Mule Deer #2	-8 ± 103	0.016 ± 0.038	-0.0802 ± 0.1350	0.0023 ± 0.0047	0.0039 ± 0.0047	-0.0017 ± 0.0024
Area 19 Mule Deer #3	-73 ± 95	-0.008 ± 0.027	-0.0086 ± 0.1620	0.0007 ± 0.0044	0.0022 ± 0.0039	0.0034 ± 0.0034
Area 17 Mule Deer	-38 ± 98	NM[e]	NM[e]	NM[e]	NM[e]	NM[e]
Off-site Mule Deer	55 ± 183	0.012 ± 0.026	-0.0608 ± 0.1020	0.0039 ± 0.0046	0.0023 ± 0.0046	0.0008 ± 0.0044
Mule Deer Average	-8	0.003	-0.0621	0.0007	0.0031	0.0006
Average MDC[d]	199	0.055	0.2310	0.0091	0.0063	0.0072
Area 14 Pronghorn (muscle)	55 ± 112	0.019 ± 0.021	0.0347 ± 0.0748	0.0022 ± 0.0028	0.0063 ± 0.0046	-0.0020 ± 0.0020
Area 14 Pronghorn (liver)	NM[e]	0.007 ± 0.025	0.0290 ± 0.0599	0.0032 ± 0.0037	0.0044 ± 0.0040	-0.0019 ± 0.0024
Area 14 Pronghorn (blood)	-176 ± 404	0.019 ± 0.024	0.1250 ± 0.4030	-0.0002 ± 0.0034	0.0007 ± 0.0034	-0.0013 ± 0.0024
Area 1 Pronghorn	-174 ± 171	-0.008 ± 0.048	-0.0379 ± 0.0994	0.0042 ± 0.0045	0.0075 ± 0.0056	0.0040 ± 0.0036
Area 3 Pronghorn	864 ± 258	0.023 ± 0.033	0.0407 ± 0.0831	0.0016 ± 0.0050	0.0016 ± 0.0045	-0.0029 ± 0.0070
Pronghorn Average	142	0.012	0.0383	0.0022	0.0041	-0.0008
Average MDC[d]	376	0.051	0.2396	0.0061	0.0058	0.0071

(a) Uncertainty is ± 2 standard deviations.

(b) Picocuries per liter water from sample.

(c) Picocuries per gram wet weight of sample.

(d) Average sample-specific MDC.

(e) Not measured.

Tritium was detected in the burro and in the pronghorn antelope from Area 3. Low concentrations of $^{239+240}$Pu were detected in the Area 19 mule deer #1 (GPS collar ID 705935), in the Area 14 pronghorn antelope (in both muscle and liver), and in the Area 1 pronghorn antelope. ^{241}Am was also detected at low levels in the Area 1 pronghorn antelope. No man-made radionuclides were detected in the mule deer taken by the hunter off the NNSS.

8.3.3 Soil

Results from measurements of gamma-emitting radionuclides in soil at the Sedan and Sedan control locations are listed in Table 8-6. One natural radionuclide (potassium-40 [^{40}K]) is reported because it is ubiquitous and has a very long half-life (1,251,000,000 years) so it makes for a good marker for comparison between measurements (it should not change through time). Man-made radionuclides detected at the Sedan location were ^{60}Co, ^{137}Cs, ^{152}Eu, and ^{241}Am. The only man-made radionuclide detected at the control location was ^{137}Cs and it was two orders of magnitude lower than that measured at Sedan. Since September 1982, concentrations of radionuclides in soil near Sedan Crater have changed in various ways. The concentrations of ^{60}Co and ^{152}Eu have declined at rates very near (>98%) of their physical decay rates, which suggests there is not significant loss of these radionuclides from the surface soil profile. The observed decline of ^{137}Cs (effective half-life = 26.5 years) is about 88% of the physical decay (half-life = 30.2 years), indicating there is some loss of ^{137}Cs from the surface soil. This loss can be due to movement to deeper soil or from loss from the surface (e.g., wind erosion, uptake and removal by plants and animals). The concentration of ^{241}Am has increased, which is expected as there is ingrowth from the decay of ^{241}Pu.

Ratios of plant-to-soil and animal-to-soil concentrations are presented in Table 8-7. Soil concentrations were converted to pCi/g by taking the activity per area reported in Table 8-6 and dividing them by the number of grams (g) of soil in 1 square meter (m^2) to a depth of 30 cm (450,000 g) (soil density = 1.5 g/cm^3). Ratios are only calculated for ^{137}Cs and ^{241}Am because neither ^{60}Co nor ^{152}Eu were detected in plants or animals from Sedan. Concentration ratios can be useful in estimating concentrations in plants and animals on the NNSS (particularly near Sedan) based on soil concentrations.

Table 8-6. Gamma-emitting radionuclides detected in soil near Sedan Crater over time

	Activity (nCi/m^2)(a)									
	Point 35					Point 36				
Date	K-40	Co-60	Cs-137	Eu-152	Am-241	K-40	Co-60	Cs-137	Eu-152	Am-241
9/15/1982	9,405	13,210	31,030	1,257	4,890	12,487	10,840	26,380	1,298	5,767
11/23/2015	11,458	156	11,414	ND(b)	9,450	11,794	129	10,920	279	7,931
6/6/2020	12,242	80	12,186	152	11,231	12,438	72	10,279	170	9,230

(a) nCi/m^2 = nanocuries per square meter.
(b) ND = not detected (no significant peak(s) detected for that radionuclide in gamma spectroscopy measurement.

Table 8-7. Vegetation-to-soil and animal-to-soil concentration ratios for Sedan in 2020

	Concentration Ratio(a)			
	^{137}Cs		^{241}Am	
Sample	Average	Range	Average	Range
Vegetation : Soil	0.0117	0.0035–0.0230	0.0021	0.00004–0.0055
Animal : Soil	0.0058	0.0049–0.0066	0.0008	0.0005–0.0012

(a) vegetation = pCi/g dry weight, animal = pCi/g wet weight, soil = pCi/g dry weight.

Sampling of soil at the Area 3 and Area 5 RWMSs took place on June 29, 2020. Composite samples of soil brought to the surface from either small mammal or ant burrowing activity were collected from each of the RWMSs and their control sites (Figure 8-2 and Table 8-8). Each sample consisted of about 500 g (17.6 ounces) of dry soil, which was submitted to a commercial laboratory for analysis of ^{90}Sr, ^{238}Pu, $^{239+240}$Pu, ^{241}Am, uranium, and gamma-emitting radionuclides (which includes ^{137}Cs).

Results of detected man-made radionuclides in animal-excavated soil are listed in Table 8-9. Low levels of ^{238}Pu, $^{239+240}$Pu, and ^{241}Am were detected in soil samples from both the Area 3 RWMS and control sites. There was no significant difference in concentrations between locations. No man-made radionuclides were detected in Area 5 RWMS soil samples. Low levels of ^{90}Sr and $^{239+240}$Pu were detected in soil from the Area 5 control site. If small mammals and/or ants were in contact with the waste at the RWMSs, then it would be expected that radionuclide concentrations would be significantly elevated at these locations. Because this was not the case, it does not appear that small mammals and ants are in contact with, or are bringing to the surface, buried waste.

Table 8-8. Animal excavated soil samples

Location	Sample Description
Area 3 RWMS ax/bl Cover	Composite from 4 small mammal burrows
Area 3 RWMS ax/bl Cover	Composite from 3 ant nests
Area 3 RWMS Control	Composite from 3 small mammal burrows
Area 5 RWMS 92 Acre Cover	Composite from 5 small mammal burrows
Area 5 RWMS 92 Acre Cover	Composite from 4 ant nests
Area 5 RWMS Control	Composite from 4 small mammal burrows

Table 8-9. Man-made radionuclides detected in animal excavated soil samples

	Radionuclide Concentrations ± Uncertainty[(a)] (pCi/g)[(b)]			
Sample	^{90}**Sr**	^{238}**Pu**	$^{239+240}$**Pu**	^{241}**Am**
Area 3 RWMS ax/bl Cover				
Composite from 4 small mammal burrows	-0.024 ± 0.057	0.0045 ± 0.0055	0.1230 ± 0.0303	0.0292 ± 0.0183
Composite from 3 ant nests	-0.022 ± 0.054	0.0023 ± 0.0055	0.2300 ± 0.0483	0.0492 ± 0.0195
Average	-0.023	0.0034	0.1765	0.0392
MDC[(c)]	0.092	0.0068	0.0068	0.0176
Area 3 RWMS Control (small mammal burrows)	0.067 ± 0.053	0.0038 ± 0.0047	0.2180 ± 0.0443	0.0192 ± 0.0131
MDC[(c)]	0.083	0.0026	0.0070	0.0169
Area 5 RWMS 92 Acre Cover				
Composite from 5 small mammal burrows	0.068 ± 0.055	0.0011 ± 0.0054	0.0033 ± 0.0054	-0.0031 ± 0.0086
Composite from 4 ant nests	0.009 ± 0.051	0.0014 ± 0.0069	0.0000 ± 0.0069	0.0012 ± 0.0109
Average	0.038	0.0013	0.0017	-0.0009
Average MDC[(c)]	0.085	0.0067	0.0093	0.0216
Area 5 RWMS Control (small mammal burrows)	0.092 ± 0.055	0.0025 ± 0.0060	0.0271 ± 0.0132	0.0109 ± 0.0120
MDC[(c)]	0.081	0.0091	0.0114	0.0180

(a) ± 2 standard deviations.
(b) Picocuries per gram wet weight of sample.
(c) Average sample specific MDC.

8.4 Data Assessment

Plant and animal sample results show that man-made radionuclide concentrations, specifically ^{3}H, are higher at the Area 5 RWMS and Sedan compared with their control locations. Elevated concentrations of ^{3}H in vegetation at the Area 5 RWMS indicates that ^{3}H in soil moisture in the root zone is elevated. This does not necessarily indicate that the roots of plants have penetrated the waste zone, but more likely indicates that ^{3}H is highly mobile and is moving away from the waste as water vapor moving upward through the soil profile. This is supported by the lack of other radionuclides which would also be highly elevated if the plant's roots had invaded the buried waste. Also, soil samples do not suggest burrowing animals have come into contact with buried waste. It is likely that elevated ^{3}H concentrations in animals come from their consuming plants on the covers and from inhalation of ^{3}H evaporating from the soil. Though NNSS-related radionuclides are detected in some plants and animals, the levels pose negligible risk to humans and biota. The potential dose to a person hunting and consuming these animals is well below dose limits to members of the public (Section 9.1.1.2). Also, radionuclide concentrations were below levels considered harmful to the health of the plants or animals; the dose resulting from observed concentrations was less than 2% of dose limits set to protect populations of plants and animals (Section 9.2).

8.5 References

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Chapter 9: Radiological Dose Assessment

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Radiological Dose Assessment Goals

Determine if the maximum radiation dose to a member of the general public from airborne radionuclide emissions at the Nevada National Security Site (NNSS) complies with the Clean Air Act, National Emission Standards for Hazardous Air Pollutants (NESHAP) limit of 10 millirems per year (mrem/yr) (0.1 millisieverts per year [mSv/yr]). Determine if radiation levels from the Radioactive Waste Management Sites (RWMSs) comply with the 25 mrem/yr (0.25 mSv/yr) dose limit to members of the public as specified in U.S. Department of Energy (DOE) Manual DOE M 435.1-1, "Radioactive Waste Management Manual." Determine if the total radiation dose (total effective dose equivalent [TEDE]) to a member of the general public from all possible pathways (direct exposure, inhalation, ingestion of water and food) as a result of NNSS operations complies with the limit of 100 mrem/yr (1 mSv/yr) established by DOE Order DOE O 458.1, "Radiation Protection of the Public and the Environment." Determine if the radiation dose (in a unit of measure called a rad) to NNSS biota complies with the following limits set by DOE Standard DOE-STD-1153-2019, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota."

The U.S. Department of Energy requires DOE facilities to estimate the radiological ***dose***[1] to the general public and to plants and animals in the environment caused by past or present facility operations. These requirements are specified in DOE O 458.1 and in DOE O 435.1, "Radioactive Waste Management" (Table 2-1). To estimate these radiological doses, ***radionuclide*** concentration data gathered on the NNSS are used along with dose conversion factors published in DOE-STD-1196-2011, "***Derived Concentration Technical Standard***." The dose conversion factors take into account the different population fractions of age and sex to give representative dose coefficients for a reference person within the U.S. population. The 2020 data are presented in Chapters 4, 5, 6, and 8 of this report, and include the results for onsite monitoring of air, water, direct radiation, and biota, and for offsite monitoring of groundwater. The independent offsite air and groundwater data presented in Chapter 7, "Community-Based Offsite Monitoring," provide extra assurance to the public that estimated doses do not underestimate potential offsite ***exposures*** to NNSS-related radiation. The specific goals for the dose assessment component of radiological monitoring are described below.

9.1 Dose to the Public

This section identifies the possible pathways by which the public could be exposed to radionuclides present in the environment due to past or current NNSS activities. It describes how field-monitoring data are used with other NNSS data sources (e.g., radionuclide inventory data) to provide input to the dose estimates, and presents the estimated 2020 public dose attributable to U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) activities from each pathway and from all pathways combined. The public dose due to radioactive waste operations on the NNSS is also assessed, and a description of the program that controls the release of NNSS materials having residual ***radioactivity*** into the public domain is provided.

9.1.1 Dose from Possible Exposure Pathways

As prescribed in the *Routine Radiological Environmental Monitoring Plan* (Bechtel Nevada [BN] 2003), air, groundwater, and biota are routinely sampled to document the amount of radioactivity in these media and to provide data to assess the radiation dose received by the general public from several pathways.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

The potential pathways by which a member of the general public residing off site might receive a radiation dose resulting from past or present NNSS operations include the following:

- Inhalation of, ingestion of, or direct external exposure to airborne radionuclide emissions transported off site by wind
- Ingestion of wild game animals that drink from surface waters and/or eat vegetation containing NNSS-related radioactivity
- Ingestion of plants containing radioactivity from NNSS-related activities
- Drinking water from underground ***aquifers*** containing radionuclides that have migrated from the sites of past underground nuclear tests or radioactive waste management sites
- Exposure to direct radiation along the borders of the NNSS

The subsections below address all of the potential pathways and their contribution to public dose estimated for 2020.

9.1.1.1 Dose from NNSS Air Emissions

Six air particulate and ***tritium (^{3}H)*** sampling stations located near the boundaries and the center of the NNSS are approved by U.S. Environmental Protection Agency (EPA) Region 9 as ***critical receptor samplers*** to demonstrate compliance with the NESHAP public dose limit of 10 mrem/yr (0.1 mSv/yr) from air emissions. The annual average concentration of an airborne radionuclide must be less than its NESHAP Concentration Level for Environmental Compliance (abbreviated as ***compliance level [CL]***) (Table 4-1). The CL for each radionuclide represents the annual average concentration of that radionuclide in air that would result in a TEDE of 10 mrem/yr. If multiple radionuclides are detected at a station, then compliance with NESHAP is demonstrated when the sum of the fractions (determined by dividing each radionuclide's concentration by its CL and then adding the fractions together) is less than 1.0.

The critical receptor sampling stations can be thought of as worst case for an offsite receptor because these samplers are close to emissions sources (Figures 4-1, 4-2). Table 9-1 displays the distances between the critical receptor monitoring stations and points where members of the public potentially live, work, and/or go to school. The distance between the sampling location and the closest onsite emission location (Figure 4-1) is also listed.

Table 9-1. Distance between critical receptor air monitoring stations and nearest points of interest

Critical Receptor Station	Distance(a) and Direction(b) to Nearest Offsite Locations and Onsite Emission Location			
	Residence	Business/Office	School	NNSS Emission Source
Area 6, Yucca	47 km SW Amargosa Valley	38 km SSE American Silica(c)	54 km SE Indian Springs	2.4 km SW Area 6, Grouped Area Sources
Area 10, Gate 700 S	49 km ENE Medlin's Ranch	56 km NNE Rachel	75 km SSE Indian Springs	2.6 km SW Area 10, Sedan Crater
Area 16, 3545 Substation	46 km SSW Amargosa Valley	46 km SSW Amargosa Valley	58 km SSW Amargosa Valley	1.6 km NW Area 16, Grouped Area Sources
Area 20, Schooner	36 km WSW Sarcobatus Flat	20 km WSW Tolicha Peak	56 km SSW Beatty	0.3 km ESE Area 20, Schooner Crater
Area 23, Mercury Track	24 km SW Crystal	6.0 km SE American Silica	31 km SSW Indian Springs	0.2 km ESE Area 23, Building 652
Area 25, Gate 510	4 km S Amargosa Valley	3.5 km S Amargosa Valley	15 km SW Amargosa Valley	21 km NNE Area 25, nearest portion of Grouped Area Sources

(a) Distance is shown in kilometers (km). For miles, multiply by 0.62.
(b) N=north, S=south, E=east, W=west in all direction combinations shown.
(c) The American Silica mine was not active in 2020 but is the closest business to the NNSS.

In 2020, the man-made radionuclides detected in samples from at least one air monitoring station included ^{3}H, cesium-137 (^{137}Cs), americium-241 (^{241}Am), plutonium-238 (^{238}Pu), and plutonium-239+240 ($^{239+240}$Pu) (Section 4.1). The annual average concentrations of these radionuclides were well below their CLs and the sum of fractions for each location were all less than 1.0 (Table 4-11). As in previous years, 2020 data from the six critical receptor stations show that the NESHAP public dose limit of 10 mrem/yr (0.1 mSv/yr) was not exceeded.

The radioactive air emissions from each 2020 NNSS source were modeled using the ***Clean Air Package, 1988***, model (CAP88, Version 4.0; EPA 2014). The highest value (0.063 mrem/yr [0.00063 mSv/yr]) is predicted to be a person residing in Amargosa Valley. More detailed information regarding the estimation of the dose to the public from airborne radioactivity in 2020 from all activities conducted by NNSA/NFO on the NNSS and its Nevada support facilities is reported in Mission Support and Test Services, LLC (MSTS) (2021).

9.1.1.2 Dose from Ingestion of Game Animals from the NNSS

Three game species, mule deer, bighorn sheep, and mourning doves, have been shown to travel off the NNSS and be available to hunters (Giles and Cooper 1985; Hall and Perry 2019; National Security Technologies, LLC [NSTec] 2009). In fact, one mule deer captured on the NNSS and fitted with a radio-collar in 2019 (MSTS 2020) was taken by a hunter near Kawich Peak in October 2020. Because of this, game animals on the NNSS are sampled annually near known radiologically contaminated areas to give conservative (worst-case) estimates of the level of radionuclides that hunters may consume if these animals are harvested off the NNSS. In 2020, the following animals were sampled (Figure 8-1 and Tables 8-4 and 8-5):

- Three jackrabbits from near Sedan Crater, Area 10
- Two cottontail rabbits sampled from the control location for Sedan, Area 16
- One composite small mammal sample each from the Area 3 RWMS ax/bl Cover and its control location. These are treated as surrogate jackrabbit samples in the dose calculations.
- One composite small mammal sample each from the Area 5 Radioactive Waste Management Complex (RWMC) 92-Acre Cover and its control location. These are treated as surrogate jackrabbit samples in the dose calculations.
- One feral burro killed by a vehicle in Area 5. This is treated as a surrogate mule deer sample in the dose calculations.
- Five mule deer that were all study animals fitted with GPS [global postioning system] collars in 2019; one died from unknown cause, three died from predation, and one was taken by a hunter.
- Three pronghorn, one killed by a vehicle in Area 1 and two study animals fitted with GPS collars in 2019; one died from a predation attack in Area 14 and one died from unknown cause in Area 1.

The potential ***committed effective dose equivalent (CEDE)*** to an individual consuming game animals was calculated for each animal sampled in 2020 unless no man-made radionuclides were detected in animals from a particular location. The following assumption/parameters were used to estimate dose:

- Analysis results from all samples were included in calculating dose from consuming a particular species as long as the radionuclide was detected, i.e., the analysis result was above the ***minimum detectable concentration***, in at least one sample of that species at a particular location. The opportunistic samples are grouped as all being from the same location (NNSS) for this assessment.
- If the analytical result for a radionuclide concentration in the sample was a negative value (resulting from a ***background*** measurement higher than what was observed in the sample), then the concentration for that sample was set to zero.
- An individual consumes one of each species of animal sampled from each location during the year:
    - one jackrabbit (513 grams [g]) each from Sedan, the Area 3 RWMS ax/bl Cover and its control location, the Area 5 RWMC 92-Acre Cover and its control location
    - one cottontail rabbit (167 g) from the Sedan control location
    - one burro from Area 5 (used the amount of meat from an adult male mule deer: 35.4 kilograms [kg])
    - one mule deer (35.4 kg)
    - one pronghorn antelope (20.0 kg)
- The moisture content of the muscle tissue samples of all species is 73%.

- Dose coefficients for a reference person as defined by DOE-STD-1196-2011 are used; they are for a hypothetical person representing an aggregate of individuals in the U.S. population.
- The entire committed dose is considered to be received during the calendar year.

Dose coefficients (mrem per picocurie [pCi] ingested), based on values listed in DOE-STD-1196-2011, were multiplied by the amount of radioactivity (pCi) potentially ingested to obtain the potential dose (CEDE) (Table 9-2). The average and maximum CEDEs for each monitored location and for each animal species are presented in Table 9-2. No man-made radionuclides were detected in the mule deer taken by a hunter in 2020 ("Offsite Mule Deer" in Table 9-2). Based on the 2020 samples, an individual who consumes one animal of each sampled species from each location (where opportunistic large game samples were considered to be from one location, i.e., the entire NNSS) may receive an estimated dose of 1.0 mrem (0.01 mSv) based on the averages. To put this dose in perspective, it is about the same dose received from naturally occurring cosmic radiation during a 2-hour airplane flight at 39,000 feet. From consuming just one animal sampled in 2020, the maximum would come from eating 35.4 kg of meat with concentrations observed in the burro sampled in Area 5 (Table 8-5) and would result in a dose of 0.49 mrem (0.0049 mSv) (Tables 9-2 and 9-3).

Table 9-2. Hypothetical CEDE from ingesting game animals

	Committed Effective Dose Equivalent (mrem)[a]								
Location and Sample	**^{3}H[b]**	**^{90}Sr**	**^{137}Cs**	**^{238}Pu**	**$^{239+240}$Pu**	**^{241}Am**	**Total**	**Location Average**	**Max**
Sedan									
Jackrabbit #1	0.0003	0.0260	0.0042	0.0052	0.0489	0.0126	0.0971	0.0682	0.0971
Jackrabbit #2	0.0006	0.0180	0.0038	0.0004	0.0000	0.0050	0.0277		
Jackrabbit #3	0.0009	0.0135	0.0031	0.0056	0.0484	0.0081	0.0797		
Sedan Control									
Cottontail #1	0.0000	0.0000	0.0000	0.0002	0.0005	0.0000	0.0007	0.0006	0.0007
Cottontail #1	0.0000	0.0000	0.0000	0.0003	0.0002	0.0000	0.0006		
RWMS Small Mammal Composites[c]									
RWMS 3 U-3 ax/bl Cover	0.0000	0.0025	0.0000	0.0002	0.0165	0.0022	0.0213	0.0213	0.0213
RWMS 3 Control	No manmade radionuclides detected in RWMS 3 Control samples								
RWMS 5 92-Acre Cover	0.0054	0.0009	0.0000	0.0001	0.0194	0.0013	0.0271	0.0271	0.0271
RWMS 5 Control	0.0000	0.0011	0.0004	0.0019	0.0015	0.0003	0.0051	0.0051	0.0051
	Opportunistic samples from natural mortality or accidental road kills								
Location and Sample	**^{3}H[b]**	**^{90}Sr**	**^{137}Cs**	**^{238}Pu**	**$^{239+240}$Pu**	**^{241}Am**	**Total**	**Species Average**	**Max**
Area 5 Burro	0.0007	0.1715	0.0000	0.1298	0.1760	0.0076	0.4856	0.4856	0.4856
Area 19 Mule Deer #1	0.0001	0.0000	0.0000	0.0000	0.1515	0.0000	0.1516	0.1516	0.1516
Area 19 Mule Deer #2	No manmade radionuclides detected								
Area 19 Mule Deer #3	No manmade radionuclides detected								
Area 17 Mule Deer	No manmade radionuclides detected								
Offsite Mule Deer	No manmade radionuclides detected								
Area 14 Pronghorn[d]	0.0001	0.0494	0.0342	0.0433	0.1354	0.0000	0.2624	0.2477	0.3129
Area 1 Pronghorn	0.0000	0.0000	0.0000	0.0817	0.1611	0.0701	0.3129		
Area 3 Pronghorn	0.0010	0.0625	0.0401	0.0306	0.0335	0.0000	0.1678		
CEDE from consuming one animal of each species, including one from each RWMS location = 1.0 mrem (using averages) and 1.28 mrem (using maximums)									

(a) Based on dose coefficients in Appendix A of DOE-STD-1196-2011 for a Reference Person.
(b) Based on assumption that the water content of all muscle tissue samples is 73%.
(c) Radionuclide concentrations from composite samples of small mammals. Treated as a surrogate jackrabbit.
(d) Based on the muscle tissue sample which resulted in highest estimated dose.

A person may consume animals from locations on the NNSS other than where samples were collected in 2020; therefore, Table 9-3 presents the maximum CEDE for humans consuming various species of wildlife from all animals sampled from 2001–2020. Table 9-3 gives a worst-case scenario based on radionuclide analyses of NNSS game animal samples over the past 20 years.

The highest CEDE from consuming just one animal (12.9 mrem or 0.129 mSv) would be from the pronghorn sampled in 2018 from Area 9 (Table 9-3). This represents 12.9% of the annual dose limit for members of the public.

Table 9-3. Maximum CEDEs to a person hypothetically ingesting NNSS game animals sampled from 2001–2020

Game Animal	Sample Location	Year Sampled	Amount Consumed	CEDE for Consumption of One Animal (mrem)
Bighorn Sheep	Area 25 (captured study animal)	2015	all muscle	0.170
Bobcat	Area 25 (roadkill)	2012	all muscle	0.032
Burro	Area 5 (roadkill)	2020	all muscle	0.486
Chuckar	Area 12 (E-Tunnel)	2001	breast muscle	0.006
Cottontail Rabbit	Area 20 (Schooner Crater)	2013	whole body	0.032
Desert Tortoise	Area 22 roadkill (Jackass Flats Road)	2020	whole body	0.009
Gambel's Quail	Area 2 (T2)	2002	all muscle	0.004
Jackrabbit	Area 10 (Sedan)	2015	all muscle	1.298
Mountain Lion	Nevada Test and Training Range (natural mortality of study lion NNSS4)	2013	all muscle	0.095
Mourning Dove	Area 20 (Palanquin control but likely from sump of Well U-20n)	2003	breast muscle	0.032
Mule Deer	Area 19 (killed by a mountain lion)	2014	all muscle	3.228
Pronghorn	Area 9 (likely killed by coyotes)	2018	all muscle	12.869

9.1.1.3 Dose from Ingestion of Plants from the NNSS

Current NNSS land-use practices discourage the harvesting of plants or plant parts for direct consumption by humans. However, it is possible that individuals with access will collect and consume edible plant material. One species in particular, the pinyon pine tree, produces pine nuts that are harvested and consumed across the western United States. Pinyon pine trees grow throughout regions of higher elevation on the NNSS. The most recent year pine nuts were sampled was in 2013. These were from three locations on the NNSS: Area 15, Area 17, and in Area 12 near the E Tunnel Ponds. The estimated dose from consuming them was shown to be extremely low (0.00056 mrem or 0.0000056 mSv) and a negligible contribution to the total potential dose to a member of the public (NSTec 2014). No other edible plant materials have been collected for analysis on the NNSS in recent history, and no edible plants were sampled in 2020.

9.1.1.4 Dose from Drinking Contaminated Groundwater

The 2020 groundwater monitoring data indicate that groundwater from offsite private and community wells and springs has not been impacted by past NNSS nuclear testing operations (Sections 5.1.3.6, 7.2, and 7.3). No man-made radionuclides have been detected in any sampled wells accessible to the offsite public or in sampled private wells or springs. These field monitoring data also agree with the forecasts of current groundwater flow and contaminant transport models discussed in Chapter 11. Therefore, drinking water from underground aquifers containing radionuclides is not a possible pathway of exposure to the public residing off site.

9.1.1.5 Dose from Direct Radiation Exposure along NNSS Borders

The direct exposure pathway from ***gamma radiation*** to the public is monitored routinely (Chapter 6). In 2020, the only place where the public had the potential to be exposed to direct radiation from NNSS operations was at Gate 100, the primary entrance to the site on the southern NNSS border. Trucks hauling radioactive materials, primarily ***low-level waste (LLW)*** being shipped for disposal at the Area 5 RWMS, park outside Gate 100 while waiting for entry. Only during these times is there a potential for exposure to the public due to NNSS activities. However, no member of the public resides or remains full-time at the Gate 100 truck parking area. Therefore, dose from direct radiation is not included as a current pathway of exposure to the public residing off site.

9.1.2 Dose from Waste Operations

DOE M 435.1-1 states that LLW disposal facilities shall be operated, maintained, and closed so that a reasonable expectation exists that annual dose to members of the public shall not exceed 10 mrem through the air pathway and 25 mrem through all pathways for a 1,000-year compliance period after closure of the disposal units. Given that the RWMSs are located well within the NNSS boundaries and public access is limited (e.g., tours), members of the public have access only for brief periods. However, for purposes of documenting potential impacts, the pathways for radionuclide movement from waste disposal facilities are monitored.

In 2020, external radiation from waste operations measured near the boundaries of the Area 3 and Area 5 RWMSs could not be distinguished from background levels at those locations (Section 6.3.4). Area 3 and Area 5 RWMS operations would have contributed negligible external exposure to a hypothetical person residing near the boundaries of these sites and would have resulted in no dose to the offsite public.

The dose from the air pathway can be estimated from air monitoring results from stations near the RWMSs (Figure 4-2 and Table 10-5). Mean concentrations of radionuclides in air at the Area 3 and Area 5 environmental sampler locations were, at the most, only 7% of their CLs (Table 10-5).

There is no exposure, and therefore no dose, to the public from groundwater beneath waste disposal sites on the NNSS. Groundwater monitoring indicates that man-made radionuclides have not been detected in wells accessible to the offsite public or in private wells or springs (Sections 5.1.3.6, 7.2, and 7.3). Also, groundwater and ***vadose zone*** monitoring at the Area 3 and Area 5 RWMSs, conducted to verify the performance of waste disposal facilities, has not detected the migration of radiological wastes into groundwater (Sections 10.3.1 and 10.3.2). Based on these results, potential dose to members of the public from LLW disposal facilities on the NNSS from all pathways are negligible.

9.1.3 Total Offsite Dose to the Public from All Pathways

The DOE-established radiation dose limit to a member of the general public from all possible pathways as a result of NNSA/NFO facility operations is 100 mrem/yr (1 mSv/yr), excluding background radiation, while considering air transport, ingestion, and direct exposure pathways. For 2020, the only plausible pathways of public exposure to man-made radionuclides from current or past NNSS activities included the air transport pathway and the ingestion of game animals and plants. The doses from these pathways are combined in Table 9-4 to present an estimate of the total 2020 dose to the ***maximally exposed individual (MEI)*** residing off site.

The MEI for the air pathway was considered to be a person residing in Amargosa Valley south of the NNSS (Section 9.1.1.1). If the offsite MEI were assumed to also eat wildlife from the NNSS, additional dose would be received. Based on 2020 samples, the additional dose from consuming one animal may range up to 0.49 mrem (0.0049 mSv) if a person ate the equivalent of 35.4 kg of meat with concentrations observed in the burro sampled in Area 5 (Table 9-2). When the 0.063 mrem (0.00063 mSv) dose from the air pathway is added, the TEDE to this hypothetical MEI from all exposure pathways combined due to NNSA/NFO activities would be 0.55 mrem/yr (0.0055 mSv/yr) (Table 9-4).

Table 9-4. Estimated radiological dose to hypothetical MEI of the general public from 2020 NNSS activities

Pathway	Dose to MEI (mrem/yr)	Dose to MEI (mSv/yr)	Percent of DOE 100 mrem/yr Limit
Air[(a)]	0.063	0.00063	0.06
Water[(b)]	0.00	0.00	0.00
Wildlife[(c)]	0.49	0.0049	0.43
Direct[(d)]	0.00	0.00	0.00
All Pathways	0.55	0.0055	0.55

(a) Based on highest offsite dose predicted from modeled 2020 air emissions (Section 9.1.1.1).
(b) Based on all offsite groundwater sampling conducted by NNSA/NFO to date (Section 5.1).
(c) Based on consuming one animal sampled in 2020, which would result in the highest dose (Table 9-2).
(d) Based on 2020 gamma radiation monitoring data at the NNSS entrance (Section 6.3.1).

The total dose of 0.55 mrem/yr to the hypothetical MEI is 0.55% of the DOE limit of 100 mrem/yr and about 0.15% of the total dose that the MEI receives from natural background radiation (360 mrem/yr [3.6 mSv/yr]) (Figure 9-1). Natural background radiation consists of cosmic radiation, terrestrial radiation, radiation from radionuclides within the composition of the human body (primarily potassium-40), and radiation from the inhalation of naturally occurring radon and its ***progeny***. The cosmic and terrestrial components of background radiation shown in Figure 9-1 were estimated from the annual mean radiation exposure rate measured with a pressurized ion chamber (PIC) at Indian Springs by the Community Environmental Monitoring Program (102.05 milliroentgens per year [mR/yr]; Table 7-4). The radiation exposure in air, measured by the PIC in units of mR/yr, is conservatively approximated to be equivalent to the unit of mrem/yr for tissue. The portion of the background dose from the internally deposited, naturally occurring radionuclides and from the inhalation of radon and its ***daughters*** were estimated at 31 mrem/yr (0.31 mSv/yr) and 229 mrem/yr (2.29 mSv/yr), respectively (Figure 9-1), using the approximations by the National Council on Radiation Protection and Measurements (2006).

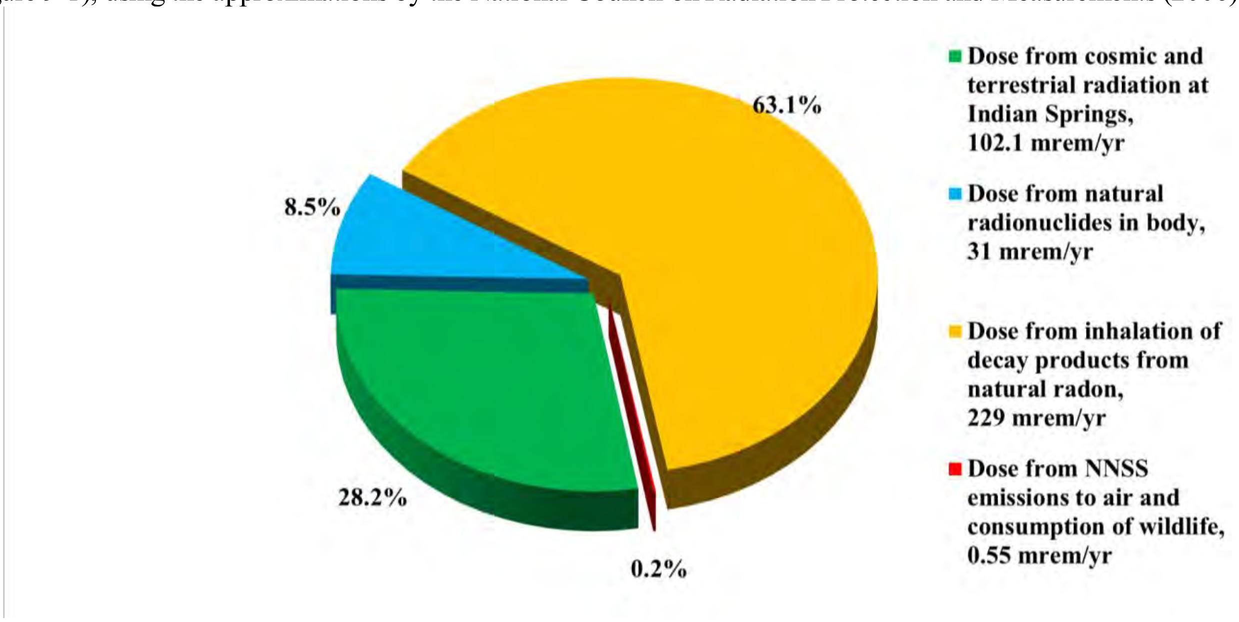

Figure 9-1. Comparison of radiation dose to the MEI from the NNSS and natural background (% of total) in 2020

9.1.4 Collective Population Dose

The ***collective population dose*** to residents within 80 km (50 miles [mi]) is the product of the predicted individual doses multiplied by the population potentially receiving those doses. The CAP88 modeled doses from 2020 air emissions for the estimated 521,300 people who lived within 80 km (50 mi) of NNSS emission sources resulted in a collective dose of 0.29 person-rem/yr. This 2020 calculation verifies the relatively low dose risk from the NNSS.

9.1.5 Release of Property Containing Residual Radioactive Material

In addition to discharges to the environment, the release of DOE property containing residual radioactive material is a potential contributor to the dose received by the public. The release of property off the NNSS is controlled. No vehicles, equipment, structures, or other materials can be released from the NNSS for unrestricted public use unless the amount of residual radioactivity on such items is less than the authorized limits. The default authorized limits for 2020 are specified in the *Nevada National Security Site Radiological Control Manual* (Radiological Control Manager's Council 2018) and are consistent with the limits set by DOE O 458.1. These limits are shown in Table 9-5.

All NNSA/NFO contractors use a graded approach for release of material and equipment for unrestricted public use. Either items are surveyed prior to release to the public, or a process knowledge evaluation is conducted to verify that the material has not been exposed to radioactive material or beams of radiation capable of generating radioactive material. In some cases, both a radiological survey and a process knowledge evaluation are performed (e.g., a radiological survey is conducted on the outside of the item, and a process knowledge form is signed by the custodian to address inaccessible surfaces). Items are evaluated/surveyed prior to shipment to the NNSA/NFO property/excess warehouse. All contractors also complete material surveys prior to release and transport to the Area 23 landfill. The only exception is for items that could be internally contaminated; these items are submitted to Waste Generator Services for disposal using one of the facilities that can accept LLW. Excess items that can be free-released are either donated to interested state agencies, federal agencies, or universities; redeployed to other onsite users; or sold on an auction website. No released items had residual radioactivity in excess of the limits specified in Table 9-5.

Independent verification of radiological surveys and process knowledge evaluations is achieved through NNSA/NFO program oversight and through assessments. DOE O 458.1, which includes the process of releasing property to the public, has been incorporated into the site's Radiological Control Manager's Council Internal Assessment Schedule, and DOE O 458.1 assessments are scheduled to occur once every 3 years. An assessment was conducted in 2019, and NNSS property release activities were found to comply with DOE O 458.1.

Table 9-5. Allowable total residual surface contamination for property released off the NNSS

	Residual Surface Contamination (dpm/100 cm²)(a)		
Radionuclide	**Removable**	**Average(b) (Fixed and Removable)**	**Maximum Allowable(c) (Fixed and Removable)**
Transuranics, ^{125}I, ^{129}I, ^{226}Ra, ^{227}Ac, ^{228}Ra, ^{228}Th, ^{230}Th, ^{231}Pa	20	100	300
Th-natural, ^{90}Sr, ^{126}I, ^{131}I, ^{133}I, ^{223}Ra, ^{224}Ra, ^{232}U, ^{232}Th	200	1,000	3,000
U-natural, ^{235}U, ^{238}U, and associated ***decay*** products, alpha emitters (α)	1,000 α	5,000 α	15,000 α
Beta (β)-gamma (γ) emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above	1,000 β+γ	5,000 β+γ	15,000 β+γ
^{3}H and tritiated compounds	10,000	N/A	N/A

(a) Disintegrations per minute per 100 square centimeters (cm²).
(b) Averaged over an area of not more than 100 cm².
(c) Applicable to an area of not more than 100 cm².

9.2 Dose to Aquatic and Terrestrial Biota

DOE requires their facilities to evaluate the potential impacts of radiation exposure to biota in the vicinity of DOE activities. To assist in such an evaluation, DOE's Biota Dose Assessment Committee developed DOE-STD-1153-2019. This standard established the following radiological dose limits for plants and animals. Dose rates equal to or less than these are expected to have no direct, observable effect on plant or animal reproduction:

- 1 radiation absorbed dose per day (rad/d) (0.01 grays per day [Gy/d]) for aquatic animals
- 1 rad/d (0.01 Gy/d) for terrestrial plants
- 0.1 rad/d (1 milligray per day) for terrestrial animals

DOE-STD-1153-2019 also provides concentration values for radionuclides in soil, water, and sediment to use as a guide to determine if biota are potentially receiving radiation doses above the limits. These concentrations are called the Biota Concentration Guide (BCG) values. They are defined as the minimum concentration of a radionuclide that would cause dose limits to be exceeded using very conservative uptake and exposure assumptions.

NNSS biologists use the graded approach described in DOE-STD-1153-2019. The approach is a three-step process consisting of a data assembly step, a general screening step, and an analysis step. The analysis step consists of site-specific screening, site-specific analysis, and site-specific biota dose assessment. The following information is required by the graded approach:

- Identification of terrestrial and aquatic habitats on the NNSS with radionuclides in soil, water, or sediment
- Identification of terrestrial and aquatic biota on the NNSS in contaminated habitats and at risk of exposure

- Measured or calculated radionuclide concentrations in soil, water, and sediment in contaminated habitats on the NNSS that can be compared to BCG values to determine the potential for exceeding biota dose limits
- Measured radionuclide concentrations in NNSS biota, soil, water, and sediment in contaminated habitats on the NNSS to estimate site-specific dose to biota

A comprehensive biota dose assessment for the NNSS using the graded approach was reported in the *Nevada Test Site Environmental Report 2003* (BN 2004). The assessment demonstrated that the potential radiological dose to biota on the NNSS was not likely to exceed dose limits. Data from monitoring air, water, and biota across the NNSS suggest no significant change to NNSS surface conditions; therefore, the biota dose evaluation conclusion remains the same for 2020.

9.2.1 Site-Specific Biota Dose Assessment

The site-specific biota dose assessment phase of the graded approach centers on the actual collection and analysis of biota. To obtain a predicted internal dose to biota sampled in 2020, the RESRAD-BIOTA, Version 1.8, computer model (DOE 2004) was used. Maximum concentrations of man-made radionuclides detected in plant and animal tissue (Tables 8-3 and 8-5) were entered into the model. External dose was based on the measured annual exposure rate using the maximum quarterly ***thermoluminescent dosimeter (TLD)*** measurement made close to each biota sampling site (Table 6-1), minus the average background exposure rate (Table 6-2). If the average background exposure rate was higher than the monitored location, then man-made external dose was set to zero.

The 2020 site-specific estimated dose rates to biota were all below the DOE limits for both plants and animals (Table 9-6). The highest dose rate (0.0058 rad/d) was predicted for vegetation on the RWMS 5 92-Acre Cover. The highest percent of the DOE dose limit was about 1% for each of jackrabbits at Sedan and small mammals on the on the RWMS 5 92-Acre Cover.

Table 9-6. Site-specific dose assessment for terrestrial plants and animals

	Estimated Radiological Dose (rad/d)		
Location [(a)]	**Internal [(b)]**	**External [(c)] (TLD)**	**Total**
Terrestrial Plants			
Sedan	0.002150	0.000234	0.002385
Sedan Control	0.000022	0.000014	0.000036
RWMS 3 U-3 ax/bl Cover	0.000216	0.000054	0.000270
RWMS 3 Control	0.000020	0.000011	0.000031
RWMS 5 92-Acre Cover	0.005734	0.000047	0.005781
RWMS 5 Control	0.000009	0.000004	0.000014
		DOE Dose Limit:	**1**
Terrestrial Animals			
Sedan Jackrabbit (Area 10)	0.000733	0.000234	0.000967
Sedan Control Cottontail Rabbit (Area 16)	0.000026	0.000076	0.000102
RWMS 3 U-3 ax/bl Cover	0.000193	0.000054	0.000247
RWMS 3 Control	No manmade radionuclides detected	0.000011	0.000011
RWMS 5 92-Acre Cover	0.000232	0.000811	0.001043
RWMS 5 Control	0.000040	0.000047	0.000087
Burro (Area 5)	0.000050	0.000004	0.000054
Mule Deer (max concentrations from various)	0.000064	0.000158	0.000221
Pronghorn (max concentrations from various)	0.000094	0.000024	0.000118
		DOE Dose Limit:	**0.1**

(a) For information on plants and animals sampled, see Chapter 8.
(b) Based on maximum concentrations of each man-made radionuclide detected in plant or animal sampled at that location.
(c) Based on TLD measured exposure rates at or near the sample location. See Chapter 6 for information on direct radiation.

9.3 Dose Assessment Summary

Radionuclides in the environment as a result of past or present NNSS activities result in a potential dose to the public or biota much lower than the dose limits set to protect the public health and the environment. The estimated dose to the MEI for 2020 was 0.55 mrem/yr (0.0055 mSv/yr), which is 0.55% of the dose limit set to protect human health. Dose to biota at the NNSS sites sampled in 2020 were less than 2% of dose limits set to protect plant and animal populations. Based on the low potential doses from NNSS radionuclides, impacts from those radionuclides are expected to be negligible.

9.4 References

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Chapter 10: Waste Management

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Waste Management Goals

Ensure disposal systems meet performance objectives. Manage and safely dispose of all types of wastes. Ensure wastes received for disposal at the Nevada National Security Site (NNSS) meet NNSS acceptance criteria. Manage and monitor wastes and waste sites for the protection of the worker, the public, and the environment.

Several federal and state regulations govern the safe management, storage, and disposal of radioactive, hazardous, and solid wastes generated or received on the NNSS (Tables 2-1 and 2-3). This chapter describes waste management operations and compliance with applicable environmental/public safety regulations. The U.S. Department of Energy (DOE) Environmental Management (EM) Nevada Program, in coordination with the National Nuclear Security Administration Nevada Field Office (NNSA/NFO), is responsible for the Area 3 and Area 5 radioactive waste facilities described in Section 10.1. NNSA/NFO is responsible for and operates all other waste disposal facilities on the NNSS (Figure 10-1).

This chapter describes several waste streams, including the following:

- ***low-level radioactive waste (LLW)***[1]
- ***mixed LLW (MLLW)***
- ***classified non-radioactive (CNR)/classified non-radioactive hazardous (CNRH)***
- ***hazardous waste (HW)***
- ***transuranic*** and mixed transuranic (TRU/MTRU)
- explosive ordnance wastes
- solid/sanitary waste
- underground storage tanks (USTs)

In addition, details are included for the management of USTs; the process to evaluate, design, construct, maintain, and monitor closure covers for radioactive waste disposal units at the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs); and monitoring radiation ***doses*** from the Area 3 RWMS and the ***Area 5 Radioactive Waste Management Complex (RWMC)*** to the levels specified in DOE Manual DOE M 435.1-1, "Radioactive Waste Management Manual."

10.1 Radioactive Waste Management

The NNSS Radioactive Waste Management facilities include the Area 5 RWMC and the Area 3 RWMS. They operate as Category II non-reactor nuclear facilities. The Area 5 RWMC (Figure 10-2) is composed of the Area 5 RWMS, the Mixed Waste Storage Unit (MWSU), Mixed Waste Disposal Unit (MWDU), and the Waste Examination Facility (WEF). The Hazardous Waste Storage Unit (HWSU) is adjacent to the Area 5 RWMC. The waste disposed at these facilities must be generated at a DOE facility or defense-affiliated site or have a clear nexus to a DOE-sponsored program. This section describes the facilities and activities conducted by the Radioactive Waste Acceptance Program (RWAP)[2] to evaluate and verify waste generators and waste streams, and NNSS Disposal Operations to ensure the safe receipt, storage, disposal, and monitoring of radioactive and mixed wastes at the NNSS.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.
[2] Information on the RWAP can be found at https://www.nnss.gov/pages/programs/RWM/Acceptance.html.

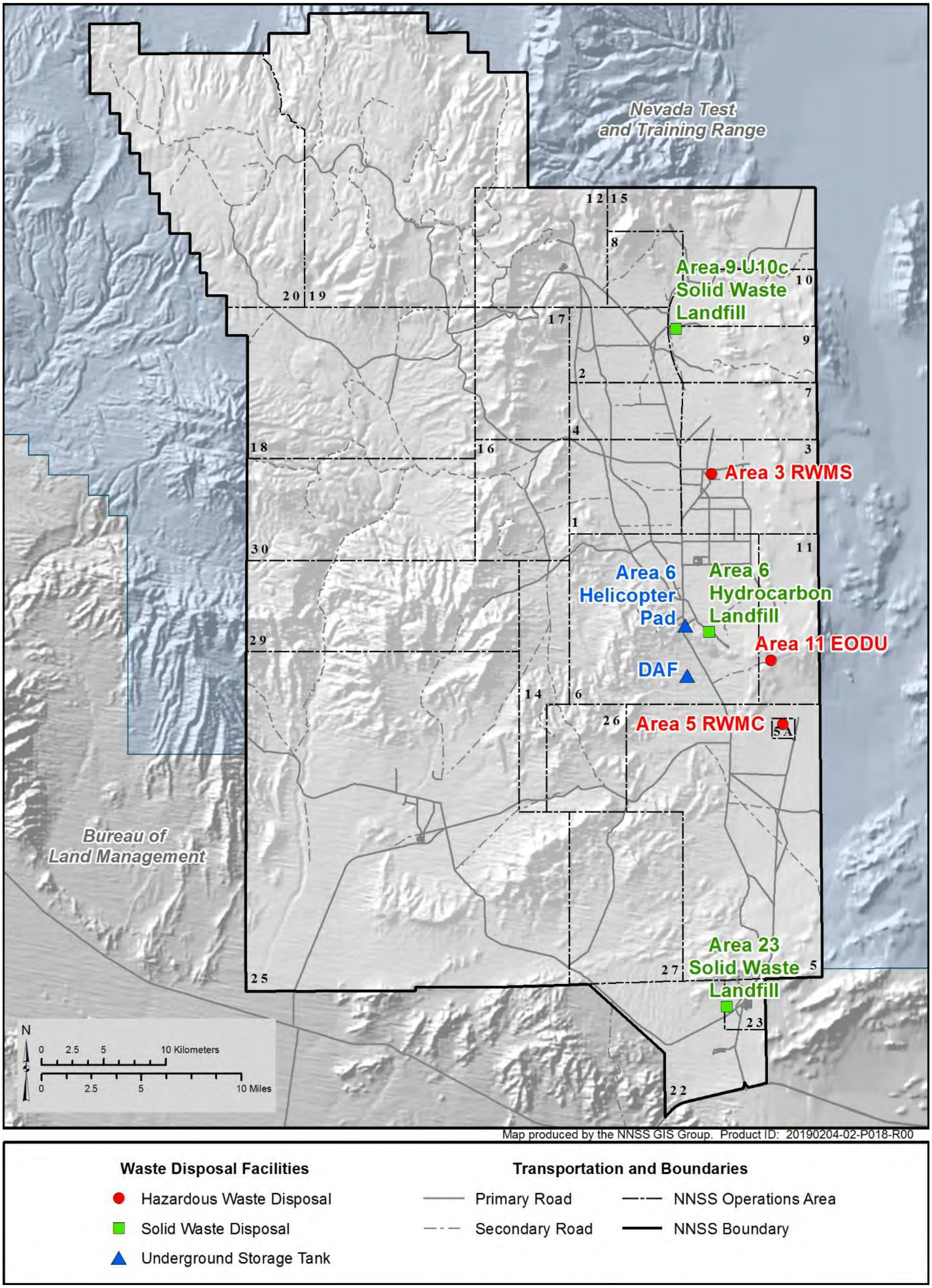

Figure 10-1. Waste disposal facilities on the NNSS

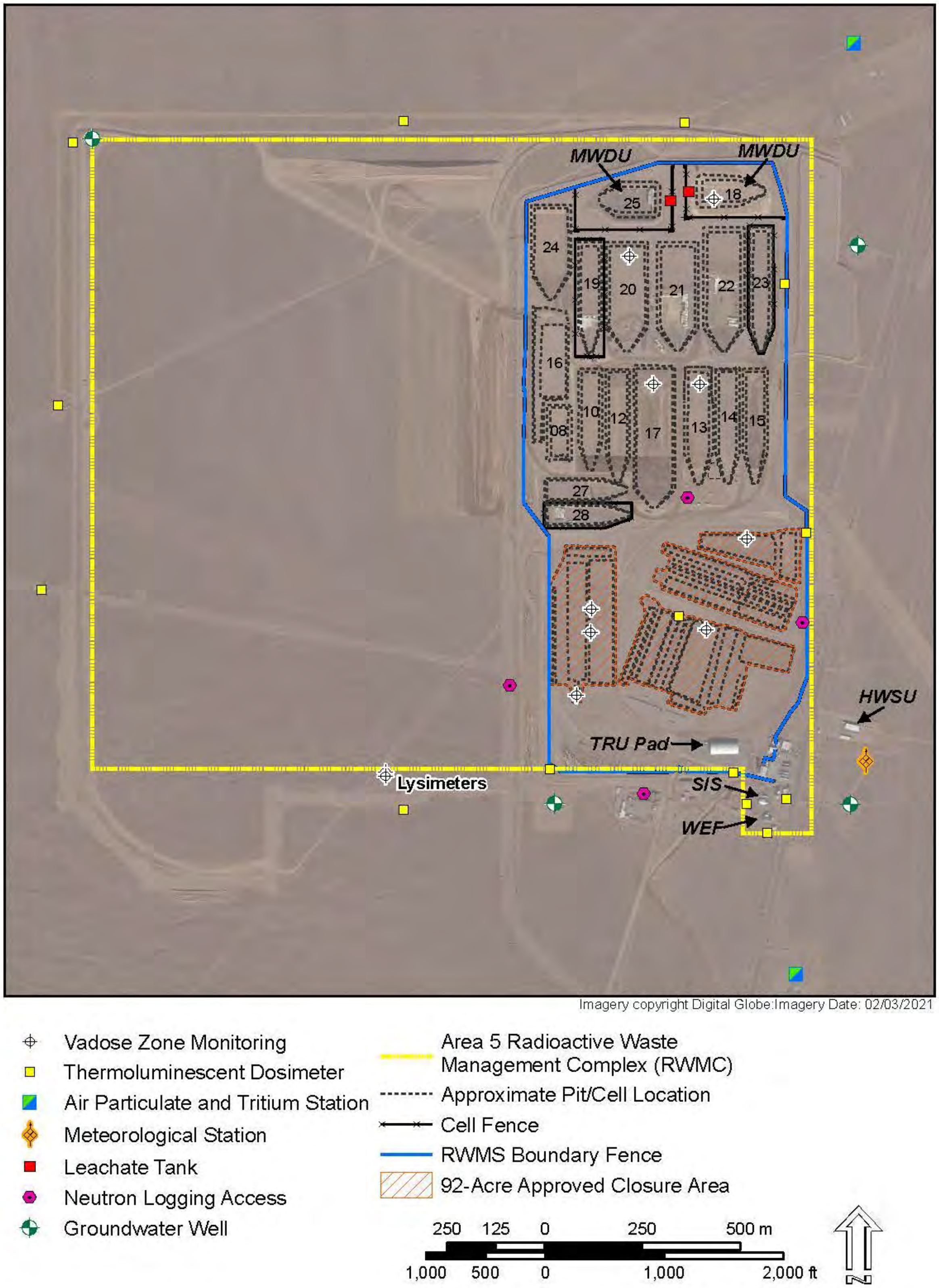

Figure 10-2. Area 5 RWMC facilities

10.1.1 Area 5 Radioactive Waste Management Site

The Area 5 RWMS is a DOE-owned radioactive waste disposal facility. It encompasses approximately 740 acres (ac), including approximately 285 ac used for historical and active permanent disposal of LLW, MLLW, CNR, and CNRH, and 435 ac of land with infrastructure established for future radioactive waste disposal, and about 20 ac that support waste management and facility operations. Waste disposal at the Area 5 RWMS occurred in a 92-acre portion of the site starting in the early 1960s. This "92-Acre Area" consists of 31 disposal cells and 13 Greater Confinement Disposal boreholes, and was used for disposal of waste in drums, soft-sided containers, large cargo containers, and boxes. The 92-Acre Area was filled and permanently closed in 2011. Closure covers for the 92-Acre Area were seeded in the fall of 2011. They have been monitored and reseeded in several attempts to produce covers supporting sustainable native plant populations.

In an effort to successfully establish an evapotranspiration landfill cover over the 92-Acre Area, it was decided by the EM Nevada Program that a test plot would be planted as the first step to establish a diversity of healthy, sustainable native plants on the cover. In 2017, the Tribal Revegetation Project commenced, and a Fieldwork Plan was developed. The Tribal Revegetation Project is an amalgamation of complex tribal perspectives based on tribal ecological knowledge and blended with Western scientific ecological methods. The project required a unique collaboration among NNSA/NFO and EM Nevada Program federal and contractor staff, a select group of tribal representatives (the Tribal Revegetation Committee [TRC], who have cultural ties to lands on the NNSS), an environmental anthropologist from Portland State University, and an ecologist from the Desert Research Institute.

The purpose of the experimental design, based on both traditional knowledge and natural science, was to test the efficacy of four different revegetation treatments (i.e., soil amendments) during two planting seasons with three plant (seed and transplants/outplants) replicates each for a total of 38 plots. Nineteen plots were planted in the fall of 2017 and nineteen plots were planted in the spring of 2018. The EM Nevada Program's Environmental Program Services contractor, Navarro, worked together with Mission Support and Test Services, LLC (MSTS), the NNSS Management and Operating contractor, to safely plant and irrigate the seeds and transplants according to the plan. Monitoring of the plots occurred regularly by the TRC personnel with the assistance of a Desert Research Institute ecologist/biologist and Navarro escort. Irrigation and monitoring was completed in September 2020, and a summary report was submitted on March 30, 2021, by the Desert Research Institute, TRC, and Portland State University.

Nine cells, developed immediately north and west of the 92-Acre Area, have been receiving wastes since 2010. They include seven LLW cells (Cells 19, 20, 21, 22, 23, 27, and 28) and two MLLW cells (Cells 18 [closed in 2019] and 25). All active Area 5 RWMS cells can accept radioactive waste contaminated with non-regulated ***polychlorinated biphenyl (PCB) bulk product waste***, but only Cell 25 can accept waste contaminated with regulated PCB remediation waste as well as asbestos-contaminated MLLW. Cells 19, 20, 22, 27, and 28 can accept asbestos-contaminated LLW. Table 10-1 lists the disposal cells that were active in 2020. MLLW disposal services are expected to continue at the Area 5 RWMS until the remaining needs of the DOE complex are met.

Disposal Cells 18 and 25 are managed under a Resource Conservation and Recovery Act (RCRA) Part B Permit (NEV HW0101), which authorizes the disposal of up to 25,485 cubic meters (m^3) (899,994 cubic feet [ft^3]) of MLLW and CNRH in Cell 18 and up to 37,000 m^3 (1,306,643 ft^3) in Cell 25. Cell 18 waste accumulation began on January 26, 2011, and the final waste packages were disposed on August 29, 2019; a cumulative total of 21,201 m^3 (748,693 ft^3) of MLLW/CNRH were disposed. Closure activities for Cell 18 (which began on October 10, 2019) have been completed and the final documentation is being prepared to address the post-closure requirements. The volume and weight of waste received at Cell 25 in 2020 are shown in Table 10-1. Cell 25 waste accumulation began on July 12, 2018; a cumulative total of 3,110 m^3 (109,847 ft^3) of MLLW/CNRH has been disposed through the end of 2020. Quarterly reports are submitted to the state to document the weight of MLLW/CNRH disposed.

In 2020, the Area 5 RWMS received shipments containing a total of 10,815 m^3 (381,938 ft^3) of radioactive waste for disposal (Table 10-1), which included both CNR and CNRH waste. The majority of waste disposed was received from offsite generators. The total number of waste shipments in Fiscal Year (FY) 2020 is reported annually (MSTS 2020b) and published on the NNSS website at https://www.nnss.gov/pages/programs/RWM/Reports.html.

Offsite waste generators delivering MLLW with regulated quantities of PCBs are issued Certificates of Disposal, as required under the Toxic Substances Control Act.

Table 10-1. Total waste volumes received and disposed at the Area 5 RWMS

Waste Type	Disposal Cell(s)	2020 Volume Received and Disposed in m^3 (ft^3)
LLW and CNR	Cells 19, 20, 21, 22, 23, 27, and 28	9,279 (327,694)
MLLW and CNRH (includes regulated PCB-contaminated LLW)	Cell 25	1,536 (54,244) [581][(a)]
Total		**10,815 (381,938)**

(a) Fees paid to the state for HW generated at the NNSS and MLLW wastes received for disposal are based on weight.

10.1.2 Waste Examination Facility

Operational units of the WEF include the TRU Pad, TRU Pad Cover Building (TPCB), TRU Loading Operations Area, WEF Yard, WEF Drum Holding Pad, Sprung Instant Structure (SIS), and the Visual Examination and Repackaging Building (VERB). Historically, the WEF was used for the staging, characterization, repackaging, and offsite shipment of legacy TRU wastes that were disposed at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico.

At present, the SIS, VERB, TRU Pad, and TPCB are authorized for the safe storage of radioactive mixed waste under the current RCRA Permit. The TPCB also accepts TRU/MTRU waste from NNSS generators. The TPCB stores the waste until it is characterized for disposal at WIPP. In 2020, the TRU waste remaining in storage at the TPCB consisted of two experimental spheres from Lawrence Livermore National Laboratory and 38 standard waste boxes from the Joint Actinide Shock Physics Experimental Research facility.

10.1.3 Area 5 Hazardous Waste Storage Unit

The HWSU is located on the east side of the 5-01 Road. It is a fenced area used for storage of NNSS-generated nonradioactive hazardous waste and PCB waste. These wastes may be stored for up to one year before shipment to an offsite disposal facility. The HWSU consists of a 30.3 m (100 ft) long by 9.1 m (30 ft) wide concrete pad with 6-inch curbs to contain spills and prevent run-on and/or run-off during precipitation events. A canopy roof protects waste containers from exposure to environmental conditions. A 90-day hazardous waste accumulation area is located east of the HWSU.

10.1.4 Area 3 Radioactive Waste Management Site

Disposal operations at the Area 3 RWMS began in the late 1960s. The Area 3 RWMS consists of seven ***subsidence craters*** configured into five disposal cells (Figure 10-3):

- 2 undeveloped cells: U-3az and U-3bg
- 2 inactive cells: U-3ah/at and U-3bh
- 1 closed cell: U-3ax/bl (Corrective Action Unit 110)

Each subsidence crater was created by an underground nuclear explosives test. Until 2006, the site was used for disposal of bulk LLW, such as soils or debris, and waste in large cargo containers. On October 1, 2018, the Area 3 RWMS was re-opened for the disposal of bulk LLW generated by environmental corrective actions conducted at the Clean Slate III site on the Tonopah Test Range, located just north of the NNSS. The final shipment of waste from this campaign was disposed at the Area 3 RWMS on August 28, 2019. At this time, only DOE waste generated within the State of Nevada may be disposed at the Area 3 RWMS. There was no waste disposed at the Area 3 RWMS in 2020.

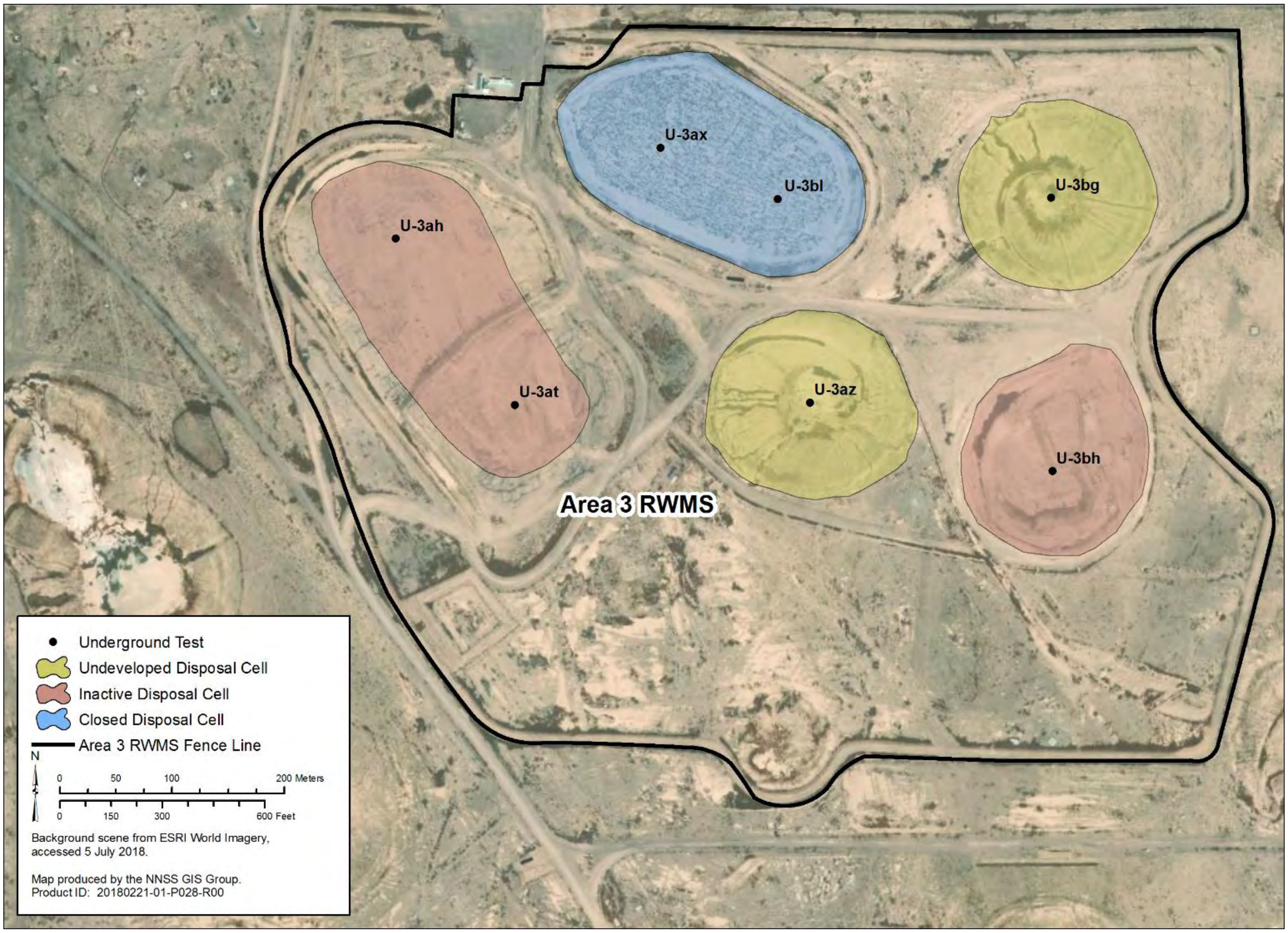

Figure 10-3. Disposal Cells of the Area 3 RWMS

10.2 Waste Characterization

Generators of classified, LLW, and MLLW proposed for disposal at the NNSS must demonstrate eligibility for waste to be disposed, submit detailed profiles of waste characteristics, demonstrate compliance with the NNSS Waste Acceptance Criteria (NNSSWAC), and obtain EM Nevada Program approval of their site waste certification program.

Characterization of the waste is determined through process knowledge of how the waste is generated, sampling and analysis, and/or non-destructive analysis. Following the characterization of a waste stream, the waste generator develops a waste profile. The waste profile delineates the pedigree of the waste, including, but not limited to, a description of the waste generating process, physical and chemical characteristics, radioactive ***isotope*** activity and quantity, and packaging information. The waste profile is reviewed by the NNSS Waste Acceptance Review Panel for recommendation and approval or disapproval by the EM Nevada Program. Generally, once a waste profile is approved, the generator packages and ships the approved waste streams to the Area 5 RWMC in accordance with U.S. Department of Transportation requirements. Some waste streams may require some activities, such as a visual verification or treatment at an offsite facility, be completed prior to shipment for disposal at the Area 5 RWMC.

Examples of LLW, MLLW, and classified waste/matter profiles include:

- Lead Solids
- Sealed Sources
- Miscellaneous Debris/Solids
- Contaminated Demolition Debris
- Contaminated Soil
- ***Depleted Uranium*** Waste

- Contaminated PCB Waste
- Compactable Trash
- Radioactive Hazardous Classified Matter/Waste
- Amalgamated Mercury
- Contaminated Asbestos Waste
- Non-radioactive Classified Matter/Waste
- ***High-Efficiency Particulate Air*** Exhaust and Filter Media

10.2.1 RWAP Activities

There are three main elements that provide the foundation for safe and compliant waste disposal at the NNSS:

- Programmatic Certification: Evaluation and approval of generator programs that addresses quality requirements, waste traceability, waste characterization (chemical and radiological), and shipping and transportation, to confidently certify compliance of waste destined for the NNSS; accomplished through surveillances and audits performed onsite and/or remotely
- Profile Certification: Review and approval of extensive documentation to verify waste complies with NNSSWAC requirements prior to shipment; accomplished through initial and recertification of profiles submitted by generators, "Deep Dive" reviews of approved profiles, split sampling and chemical screening of waste, and LLW/MLLW verifications
- Container Certification: Reviewing official documentation certifying that each container used to ship waste meets required specifications, conditions, and instructions of the approved profile, ensuring NNSSWAC compliance; accomplished through visual and chemical LLW/MLLW verifications at generator sites to validate container certifications and real-time radiography (RTR) performed at the NNSS to validate container contents are consistent with the approved waste profile

Table 10-2 reflects the evaluation activities conducted by RWAP in 2020. It should be noted that RWAP's planned activities were adjusted in 2020 in response to the coronavirus disease 2019 (COVID-19) pandemic. This included deferring some onsite generator evaluations, conducting others remotely, and delaying some until travel could be safely accomplished. The volume of waste disposed at the NNSS was also significantly less than anticipated due to the pandemic. No negative impacts to verification of waste compliance were experienced as a result of adjustments to RWAP planned activities.

Table 10-2. Calendar Year 2020 summary of RWAP evaluation activities

Period Involved	"Deep Dive"(a) Profile Reviews	LLW/ MLLW Verifications	Onsite Surveillances	Tabletop Surveillances	Audits(b)	RTR(c)	Split Sampling/ Chemical Screening	Profile Approvals/ Recertifications
2nd QTR FY 2020 (Jan-Mar 2020)	3	1 (LLW)	4(d)		1	3 (12)		10/14
3rd QTR FY 2020 (Apr-Jun 2020)	1	1 (MLLW)	NP(e)		NP	NP		10/9
4th QTR FY 2020 (Jul-Sep 2020)	2	5 (MLLW)	NP	3	NP	5 (27)		17/9
1st QTR FY 2021 (Oct-Dec 2020)	3	4 (3 MLLW and 1 LLW)	3		1	3 (12)	2	10/10

(a) In-depth review generally conducted at the generator's site to scrutinize and confirm accuracy of waste profile supporting documentation and to probe into specific wastes included in the profile.
(b) Comprehensive evaluation performed at a waste generator's facility to verify compliance of the five foundational elements comprising the waste certification program: 1) radiological constituent characterization; 2) chemical constituent characterization; 3) quality assurance; 4) waste packaging and transportation; and 5) waste traceability.
(c) RTR numbers reflect the "number of generator waste streams and (containers)" verified consistent with approved profiles and free from prohibited items.
(d) Includes assist visit at Y-12 in January 2020.
(e) Not Performed: onsite surveillances and audits were not performed due to RWAP travel being suspended in accordance with COVID-19 protective measures. RTR verifications were not performed from February 11 until July 22, 2020, primarily due to the implementation of COVID-19 protective measures.

10.2.2 Mixed Waste and Classified Non-Radioactive Hazardous Matter Verification

Waste verification is an inspection process that confirms the waste stream data supplied by approved waste generators before MLLW or CNRH is accepted for disposal at the NNSS. Verification may involve visual inspection, RTR, and/or chemical screening on a designated percentage of MLLW or CNRH. The objectives of waste verification include verifying that HW treatment objectives are met, confirming that waste containers do not contain free liquids, and validating that waste containers are at least 90% full, per RCRA and State of Nevada requirements. Offsite-generated waste is verified either upon receipt at the NNSS or while still at a generator facility or a designated treatment, storage, or disposal facility. The first choice for the method of verification is visual inspection at the site of generation.

In 2020, offsite visual inspections were completed on 43 MLLW packages from 9 separate waste streams. One waste stream required chemical screening. No onsite RTR was conducted on MLLW or CNRH. No MLLW or CNRH packages were rejected.

10.2.3 Waste Receipt and Disposal Operations

Upon arrival at the NNSS, waste shipment validation activities occur prior to permanent disposal and following disposal, monitoring of radioactive and mixed wastes is conducted to further provide for the long-term health and safety of workers, the public, and the environment. Disposal Operations staff also collect shipment transportation data for reporting to stakeholders, including the public. The key tasks performed upon receipt of a waste shipment include:

- Reviewing shipment documentation to verify consistency with the information submitted during the waste approval process.
- Shipment drivers providing transportation routing information.

- Performing radiological surveys of all trucks, trailers, and containers entering the disposal facility.
- Verifying security seals are in place and packages are intact and appropriately labeled.
- Inspecting the contents of some waste packages using onsite RTR x-ray technology to verify consistency with the approved waste profile.

Once a shipment successfully completes the receipt process, trucks are allowed access and directed to the appropriate disposal cell. During off-loading, radiological surveys are conducted on each waste package, container bar codes are scanned, and the waste is placed in its permanent disposal position.

Reports containing waste transportation and disposal volume information are publicly available on the NNSS website at http://nnss.gov/pages/programs/RWM/Reports.html.

10.3 Annual Performance Assessments and Composite Analyses

As required by DOE Order DOE O 435.1, "Radioactive Waste Management," NNSA/NFO must conduct a ***Performance Assessment (PA)*** and ***Composite Analysis (CA)*** of each of its radioactive waste disposal facilities. A PA is a systematic analysis of the potential risks posed to the public and environment by a waste disposal facility for LLW disposed after 1988. A CA is an assessment of the risks posed by all wastes disposed in an LLW disposal facility and by all other sources of residual contamination that may interact with the disposal site. Current PAs and CAs are maintained for the Area 3 and Area 5 RWMSs (Table 10-3). DOE O 435.1 further requires an annual review of the PAs and CAs to be submitted to DOE EM each March. The annual reviews include tracking through closure all unresolved secondary issues identified by EM's PA/CA assessments. The unresolved secondary issues are also tracked in a Maintenance Plan (MSTS 2019).

In 2020, the EM Nevada Program performed an annual review of the Area 3 and Area 5 RWMS PAs and CAs. Operational factors (e.g., waste forms and containers, facility design), closure plans, monitoring results, and research and development activities in or near the facilities were also reviewed. The FY 2020 summary report submitted to DOE EM in February 2021 (MSTS 2021b) presents data and conclusions that verify the adequacy of both the Area 3 and Area 5 PAs and CAs. Table 10-3 lists the necessary documents required and maintained for RWMS disposal operations.

Table 10-3. Key documents required for Area 3 RWMS and Area 5 RWMS disposal operations

- **Disposal Authorization Statement**
  - Disposal Authorization Statement for Area 5 RWMS, December 2000
  - Disposal Authorization Statement for Area 3 RWMS, October 1999
- **Performance Assessment**
  - Addendum 2 to Performance Assessment for Area 5 RWMS, June 2006
  - Performance Assessment/Composite Analysis for Area 3 RWMS, Revision 2.1, October 2000
  - Annual Summary Report for the Area 3 and 5 Radioactive Waste Management Sites at the Nevada National Security Site (Review of Performance Assessments and Composite Analyses), February 2021
- **Composite Analysis**
  - Composite Analysis for Area 5 RWMS, Addendum 1, September 2001
  - Performance Assessment/Composite Analysis for Area 3 RWMS, Revision 2.1, October 2000
- **NNSS Waste Acceptance Criteria**
  - NNSS Waste Acceptance Criteria, DOE/NV—325-16-00, Issued November 2016 and Effective February 2017
- **Integrated Closure and Monitoring Plan**
  - Closure Plan for the Area 3 RWMS at the NNSS, September 2007
  - Closure Plan for the Area 5 RWMS at the NNSS, September 2008
- **Documented Safety Analysis**
  - Documented Safety Analysis (DSA) for the NNSS Areas 3 and 5 Radioactive Waste Facilities, Revision 7, Change Notice 2, March 2021
  - Safety Evaluation Report (SER) Addendum for Change Notice (CN) 2 to the Area 3 and 5 Radioactive Waste Facilities (RWF) Documented Safety Analysis (DSA), Revision 7, and the Area 5 Radioactive Waste Management Complex (RWMC) Transuranic (TRU) Waste Activities Technical Safety Requirements (TSR), Revision 12, December 2020 (Revision 0)
  - TSR for the Area 5 RWMC TRU Waste Activities, Revision 12, Change Notice 2, March 2021
  - TSR for the Areas 3 and 5 RWMS LLW Activities, Revision 9, December 2016

10.3.1 Groundwater Protection Assessment

Hazardous waste disposal in Cells 18 and 25 complies with RCRA standards and DOE O 435.1 requirements. Title 40 ***Code of Federal Regulations (CFR)*** Part 264, Subpart F (40 CFR 264.92), requires groundwater monitoring to verify that the design and construction of active hazardous waste cells are adequate to protect groundwater from contamination by buried waste. Specifically, groundwater monitoring at the Area 5 RWMS is conducted in accordance with 40 CFR 264.97, "General Ground-Water Monitoring Requirements," and 40 CFR 264.98, "Detection Monitoring Program." Groundwater samples are analyzed for indicators of contamination (pH, specific conductance, total organic carbon, total organic halides, and ***tritium***) and, beginning in 2017, toxicity characteristic metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). Limits for each parameter were established by the Nevada Division of Environmental Protection (NDEP) RCRA Permit NEV HW0101. Groundwater samples are collected and analyzed semiannually at wells UE5 PW-1, UE5 PW-2, UE5 PW-3, and beginning in 2021, a new monitoroing well UE5MW-4 will be sampled to meet groundwater monitoring requirements. All samples collected semiannually from the wells in 2020 had concentration levels below their Investigation Levels (ILs) (Table 10-4), with the exception of Selenium (Se). The laboratory's Se Method Detection Limit (MDL) was 0.006 milligrams per liter (mg/L) and the Reporting Limit (RL) was 0.03 mg/L. Results falling between the MDL and RL are considered to be estimated. Some of the results reported in this range exceeded the Se IL of 0.01 mg/L. However, being estimated, the results are reported as less than (<) the RL of 0.03 mg/L. Static water levels and general water chemistry parameters are also monitored. All sample analysis results are presented in the annual groundwater monitoring report (MSTS 2021d). The tritium results were all below their sample-specific ***minimum detectable concentration (MDC)*** of between 180 and 290 picocuries per liter (pCi/L). Table 5-5 presents the sample-specific MDCs for each water sample collected from these wells in 2020. No groundwater contamination is indicated by the 2020 results.

Table 10-4. Area 5 groundwater monitoring results

Parameter	Investigation Level	2020 Sample Levels[(a)]
pH	< 7.6 or > 9.2 S.U.[(b)]	8.10 to 8.47 S.U.
Specific conductance	0.440 mmhos/cm[(c)]	0.356 to 0.379 mmhos/cm
Total organic carbon	2 mg/L[(d)]	ND[(e)]
Total organic halides	0.1 mg/L	ND to 0.011 mg/L
Tritium (^3H)	2,000 pCi/L[(f)]	ND
Arsenic (As)	0.05 mg/L	< 0.03 mg/L
Barium (Ba)	1 mg/L	<0.005 to 0.016 mg/L
Cadmium (Cd)	0.01 mg/L	ND
Chromium (Cr)	0.05 mg/L	< 0.01 mg/L
Lead (Pb)	0.05 mg/L	ND to < 0.02 mg/L
Mercury (Hg)	0.002 mg/L	ND
Selenium (Se)	0.01 mg/L	< 0.03 mg/L[(g)]
Silver (Ag)	0.05 mg/L	ND

(a) Levels shown are the lowest and highest values for each well for each sample date.
(b) S.U. = standard unit(s) (for measuring pH).
(c) mmhos/cm = millimhos per centimeter.
(d) mg/L = milligrams per liter.
(e) ND = not detected; levels were below the MDC or Method Detection Limit.
(f) pCi/L = picocuries per liter.
(g) MDL < IL < RL

10.3.2 Vadose Zone Assessment

Monitoring of the ***vadose zone*** (***unsaturated zone*** above the ***water table***) is conducted at the Area 3 and Area 5 RWMSs to demonstrate (1) the PA assumptions are valid regarding the hydrologic conceptual models used, including soil water contents, and upward and downward flux rates; and (2) there is negligible infiltration and percolation of precipitation into zones of buried waste. Vadose zone monitoring (VZM) offers many advantages over groundwater monitoring, including detecting potential problems long before groundwater resources would be impacted, allowing corrective actions to be made early, and being less expensive than groundwater monitoring. The components of the VZM program include the Drainage Lysimeter Facility northwest of U-3ax/bl within the Area 3 RWMS, the Area 5 Weighing Lysimeter Facility on the southern border of the Area 5 RWMS, a meteorology tower at both RWMSs, and eight stations that measure water content and water potential at varying depths in the waste covers . These eight stations include four stations in the 92-Acre Area, three stations in the

CAU 577 closure area, and one in the Cell 18 RCRA cover. Data from these components are used to monitor the natural water balance at the RWMSs. Descriptions of the VZM components and the results of monitoring in 2020 are provided in an annual report (MSTS 2021g). All VZM continued to demonstrate negligible infiltration of precipitation into zones of buried waste at the RWMSs, and performance criteria to prevent contamination of groundwater and the environment are being met.

10.4 Assessment of Radiological Dose to the Public

DOE M 435.1-1 states that LLW disposal facilities shall be operated, maintained, and closed so that a reasonable expectation exists that annual dose to members of the public shall not exceed 10 millirem (mrem) through the air pathway and 25 mrem through all pathways for a 1,000-year compliance period after closure of the disposal units. Given that the RWMSs are well within the NNSS boundaries, no members of the public can currently access the areas for long periods of time. However, to document compliance with DOE M 435.1-1, the possible pathways for ***radionuclide*** movement from waste disposal facilities are monitored. Long-term compliance with the DOE M 435.1-1 dose limits is evaluated by performance assessment modeling. As discussed below, waste operations would contribute negligible ***exposure*** to a hypothetical person residing near the boundaries of the RWMSs and would contribute no dose to the offsite public (Chapter 9).

10.4.1 Dose from Air and Direct Radiation

Air samplers operate continuously to collect air particulates and atmospheric moisture near each RWMS. These samples are analyzed for radionuclides, and results are used to assess potential dose. Details of the air sampling and a summary of the analysis results are given in Chapter 4. In 2020, three environmental sampling stations operated in/near the Area 3 RWMS (U-3ax/bl S, Bilby Crater, and Kestrel Crater N), and two air monitoring stations operated near the Area 5 RWMS (DoD and RWMS 5 Lagoons). The dose from the air pathway was estimated based on the highest annual mean concentration results for each measured radionuclide from among these five stations in order to estimate the most conservative dose for a member of the public at either of the RWMSs.

The highest annual mean concentration of each measured radionuclide among the five stations, and the station at which the highest concentration occurred, are shown in Table 10-5. The highest concentration of any radionuclide was 1,283 × 10^{-15} microcuries per milliliter (µCi/mL) for ^{3}H at RWMS 5 Lagoons. All four of the highest mean concentrations were far below their established National Emission Standards for Hazardous Air Pollutants (NESHAP) Concentration Levels (CLs) for Environmental Compliance (Table 10-5, fourth column). The highest mean concentration of each measured radionuclide is divided by its respective CL to obtain a “fraction of CL” (Table 10-5, right-most column). The fractions are then summed, and if the sum is less than 1, it demonstrates that the NESHAP dose limit of 10 millirem/year (mrem/yr) was not exceeded at a location having all those radionuclides at those concentrations. Summing the fractions of CLs gives 0.07, which is only 0.7% of the limit in this extremely conservative scenario.

Table 10-5. Highest annual mean concentrations of radionuclides detected at Area 3 and Area 5 RWMS

Radionuclide	RWMS Sampler	2020 Highest Annual Mean Concentration (× 10^{-15} µCi/mL)	NESHAP CL[(a)] (× 10^{-15} µCi/mL)	Fraction of CL
^{3}H	RWMS 5 Lagoons	1,283	1,500,000	0.0009
^{238}Pu	DoD	0.0038	2.1	0.0018
^{239}Pu	U-3ax/bl S	0.11 ($^{239+240}$Pu)	2	0.0550
^{241}Am	U-3ax/bl S	0.016	1.9	0.0084
			Sum of Fractions:	**0.07**

(a) CL values represent an annual average concentration that would result in a ***total effective dose equivalent*** of 10 mrem/yr, the federal dose limit to the public from all radioactive air emissions (from Table 2, Appendix E of 40 CFR 61, “National Emission Standards for Hazardous Air Pollutants,” 1999).

Thermoluminescent dosimeters (TLDs) are used to measure ***ionizing radiation*** exposure at nine locations in and around the Area 3 RWMS and 14 locations in and around the Area 5 RWMS. The TLDs have three calcium sulfate elements used to measure the total exposure rate from penetrating ***gamma radiation***, including ***background*** radiation. Penetrating gamma radiation makes up the deep dose, which is compared to the

25 mrem/yr limit when background exposure is subtracted. Details of the direct radiation monitoring are provided in Chapter 6. During 2020, the external radiation measured near the boundaries of the Area 3 and Area 5 RWMSs could not be distinguished from background levels (Section 6.3.4). Area 3 and Area 5 RWMS operations would have contributed negligible external exposure to a hypothetical person residing near the boundaries of these sites, and no dose to the offsite public.

10.4.2 Dose from Groundwater

Groundwater and vadose zone monitoring at the RWMSs is conducted to verify the performance of waste disposal facilities. Such monitoring has not detected the migration of radiological wastes into groundwater (Sections 10.3.1 and 10.3.2). Also, the results of monitoring offsite public and private wells and springs indicate that man-made radionuclides have not been detected in any public or private water supplies (Table 5-4, and Sections 7.2 and 7.3). Based on these results, potential doses to members of the public from LLW disposal facilities on the NNSS from groundwater, and from all pathways combined, are negligible.

10.5 Hazardous Waste Management

HW regulated under RCRA is generated at the NNSS from a broad range of activities, including onsite laboratories, site and vehicle maintenance, communications operations, and environmental corrective actions at historically contaminated sites. The RCRA Part B Permit regulates operation of the Area 5 MWDU, consisting of a Subtitle C landfill (Cells 18 and 25) and two leachate collection tanks, the Area 5 HWSU, and the Area 11 Explosives Ordnance Disposal Unit (EODU) facilities. Included in the RCRA Part B permit is authorization for MLLW storage at the MWSU, which comprises the TRU Pad/TPCB, the SIS Building, the VERB, and the Drum Holding Pad.

The HWSU (Figure 10-2) is a prefabricated, rigid-steel-framed, roofed shelter and is permitted to store a maximum of 61,600 liters (16,300 gallons) of approved waste at a time. HW generated at environmental corrective action sites off the NNSS (e.g., Tonopah Test Range) or generated at the North Las Vegas Facility is direct-shipped to approved disposal facilities. HW generated on the NNSS is direct-shipped to approved disposal facilities if the NNSS site generates bulk, non-packaged HW that is not accepted for storage at the HWSU. HW would also be direct-shipped from NNSS sites in the unlikely case the waste volume capacity of the HWSU is approaching permitted limits. Satellite Accumulation Areas (SAAs) and 90-day Hazardous Waste Accumulation Areas (HWAAs) are temporary storage at the NNSS for HW prior to direct shipment off site or to the HWSU.

The Area 11 EODU is permitted to treat explosive ordnance wastes by open detonation of not more than 45.4 kilograms (100 pounds) of approved waste at a time, not to exceed one detonation event per hour. Conventional explosive wastes are generated at the NNSS from explosive operations at construction and experiment sites, the NNSS firing range, the resident national laboratories, and other activities.

10.5.1 Hazardous Waste Activities

The RCRA permit requires preparation of a U.S. Environmental Protection Agency Biennial Hazardous Waste Report of all HW volumes generated and disposed or stored at the NNSS. This report is prepared for odd-numbered years only. It was most recently prepared for 2019 and electronically submitted to the State of Nevada on February 12, 2020. The next biennial report will be prepared for 2021 and submitted to the state in 2022. The calendar year 2020 report was submitted to the State of Nevada in February 2021 (MSTS 2021c). It includes the amount of wastes received in calendar year 2020 at the Area 5 MWDU, MWSU, HWSU, and Area 11 EODU.

Table 10-6 lists the quantities of HW generated either on or off site that were managed (received, stored, shipped, or disposed) at the various NNSS waste units during calendar year 2020. It includes the tons of MLLW received and disposed on site in MWDU Cell 18 and Cell 25; the tons of MLLW received at the MWSU; the tons of MLLW shipped off site from the MWSU for disposal; the tons of HW with and without PCBs received, stored, and shipped off site from the HWSU; and the tons of HW stored and then shipped off site from one or more HWAAs. Quarterly 2020 HW volume reports were submitted on schedule to NDEP.

Table 10-6. Hazardous waste managed at the NNSS

Waste Unit	2020 Amount (tons)		
	Received[a]	Shipped	Disposed
MWDU	384	0	384
MWSU	0.19	0.19	--
HWSU	1.83	2.55	--
HWSU – PCB Waste	0.116	0.161	--
HWAA	NA[b]	0	--
EODU	0.624	0	0.624[c]

(a) Fees paid to the state for HW generated at the NNSS and MLLW wastes received for disposal are based on weight (tons).
(b) Not applicable; amounts of HW received at HWAAs are not tracked. Only the length of time they are stored and the amounts shipped off from all HWAAs combined are tracked.
(c) 0.624 tons (1,248 lbs) is the weight of explosive ordnance detonated at the EODU.

Each year NDEP performs a Compliance Evaluation Inspection (CEI) of the RCRA permitted HW units at the NNSS. On October 5 and 6, 2020, NDEP conducted its CEI of the waste units listed in Table 10-6, selected SAAs, Universal Waste Collection Centers, and closed historic RCRA waste management units at the NNSS (Section 11.4). The October 2020 CEI documented that NNSA/NFO was compliant with the NNSS Part B Permit.

On July 3, 2019, the EM Nevada Program and NNSA/NFO notified NDEP that a classified waste stream had been transported from the Y-12 National Security Complex in Oak Ridge, Tennessee, and disposed at the Area 5 RWMC. Subsequent communications determined that between January 2013 to December 2018, there were 10 shipments of NNSSWAC non-compliant shipments involving 33 waste containers that had been shipped from Y-12 to the NNSS and had been disposed at the Area 5 RWMC. On June 15, 2020, NDEP issued to NNSA/NFO a Finding of Alleged Violation and Order citing the 33 waste containers received from Y-12.

On April 13, 2020, NNSA/NFO received a Notice of Violation and report from U.S. Environmental Protection Agency Region 9 that provided the results of a RCRA Compliance Evaluation Inspection (CEI) conducted in August 2019. The report detailed three items as areas of potential violations and one item as an area of concern. The potential violations addressed in the CEI were: 1) lack of confirmatory data regarding the status of the waste associated with a low-level waste profile, 2) adequacy of groundwater monitoring data in past submittals of groundwater reports, and 3) the hazardous waste compliance status of the Y-12 waste containers. The area of concern addressed in the CEI was the location of groundwater monitoring wells and the constituents tested in the groundwater monitoring program.

Following a series of collaborative conversations, on June 22, 2021, DOE and the State of Nevada reached a mutually beneficial resolution to all regulatory actions resulting from the July 2019 waste issue. The final agreement builds upon the Department's continued commitment to enhancing the rigor of its waste management activities for the protection of the DOE workforce, the public, and the environment.

10.6 Underground Storage Tank Management

RCRA regulates the storage of regulated substances to prevent contaminants from leaching into the environment from USTs. Nevada Administrative Code NAC 459.9921–459.999, "Storage Tanks," enforces the federal regulations under RCRA pertaining to the maintenance and operation of USTs and the regulated substances contained in them so as to prevent environmental contamination. On October 13, 2018, new UST regulations went into effect that changed the regulatory status of one UST at the Device Assembly Facility (DAF) and one UST at the Remote Sensing Laboratory–Nellis (RSL-Nellis). These tanks were deferred prior to the new UST regulations and now are fully regulated. NNSA/NFO operates one fully regulated UST and three excluded USTs at the DAF; one fully regulated UST at the Area 6 Helicopter pad, which was in temporary closure until it was permanently closed (removed and disposed) in September 2020 and NDEP acknowledged the closure as satisfactory in a letter in January 2021; and one fully regulated UST and three temporarily closed USTs at RSL-Nellis.

NDEP has oversight authority of the NNSS USTs, and the Southern Nevada Health District (SNHD) has oversight authority of USTs in Clark County (see Section A.2.3 of Appendix A regarding UST management at RSL-Nellis). NDEP usually conducts inspections of NNSS USTs once every 3 years. NDEP's most recent inspection of the USTs at the NNSS was in November 2020, and no issues were identified. No NNSS USTs were upgraded in 2020.

The SNHD has oversight authority of the RSL-Nellis USTs in Clark County. The UST program at RSL-Nellis consists of three excluded tanks and one regulated diesel tank and three temporarily closed UTSs (one unleaded gasoline, one diesel fuel, and one used oil). The fully regulated UST is operated under the RSL-Nellis UST Permit PR0064276. The fully regulated active and temporarily closed tanks are inspected annually by the SNHD; in December 2020, the SNHD inspected the fully regulated UST at RSL-Nellis and no deficiencies were noted.

10.7 Solid and Sanitary Waste Management

Three landfills for ***solid waste*** disposal were operated at the NNSS in 2020. The landfills are regulated and permitted by the State of Nevada (see Table 2-3 for list of permits). No liquids, HW, or radioactive waste are accepted in these landfills. These are:

- Area 6 Hydrocarbon Landfill – accepts hydrocarbon-contaminated wastes, such as soil and absorbents.
- Area 9 U10c Solid Waste Landfill – designated for industrial waste such as construction and demolition debris and asbestos waste under certain circumstances.
- Area 23 Solid Waste Landfill – accepts municipal-type wastes such as food waste and office waste. Regulated asbestos-containing material is also permitted in a special section. The permit allows disposal of no more than an average of 20 tons/day at this site.

These landfills are designed, constructed, operated, maintained, and monitored in adherence to the requirements of their state permits. NDEP visually inspects the landfills annually for compliance; however, no inspections were performed in 2020 due to COVID-19 restrictions. The amount of waste disposed in each landfill is shown in Table 10-7. Biannual reports for the Area 23 solid waste landfill were submitted in July 2020 and January 2021 to NDEP (MSTS 2020a and 2021a).

The VZM schedule for the Area 6 hydrocarbon landfill and the Area 9 U10c solid waste landfill was amended by NDEP to biennial events beginning with 2017 and 2018. VZM is performed biennially or after a 24-hour rain event in lieu of groundwater monitoring to demonstrate that contaminants from the landfills are not leaching into the groundwater. VZM in 2017 indicated no soil moisture migration and, therefore, no waste leachate migration to the water table. Soil moisture monitoring reports for the Area 6 and Area 9 sites were submitted in March 2017 to NDEP. The monitoring reports for 2019 through 2020 were submitted to NDEP in May 2021 (MSTS 2021e, 2021f).

Table 10-7. Quantity of solid wastes disposed in NNSS landfills

2020 Waste Disposed in Landfills in Metric Tons (Tons)		
Area 6	**Area 9**	**Area 23**
2,249.15	4,700.43	286.68
(2,479.26)	(5,181.34)	(316.01)

10.8 References

Mission Support and Test Services, LLC, 2019. *Maintenance Plan for Performance Assessments and Composite Analyses for the Area 3 and Area 5 Radioactive Waste Managements Sites at the Nevada National Security Site, Revision 3.0*. DOE/NV/03624--0423, Las Vegas, Nevada, March 2019.

———, 2020a. *Area 23 Semi-Annual Solid Waste Disposal Site (SWDS) Report for the Nevada National Security Site (NNSS) – January 1, 2020 through June 30, 2020.* Las Vegas, Nevada, July 2020.

———, 2020b. *Fourth Quarter / Annual Transportation Report Fiscal Year 2020, Waste Shipments to and from the Nevada National Security Site, Radioactive Waste Management Complex*. DOE/NV/03624--0922, Las Vegas, Nevada, October 2020.

———, 2021a. *Area 23 Semi-Annual Solid Waste Disposal Site (SWDS) Report for the Nevada National Security Site (NNSS) – July 1, 2020 through December 31, 2020.* Las Vegas, Nevada, January 2021.

———, 2021b. *FY 2020 Annual Summary Report for the Area 3 and 5 Radioactive Waste Management Sites at the Nevada National Security Site, Nye County, Nevada*. DOE/NV/03624--1001, Las Vegas, Nevada, February 2021.

———, 2021c. *Annual Summary/Waste Minimization Report, Calendar Year 2020.* Las Vegas, Nevada, February 2021.

———, 2021d. *Nevada National Security Site 2020 Data Report: Groundwater Monitoring Program Area 5 Radioactive Waste Management Site*. DOE/NV/03624--1040, Las Vegas, Nevada, March 2021.

———, 2021e. *Soil Moisture Monitoring Reports for the Nevada National Security Site (NNSS) Area 6 Hydrocarbon Landfill for Reporting Period Calendar Years 2019-2020*. Las Vegas, Nevada, May 2021.

———, 2021f. *Soil Moisture Monitoring Reports for the Nevada National Security Site (NNSS) Area 9 Landfill for Reporting Period Calendar Years 2019-2020*. Las Vegas, Nevada, May 2021.

———, 2021g. *Nevada National Security Site 2020 Waste Management Monitoring Report, Area 3 and Area 5 Radioactive Waste Management Site* (in review). Las Vegas, Nevada.

MSTS, see Mission Support and Test Services, LLC.

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Chapter 11: Environmental Corrective Actions

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Environmental Corrective Action Objectives for All Sites

Characterize sites contaminated by activities related to nuclear testing. Remediate contaminated sites in accordance with Federal Facility Agreement and Consent Order (FFACO)-approved planning documents. Conduct post-closure monitoringof sites in accordance with FFACO closure documents.

The Environmental Management (EM) Nevada Program is responsible for evaluating and implementing corrective actions at sites identified in the FFACO[1] that were impacted by historical nuclear testing, research, and development activities. These corrective action sites (CASs) are located on the Nevada National Security Site (NNSS), the Nevada Test and Training Range (NTTR), and the Tonopah Test Range (TTR) and are grouped into larger, geographic corrective action units (CAUs) according to location, physical and geological characteristics, and/or contaminants. Environmental corrective action strategies are developed and completed based on the nature and extent of contamination, the risks posed by contamination, and future land use. Since 1989, the EM Nevada Program has completed corrective actions at 99% of the nearly 2,200 surface and near-surface CASs and transitioned 91% of the 878 deep subsurface CASs into long-term monitoring.

CASs are broadly organized into four categories based on the source of contamination: Underground Test Area (UGTA), Industrial Sites, Soils, and Nevada Offsites. UGTA deep subsurface sites are directly related to groundwater impacted by past underground nuclear testing. Industrial Sites are facilities and land that may have become contaminated due to activities conducted in support of nuclear research, development, and testing; and include an extensive complex of research/development/testing facilities, disposal wells, inactive tanks, contaminated waste sites, inactive ponds, muck piles, spill sites, drains and sumps, and ordnance sites. Soils CASs include areas where nuclear tests have resulted in extensive surface and/or shallow subsurface contamination from radioactive materials and potentially from oils, solvents, heavy metals, and contaminated instruments and test structures used during testing activities. Nevada Offsites are associated with underground nuclear testing at the Project Shoal Area and the Central Nevada Test Area, located in northern and central Nevada, respectively. The U.S. Department of Energy (DOE) Office of Legacy Management (LM) has responsibility for long-term stewardship of the Nevada Offsites and, as of September 30, 2020, 70 FFACO sites on the NTTR/TTR where environmental corrective actions were completed by the EM Nevada Program.

In May 1996, the DOE, the U.S. Department of Defense, and the State of Nevada entered into the FFACO to address the environmental remediation of CASs. DOE LM became a signatory to the FFACO in June 2006 after assuming responsibility for the Nevada Offsites. Appendix VI of the FFACO (1996, as amended), describes the strategy to plan, implement, and complete environmental corrective actions (i.e., to "close" the CASs). The State of Nevada Division of Environmental Protection (NDEP) provides regulatory oversight and approval throughout the FFACO closure process, and the public is kept informed of progress through the Nevada Site Specific Advisory Board (NSSAB)[2]. The NSSAB is a federally chartered group of volunteer members representing Nevada stakeholders who review and provide the EM Nevada Program informed recommendations and comments that are strongly considered throughout the corrective action process. This chapter provides an update on EM Nevada Program corrective action progress and post-closure activities at UGTA, Industrial Sites, and Soils CASs in calendar year (CY) 2020 and summarizes the NSSAB's CY 2020 activities and recommendations.

[1] A fact sheet on the FFACO is available via http://nnss.gov/docs/fact_sheets/DOENV_964.pdf.
[2] NSSAB activities can be accessed at http://www.nnss.gov/NSSAB/.

11.1 Corrective Actions Progress

Figure 11-1 depicts the progress made since 1996 to complete environmental corrective actions at historically contaminated sites managed under the FFACO (1996, as amended). A total of 2,949 of the 3,044 CASs managed under the FFACO (1996, as amended) have been closed; this includes sites that are the responsibility of DOE LM, the Defense Threat Reduction Agency, or other owners. Of the 95 CASs yet to be closed under the FFACO (883 of which are the responsibility of the EM Nevada Program), 82 (86%) of them are UGTA CASs.

The public can view an interactive map that shows all CASs on the NNSS, NTTR, and TTR at the following NNSS Remediation Sites website: http://www.nnssremediation.dri.edu/. The website identifies all CASs that have been closed and those still open.

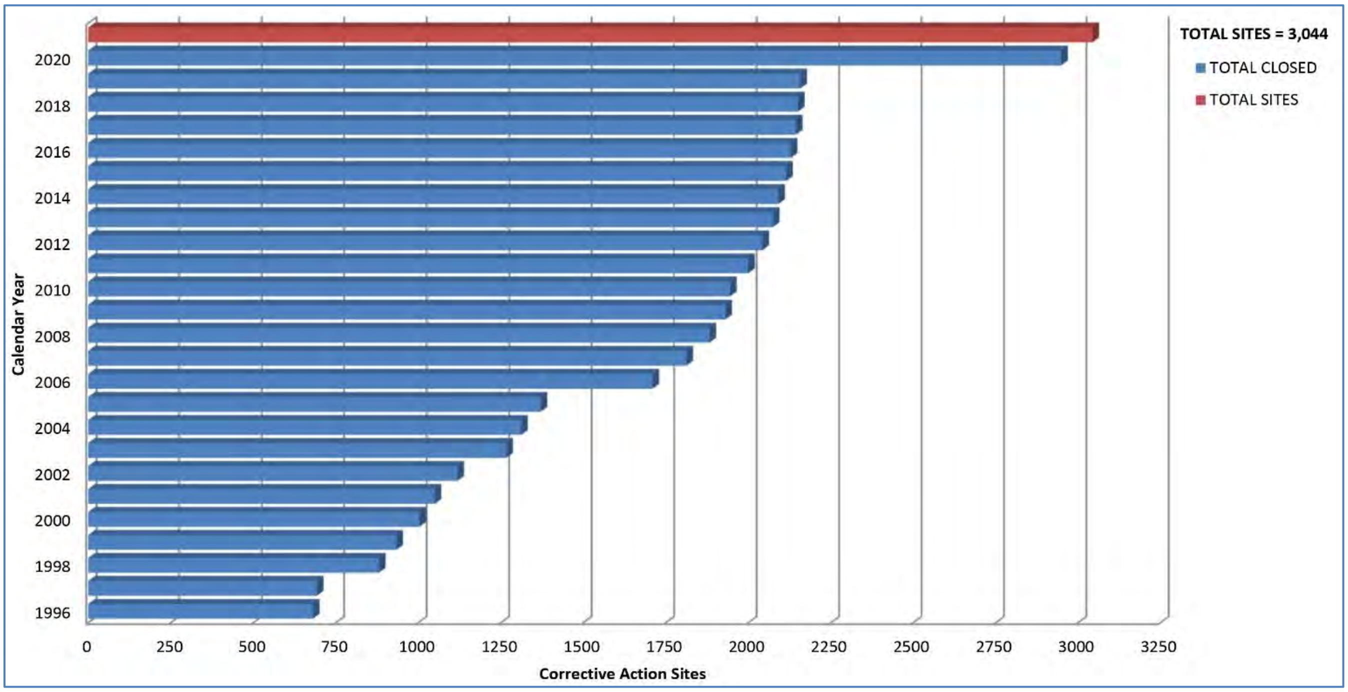

Figure 11-1. Annual cumulative totals of FFACO CAS closures

All 2020 FFACO milestones were met by the EM Nevada Program and include reports on:

- Closure for Yucca Flat/Climax Mine (CAU 97).
- Fiscal Year (FY) 2020 Closure Monitoring for Yucca Flat/Climax Mine (CAU 97).
- CY 2019 Closure Monitoring for Frenchman Flat (CAU 98).
- CY 2019 Post-Closure Inspections for TTR and Non-Resource Conservation and Recovery Act (RCRA) sites.
- CY 2019 UGTA Annual Sampling (CAUs 97/98/101/102).
- Draft Corrective Action Decision Document/Corrective Action Plan for CAU 577.

These milestones and other accomplishments for 2020 represent significant achievements for the UGTA Activity. NDEP approval of the Closure Report for Yucca Flat/Climax Mine (CAU 97) allowed for 720 CASs to transition into long-term monitoring (see Section 11.3.1.3). Final use restriction and regulatory boundaries along with the long-term monitoring strategy, all jointly identified by DOE and NDEP, are presented within this report. NDEP approval of the Rainier Mesa/Shoshone Mountain (CAU 99) Closure Report was also granted in 2020, allowing for closure of an additional 66 CASs (see Section 11.3.1.2). The requirements established by Closure Reports are designed to maintain the long-term protection of public health and the environment.

The Closure Monitoring and Post-Closure Inspection reports completed in 2020 present the monitoring and inspection results used to verify compliance and corrective action effectiveness. The CY 2019 UGTA Annual Sampling Report presented sampling results for four UGTA CAUs not yet in closure in 2019 (CAUs 97/98/101/102). This report presents results associated with the NNSS Integrated Groundwater Sampling Plan (EM Nevada Program 2018a) developed to ensure that appropriate analytical data are available to support the FFACO closure process. In November 2020, the Sampling Plan was updated to focus on the Pahute Mesa CAUs (CAUs 101/102), which are the only UGTA CAUs that are undergoing further investigation before completing the closure process (EM Nevada Program 2020j). The characterization process is more complex for these CAUs because many larger-yield nuclear tests were conducted on Pahute Mesa where about two-thirds of the total NNSS underground radionuclide inventory was deposited, including about 70% of the tritium (^{3}H) inventory at or below the water table (more than 2,000 feet deep).

11.2 Corrective Action Sites – Active Investigations

The location and status (open or closed) of UGTA, Industrial Sites, and Soils CASs are shown in Figure 11-2. All Soils CASs have been closed and, effective September 30, 2020, long-term stewardship of those located on the NTTR/TTR are the responsibility of DOE LM. Only 82 UGTA CASs in two CAUs and 13 Industrial Sites CASs in three CAUs and have not yet reached closure. Investigations continued within these CAUs in 2020.

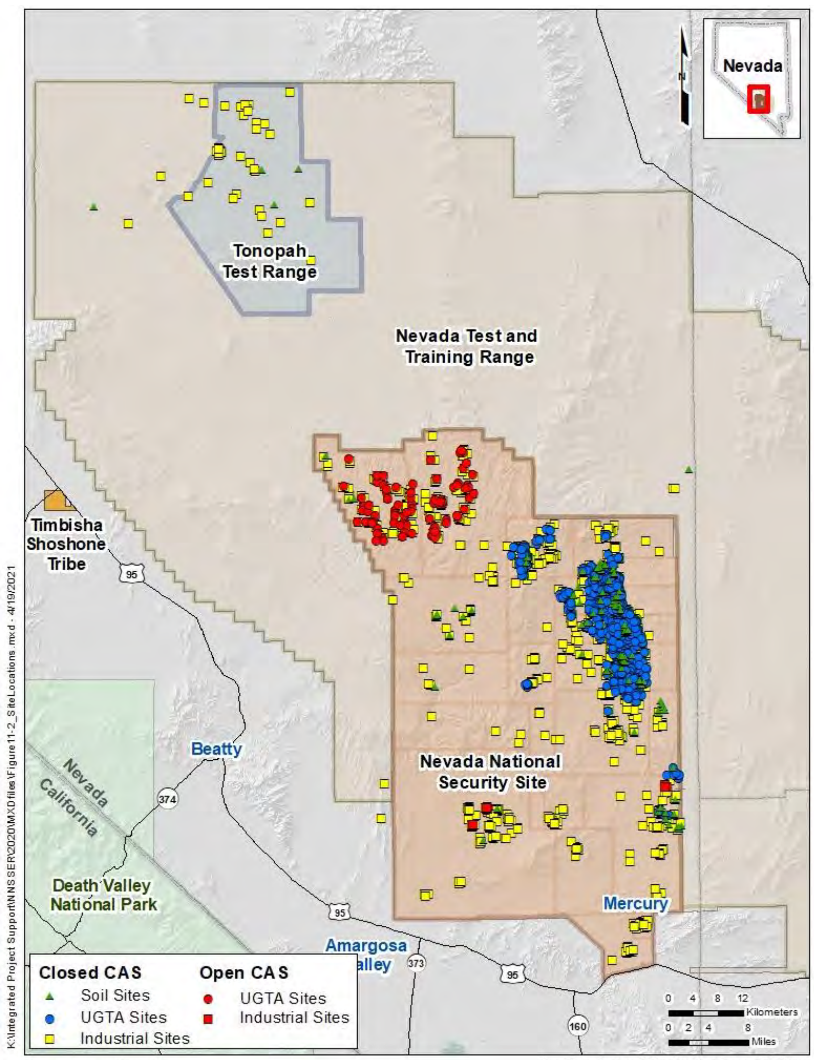

Figure 11-2. Map of closure status for UGTA, Industrial Sites, and Soils CASs

11.2.1 Underground Test Area Sites

The agreed-upon corrective action for UGTA CASs is closure in place with institutional controls and monitoring (FFACO, 1996, as amended). This corrective action is based on three assumptions: (1) groundwater technologies for removal or stabilization of subsurface radiological contamination are not cost effective; (2) because of high remediation costs, closure in place with monitoring and institutional controls is the only likely corrective action; and (3) in order for workers, the public, and the environment to be exposed to the potential risks from radiological contamination in groundwater, the contaminated groundwater must first be accessed.

The corrective action is implemented in four stages: 1) *planning*; 2) *investigation* (characterization and modeling; 3) *model evaluation*; and 4) *closure*. NDEP approval is required before advancing to the next stage. Characterization and modeling studies are evaluated throughout the *investigation* and *model evaluation stage* by a committee of scientists (preemptive review committee) specializing in the fields of geology, hydrology, chemistry, and nuclear testing from Navarro Research and Engineering, Inc. (Navarro), Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), the U.S. Geological Survey (USGS), the Desert Research Institute (DRI), and the Mission Support and Test Services, LLC. CAU-specific preemptive review committees provide internal technical review of ongoing work to assure work is comprehensive, accurate, in keeping with the state of the art modeling and data analysis methods, and consistent with CAU goals (EM Nevada Program 2019c). In addition, a scientific external peer review process follows the *investigation stage*.

Environmental Corrective Action Objectives for UGTA Sites

- *Collect data (e.g., new wells, groundwater samples, water levels, geologic, hydrologic testing, field and laboratory studies) to characterize the hydrogeological setting and nature and extent of contamination.*
- *Develop CAU-specific models of groundwater flow and contaminant transport.*
- *Identify boundaries within which contaminants are forecasted to potentially (95th percentile) exceed the Safe Drinking Water Act (SDWA) limits at any time within a 1,000-year compliance period.*
- *Negotiate and implement regulatory boundary objectives and regulatory boundaries to protect the public and environment from the effects of radioactive contaminant migration.*
- *Negotiate and implement use-restriction boundaries to restrict access to contaminated groundwater.*
- *Develop and implement a long-term closure monitoring network to verify consistency with the groundwater flow and transport models, compliance to the regulatory boundary, and protection of human health and the environment.*

The location of UGTA CAUs and CASs are shown in Figure 11-3. Central and Western Pahute Mesa CAUs (101 and 102), comprising a total of 82 CASs, are the only two UGTA CAUs remaining to be closed. The CASs are composed of nuclear test cavities produced from the underground nuclear detonations. These roughly spherical cavities, with diameters greater than 200 meters (m) in some cases are located in complex geologic units at depths ranging from 30 to 1,450 m below ground surface (Carle et al. 2021). The majority of these cavities are near or below the water table (Figure 11-3).

Corrective action activities are combined for these CAUs. Phase II of the *investigation stage* for the Pahute Mesa CAUs was initiated in 2009 as outlined in the Corrective Action Investigation Plan (National Nuclear Security Administration [NNSA] Nevada Site Office [NNSA/NSO] 2009). Eleven new wells were drilled, developed, tested, and sampled as part of the Phase II investigations. In 2020, the Corrective Action Investigation Plan was updated to document further investigations and modeling activities planned for the PM CAUs. The investigation plan was updated based on the large amount of new data obtained through the Phase II drilling activities (EM Nevada Program 2020j). The new data from the Phase II drilling supported groundwater flow and transport modeling to estimate the potential extent of contamination over the next 1,000 years (i.e., contaminant boundaries). Data (geologic, hydrologic, geochemical, and radiological) analysis to characterize the hydrogeology of the area downgradient of underground nuclear testing continued in 2020 with multiple documents published by the participating agencies, including Navarro, LANL, LLNL, USGS, and DRI. A multi-agency evaluation of the groundwater geochemistry data collected from the Phase II wells was completed in 2020 (Navarro 2020, Kwicklis et al. 2020, Visser et al. 2020). This analysis used the groundwater geochemistry to identify potential groundwater flow paths and groundwater sources (Navarro 2020; Visser et al. 2021, Kwicklis et al. 2021). Halford and Jackson (2020) used groundwater-flow models to characterize groundwater flow and development in groundwater basins of the Death Valley regional flow system in Nevada and California. In addition, an evaluation of radionuclides in groundwater near nuclear test cavities was completed in 2020 (Carle et al. 2020). This evaluation identified radionuclides that are relevant to the contaminant transport models for the Pahute Mesa CAUs. Multiple articles were also published in the 2019 Waste Management Symposium proceedings (Bourret and Kwicklis 2020, Farnham et al. 2020, Frus and Imbrigiotta 2020, and Rehfeldt and Wilborn 2020). Each paper highlights significant work in support of the UGTA Activity.

Table 11-1. UGTA publications published in 2020

Report	Reference
Achieving the End State for the Pahute Mesa Corrective Action Units at the Nevada National Security Site	Rehfeldt and Wilborn 2020
Additional Background on Proposed Monitoring Well "AT-1" on Pahute Mesa, Nevada National Security Site	Tompson 2020
A comparison of groundwater sampling technologies, including passive diffusion sampling, for radionuclide contamination	Frus and Imbrigiotta 2020
Calendar Year 2019 Underground Test Area Annual Sampling Report Nevada National Security Site, Nevada	EM Nevada Program 2020a
Database of groundwater levels and hydrograph descriptions for the Nevada Test Site area, Nye County, Nevada	Elliott and Fenelon 2020
Discrete Fracture Network Modeling to Estimate Upscaled Parameters for the Topopah Spring, Lava Flow, and Tiva Canyon Aquifers at Pahute Mesa, Nevada National Security Site	Makedonska et al. 2020
Groundwater characterization and effects of pumping in the Death Valley regional groundwater flow system, Nevada and California, with special reference to Devils Hole	Halford and Jackson 2020
Groundwater noble gas measurements confirm paleorecharge hypotheses at Pahute Mesa, Nevada National Security Site, Nevada, USA	Visser et al. 2020
Hydrologic monitoring networks in the Death Valley Regional Flow System, Nye County, Nevada and Inyo County, California,	Reiner et al. 2020
Interpretation of Mineralogical Diagenesis for Assessment of Radionuclide Transport at Pahute Mesa, Nevada National Security Site	Carle 2020
A Method to Represent a Well in a Three-dimensional Discrete Fracture Network Model	Pham et al. 2020
The Nature and State of Groundwater Contamination at the NNSS: What Have We Learned from Decades of Groundwater Analysis?	Farnham et al. 2020
Pahute Mesa-Oasis Valley Hydrostratigraphic Framework Model for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada	EM Nevada Program 2020c
A Perspective on the Successes of the Nevada National Security Site (NNSS) Underground Test Area (UGTA) Activity	Bourret and Kwicklis 2020
Phase II Geochemical and Isotopic Evaluation of Groundwater Flow in the Pahute Mesa-Oasis Valley Flow System, Nevada	Navarro 2020
Radionuclide Screening Analysis and Transport Parameters for Pahute Mesa Detonations, Nevada National Security Site	Carle et al. 2020
Interpretation of Mineralogical Diagenesis for Assessment of Radionuclide Transport at Pahute Mesa, Nevada National Security Site, LLNL-TR-810225. Livermore, CA: Lawrence Livermore National Laboratory.	Carle 2020

Table 11-1. UGTA publications published in 2020

Report	Reference
UGTA Modeling Subcommittee Meeting: Consolidated Notes and Observations on the Proposed UGTA Pahute Mesa Modeling Strategy	Tompson et al. 2020
Underground Test Area Calendar Year 2019 Quality Assurance Report Nevada National Security Site, Nevada	EM Nevada Program 2020g
Underground Test Area (UGTA) Sampling Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada National Security Site, Nevada	EM Nevada Program 2020j
Understanding long-term groundwater flow at Pahute Mesa and vicinity, Nevada National Security Site, USA, from naturally occurring geochemical and isotopic tracers	Kwicklis et al. 2020
Update to the Phase II Corrective Action Investigation Plan for Corrective Action Units 101 and 102, Central and Western Pahute Mesa, Nevada National Security Site, Nye County, Nevada	EM Nevada Program 2020k

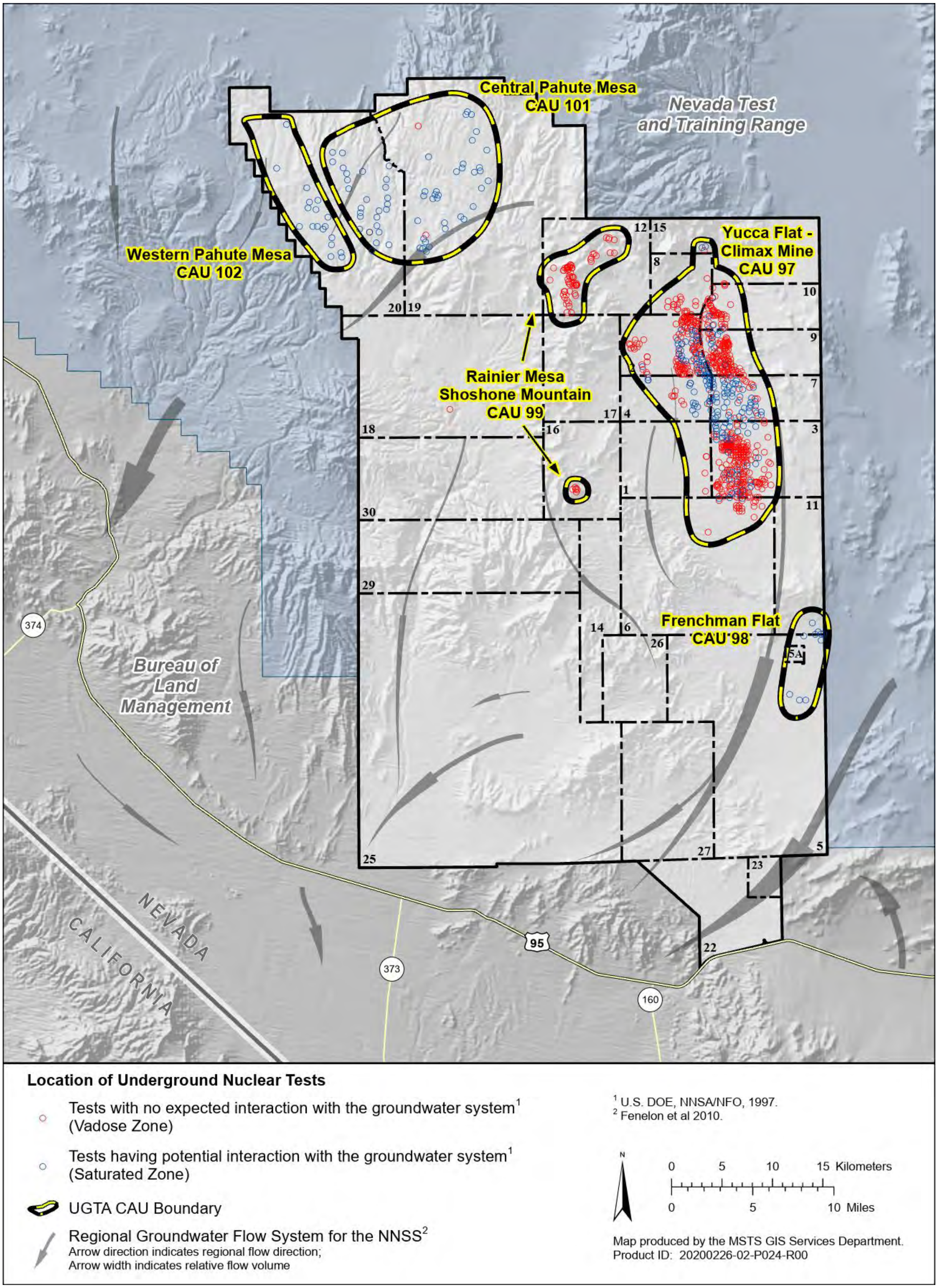

Figure 11-3. UGTA CAUs

11.2.2 Industrial Sites

There are 13 Industrial Sites CASs where environmental corrective actions are in progress (Figure 11-4). Five of these CASs are Chromium Containing Waste Disposal Cells (CAU 577) located at the Area 5 Radioactive Waste Management Complex. This CAU was established in the FFACO under a 2019 Settlement Agreement with NDEP. Environmental corrective actions for three of the CASs (Phase 1) involve construction of a RCRA-compliant closure cover over the waste disposal cells, which began in CY 2020. Completion of construction and revegetation of the closure cover for Phase 1 continued into CY 2021 with the Closure Report planned for submission to NDEP in September 2021. Environmental corrective actions for the remaining two CASs will be consistent with Phase 1 and occur following closure of the disposal cells, which is expected to be 2022 for the first cell (Cell 20) and 2023 for the second cell (Cell 21).

The remaining eight active Industrial Site CASs are Test Cell C Ancillary Building and Structures (CAU 572) and the Engine Maintenance, Assembly, and Disassembly (E-MAD, CAU 114) site, which are planned for Decontamination and Decommissioning (D&D). FFACO closure of these two Industrial Sites D&D facilities is accomplished through the Streamlined Approach for Environmental Restoration process. The goal of D&D is to reduce risks to site workers, the public, and the environment, and limit the long-term cost of surveillance and maintenance. D&D removes the Industrial Site from service through demolition and proper disposal of the generated waste. Prior to demolition, radiological surveys, sampling, decontamination, dismantlement, and other related activities occur.

Test Cell C Ancillary Building and Structures and E-MAD were part of a larger complex of facilities constructed to support the historical Nuclear Rocket Development Station that was jointly administered by the Atomic Energy Commission (predecessor to DOE) and the National Aeronautics and Space Administration's Space Nuclear Propulsion Office between 1958 and 1971.

Test Cell C Ancillary Building and Structures consist of a 6,800 square foot (ft^2) single-story masonry building with multiple rooms (i.e., cryogenic bench lab, pump and electric shops, control room, etc.), a large steel-framed building containing three large electric motors, a 750 ft^2 single-story concrete-framed pump house, a 1,700 ft^2 light steel-framed building used for cryogenic experiments and storage, and 10 large ancillary structures (i.e., dewars for storing liquid hydrogen, cooling towers, storage tanks, and piping). The E-MAD facility encompasses a 100,000 ft^2 80-feet tall four-story building with 6-feet thick concrete walls and the largest "hot cell" in the world, a steel-framed building that was used for railcar maintenance and treatability tests on plutonium-contaminated soil, a 32-feet long 107-ton manned control car, and a 60-feet long 70-ton engine installation vehicle. Site characterization, to include sampling and radiological surveys, was performed at these facilities in CY 2020 in preparation for the scheduled D&D of Test Cell C Ancillary Building and Structures to begin in FY 2022 and E-MAD in FY 2023.

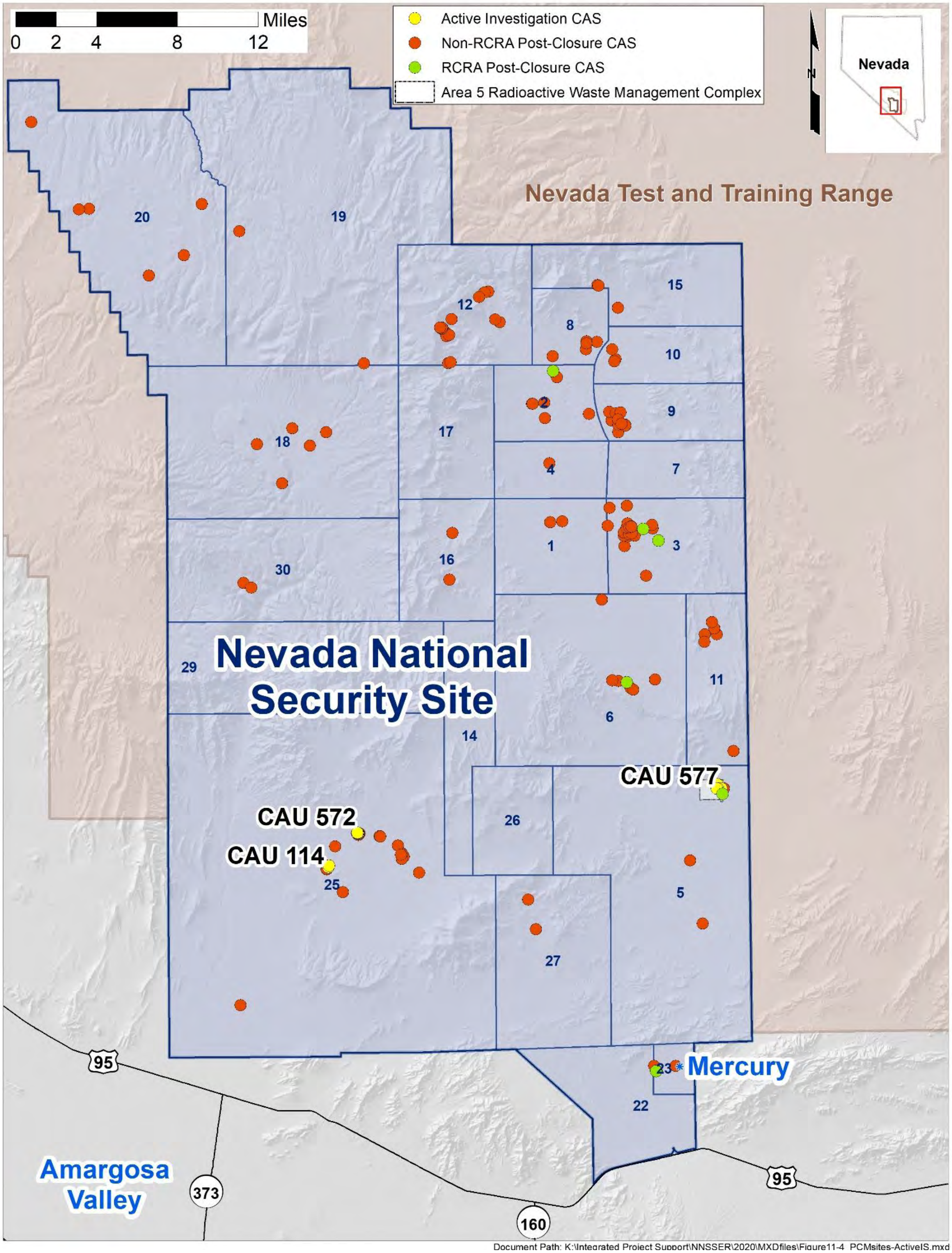

Figure 11-4. Soils and Industrial Sites active and post-closure CASs

11.3 Corrective Action Sites – Post-Closure Activities

11.3.1 Underground Test Area Sites

Three UGTA CAUs, Frenchman Flat (CAU 98), Rainier Mesa/Shoshone Mountain (CAU 99), and Yucca Flat/ Climax Mine (CAU 97), are in the closure stage. During the *closure stage*, contaminant, regulatory, and use-restriction boundaries are identified in agreement between DOE and NDEP. The boundaries for each CAU are presented in Figure 11-5. If radionuclides exceeding the agreed upon level reach the regulatory boundary, the EM Nevada Program is required to submit to NDEP a plan that meets the CAUs regulatory boundary objectives.

A Closure Report is developed at the beginning of the *closure stage* to document these boundaries and describe the monitoring well network and land-use restrictions. Three types of monitoring are performed during closure: water quality, water level, and institutional control monitoring. The monitoring objective is to determine if use-restriction boundaries remain protective of human health and the environment. Additionally, water quality and water-level monitoring is used to evaluate consistency with the groundwater flow and contaminant transport conceptual and numerical models. Such consistency is important because the models are the primary basis for use-restriction boundaries.

11.3.1.1 Frenchman Flat

The Frenchman Flat CAU comprises ten CASs (Figure 11-3) and is the first of the UGTA CAUs to reach the *closure stage*. The Closure Report for the Frenchman Flat CAU, approved by NDEP in 2016, specifies a monitoring program for the first 5 years post-closure (NNSA Nevada Field Office [NNSA/NFO] 2016). The detailed monitoring reports are published each year of the initial 5-year period (EM Nevada Program 2017, 2018b, 2019b, and 2020b).

The objective of the Frenchman Flat CAU regulatory boundary is to protect receptors downgradient of the Rock Valley fault system from radionuclide contamination. Although contaminants resulting from underground nuclear tests are not forecast to migrate out of the basin within the next 1,000 years, the Rock Valley fault system is the expected groundwater migration pathway. The negotiated regulatory boundary is established at the interface of the Alluvial/Volcanic aquifer and the Rock Valley fault (Figure 11-5). All monitoring results indicate that the regulatory boundary objective has been met.

Institutional control monitoring confirmed that use restrictions are recorded in land management systems maintained by NNSA/NFO and the U.S. Air Force, and no activities within Frenchman Flat basin are occurring that could potentially affect the contaminant boundaries. A survey of groundwater resources in basins surrounding Frenchman Flat similarly identified no current or pending development that would indicate the need to increase monitoring activities or otherwise cause concern for the closure decision. Use restrictions continue to prevent exposure to the public, workers, and the environment from contaminants of concern by preventing access to potentially contaminated groundwater.

The Frenchman Flat Post-Closure Monitoring Network includes 17 wells (11-5), five of which are sampled for water quality and water levels, one for water quality only, and 11 for water levels only. The contaminants for which each of the six wells were sampled, based on location type, are described in Section 5.1.1, and the 2020 analytical results for ^{3}H are presented in Table 5-4. As a result of a historical radionuclide migration experiment, ^{3}H at a concentration above the regulatory-approved minimum detection limit is present in two wells, RNM-2S and UE-5n. Results of sampling conducted in 2020 indicates that the ^{3}H concentration in well RNM-2S is on average 6.9% lower than in 2019 and the ^{3}H concentration in well UE-5n also continues to slowly decrease, being almost 3.3% lower than in 2019.

Depth to water measured in 2020 in the 16 water level monitoring wells is generally consistent with measurements taken in recent years. A long-term declining water level trend exists in most of the wells completed in the alluvium and is primarily attributed to drawdown from basin-scale pumping. Groundwater has been pumped from wells in the central and southern part of the Frenchman Flat basin since the 1950s. Water levels are also declining in supply wells completed in the volcanic aquifer in the northwestern part of the basin. A rising water level is observed in a former water supply well in southern Frenchman Flat.

11.3.1.2 Rainier Mesa/Shoshone Mountain Corrective Action Unit 99

The Rainier Mesa/Shoshone Mountain CAU, comprised of 66 CASs, is unique when compared to other UGTA CAUs because most of its CASs are associated with nuclear tests conducted in tunnels rather than in vertical shafts, where most tests were conducted in the other CAUs. Monitoring therefore includes sampling from tunnels and tunnel effluent, as opposed to wells. Advancement to closure for this CAU was approved based on the conclusions of the flow and transport models that the potential for the public to be exposed to contaminated groundwater on or near the CAU was very small (EM Nevada Program 2018c, 2019a). Tritium was the radionuclide that exceeded the Environmental Protection Agency SDWA standards the farthest away from CASs in the southwesterly flow direction. To the southwest, the contamination was forecast to remain within the boundaries of the NNSS, where institutional controls can prevent inadvertent access to contaminated groundwater. These potential areas of contamination (contaminant boundaries) are shown in Figure 11-5.

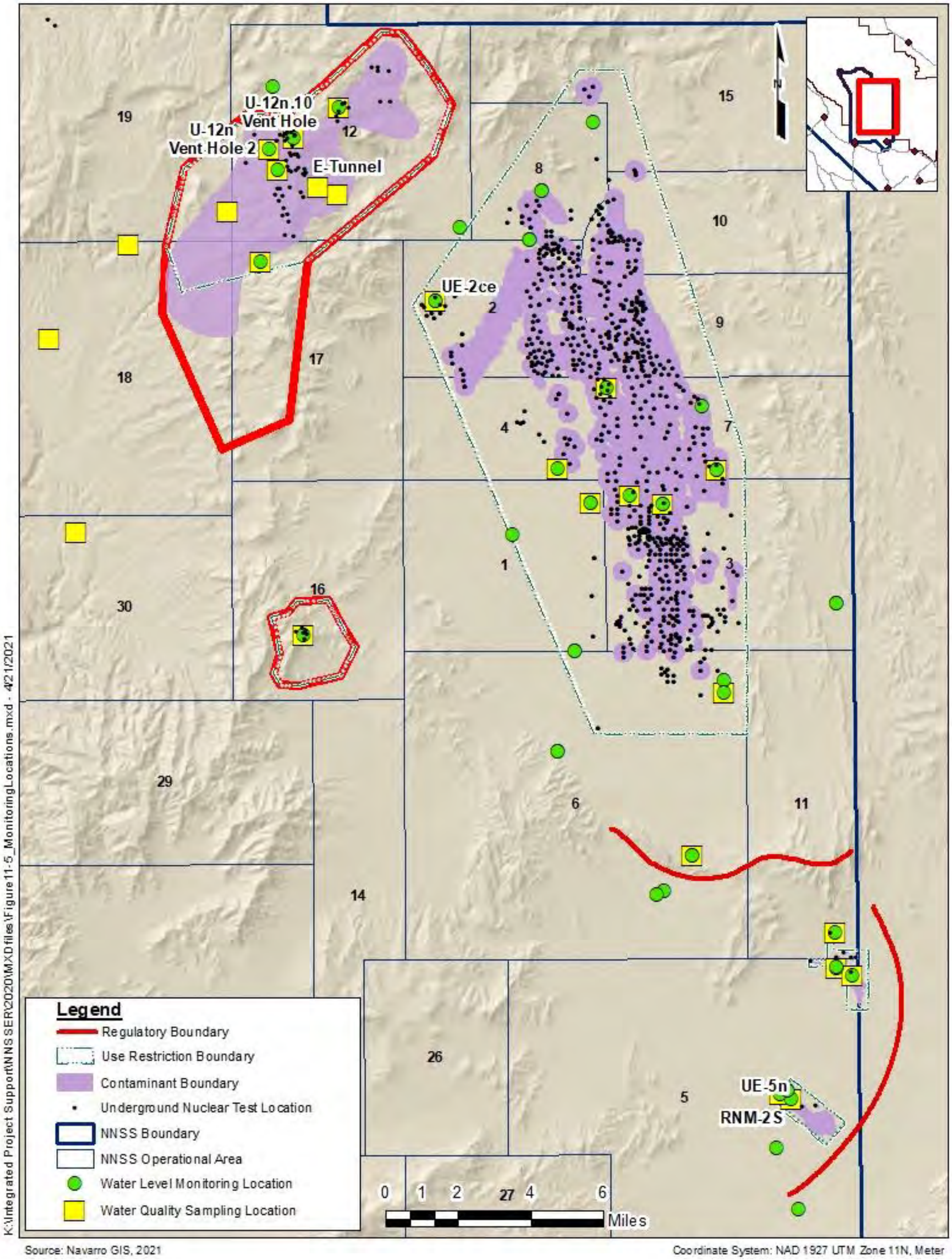

Figure 11-5. Boundaries and monitoring wells for closed UGTA CAUs

The regulatory boundary objective for Rainier Mesa is to protect receptors of groundwater from radionuclide contamination within the three downgradient groundwater basins that receive recharge from Rainier Mesa (Pahute Mesa-Oasis Valley, Ash Meadows, and Alkali Flat-Furnace Creek). The regulatory boundary objective for Shoshone Mountain is to verify that radionuclide contamination does not reach the lower carbonate aquifer (LCA) (i.e., the regional aquifer) below Shoshone Mountain. The use-restriction boundary for Rainier Mesa follows the regulatory boundary except in the southwest direction, where the use-restriction boundary generally corresponds with Rainier Mesa Road and Pahute Mesa Road. The use-restriction boundary for Shoshone Mountain coincides with the regulatory boundary (Figure 11-5).

The Closure Report for the Rainier Mesa/Shoshone Mountain CAU, establishing the post-closure monitoring network and the boundaries described above, was approved by NDEP in 2020 (EM Nevada Program 2020i). The monitoring network includes 16 locations, of which seven are sampled for water quality and water levels, seven for water quality only, and two for water levels only. Sampling for ^{3}H is required every 6 years; additional radionuclides are analyzed at three locations that sample water from the tunnels. Water-level measurements and sampling was completed for this CAU in 2020. The analytical results for ^{3}H are presented in Table 5-4. Tritium at a concentration above the regulatory approved minimum detection limit is present in three locations accessing the tunnels. No ^{3}H is observed in monitoring locations downgradient of the tunnels. Water-level and use-restriction monitoring results will be published in the post-closure monitoring report scheduled for 2021.

11.3.1.3 Yucca Flat/Climax Mine Corrective Action Unit 97

Supported by the extensive model evaluation activities and associated results documented in the Model Evaluation Report (Navarro 2019), the Yucca Flat/Climax Mine CAU (comprising 720 CASs) advanced to the closure stage in 2020. The Closure Report for this CAU was approved by NDEP in 2020 and identifies the use-restriction and regulatory boundaries (EM Nevada Program 2020h). The regulatory boundary objective is to verify that radionuclide contamination from this CAU is contained within the Yucca Flat basin, thus not impacting the Frenchman Flat LCA or downgradient receptors. The LCA aquifer is a regional aquifer and is the only pathway out of Yucca Flat (Navarro 2019). The regulatory boundary aligns with the southern extent of the Yucca Flat hydrographic basin (Basin 159) and supports the regulatory boundary objective.

The Yucca Flat/Climax Mine post-closure monitoring network includes 26 locations, nine of which are sampled for water quality (i.e., ^{3}H) and water levels, one for water quality only, and 16 for water levels only. Eight wells in Yucca Flat and one well in Frenchman Flat are sampled every 6 years and one well in Yucca Flat is sampled annually for the next 6 years. These wells were all sampled in 2020 and the analytical results for ^{3}H are presented in Table 5-4. Tritium at a concentration above the regulatory approved minimum detection limit is present in only one well (UE-2ce) as a result of a radionuclide migration experiment. The ^{3}H concentration in Well UE-2ce is on average 38% lower than when last sampled in 2016. Water-level and use-restriction monitoring results will be published in the post-closure monitoring report scheduled for 2021.

11.3.2 Industrial Sites and Soils

Environmental corrective actions have been completed at 2,153 Industrial Sites and Soils CASs on and off the NNSS. Characterization and closure of these CASs were completed in accordance with the FFACO (1996, as amended). Closure strategies include removal of debris, excavation of soil, decontamination and decommissioning of facilities, and closure-in-place with subsequent monitoring. The contaminants of concern include hazardous chemicals/materials, unexploded ordnance, and low-level radiological materials. Clean closures are those where pollutants, hazardous wastes, and solid wastes have been removed and properly disposed, and where removal of all contaminants is verified in accordance with corrective action plans approved under the FFACO. Closure-in-place entails the stabilization or isolation of pollutants, hazardous wastes, and solid wastes, with or without partial treatment, removal activities, and/or post-closure monitoring in accordance with corrective actions plans approved under the FFACO. Radioactive materials removed from sites are either disposed as low-level waste (LLW) or mixed low-level waste at the Area 5 Radioactive Waste Management Site (Section 10.1). Solid waste (e.g., demolition debris) containing asbestos is disposed of at the Area 9 U10c Solid Waste Landfill. Hazardous waste removed from CASs is shipped to approved offsite treatment and disposal facilities or recycled. Post-closure monitoring requirements are established as needed to provide for the long-term protection of the public and the environment.

Following NDEP's December 2019 approval of the Closure Report for the final Soils CAS located on the NTTR/TTR, the EM Nevada Program completed post-closure activities at this site and others in CY 2020 to prepare for transferring long-term stewardship responsibility of the sites to DOE LM. Post-closure activities on the NTTR/TTR consisted of revegetation of Clean Slate II and III remediated areas, annual post-closure inspections of closed and use-restricted Industrial Sites, and radiological surveys at the Clean Slate I, II, III, and Double Tracks sites for clearance of 10 CFR 835 requirements. In addition to these activities, an extensive Site Transition Plan was completed by the EM Nevada Program in coordination with DOE LM to document the transfer process that involved the review and transmission of more than 7,200 documents and records. Numerous presentations were also held to brief the NTTR/TTR landlord and managers and NDEP for demonstrating transfer preparedness and ensuring agreement by FFACO signatories. The transfer of long-term stewardship responsibilities to DOE LM for the 70 FFACO sites on the NTTR/TTR became official on September 30, 2020. Therefore, beginning in CY 2021, environmental reporting of long-term surveillance and maintenance activities at the sites will be performed by DOE LM and published by Sandia National Laboratories (SNL) in the TTR annual environmental report, available online at www.sandia.gov/news/publications/environmental/index.html.

Since the EM Nevada Program transferred these sites in the fall of CY 2020, the following monitoring activities are described in both this report and the SNL 2020 Annual Site Environmental Report. Airborne (wind, dust) radiation and meteorological parameters have been monitored at selected locations on the TTR to determine if there is wind transport of man-made radionuclides from Clean Slate I, II, and III Plutonium Dispersion CAUs (CAUs 412, 413, and 414, respectively). Monitoring occurred at five stations in 2020, with a focus on the ground disturbing environmental corrective actions at Clean Slate II and III. Design of the air monitoring stations is similar to that used in the Community Environmental Monitoring Program (Section 7.1).

Monitoring Station 400 is located in the general vicinity of the TTR Range Operations Center. It measures potential radionuclide concentrations associated with airborne particulates at the location of the closest to regular site workers. Stations 401 and 403 are located near Clean Slate III and Stations 404 and 405 are located near Clean Slate II. The monitoring stations at Clean Slate II and III are located downwind of the contamination areas when winds are from either of the two predominant directions (north and south). Additional information on the TTR monitoring effort is available in the 2020 TTR Annual Site Environmental Report.

Post-closure inspections are required for 138 closed FFACO Soils and Industrial Sites CASs and eight CASs identified in the RCRA Part B Permit (U.S. Department of Energy, Nevada Operations Office [DOE/NV] 1999) (Figure 11-4 Soils and Industrial Sites Active and Post-Closure CASs). In 2020, the EM Nevada Program conducted inspections at 114 closed CASs managed under the FFACO and a total of 18 inspections were conducted at the eight RCRA Part B Permit sites. In 2020, two annual inspection reports for non-RCRA and RCRA post-closure sites on the NNSS were prepared and submitted to NDEP in May (EM Nevada Program 2020d, 2020f). In addition, a report of the annual inspections performed in 2019 at post-closure sites on the TTR was prepared and submitted to NDEP in May 2020 (EM Nevada Program 2020e).

11.4 Environmental Management Nevada Program Public Outreach

Traditional public outreach activities conducted by the EM Nevada Program in CY 2020 were affected by the COVID-19 pandemic. However, prior to the EM Nevada Program transitioning to a completely telework posture in mid-March and canceling all planned in-person outreach events, the EM Nevada Program Strategic Communications team in February 2020 conducted an interactive groundwater demonstration for 92 high school science students and promoted the availability of *Operation Clean Desert*[3] learning materials at no cost to

[3] *Operation Clean Desert* learning materials are activities geared toward teaching children about ongoing efforts to address environmental challenges at the NNSS, such as contaminated groundwater and radioactive waste disposal. These materials are available online at www.nnss.gov/pages/PublicAffairsOutreach/KidsZone/OpCleanDesert.html and include an activity book, a teacher's guide, and interactive computer game.

educators who participated in the Nevada State Science Teachers' Association Conference (Figure 11-5). In addition, overviews of the EM Nevada Program mission were presented at Commission Meetings for both Nye and Lincoln Counties in January and early March, respectively. And during the 2020 Waste Management Symposia in early March, numerous technical papers were presented on the EM Nevada Program mission and science that occurs in support of the completion of environmental corrective actions.

The Low-Level Waste Stakeholders Forum, Intergovernmental Liaisons, and NSSAB[4] Full Board meetings were also held as scheduled in January and February 2020. However, as the national health crisis took hold across the nation, the EM Nevada Program successfully transitioned stakeholder interactions to a virtual format. This included conducting one Administrative and three NSSAB Full Board meetings virtually with the Full Board meetings open to the public (all NSSAB meetings are posted by the EM Nevada Program on their NSSAB web page).

Whether in-person or virtual, NSSAB public meetings continued to cover a range of topics and in CY 2020 the NSSAB provided informed recommendations for the following items:

- Test Cell C Path Forward
- Yucca Flat/Climax Mine Long-Term Monitoring Network
- Waste Verification Strategy
- E-MAD Path Forward

The meeting agendas, handouts, and minutes for CY 2020 NSSAB meetings can be found at https://www.nnss.gov/NSSAB/pages/MM_FY20.html and http://www.nnss.gov/NSSAB/pages/MM_FY21.html.

During CY 2020, the EM Nevada Program also conducted a virtual membership recruitment drive that resulted in nine new members joining the NSSAB from communities in southern Nevada that are in close proximity to the NNSS.

The EM Nevada Program also hosted three Low-level Waste Stakeholders Forum meetings virtually in CY 2020 that resulted in attendance by more members, who include representatives of Clark County, Nye County, Lincoln County, State of Nevada, local emergency response personnel, and the NSSAB. The meetings provide participants an opportunity to discuss topics related to the transportation and disposal of low-level radioactive waste at the NNSS.

Requests for *Operation Clean Desert* learning materials were less in CY 2020, with only 743 *Operation Clean Desert* activity books and teacher's guides distributed, down from 3,875 in CY 2019. Since 2008, more than 49,000 *Operation Clean Desert* activity books, teacher's guides, and CDs have been distributed nationwide.

[4] The NSSAB (www.nnss.gov/NSSAB/) is chartered under the Environmental Management Site-Specific Advisory Board, a stakeholder board that provides EM Senior Management with recommendations on issues affecting the EM program at eight DOE sites across the country. Among those issues are clean-up activities and environmental restoration, waste management and disposition, excess facilities, future land use and long-term stewardship, risk assessment, and communications.

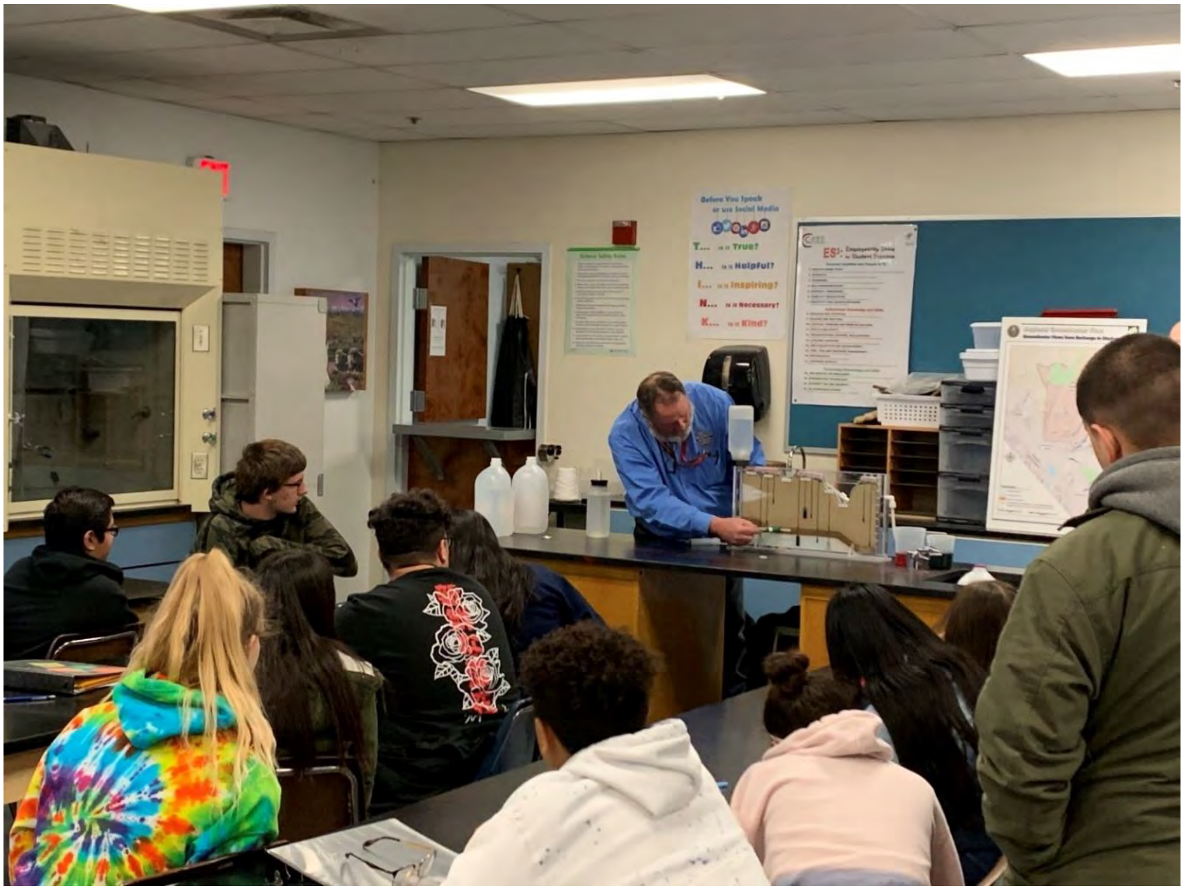

Figure 11-6. Navarro scientist demonstrates groundwater hydrologic concepts to Beatty High School students using a geologic display similar to an "ant farm"

11.5 References

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Chapter 12: Historic Preservation and Cultural Resources Management

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Cultural Resources Management Program Goals

Ensure compliance with all regulations pertaining to cultural resources. Identify, evaluate, and manage cultural resources. Evaluate the potential effects of proposed projects on cultural resources and, when necessary, mitigate adverse effects. Curate archaeological collections in accordance with Title 36 Code of Federal Regulations (CFR) Part 79, "Curation of Federally Owned and Administered Archeological Collections." Consult with American Indians regarding places and items of importance to 16 Tribes culturally affiliated with the Nevada National Security Site lands.

The Nevada National Security Site (NNSS) contains a wide range of cultural resources—including prehistoric and historic archaeological sites, buildings, and structures—that are part of the historic built environment, as well as places of religious and cultural importance to American Indians and others interested in history. Attachment A, Section A.5, provides a summary of the known human occupation and uses of the NNSS from the earliest known prehistoric societies in North America, circa 13,000 year ago, through the millennia to the Cold War era and nuclear testing from 1951 to 1992.

U.S. Department of Energy (DOE) Order DOE O 436.1, "Departmental Sustainability," requires the DOE National Nuclear Security Administration Nevada Field Office (NNSA/NFO) to develop policies and directives for the conservation and preservation of these resources. The Cultural Resources Management Program (CRMP) at the NNSS was established by NNSA/NFO. The Desert Research Institute (DRI) implements the mandates of this program to aid in conserving and preserving cultural resources that may be affected by proposed NNSA/NFO activities. NNSA/NFO must also comply with applicable federal and state regulations to protect and manage those cultural resources eligible for listing in the National Register of Historic Places (NRHP). These eligible resources are technically known as *historic properties* regardless of the age of the resource.

To meet federal and state requirements and achieve CRMP goals, the NNSA/NFO program contains the following major components: (1) NNSS project reviews for cultural resource compliance; (2) archival research, field inventories, built-environment surveys, and evaluations of NRHP eligibility; (3) the curation of archaeological collections and program records; and (4) the American Indian Consultation Program (AICP). Guidance for CRMP work is provided in the NNSS Cultural Resources Management Plan (Rhode et al. in draft). DRI historic preservation personnel and archaeologists, who meet the professional qualification standards set by the Secretary of the Interior (SOI), carry out these activities.

The methods used to identify cultural resources vary according to the type of resource under consideration. Archaeological sites are typically identified through an intensive pedestrian surface inventory, which is sometimes supplemented by small-scale subsurface testing to assess the potential presence of intact subsurface cultural deposits at potentially significant archaeological sites. Historic architectural properties, structures, and objects are identified during architectural surveys using maps and aerial imagery, historical archives, and information from individuals who may have direct knowledge of the functions and historical events associated with particular buildings or structures. Direct communication and consultation are also necessary to identify and characterize resources that are culturally important to American Indians, such as sacred sites or traditional-use areas.

12.1 Cultural Resources Inventories and NRHP Eligibility Evaluations

Cultural resources inventories and built-environment surveys are conducted to meet the requirements of the National Historic Preservation Act (NHPA). These are completed prior to proposed projects or activities that have the potential to affect historic properties. The information resulting from these inventories and NRHP-eligibility evaluations include the following:

- Identification of the numbers and types of cultural resources at each proposed project location on the NNSS
- Evaluations and eligibility recommendations for listing in the NRHP
- Findings of effect of proposed activities
- Reports detailing the results of the identification efforts, evaluations, and findings of effect
- Recommendations for mitigating adverse effects on cultural resources, when required

In 2020, DRI completed cultural resources inventories and architectural surveys for nine projects in seven areas of the NNSS (Table 12-1). A total of 266.5 acres were inventoried and 27 cultural resources were identified and recorded. Of these resources, 25 resources were determined eligible for the NRHP. Documented cultural resources consist of prehistoric and historic sites, buildings, and structures. In accordance with the NHPA, NNSA/NFO consults with the Nevada State Historic Preservation Office (SHPO) regarding the adequacy of the identification efforts, eligibility determinations, and findings of effect prior to initiating an undertaking that has the potential to affect historic properties.

Table 12-1. 2020 cultural resources inventories, eligibility evaluations, and finding of effect reports

Project	NNSS Area(s)	Project Size (acres)	Cultural Resources	NRHP Eligible	Reference
			Section 110		
Sites associated with Grable Test	5	52	3	3	Keach 2020
			Section 106		
Expansion of U1a Modernization	1	138	3	2	Lancaster et al. 2020a
Expansion of Parking Lot at the Dense Plasma Focus Facility	11	37	2	1	Haynes and Person 2020
Demolition of Subdock Buildings	1	2	2	2	Collins and Menocal 2020
Removal of Surface-laid Cable	2	35	3	3	Menocal 2019
Area 6 Control Point Building Demolitions	6	2.5	14	14	Menocal et al. 2020
Finding of Effect to Control Point Historic District from 138-kV Transmission Line	6	NA	NA	NA	Menocal and Rowe 2020a
Finding of Effect to Area 12 Camp	12	NA	NA	NA	Edwards 2020
Finding of Effect from Installation of 138-kV Transmission Line	5, 6, 23	NA	NA	NA	Menocal and Rowe 2020b
Total		266.5	27	25	

To comply with Section 106 of the NHPA, DRI prepares identification and evaluation and finding of effect reports for SHPO review. During 2020, five cultural resource inventories were initiated by proposed NNSS undertakings with the potential to affect historic properties. Five identification and evaluation reports were submitted concurrently with finding of effect assessments and three finding of effect reports were completed. One additional inventory report was prepared as part of Section 110 efforts.

For Section 106 compliance, DRI completed an inventory for the proposed expansion of the U1a modernization project in Area 1 of the NNSS (Lancaster et al. 2020a). The U1a Complex is an underground laboratory used for subcritical and physics experiments that will be expanded by the addition of a sewage lagoon. The inventory area totaled 138 acres and DRI documented one previously recorded resource, a 138-kilovolt (kV) transmission line, which was updated to include a 34.5-kV distribution line, and two newly recorded resources, both World War II (WWII) training targets associated with the Tonopah Bombing and Gunnery Range and WWII military training in southern Nevada. One of the air-to-ground gunnery targets is recommended eligible to the NRHP under Criterion A for its association with the Tonopah Bombing and Gunnery Range and WWII military training in southern Nevada. The other lacks sufficient integrity for eligibility to the NRHP. Although the 138-kV line is not individually eligible for the NRHP, it remains unevaluated as a contributing element to a potential historic district.

DRI also conducted identification and evaluation efforts for proposed off-road travel areas and the expansion of the parking lot at the Dense Plasma Focus Facility in Area 11 (Haynes and Person 2020). NNSA/NFO intends to construct new parking and turnaround areas along the shoulders of existing roads, develop a new dirt road connector, delineate an off-road travel area for training maneuvers, and expand the existing parking area. DRI inventoried a total of 37 acres and identified two previously recorded resources, a concentration of fences and T-posts, and a 138-kV transmission line, which was updated to include two 34.5-kV distribution lines. These distribution lines are both adjacent to travel corridors and within the current project's area of potential effects (APE). The fences and T-posts are not eligible for the NRHP nor is the 138-kV line. However, the line remains unevaluated as a contributing element to a potential historic district.

DRI conducted an inventory of 35 acres in Area 2 where proposed activities from the removal of surface-laid cable may cause alterations in the character or use of historic properties (Menocal 2019). The APE consisted of the ground upon which 2.9-miles of surface-laid cable is placed and 50 feet on either side of the cable to provide sufficient space for construction equipment and vehicle traffic to conduct ground-disturbing and removal activities. DRI documented one previously recorded property, one unevaluated property, and one newly recorded property. The 2-300 Bunker Complex, a concentration of atmospheric testing-related instrument stations, was previously determined eligible for the NRHP under Criterion A. The main 138-kV transmission line, which crosses the APE, has been determined not individually eligible but remains unevaluated as a possible contributing element to unrecorded districts. For the purposes of this undertaking, S1725 will be treated as NRHP-eligible. DRI also identified one new site, which consists of 33 features and five artifacts. The orientation of the features and manufacturer's marks on the cable suggest the site supported testing operations on Yucca Flat in the 1980s. This site is recommended eligible for the NRHP under Criterion A for its association with nuclear testing.

DRI conducted an architectural survey for the identification and evaluation of 14 resources in the Area 6 Control Point and in its vicinity scheduled for demolition (Menocal et al. 2020). The Control Point refers to the Control Point Facility, an unrecorded historic district that was the command center for timing and firing operations for nuclear testing on the NNSS (Figure 12-1). The "vicinity" refers to the geographic area extending north of the Control Point for approximately 1.5 miles. Of the 14 resources scheduled for demolition, nine buildings and an underground tank are in the Control Point and four buildings are in the vicinity. The project APE consisted of a 2.45-acre discontiguous area where demolition activities would occur and the geographic areas in which visual or cumulative effects may be introduced. Eight historic properties scheduled for demolition are either individually eligible for listing on the NRHP or are contributing accessories to eligible historic properties. Six resources are NRHP eligible as contributing elements to the unrecorded historic district.

Figure 12-1. Overview of the Area 6 Control Point Facility (Remote Sensing Laboratory 2016)

Other important Section 106 projects included the architectural surveys of two buildings located in the Area 1 Subdock (Collins and Menocal 2020). These buildings are proposed for removal and were documented and evaluated for eligibility for the NRHP. The Subdock Office Building and the Drilling Operations Building are both associated with big hole drilling that supported nuclear testing activities from 1985 to 1992. Although not individually eligible to the NRHP, the buildings are contributing resources to the unrecorded Area 1 Subdock Historic District and their demolition will result in an adverse effect to the district. Other significant reports are the finding of effect assessments for undertakings at the Control Point Historic District (Menocal and Rowe 2020a), the Area 12 Camp (Edwards 2020), and the proposed installation of a 138-kV transmission line (Menocal and Rowe 2020b). NNSA/NFO determined that the installation of the 138-kV transmission line would result in adverse effects to three historic properties: the Mercury Historic District, the atmospheric viewing benches at New Nob, and the historic 138-kV line. NNSA/NFO also determined the demolitions at the Area 1 Subdock and the Area 12 Camp would have adverse effects on historic properties. The SHPO concurred with these finding of effect assessments and the NNSA/NFO is moving forward in developing memorandums of agreement to resolve the adverse effects.

During 2020, DRI conducted a Section 110 evaluation in Area 5 of three sites associated with the Grable Test (Keach 2020). The Grable Test, or event, was the first and only firing of a nuclear projectile in a U.S. Army tactical nuclear weapon system. This weapon system (Figure 12-2), commonly referred to as Atomic Annie or the Atomic Cannon, was the first of its kind and numerous locations in Area 5 were involved. This Section 110 recordation and evaluation focused on the main firing site, one of seven outlying observation stations, and the troop trenches used for Exercise Desert Rock V. The associated observation station was used to refine the gun's firing range but is not individually eligible for the NRHP because of the site's lack of integrity. Both the main firing site and the troop trenches are eligible for the NRHP at the national level of significance related to the Nuclear Testing and Cold War era. The main firing site is eligible under Criteria A and D and the troop trenches are eligible under Criterion A. All three resources are contributing elements to the Frenchman Flat Historic District.

Figure 12-2. Atomic Annie firing during the dress rehearsal (NTA 1953a)

12.2 Mercury Modernization

The NNSA/NFO determined that the Mercury Modernization undertaking will have adverse effects on historic properties eligible for the NRHP and executed a programmatic agreement (PA) with the SHPO that specifies the approach NNSA/NFO will take to streamline the Section 106 compliance process for modernization activities in Mercury (PA 2018). The PA stipulates the level of mitigation efforts for the proposed upgrade activities and how to determine when mitigation efforts are sufficient for future activities. Reports and mitigation documents governed by the PA will be archived in the Nuclear Testing Archive (NTA). Pursuant to the PA, in 2020, DRI completed research, building surveys, and required mitigation documentation for the Craft Shops Building, the Power and Communications System, the Bus Parking Lot, the Mercury Street System, the Mercury Stormwater Drainage System, and the Electrical (Tap and Meter) Substation Foundation (Table 12-2). A few of these activities are discussed below.

Table 12-2. 2020 buildings and structures evaluated for individual NRHP eligibility and mitigated pursuant to the Mercury programmatic agreement

Project	NNSS Area(s)	Project Size (acres)	Cultural Resources	NRHP Eligible	Reference
Craft Shops Building	23	NA	1	†	Lancaster and Collins 2020
Power and Communications System	23	32	1	†	Collins et al. 2020
Mercury Bus Parking Lot	23	5.6	1	†	Collins 2020
Mercury Street System	23	††	1	†	Collins 2020
Mercury Stormwater Drainage	23	††	1	†	Collins 2020
Electrical (Tap and Meter) Substation Foundations	23	††	1	†	Collins 2020
Total		37.6	6		

†Contributes to the eligibility of the Mercury Historic District although not individually eligible.
††Included in the 5.6 acres listed above for the Bus Parking Lot.

The Craft Shops Building 23-710 is within the Mercury Historic District (MHD) at the NNSS (Figure 12-3). The NNSA/NFO plans to make modifications to the heating, ventilation, and air-conditioning systems in the building. The MHD is eligible for the NRHP under Criteria A and C at the national level during the period of significance between 1951 and 1992, which encompasses nuclear testing at the NNSS. The modifications will occur within the framework of the PA developed to guide Mercury modernization activities. Per Stipulation VI.A of the PA, the Craft Shops Building was reevaluated for individual eligibility to the NRHP (Lancaster and Collins 2020). Although the building is not individually eligible, it is considered a contributing element to the significance of the MHD under Criteria A and C. After review and consultation with NNSA/NFO, the SHPO determined the planned modifications will have no adverse effect on either the building or the MHD.

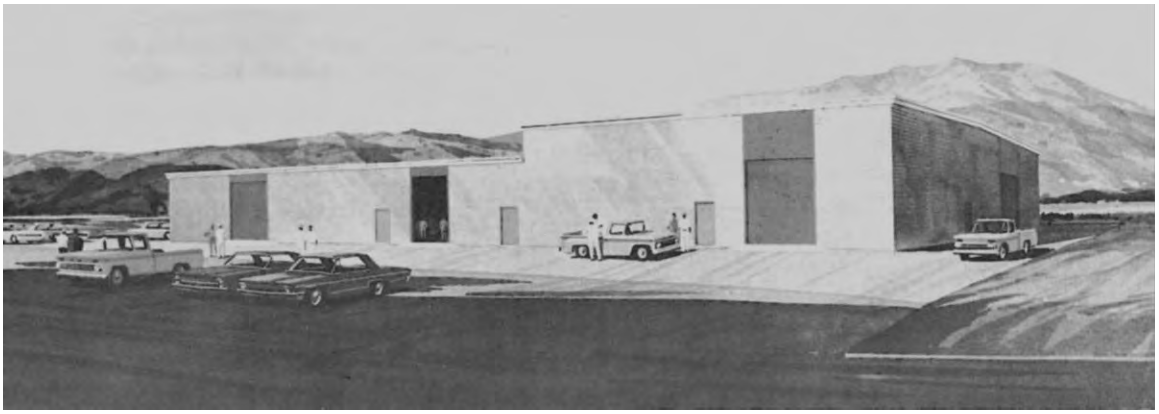

Figure 12-3. Architectural rendering of Building 23-710 (*NTS News* 2/26/1965)

The NNSA/NFO proposes consolidating and upgrading existing segments of Mercury's power and communications system. The activities will include rerouting and consolidating lines, installing new poles, installing equipment boxes and pole-mounted fixtures, installing new communications cabinets, and restringing utility lines. Existing poles and cables that are bypassed or no longer active will be removed. The current configuration of the power system was originally designed and installed during the early 1960s, and very little information is available about Mercury's communications infrastructure. Pursuant to Stipulation VIII.C of the Mercury PA, high-quality digital images were taken that are consistent with the photography plan in the PA and images were keyed to a plan map to show location (Collins et al. 2020). Because the system is composed of hundreds of poles with miles of wires and cables, photographs were taken to provide a sample of the various elements. Efforts were made to include any unusual components found attached to the poles, although few of these were encountered while examining the system.

As part of modernization activities addressed by the Mercury PA, substantial changes are proposed for one block and the street segment immediately south of it (Collins 2020). In consultation with the SHPO, NNSA/NFO determined there would be adverse effects from modernization activities on four resources and these resources were mitigated following the stipulations of the PA. Two of the resources are portions of the street system and the stormwater drainage system, which are elements of Mercury's infrastructure and contribute to the historical significance of the MHD. Two resources will be demolished. The first is what remains of a 1960s electrical substation. The foundations of this substation, which held the structural components, will be removed and the lot will be graded. The second resource is a bus parking lot. The foundations of the substation and the parking lot will be replaced by new parking or landscaping. The existing drainage constructed to control the flow of stormwater around the electrical substation will be filled and graded, and Hardtack Avenue between Mercury Highway and Teapot Street will be demolished to construct part of a large pedestrian walkway that will connect several existing and anticipated future buildings on the upgraded Mercury campus.

12.3 Mitigation Projects

The implementing regulations of the NHPA (36 CFR Part 800) direct the federal agency to apply the criteria of adverse effect to determine when a proposed undertaking may alter—directly or indirectly—any of the characteristics of a historic property that qualify that property for inclusion in the NRHP in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Adverse effects include the physical destruction of or damage to all or part of a property; the alteration of a property, including restoration, rehabilitation, repair, maintenance, stabilization, hazardous material remediation, or other activities that are not consistent with the SOI's Standards for the Treatment of Historic Properties (36 CFR Part 68) and applicable guidelines; a change in the character of the property's use or features within the property's setting that contribute to its historic significance; the introduction of visual, atmospheric, or audible elements that diminish the integrity of the property's significant historic features; or other examples as outlined in 36 CFR 800.5(a).

If an adverse effect is found, the agency will continue to consult with the SHPO, tribes, and other stakeholders to develop and evaluate alternatives or modifications to the undertaking that could avoid, minimize, or mitigate the adverse effect on the historic property. Once the agency and the SHPO agree on how the adverse effect will be resolved, a memorandum of agreement (MOA) is executed. Once the MOA is implemented in accordance with its stipulations, then the adverse effect of the federal agency's undertaking on the historic property is resolved and the agency's Section 106 responsibilities have been satisfied.

During 2019, the SHPO concurred with NNSA/NFO's finding of adverse effect to repurpose the U12n Vent Hole #2 and the U12n.10 Vent Hole for water sampling at the U12n Tunnel. The vent holes are part of the historic ventilation and containment systems for the U12n Tunnel Historic District, a historic property determined eligible for the NRHP. To resolve adverse effects, NNSA/NFO and the SHPO executed the *Memorandum of Agreement Between the National Nuclear Security Administration Nevada Field Office, Environmental Management Nevada Program Office, and the Nevada State Historic Preservation Officer Regarding Repurposing of Portions of the Ventilation System of the U12n Tunnel Complex Located in Area 12 at the Nevada National Security Site.*

During 2020, in accordance with the stipulations of the MOA, DRI prepared a manuscript that provides a historic context that describes the development and functioning of the historic U12n Tunnel ventilation system for underground nuclear tests (Lancaster et al. 2020b). Documentation included digital color images of the vent hole containment doors, nearby elements, and overviews (Figure 12-4). This documentation was reviewed by the SHPO and found adequate for meeting the terms of the MOA.

Figure 12-4. Overview of the U12n.10 Vent Hole System (DRI 2020)

In 2019, a finding of adverse effect was also found for the proposed demolition of the Engine Maintenance Assembly and Disassembly Facility and the Test Cell C Historic District, which are historic properties that were determined eligible for the NRHP and contributed to the eligibility of the Nuclear Rocket Development Station (NRDS). During 2020, NNSA/NFO consulted with the SHPO, tribes, and other stakeholders regarding the adverse effect. DRI assisted with the development of an MOA to resolve these adverse effects and NNSA/NFO and the SHPO executed the *Memorandum of Agreement Between the U.S. Department of Energy and the Nevada State Historic Preservation Officer Regarding Corrective Action Activities and Demolition of the Test Cell C Historic District, Major Components of the Nuclear Rocket Development Station Historic District Located in Area 25 at the Nevada National Security Site, Nye County*. In accordance with the MOA, DRI initiated the agreed upon mitigation activities, which focused on the recording and evaluation of the NRDS.

12.4 Other Cultural Resources Projects

Prior to initiating proposed projects, cultural resources records at DRI and the Nevada Cultural Resource Information System database are consulted to identify previous cultural resources inventories and NRHP-eligible cultural resources near or within the project area. This helps determine whether an inventory is required and the potential of a proposed project to affect historic properties. In addition to the projects in Tables 12-1 and 12-2, which required cultural resources inventories and built-environment surveys, reviews also included proposed projects that were in areas previously inventoried for cultural resources. In some cases, additional inventories or evaluations were not required and no reports were prepared. In 2020, subject matter experts who meet the professional qualification standards set by the SOI reviewed 70 proposed projects. Of these projects, only 11 required more in-depth studies or pedestrian inventories to comply with Section 106.

Other projects and activities carried out by DRI in 2020 that resulted in reports are listed below and referenced in Table 12-3.

- Annual report regarding the progress in the implementation of the Mercury Historic District programmatic agreement during fiscal year (FY) 2019.
- Annual report for curation tasks completed in support of the NNSS artifact collection and records in the NNSA/NFO records facility managed by DRI.
- CRMP Monitoring Procedures Manual for the NNSS detailing how to conduct pre-field, field, and post-field activities for the monitoring of cultural resources.
- Cultural resources monitoring, which entailed revisiting a sample of six historic properties, documenting current site conditions, and determining if they maintain enough integrity to still be eligible for the NRHP.
- Cultural Resources Management Plan summarizing the overall NNSS cultural resource landscape and approach to management (in draft).
- Sitewide Programmatic Agreement for the NNSS (in progress).
- Preserve America Report in response to the requirements of Executive Order 13287.

Table 12-3. Other 2020 cultural resources projects

Project	Reference
Mercury Annual Progress Report	Collins and King 2020
Annual Curation Compliance Report	Menocal 2020b
CRMP Monitoring Procedures Manual	Menocal and Haynes 2020
NNSS Cultural Resources Monitoring	Menocal 2020a
Cultural Resources Management Plan	Rhode et al. in draft
Sitewide Programmatic Agreement for NNSS	Rhode et al. in progress
Preserve America Report	Rowe and King 2020

12.5 Curation

The NHPA requires that archaeological collections and associated records be maintained at professional standards. The specific requirements are delineated in 36 CFR 79. The NNSS Archaeological Collection currently contains approximately 467,000 artifacts and is curated in accordance with 36 CFR 79. Curation requirements include:

- Maintaining an inventory catalog of the items in the NNSS collection.
- Packaging the NNSS collection in materials that meet archival standards (e.g., acid-free boxes).
- Maintaining the NNSS collection and records in a secure facility with environmental controls.
- Following established procedures for the NNSS collection and curation facility.
- Complying with the Native American Graves Protection and Repatriation Act.

As part of routine curatorial maintenance, DRI staff conducts random spot-check inventories to assess the condition of the fragile artifacts in the collections room. DRI staff noted a paper historic mining claim needed stabilization to prevent deterioration. The paper artifact was repackaged in an archival-quality sleeve and returned to the collection. DRI staff also conducts random inventories of catalog records against materials remains in the NNSA/NFO curation facility. No errors were identified during 2020.

Early in 2020, DRI received a prehistoric seed basket recovered from the NNSS and retrieved a collection of cameras and instruments owned by NNSA/NFO and stored in a Mercury warehouse. All artifacts were accessioned, packaged, and cataloged. The associated records for these acquisitions are now in the NNSA/NFO curation facility's records room.

DRI staff also continued a collection-level inventory for the McKinnis artifact collection. The McKinnis collection consists of prehistoric artifacts from multiple locations on the NNSS that were collected by William McKinnis, a Lawrence Livermore National Laboratory engineer. This inventory is an ongoing effort to sort the material remains in storage boxes by general artifact class (e.g., stone or ceramic) and to verify the digital catalog record of each artifact.

On June 10, 2020, DRI received a research request from the Crow Canyon Archaeological Center and the Pueblo of Hopi Cultural Preservation Office about possible maize specimens in the curation facility. DRI located one specimen and provided information to Crow Canyon and the Hopi Cultural Preservation Office the next day.

In 2020, DRI staff archived all project files associated with the NNSA/NFO CRMP from FY 2015 and FY 2016. DRI staff also archived hard copies of cultural resources reports completed in FY 2020 and their associated resource forms.

One loan agreement was renewed between NNSA/NFO and the National Atomic Testing Museum (NATM) for the McGuffin Collection, which consists of 39 chipped stone artifacts from a site in Fortymile Canyon arranged in a glass picture frame. The McGuffin Collection has been on exhibit in the NATM since 2005 and the loan is renewed yearly.

12.6 American Indian Consultation Program

NNSA/NFO created the AICP in 1991 to formalize its consultations with 16 Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone tribes with cultural and historic ties to the NNSS. The history of this program and a list of the 16 culturally affiliated tribes can be found in *American Indians and the Nevada Test Site: A Model of Research and Consultation* (Stoffle et al. 2001). The program operates in accordance with DOE O 144.1, "Department of Energy American Indian Tribal Government Interactions and Policy," which provides a foundation for engaging tribal leadership and their designated representatives in activities that occur on the NNSS.

The goals of the AICP are to:

- Provide a government-to-government forum for tribal members to interface directly with NNSA/NFO management on activities associated with NNSA/NFO undertakings.

- Provide tribal members with opportunities to actively participate in and help guide decisions that involve culturally significant places, resources, and locations on the NNSS.
- Involve tribal members in the management, curation, display, and protection of American Indian artifacts originating from the NNSS.
- Enable tribal representatives to engage in religious and traditional activities within the boundaries of the NNSS.
- Provide opportunities for AICP subgroups to participate in the review and evaluation of program documents on an interim basis between regularly scheduled meetings.
- Include tribal members' views in the development of tribal text in the agency's National Environmental Policy Act documents.
- Work with the AICP Coordinator to develop approaches for expanding tribal involvement in NNSA/NFO activities on the NNSS.

In 2020, NNSA/NFO management interacted with the AICP Coordinator to identify topics of interest and explore options for enhancing communications with tribal representatives. Interactions included sharing project updates and information related to NNSS activities that continue to serve as the foundation for sustaining the AICP. One key element of the AICP is supporting the NNSA/NFO Annual Tribal Update Meeting (TUM), which brings together culturally affiliated tribes and managers from DOE to discuss NNSS activities. Because of safety considerations associated with COVID-19, NNSA/NFO cancelled the 2020 TUM initially scheduled for April 7–8, 2020, until the following year.

In the absence of the 2020 TUM, NNSA/NFO held quarterly meetings with the Tribal Planning Committee (TPC), which is composed of six individuals representing Southern Paiute, Western Shoshone, and Owens Valley Paiute-Shoshone ethnic groups. The TPC interacts with NNSA/NFO to receive project briefings and address tribal topics of mutual interest. TPC quarterly meetings were held on February 25, May 5, July 11, and December 15, 2020. In addition to NNSA/NFO quarterly interactions, the TPC participated in a combined NNSS site visit (Figure 12-5) to evaluate the condition of cultural resources at Jailhouse Rockshelter (26NY3187) located in Area 17; a contextual overview of Buildings 1-101 and 1-102 in the Area 1 Subdock Historic District; and the Control Point Facility located in Area 6.

Figure 12-5. TPC representatives on a 2020 NNSS site visit to the Area 1 Subdock (DRI 2020)

During the site visit to Jailhouse Rockshelter, the TPC noted no disturbance to the site or surrounding area. The TPC agreed that visits to Buildings 1-101 and 1-102 in addition to the visit to the Control Point facility provided additional context to supplement previous NNSA/NFO project briefings. The TPC will share tribal observations about the site visits during the next scheduled TUM planned in 2021.

Part of the responsibilities of the AICP Coordinator include reviewing proposed activities and developing summary reports that include tribal perspectives related to the project areas. During 2020, the AICP Coordinator developed six reports, including an AICP Annual Report, four TPC meeting summaries, and a report describing site visits to Jailhouse Rockshelter, Buildings 1-101 and 1-102, and the Area 1 Control Point facility. The annual AICP report documents program activities that include TPC quarterly meeting summary reports (see Table 12-4). Collectively, these reports share tribal perspectives and program accomplishments that occurred during 2020. Another important element is the AICP Coordinator's review of DRI cultural resources inventory reports that focus on describing the archaeological or built environment resources associated with proposed project areas on the NNSS. In 2020, seven reports were reviewed and evaluated for cultural sensitivities to expand noted cultural perspectives based upon cultural insight and tribal recommendations.

In 2020, the DOE Environmental Management Nevada Program (EM NV) supported the continuation of the Tribal Revegetation Project on the 92-Acre-area located at the Radioactive Waste Management Complex (RWMC) in Area 5. The project integrates traditional ecological knowledge and scientific ecological methods in collaboration with DRI and Portland State University (PSU). In 2020, the Tribal Revegetation Committee (TRC) modified monitoring activities because of COVID-19 safety considerations, which included limited involvement by the AICP Coordinator and DRI biologist who recorded and evaluated plant growth and other monitoring criteria from May to September 2020. Concurrently, the TRC participated in five virtual meetings to discuss the results of the monitoring activities and coordinate efforts for an annual meeting with the TRC, DRI, PSU, EM NV, and the Nevada Division of Environmental Protection during October 2020. Project updates focused on revegetation outcomes and concluded with discussions about the contents of a final TPC annual report that was published in March 2021 (Spoon et al. 2021). A project overview will be presented at the 2021 NNSA/NFO Annual TUM.

Table 12-4. AICP reports

Project	Reference
AICP Annual Report FY 2020	Arnold 2020a
TPC FY 2020 Second Quarterly Meeting Report	Arnold 2020b
TPC FY 2020 Third Quarterly Meeting Report	Arnold 2020c
TPC FY 2020 Fourth Quarterly Meeting Report	Arnold 2020d
TPC FY 2021 First Quarterly Meeting Report	Arnold 2020e
TPC Assessment of Jailhouse Rockshelter, Subdock, Control Point	Arnold 2020f

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Chapter 13: Ecological Monitoring

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Ecological Monitoring and Compliance Program Goals

Ensure compliance with all state and federal regulations and stakeholder commitments pertaining to Nevada National Security Site (NNSS) flora, fauna, wetlands, and sensitive vegetation and wildlife habitats. Ecosystem monitoring to identify impacts of climate and other environmental changes on the NNSS. Provide ecological information that can be used to evaluate the potential impacts of proposed projects and programs on NNSS ecosystems and important plant and animal species. Provide fuels assessments to examine fire risk and monitor for the success of restoration programs.

The Ecological Monitoring and Compliance (EMAC) Program provides ecological monitoring and biological compliance support for activities and programs conducted at the NNSS. Major program activities include (a) biological surveys at proposed activity sites, (b) desert tortoise permit compliance, (c) ecosystem monitoring, (d) sensitive and protected/regulated plant species monitoring, (e) sensitive and protected/regulated animal monitoring, and (f) habitat restoration monitoring. Brief descriptions of these programs and their 2020 accomplishments are provided in this chapter. Detailed information may be found in the most recent annual EMAC report (Hall and Perry 2021). EMAC annual reports are available at http://www.nnss.gov/pages/resources/library/EMAC.html. The reader is also directed to *Attachment A: Site Description*, a separate file on the compact disc of this report, where the ecology of the NNSS is described.

13.1 Desert Tortoise Compliance Program

The Mojave Desert tortoise (*Gopherus agassizii*), hereinafter *tortoise*, which inhabits the southern one-third (544 square miles) of the NNSS (Figure 13-1), is listed as threatened under the federal Endangered Species Act. Activities conducted in tortoise habitat on the NNSS must comply with the terms and conditions of a Programmatic Biological Opinion (Opinion) issued to the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) by the U.S. Fish and Wildlife Service (FWS). On February 27, 2019, NNSA/NFO provided FWS with a Biological Assessment of anticipated activities on the NNSS from 2019 through 2029 and entered into a formal consultation with FWS to obtain an updated Opinion. NNSA/NFO received the new Opinion on August 27, 2019. The Opinion is effectively a permit to conduct activities in tortoise habitat in a specific manner. It authorizes the ***incidental take***[1] of tortoises that may occur during the activities, which, without the Opinion, would be illegal and subject to civil or criminal penalties.

The Opinion states that proposed NNSS activities are not likely to jeopardize the continued existence of the Mojave population. It sets limits for the acres of tortoise habitat that can be disturbed; the number of accidentally injured and killed tortoises; and the number of captured, displaced, and relocated tortoises (Table 13-1). It also establishes mitigation requirements for habitat loss. The focus of the Desert Tortoise Compliance Program is to implement the Opinion's terms and conditions, document compliance actions, and assist NNSA/NFO in continued FWS consultations.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

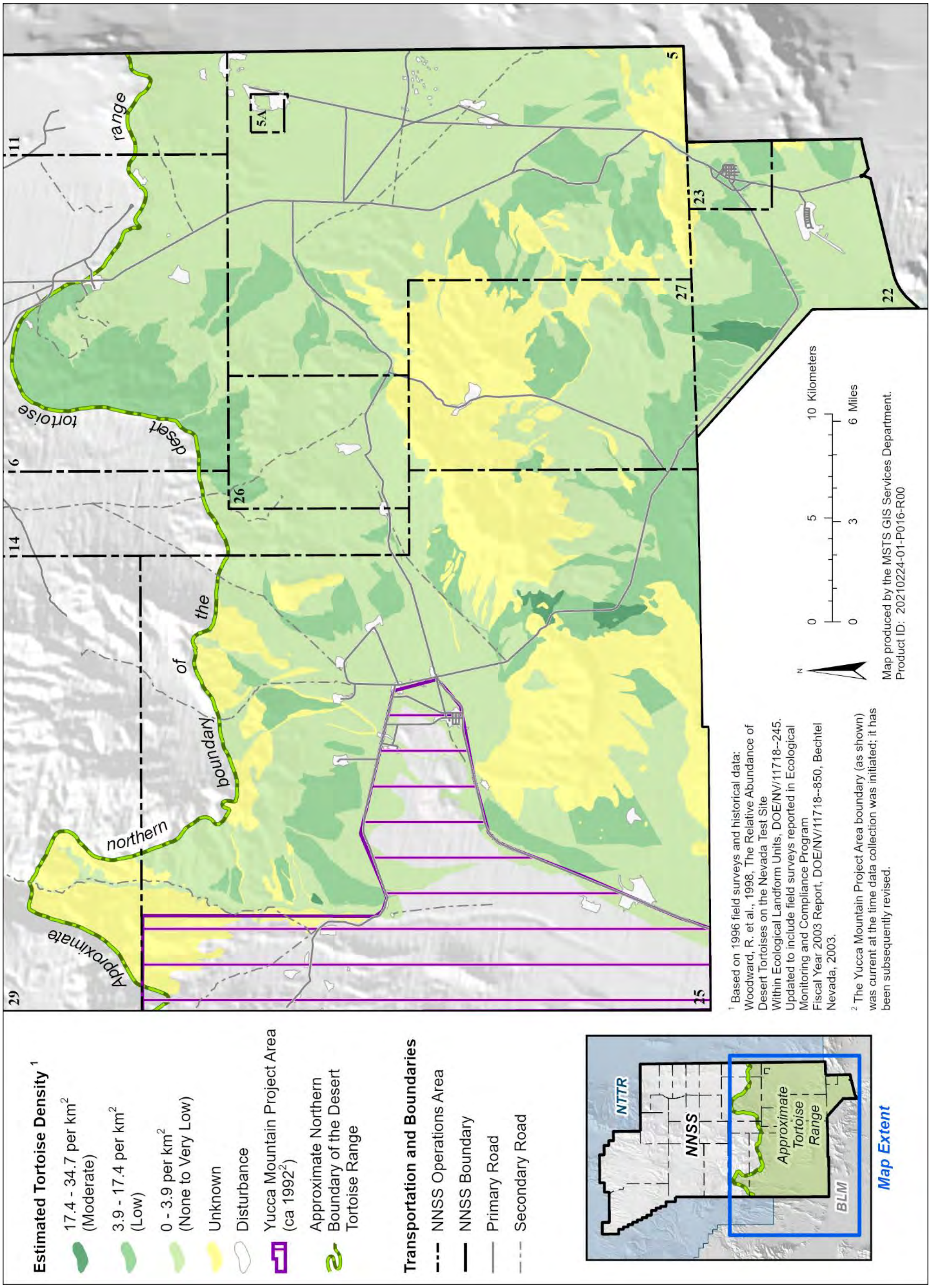

Figure 13-1. Tortoise distribution and abundance

13.1.1 Desert Tortoise Surveys and Compliance

Thirty-four projects occurring within the range of the tortoise were reviewed by biologists in 2020 and six projects in progress were carried over from previous years. Seventeen of the projects required a biological survey prior to start of the project, two projects that came to completion late in 2019 required a post-activity survey, two projects did not conduct activities in 2020, and the remaining nineteen projects were determined to have no impact to the tortoise (i.e., did not require surveys). These determinations were based on the amount of anticipated habitat disturbance, habitat quality, and location of projects (e.g., within developed versus undisturbed areas). Appropriate surveys were conducted to protect tortoises and no tortoises were reported injured or killed due to project activities. A total of 24.4 acres of tortoise habitat was disturbed in 2020.

Limits for the acres of tortoise habitat that can be disturbed; the number of accidentally injured and killed tortoises; and the number of captured, displaced, and relocated tortoises began on August 27, 2019, with the new Opinion (Table 13-1). The threshold level for moving tortoises safely off of NNSS roads was set at 350 for the term of the Opinion and includes only large tortoises (>180 millimeters [mm] in length). Small tortoises (≤180 mm in length) that are encountered will be reported to FWS but not counted toward the threshold due to their low detectability.

There were 41 reported tortoise roadside sightings during 2020 and one observation on the northbound onramp of the I95 Highway, an area managed by Nevada Department of Transportation. Thirty-two tortoises were determined to be in harm's way and moved off the road following FWS-approved protocol (11 tortoises ≤180 mm, 21 tortoises >180mm). The smallest tortoise moved off a road was 76 mm in length and it was moved off the 27-01 Road in November after a rainstorm (Figure 13-2). Of the 41 tortoises observed on NNSS roads, two were roadkills and one was a predation. The two roadkills were small (≤180mm); therefore, they did not count as incidental take, but were detected and reported to FWS.

In January 2021, NNSA/NFO submitted an annual report to the FWS Southern Nevada Field Office; the report summarizes tortoise compliance activities on the NNSS from January 1 through December 31, 2020.

Table 13-1. Cumulative totals and permit limits for tortoise habitat disturbance and take of large tortoises (>180 mm)

Program	Actual Number of Acres Impacted (Limit Allowed)	No. of Tortoises Incidentally Taken (Maximum Allowed)	
		Non-injury or Non-mortality [(a)]	Detected Injury or Mortality [(b)]
Continued Use of Existing Roads	NA	30 (350) [(c)]	0 (15) [(d)]
Defense	0.7 (500)	0 (10)	0 (2)
Waste Management	5.9 (250)	0 (10)	0 (2)
Environmental Restoration	0.0 (250)	0 (10)	0 (2)
Nondefense Research and Development	0.0 (1,000)	0 (20)	0 (4)
Work-for-Others	0.0 (500)	0 (20)	0 (2)
Infrastructure	17.8 (500)	0 (20)	0 (4)[(e)]
Totals by Permit Term	**24.4 (3,000)**	**30 (440)**	**0 (31)**
Totals for 2020	**24.4**	**21**	**0**

(a) All tortoises observed in harm's way may be moved to a safe location as outlined in the Opinion.
(b) The numbers in parentheses in this column represent triggers that if exceeded require reinitiation of the Opinion.
(c) No more than 35 non-injury/non-mortality tortoises in a given year. Going over this limit would require concurrence with the FWS.
(d) No more than 4 tortoises killed in a given year and no more than 15 killed during the term of the Opinion.
(e) No more than 2 tortoises killed in a given year and no more than 4 killed during the term of the Opinion.

Figure 13-2. Small tortoise moved off the 27-01 Road in November after a rainstorm (Photo by J.A. Perry, November 3, 2020)

13.1.2 Desert Tortoise Conservation Projects

Biologists continue to increase tortoise awareness by updating and increasing tortoise signage throughout the NNSS. In response to a small tortoise roadkill found last year at the Area 5 Radioactive Waste Management Complex, three new tortoise awareness signs were installed. The signs were placed at the three entrances to the facility. Biologists also began placing temporary signs on either side of the road at recent tortoise roadkill locations. Signs are left out for two weeks following a tortoise mortality to increase awareness.

As a recommendation from FWS, NNSS biologists implemented a study in 2019 of tortoise exposure to radiological sources or fallout from nuclear testing by opportunistically testing tortoise carcasses found on the NNSS for radionuclides. Carcasses are obtained from roadkills or found during the juvenile translocation study. Two roadkill carcasses were approved by FWS to be processed and tested in 2019. The only human-made radionuclide detected was Sr-90 (Strontium-90). This is a calcium analog that accumulates in bone. It is a fission product that can be measured around the world due to global fallout from past atmospheric weapons testing. The concentrations were detectable but very low and would not result in a dose exceeding limits set by the U.S. Department of Energy to protect biota. No carcasses were tested in 2020.

NNSS biologists are conducting two tortoise projects on the NNSS, approved by FWS. Field work for the roadside movements study was complete in 2018. The study tracked tortoise movement patterns for resident adult tortoises found along paved NNSS roads. The goals of the study were to determine patterns of habitat use near roads on the NNSS and assess the risk of road mortality. The second study involves monitoring the survival of 60 juvenile tortoises translocated to the NNSS in September 2012. Prior to their release, the tortoises were in the care of the San Diego Zoo Institute for Conservation Research at the Desert Tortoise Conservation Center located near Las Vegas, Nevada. NNSS biologists use radiotelemetry to track the location of study tortoises, record habitat characteristics and use, and collect other ecological data. Since 2013, NNSS biologists have conducted and supported these projects in lieu of the NNSS paying remuneration fees to FWS for habitat loss that may result from NNSS projects (i.e., all projects except for the Work for Others Program [also referred to as the Strategic Partnership Projects]).

The roadside movements study monitored a total of 30 tortoises (the maximum allowed by FWS) for a minimum of three active seasons (March through October) per individual. Each tortoise was affixed with a GPS [global positioning system] unit; an analysis of the data logged in these units will help NNSS and FWS understand tortoise use of roads and adjacent habitats and the risk of mortality or injury associated with that use. Preliminary results from the study are included in the 2018 EMAC report (Hall and Perry 2019) and 2020 EMAC report (Hall and Perry 2021). A more detailed topical report on the study is in progress.

Of the 60 juvenile tortoises released in 2012, 18 tortoises remain alive and continue to be monitored. Six tortoises (2 females, 4 males) were found dead during 2020. Four were assumed to be killed by canid predation, one from exposure, and one from an unknown cause. Monitoring of the remaining animals includes location tracking and annual health assessments. The tortoises had a good spring with winter and spring precipitation above average, creating an abundant, diverse community of native forbs available as food in the spring. However, the lack of summer and fall precipitation resulted in reduced foraging opportunities prior to hibernation. Tortoises grew an average of 2.6 mm in length (range = 0–12 mm) between spring and fall. This study will continue for the next several years and will provide valuable data for future juvenile desert tortoise translocations.

13.2 Biological Surveys at Proposed Project Sites

Biological surveys are performed at proposed project sites where project activities may have impacts to plants, animals, associated habitat, and other biological resources (e.g., the demolition of structures that may contain bird nests). The goal is to minimize the adverse effects to important biological resources (Section 13.3). Important biological resources include such things as cover sites, nest/burrow sites, roost sites, wetlands, or water sources that are vital to important species.

In 2020, biologists surveyed a total of 364 acres (ac) for 35 proposed projects on the NNSS. Although projects target previously disturbed areas (e.g., road shoulders, utility corridors), a total of 72 ac, including 3.8 ac of pristine habitat, 12.8 ac of sensitive habitat, and 4.9 ac of habitat considered unique and sensitive, were disturbed in 2020. The total area of disturbed important habitats has been tracked since 1999; totals to date are 27.2 ac (Pristine), 53.7 ac (Unique), 950.8 ac (Sensitive), and 215.1 ac (Diverse).

Important Habitat Categories

Pristine Habitat: having few human-made disturbances

Unique Habitat: containing uncommon biological resources such as a natural wetland

Sensitive Habitat: containing vegetation associations that recover very slowly from direct disturbance or are susceptible to erosion

Diverse Habitat: having high plant species richness

Important animal species and other biological resources observed included several predator burrows; western red-tailed skink (*Plestiodon gilberti rubricaudatus*) habitat; one active red-tailed hawk (*Buteo jamaicensis*) nest; cottontail rabbit (*Sylvilagus audubonii*); pronghorn antelope (*Antilocarpra americana*); burrowing owl (*Athene cunicularia*); and chukar (*Alectoris chukar*). Important plant species observed were *Camissonia megalantha* (Cane Spring suncup); Pahute Mesa beardtongue (*Penstemon pahutensis*); cacti, including one formerly on the NNSS sensitive plant list (*Grusonia pulchella*); yucca; and pine trees. In addition, pronghorn antelope, mule deer, burro, and horse sign were observed at several project sites. Biologists communicated to ground crews and provided written reports of survey findings and mitigation recommendations. Important biological resources within project sites were flagged, avoided, or removed.

13.3 Sensitive and Protected/Regulated Species and Ecosystem Monitoring

NNSA/NFO strives to protect and conserve sensitive plant and animal species found on the NNSS and to minimize cumulative impacts to those species as a result of NNSA/NFO activities. Important species known to occur on the NNSS include one mollusk, two reptiles, 241 birds, 23 mammals, 20 sensitive plants, and 23 plants protected from unauthorized collection. They are identified in Table A-10 of *Attachment A: Site Description*, included on the compact disc of this document. They are classified as important due to their sensitive, protected, and/or regulatory status with state or federal agencies, and they are evaluated for inclusion in long-term monitoring activities on the NNSS. NNSA/NFO has produced numerous documents reporting the occurrence, distribution, and susceptibility to threats for predominately sensitive species on the NNSS (Wills and Ostler 2001).

Field monitoring activities in 2020 related to important NNSS plants and animals and to ecosystem monitoring are listed in Table 13-2. A description of the methods and a more detailed presentation of the results of these activities are reported in Hall and Perry (2021).

Table 13-2. Activities conducted in 2020 for important species and ecosystem monitoring on the NNSS

Sensitive Plants (Table A-10 of *Attachment A: Site Description*)

The sensitive plant list for the NNSS is reviewed annually to include the appropriate species in the NNSS sensitive plant monitoring program. Along with this review in 2020, a review of plant rankings, past monitoring surveys, known and historical populations, and the database of the known sensitive plant species on the NNSS was completed. There were several updates to the NNSS sensitive plant monitoring program. Two cacti species were removed: Sand cholla (*Grusonia pulchella*) and Redspined fishhook cactus (*Sclerocactus polyancistrus*). Both species continue to be monitored and avoided during construction projects, as well as protected by the state from unauthorized collection. Nye milkvetch (*Astragalus nyensis*) was removed pending more surveys to confirm its occurrence on the NNSS. Two species were added after confirmed as occurring on the NNSS: Clokey's cryptantha (*Cryptantha clokeyi*) and Lahontan beardtongue (*Penstemon palmeri var. macranthus*). Currently there are 19 vascular plants and one non-vascular plant considered sensitive that warrant inclusion in the NNSS sensitive plant monitoring program.

The NNSS sensitive plant rankings, which were last evaluated in 2012, were revisited. Ranking criteria and associated numerical ratings can be found in Hall and Perry 2021. Four plants shifted rank: Sanicle biscuitroot (*Cymopterus ripleyi* var. *saniculoides*), Death Valley beardtongue (*Penstemon fruticiformis* ssp. *amargosae*), Clarke phacelia (*Phacelia filiae*), and Weasel phacelia (*Phacelia mustelina*). Sanicle biscuitroot is more widespread than originally known, which would account for its reduction from *moderate* ranking to *watch*. Death Valley beardtongue currently has one known remote location on the NNSS in the Striped Hills at the southern border of Area 25, with majority of its distribution off site and in California. With no threats on the NNSS, its ranking was reduced from *high* to *moderate*. Clarke phacelia is widespread throughout the southern portion of the NNSS with 62 monitoring locations within five populations. The plant is rarely encountered during NNSS activities, which justifies its reduction from *moderate* ranking to *watch*. Lastly, Weasel phacelia's ranking was changed from *marginal* to *watch*, simply due to the elimination of the *marginal* ranking.

Surveys in 2020 focused on several plants under evaluation, as well as long-term monitoring. Evaluation surveys for four plants occurred: Clokey's cryptantha, Lahontan beardtongue, Nye milkvetch, and Sand cholla. Clokey's cryptantha and Lahontan beardtongue were confirmed to occur on the NNSS. Nye milkvetch has not been found on the NNSS since 1995 and was not found in 2020. Information from surveys for Sand cholla from 2019 and 2020, as well as historical occurrences, led to the decision to remove it from the NNSS sensitive plant monitoring program.

Long-term monitoring surveys were conducted for seven plants: Cane Spring suncup (*Chylismia megalantha*), Clarke phacelia, Kingston Mountains bedstraw (*Galium hilendiae* ssp. *kingstonense*), Pahute Mesa beardtongue (*Penstemon pahutensis*), Sanicle biscuitroot, Weasel phacelia, and White bearpoppy (*Arctomecon merriamii*). A new population of Cane Spring suncup was identified at well pad ER 11-2 and surveyed, as well as two known populations revisited. Seeds were collected from Clarke phacelia from a known Rock Valley population, and another population in Rock Valley, which had not been visited since 1995, was revisited but no plants were found. A possible new population of Kingston Mountains bedstraw may have been identified on Yucca Mountain, but requires a revisit during the bloom season. A known population of Kingston Mountains bedstraw at Tub Springs was also surveyed. An expansion of a known population of Pahute Mesa beardtongue was identified during a pre-construction survey on Rainier Mesa. Two new locations of Sanicle biscuitroot in Rock Valley were identified, as well as a revisit to a known population in Rock Valley. Two new locations of Weasel phacelia were identified at the southern base of Skull Mountain and one population of White bearpoppy just north of Mercury was revisited. More detailed information can be found in Hall and Perry 2021.

Reptiles

No trapping or roadkill surveys were conducted in 2020. Opportunistic observations were documented.

Migratory Birds (protected under the Migratory Bird Treaty Act)

A total of 8 dead birds were documented on the NNSS in 2020, the lowest number of mortalities recorded since 2012. Five (4 red-tailed hawks [*Buteo jamaicensis*] and 1 common raven [*Corvus corax*]) were electrocuted, one prairie falcon (*Falco mexicanus*) and one unknown passerine were found dead from unknown causes, and one green-tailed towhee (*Pipilo chlorurus*) was euthanized after being severely injured from being stuck on a glue trap. No golden eagle (*Aquila chrysaetos*) deaths were documented.

Numerous poles were identified by NNSS biologists and the power group to install retrofits or reconfigure to make them avian-friendly. A total of 87 poles were retrofitted or reconfigured during 2020. A variety of retrofits were made, including installing insulator covers, conductor wire covers, and extending the length of the cross arms. In addition, the FWS issued a Special Purpose Utility permit to NNSA/NFO, which allows NNSS biologists to remove active nests at project sites in emergencies, and to possess and transport carcasses of golden eagles and other bird species. All permit conditions were met in 2020, and an annual report summarizing activities was submitted to FWS. In May, a red-tailed hawk nest with three chicks was successfully relocated from a hazardous location on an active pole to a new, artificial nest platform.

Two winter raptor survey routes were sampled in January and February; 24 raptor sightings, representing three species, were recorded. Surprisingly, no golden eagles were documented. Data were shared with the Nevada Department of Wildlife (NDOW) for their statewide monitoring effort.

Table 13-2. Activities conducted in 2020 for important species and ecosystem monitoring on the NNSS

The western burrowing owl (*Athene cunicularia*) is a National Species of Conservation Concern that has been declining in certain parts of its range for many years. Western burrowing owls have been studied on the NNSS since 1996 and much has been learned about their natural history and ecology on their summer range. Little is known about their migration ecology, including where they spend the winter, migration routes, and stopover sites. This type of information is important to understand threats to this species during migration and on their wintering range.

In June 2019, a collaborative study between NNSS biologists, Dr. Courtney Conway (United States Geological Survey [USGS], University of Idaho), and Carl Lundblad resulted in the capture of seven western burrowing owls. Transmitters were attached to each owl (Figure 13-3) and owl locations were monitored. Results from the fall migration revealed that three owls wintered in southern California, three in Baja, Mexico, and one presumably on the NNSS. Two owls with functional transmitters continued to be monitored in 2020. During spring migration, Male #180443 left southern California in late March and returned to the NNSS. He mated with a different female than in 2019 within 1.5 kilometers (km) of its 2019 capture location. He left the NNSS around mid-October and within a couple of weeks was back at the same location near the Salton Sea in southern California where he wintered in 2019. Male #180446 left its winter territory in Mexico in early April and ended up spending the summer of 2020 about 30 km northeast of Tonopah. His transmitter stopped working and it is unknown if the owl died or the transmitter failed.

Feral Horses (*Equus caballus*) (protected under the Wild and Free-Roaming Horses and Burros Act)

Horse monitoring during 2020 entailed opportunistic observations rather than focused surveys. At least 21 individual horses were observed, including three juveniles and five foals. Gold Meadows Spring and Camp 17 Pond continue to be valuable resources for these animals, especially during the hot, dry summer. A total of 3,644 and 1,716 photos of horses were recorded using a motion-activated camera at Gold Meadows Spring and Camp 17 Pond, respectively.

Mule Deer (*Odocoileus hemionus*) (managed as a game mammal by NDOW)

Mule deer surveys were conducted on Pahute and Rainier mesas, and the average number of deer counted was 37.0 deer/night, which is nearly double that of 19.8 deer per night in 2019. The observed buck/doe ratio was 63 bucks/100 does, one of the lowest ratios observed since 2006. The observed fawn/doe ratio was 17 fawns/100 does, which is lower than the average of 24 fawns/100 does observed since 2006.

Desert Bighorn Sheep (*Ovis canadensis nelsoni*) (managed as a game mammal by NDOW)

2020 monitoring of the NNSS sheep population was done by documenting sheep presence at several water sources using motion-activated cameras. Only 8 marked sheep (6 ewes, 2 rams) were documented in 2020, compared to 13 (8 ewes, 5 rams) the last 3 years. At least another 5 unmarked sheep were also observed in photos.

Sensitive Bats (see Table A-11 of *Attachment A: Site Description*)

Bat monitoring in 2020 was restricted to documenting roost sites in buildings.

NNSS biologists responded to seven reports of bats in NNSS buildings.

Mountain Lions (*Puma concolor*) (managed as a game mammal by NDOW)

A collaborative effort with USGS scientist Dr. Kathy Longshore continued in 2020 to investigate mountain lion distribution and abundance on the NNSS using remote, motion-activated cameras. Cameras collected a total of 148 photographs/video clips of mountain lions from nine of 26 camera sites. A minimum of four lions (one adult male, one adult female, and two subadults) inhabited the NNSS in 2020 based on photographic data.

Natural and Man-made Water Sources

Nine natural water sources, one well pond, five wildlife water troughs, and four well sumps that periodically retain tritium-contaminated groundwater discharged from monitoring wells (Chapter 5, Section 5.1.3) were monitored with motion-activated cameras to document wildlife use. Tritium-contaminated well sumps are monitored to identify which species are being exposed and which may provide an exposure pathway to offsite hunters who may consume them. Several species of birds, coyotes, and bats were photographed at the monitored well sumps.

Figure 13-3. Western burrowing owl with transmitter attached (Photo by D.B. Hall, June 17, 2019)

13.3.1 Mule Deer and Pronghorn Antelope Distribution

Mule deer and pronghorn antelope (*Antilocapra americana*) are mobile game animals that inhabit the NNSS. Both are generally considered to be migratory with distinct winter and summer ranges. Mule deer typically prefer the forested, mountainous habitats in the northern and western portions of the NNSS, while pronghorn typically prefer the open valleys in the southern and eastern portions of the NNSS. Mule deer are much more abundant than pronghorn on the NNSS. Mule deer movements on the NNSS were studied more than 30 years ago (Giles and Cooper 1985) using radio-collars that lacked the accuracy of current GPS radio-collars. They identified summer and winter ranges and a couple of long-distance movements of mule deer into areas where hunting is allowed on public land. Mule deer in their study were not necessarily those known to be using radioactively contaminated locations. Pronghorn are relatively new residents to the NNSS (first observed in 1991) and their use of the NNSS has never been studied. Tsukamoto et al. (2003) report the distribution of pronghorn in Nevada as of 2002 with the nearest population to the NNSS being just north in Emigrant Valley. The NNSS represents an expansion of pronghorn range in Nevada.

A research study funded by NNSA/NFO and the Environmental Management Nevada Program (EM Nevada) was initiated on the NNSS in November 2019 to better understand the potential radiological dose to the offsite public via the hunter pathway. This was a collaborative effort involving USGS, NDOW, the Nevada Test and Training Range, NNSS Management and Operating Contractor biologists, and several volunteers. Native Range Capture Services captured the animals. Study objectives include: 1) determine the distribution, abundance, and range of movements of mule deer and pronghorn, 2) estimate the potential for hunters to harvest animals that use the NNSS, 3) evaluate the animal's use of contaminated areas, 4) obtain information on the potential radiological dose to someone consuming animals from the NNSS, 5) determine the potential radiological dose to animals on the NNSS, 6) document survival and causes of mortality, 7) refine habitat use patterns for both mule deer and pronghorn using resource selection functions and correlate that with phenological changes in the vegetation, and 8) assess the overall health, disease status, and genetics of NNSS mule deer and pronghorn.

In November 2019, a total of 23 mule deer (16 does, 7 bucks) and 20 pronghorn (14 does, 6 bucks) were captured. All 23 mule deer were radio-collared and ear-tagged. Eighteen pronghorn (12 does, 6 bucks) were radio-collared and ear-tagged. Two pronghorn does died within a few days of capture and were killed or scavenged by coyotes (*Canis latrans*).

The remaining collared animals were monitored during 2020. Six pronghorn (3 bucks, 3 does) and 5 mule deer (2 buck, 3 does) were found dead. One pronghorn buck had been attacked by a mountain lion and the other 5 had either been killed by coyotes or scavenged by coyotes after dying from other causes. Two mule deer were killed by mountain lions, 1 buck was legally harvested by a hunter near Kawich Peak (90 km north of its capture location), and 2 were scavenged or killed by unknown predators. Pronghorn spent a majority of time in Frenchman Flat and Yucca Flat with no large seasonal migrations, although they remained close to water sources and shade during the hot, dry summer. Mule deer made seasonal migrations, migrating primarily off the high elevation portions of Rainier and Pahute mesas to lower-elevation areas in the CP Hills, Eleana Range, Pahute Mesa, and eastern slopes of Rainier Mesa. A buck and a doe migrated from their wintering areas in the Eleana Range and Pahute Mesa to spend the summer in the Kawich Peak area, a distance of nearly 90 km.

The distribution study will continue through 2022, at which time the GPS collars will automatically drop off the tracked animals. For more detailed information on capture method, health assessments, and distribution, refer to the EMAC (Hall and Perry 2020, 2021).

13.4 Habitat Restoration Program

The Habitat Restoration Program revegetates disturbances and evaluates previous revegetation efforts. Sites that have been revegetated are periodically monitored or sampled, and the information obtained is used to develop site-specific revegetation plans for future restoration efforts on the NNSS. Revegetation supports the intent of Executive Order E.O. 13112, *Invasive Species*, to prevent the introduction and spread of non-native species and restore native species to disturbed sites. Revegetation also may qualify as mitigation for the loss of desert tortoise habitat under the current Opinion. NNSA/NFO revegetation projects include lands disturbed in desert tortoise habitat, wildland fire sites, abandoned industrial or nuclear test support sites classified into Corrective Action Units (CAUs) that are remediated by EM Nevada, and EM Nevada soil closure covers (or cover caps) over closed waste disposal pits. Sites that have been revegetated are periodically sampled as needed to monitor success or identify further needed actions.

Activities conducted in 2020 included visually assessing the vegetation at the U-3ax/bl closure cover (CAU 110) (Area 3 Radioactive Waste Management Site) and the "92-Acre Area" (CAU 111) (Area 5 Radioactive Waste Management Complex [RWMC]), preparing for the revegetation of CAU577 East and West Cover Caps (Area 5 RWMC), and revegetating Cell 18 (Area 5 RWMC).

13.4.1 CAU 110, U-3ax/bl, Closure Cover

A qualitative assessment of the vegetation on CAU 110, U3-ax/bl closure cover was made on July 30, 2020. A meandering transect covering the entire cap was walked. The vigor of perennial plant species was assessed based on current year's growth, whether plants were flowering, and if any showed signs of stress, i.e., dead stems or leaves. Shadscale (*Atriplex confertifolia*) continues to be the most abundant shrub species on the closure cover (Figure 13-4). None of the plants observed showed signs of stress; however, some dead shadscale saltbush plants were noted. Flowering plants were uncommon because of the time of sampling. However, many of the shadscale plants were fruiting and had good seed production. Nevada jointfir (*Ephedra nevadensis*), the second most common perennial species, was doing well, although no evidence of seed production was observed. A few winterfat (*Krascheninnikovia lanata*) plants were also noted. No perennial plant seedlings were seen.

No perennial grasses have been found on the closure cover for several years and none were found again this year. Annual plant cover was moderate with abundant cheatgrass (*Bromus tectorum*) growing amongst the shadscale and Nevada jointfir plants. This will be tracked in future years to help ensure it doesn't negatively impact shrub survival. Some native annual forbs, cushion crypantha (*Crypantha circumscissa*) and flatcrown buckwheat (*Eriogonum deflexum*), were growing in the shrub interspaces. Saltlover (*Halogeton glomeratus*) and prickly Russian thistle (*Salsola tragus*) were found in small numbers on the cover cap but were the dominant species, along with flatcrown buckwheat, on the unseeded portion on the periphery of the cover cap, highlighting the importance of seeding to establish a perennial vegetation community.

During the vegetation surveys, small mammal activity on the CAU 110, U-3ax/bl closure cover was evaluated. Several burrow complexes were noted but not counted. Many of the burrows were inactive. A small mammal trapping effort for another project revealed a pattern of low numbers of small mammals on the cover cap. The number of burrows on the cover cap is far less than in the native undisturbed areas in Yucca Flat. Trapping for small mammal removal is not recommended at this time. No rabbits were observed or evidence of herbivory on the vegetation. One passerine bird was observed on the cover cap.

Figure 13-4. Plant community established on the U3ax/bl cover cap (Photo by D.B. Hall, July 30, 2020)

13.4.2 CAU 111, 92-Acre Area, Closure Covers

A qualitative assessment of vegetation at the 92-Acre Area on July 30, 2020, found very few perennial plants on any of the cover caps. There were about 20 large fourwing saltbush (*Atriplex canescens*) plants on the North South Cover. These plants were from the prior revegetation efforts that had survived the extensive rabbit herbivory before the site was fenced.

Overall the integrity of the cover caps was very good. Weed densities were pretty high due to the abundant precipitation earlier in the spring and early summer with saltlover, Arabian schismus, and prickly Russian thistle being the most common species (Figure 13.5). No rabbits or fresh rabbit sign were observed. Light rodent burrowing activity was detected.

Figure 13-5. North Cover on the "92-Acre Area" with an abundance of weeds, primarily saltlover, Arabian schismus, and prickly Russian thistle (Photo by D.B. Hall, July 30, 2020)

13.4.3 CAU 577 East and West Cover Cap Revegetation Preparation

During 2020, several actions were taken to prepare for the revegetation of CAU 577 East and West Cover Caps (respectively, 12.9 ac, or 5.2 hectares [ha]; and 17.2 ac, or 7.0 ha). These included procuring commercial seed; collecting white bursage (*Ambrosia dumosa*), creosote bush (*Larrea tridentata*), desert pepperweed (*Lepidium fremontii*) and desert globemallow (*Sphaeralcea ambigua*) seed at the NNSS to include in the seedmix and for growing the transplants; contributing to the design of the wheel line irrigation system; overseeing the writing of the revegetation plan; and providing input to Procurement in setting up the revegetation subcontracts.

13.4.4 Area 5 RWMC, Cell 18 Revegetation

Revegetation of the Cell 18 Cover Cap was initiated in late October. First, the site was ripped to a depth of 30–45 centimeters (cm) using a low, load-bearing bulldozer with a ripper bar. Then a wildland seedmix of native species (7 shrubs, 2 grasses, 3 forbs) was broadcast seeded over the site with a drill seeder at a rate of 30 pounds of pure live seed per acre. Seed was lightly covered using a custom chain harrow dragged behind the seeder (Figure 13-6).

Figure 13-6. Seeding Cell 18 Cover Cap with chain harrow to cover the seed
(Photo by D.B. Hall, October 22, 2020)

Following seeding, a straw mulch plus soil binder product (HydroStraw Guar Plus Formulation) was applied over the site (Figure 13-7) at a rate of 2,240 kilograms/ha for soil moisture retention, organic matter additive, and erosion control. Then a wheel line irrigation system (Figure 13-8) was installed at the site to apply the supplemental water. A total of 5 cm of irrigation was applied over the whole site in November to moisten the soil profile as deep as possible to recharge the water content in the soil profile so the roots of germinated seed had moist soil to grow into. The soil profile was extremely dry due to drought conditions, with little to no precipitation at the site since April. Another 2.5 cm was applied in early December to provide a moist chill to break dormancy of certain species like shadscale.

The Nevada Division of Forestry nursery is growing about 4,000 plants (~2,000 white bursage, ~2000 creosote bush) to be transplanted at Cell 18 in April 2021. These plants were seeded with seed collected from Area 5 in 2019. Additional irrigation is planned at the site for germination irrigation in the spring and seedling density counts will be made to assess revegetation progress in late spring.

Figure 13-7. Applying hydromulch at the Cell 18 Cover Cap
(Photo by D.B. Hall, October 26, 2020)

Figure 13-8. Irrigating with wheel line irrigation system at Cell 18 Cover Cap
(Photo by D.B. Hall, October 29, 2020)

13.5 Wildland Fire Hazard Assessment

An NNSS Wildland Fire Management Plan requires the protection of site resources from wildland and operational fires. An annual vegetation survey to determine wildland fire hazards is conducted on the NNSS each spring. Survey findings are submitted to the NNSS Fire Marshal and summarized in the annual EMAC report (Hall and Perry 2021). Between April and June 2020, NNSS biologists visited sampling stations to assess a fuel index that can range from 0 to 10 (lowest to highest risk of wildfires). The mean combined fuels index (which includes both fine [non-woody] and woody fuels) for all sampling stations was 5.13, which represented above-average fuels and increased wildland fire potential. Due to the above-average precipitation received during winter/spring 2019–20, production of annual grasses was high and annual forb production was moderate. Production of perennial herbaceous grasses and forbs was also moderate.

Five wildland fires were reported on the NNSS in 2020. The largest of these, named the Area 16 Fire, started in late July, from a lightning strike. It burned about 3,149 ac in Area 16 and Area 1, primarily in the Blackbrush-Nevada jointfir shrubland association. The other four fires were caused by lightning (one), electrocuted raptor (one), and manmade activities (two) but were all small, <0.25 ac in size. These fires were extinguished by NNSS Fire and Rescue personnel or carefully monitored until they burned out.

13.6 References

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Chapter 14: Quality Assurance Program

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Required Criteria of a Quality Program
• Quality assurance program • Personnel training and qualification • Quality improvement process • Documents and records • Established work processes • Established standards for design and verification • Established procurement requirements • Inspection and acceptance testing • Management assessment • Independent assessment

The environmental monitoring work conducted for the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) and the Environmental Management (EM) Nevada Program is performed in accordance with the Quality Assurance Program (QAP) established by the current Management and Operating (M&O) Contractor, Mission Support and Test Services, LLC (MSTS), or with the Underground Test Area (UGTA) QAP implemented by Navarro Research and Engineering, Inc. (Navarro). The QAPs describe the methods used to ensure quality is integrated into monitoring work, and to comply with Title 10 ***Code of Federal Regulations***[1] Part 830, Subpart A, "Quality Assurance Requirements," and with U.S. Department of Energy (DOE) Order DOE O 414.1D, "Quality Assurance." The 10 criteria of a quality program specified by these regulations are shown in the box above. The QAPs require a graded approach to quality for determining the level of rigor that effectively provides assurance of performance and conformance to requirements.

A Data Quality Objective (DQO) process is cited by most organizations as the planning approach used to ensure that environmental data collection activities produce the appropriate data needed for decision-making. Sampling and Analysis Plans are developed prior to performing an activity to ensure complete understanding of the data-use objectives. Personnel are trained and qualified in accordance with company- and task-specific requirements. Access to sampling locations is coordinated with organizations conducting work at or having authority over those locations in order to avoid conflicts in activities and to communicate hazards to better ensure successful execution of the work and protection of the safety and health of sampling personnel. Sample collection activities adhere to organization instructions and/or procedures designed to ensure that samples are representative and data are reliable and defensible. Sample shipments on site and to offsite laboratories are conducted in accordance with U.S. Department of Transportation and International Air Transport Association regulations, as applicable. ***Quality control (QC)*** in the analytical laboratories is maintained through adherence to standard operating procedures based on methodologies developed by nationally recognized organizations such as DOE, the Environmental Protection Agency (EPA), and ASTM International. Key quality-affecting procedural areas cover sample collection, preparation, instrument calibration, instrument performance checking, testing for precision and accuracy, obtaining a measurement, and laboratory data review. Data users perform reviews as required by the project-specific objectives before the data are used to support decision-making.

The key elements of the environmental monitoring process workflow are listed below. Each element is designed to ensure that applicable ***quality assurance (QA)*** requirements are implemented. A discussion of these elements follows.

- A **Sampling and Analysis Plan** (SAP) is developed consistent with a DQO process to ensure clear goals and objectives are established for the environmental activity. The SAP is implemented in accordance with EPA, DOE, and other requirements addressing environmental, safety, and health objectives.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

- **Environmental Sampling** is performed in accordance with the SAP, procedures, and site work controls to ensure defensibility of the resulting data products as well as protection of the worker and the environment.
- **Laboratory Analyses** are performed to ensure the resultant data meet DOE, MSTS (the current M&O Contractor), and UGTA regulation-defined requirements.
- **Data Review** ensures the SAP DQOs have been met, and determines whether the data are suitable for their intended purpose.
- **Assessments** ensure monitoring operations are conducted according to procedure and analytical data quality requirements are met in order to identify nonconforming items, investigate causal factors, implement corrective actions, and monitor for corrective action effectiveness.

14.1 Sampling and Analysis Plan

Sampling is specifically mandated to demonstrate compliance with a variety of requirements, including federal and state regulations and DOE orders and standards. Developing the SAP using the DQO approach ensures those requirements are considered in the planning stage. The following statistical concepts and controls are vital in designing and evaluating the system design and implementation.

14.1.1 Precision

Precision is the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Precision is a data quality indicator and is usually expressed as standard deviation, variance, or range, in either absolute or relative terms (EPA 2021).

In practice, precision is determined by comparing the results obtained from performing analyses on split or duplicate samples taken at the same time from the same location or locations very close to one another, maintaining sampling and analytical conditions as nearly identical as possible.

14.1.2 Accuracy

Accuracy refers to the degree of agreement between an observed value and an accepted reference value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations. Accuracy is a data quality indicator (EPA 2021) and is monitored by performing measurements and evaluating results of control samples containing known quantities of the ***analytes*** of interest.

14.1.3 Representativeness

Representativeness is the degree to which measured analytical concentrations represent concentrations in the medium being sampled (Stanley and Verner 1985).

At each point in the sampling and analysis process, samples of the medium of interest are obtained. The challenge is to ensure each sample maintains the character of the larger population being sampled. From a field sample collection standpoint, representativeness is managed through sampling plan design and execution. Sampling locations are/have been determined historically by consensus and/or agreement with authorities, in many cases, or are determined based on the properties of the operation being monitored (such as environmental remediation).

Representativeness related to laboratory operations addresses the ability to appropriately subsample and characterize for analytes of interest. For example, to ensure representative characterization of a heterogeneous matrix (soil, sludge, solids, etc.), the sampling and/or analysis process should evaluate whether homogenization or segregation should be employed prior to sampling or analysis. Water samples are generally considered homogeneous unless observation suggests otherwise. Each air monitoring station’s continuous operation at a fixed location results in representatively sampling the ambient atmosphere. Field sample duplicate analyses are additional controls allowing evaluation of representativeness and heterogeneity; these are employed for air monitoring and direct radiation monitoring measurements. Generally, monitoring measurements are compared with historical measurements at the same location.

14.1.4 Comparability

Comparability refers to "the confidence with which one data set can be compared to another" (Stanley and Verner 1985). Comparability from an overall monitoring perspective is ensured by consistent execution of the sampling design for sample collection and handling, laboratory analyses, and data review and through adherence to established procedures and standardized methodologies. Ongoing data evaluation compares data collected at the same locations from sampling events conducted over multiple years and produced by numerous laboratories to detect any anomalies that might occur.

14.1.5 Completeness

Completeness refers to "the amount of valid data obtained compared to the planned amount" (EPA 2016). Field operations completeness is a measure of the number of samples collected that are valid for further processing (e.g., field measurements, laboratory analyses) versus the number of samples planned. Field measurements completeness compares the number of valid measurements obtained compared to those planned. Laboratory analyses completeness is a measure of the number of valid measurements compared to the total number of measurements planned. Data use completeness is a measure of the number of results determined to be valid for their intended use compared to the number of results planned.

14.2 Environmental Sampling

Environmental samples are collected in support of various environmental programs. Each program executes field-sampling activities in accordance with the SAP to ensure usability and defensibility of the resulting data. The key elements supporting the quality and defensibility of the sampling process and products include the following:

- Training and qualification
- Procedures and methods
- Field documentation
- Inspection and acceptance testing

14.2.1 Training and Qualification

The environmental programs ensure that personnel are properly trained and qualified prior to doing the work. In addition to procedure-specific and task-specific qualifications for performing work, training addresses environment, safety, and health aspects for protection of workers, the public, and the environment. Recurrent training is also conducted as appropriate to maintain proficiency.

14.2.2 Procedures and Methods

Sampling is conducted in accordance with established procedures to ensure consistent execution and continuous comparability of the environmental data. Descriptions of the analytical methods to be used are also consulted to ensure that, as methods are revised, sample collection is performed appropriately and viable samples are obtained.

14.2.3 Field Documentation

Field documentation is generated for each sample collection activity. This may include chain of custody documentation, sampling procedures, analytical methods, equipment and data logs, maps, Safety Data Sheets, and other materials needed to support the safe and successful execution and defense of the sampling effort. Chain-of-custody practices are employed from point of generation through disposal (cradle-to-grave); these are critical to the defensibility of the decisions made as a result of the sampling and analysis. Sampling data and documentation are stored and archived so they are readily retrievable for use later. In many cases, the data are managed in electronic data management systems. Routine assessments or surveillances are performed to ensure that sampling activities are performed in accordance with applicable requirements. If deficiencies are noted, then causal factors are determined, corrective actions are implemented, and follow-up assessments are performed to ensure effective resolution. Field data log notes are reviewed as a first step in data evaluation. This data management approach ensures the quality and defensibility of the decisions made using analytical environmental data.

14.2.4 Inspection and Acceptance Testing

Sample collection data are reviewed for appropriateness, accuracy, and fit with historical measurements. In the case of groundwater sampling, water quality parameters are monitored during purging. Stabilization of these parameters generally indicates that the water is representative of the ***aquifer***, at which time sample collection may begin. After a sampling activity is complete, data are reviewed to ensure the samples were collected in accordance with the SAP. Samples are further inspected to ensure that their integrity has not been compromised, either physically (leaks, tears, breakage, custody seals) or administratively (labeled incorrectly), and that they are valid for supporting the intended analyses. If concerns are raised at any point during collection, the data user, in consideration of data usability, is consulted for direction on proceeding with or canceling the subsequent analyses.

14.3 Laboratory Analyses

Samples are transported to a laboratory for analysis. Several DOE contractor organizations maintain measurement capabilities that may be used to support planning or decision-making activities. However, unless specifically authorized by NNSA/NFO, the EM Nevada Program, or the regulator, data used for demonstrating regulatory compliance are generated by a DOE- and contractor-qualified laboratory whose services have been obtained through subcontracts. Ensuring the quality of procured laboratory services is accomplished through focus on three specific areas: (1) procurement, (2) initial and continuing assessment, and (3) data evaluation.

14.3.1 Procurement

Laboratory services are procured through subcontracts in accordance with the Competition in Contracting Act, the Federal Acquisition Regulations, the DOE Acquisition Regulations, contractor terms and conditions for subcontracting, and other relevant policies and procedures. The analytical services technical basis is codified in the Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories (DOE 2019). The QSM is based on Volume 1 of The NELAC [National Environmental Laboratory Accreditation Conference] Institute Standards (September 2009), which incorporates International Organization for Standards (ISO)/International Electrotechnical Commission (IEC) 17025:2005, "General requirements for the competence of testing and calibration laboratories," and ISO/IEC 17025:2017. Subcontracted laboratories are assessed to comply with the QSM and are audited by the DoD Environmental Laboratory Accreditation Program Accreditation Bodies and the DOE Consolidated Audit Program – Accreditation Program (DOECAP-AP) Accreditation Bodies.

A request for proposal (RFP) is posted to the government website, laboratory responses are evaluated, and subcontracts awarded. The RFP cites the QSM as the base technical requirement, participation in the DOECAP-AP is required or advised, and addresses site-specific conditions. Multiple laboratories may receive a subcontract through one RFP.

The laboratories are primarily those providing a wide range of analytical services to DOE. Other services can be subcontracted by the laboratory (i.e., lower-tier subcontractor) or contracted directly from a vendor. In either case, requirements are established for the specific services provided.

The subcontract places numerous requirements on the laboratory, including the following:

- Maintaining the following documents:
  - A Quality Assurance Plan and/or Manual describing the laboratory's policies and approach to the implementation of QA requirements
  - An Environment, Safety, and Health Plan
  - A Waste Management Plan
  - Procedures pertinent to subcontract scope

- The ability to generate data deliverables, both hard copy reports and electronic files
- Responding to all data quality questions in a timely manner
- Mandatory participation in proficiency testing programs
- Maintaining specific licenses, accreditations, and certifications
- Conducting internal audits of laboratory operations as well as audits of vendors
- Allowing external audits by DOECAP-AP, EM Nevada Program, and NNSA/NFO contractors and providing copies of other audits considered to be comparable and applicable

14.3.2 Initial and Continuing Assessment

An initial assessment is made during the RFP process, including a pre-award audit. If an acceptable audit has not been performed within the past year, MSTS or Navarro will consider performing an audit (or participating in a DOECAP-AP audit) of those laboratories awarded the contract. Neither contractor will initiate work with a laboratory without authorized approval from those personnel responsible for ensuring vendor acceptability.

A continuing assessment consists of the ongoing monitoring of a laboratory's performance against contract terms and conditions, of which the technical specifications are a part. Tasks supporting continuing assessment are listed below:

- Conducting regular audits or participating in evaluation of DOECAP-AP audit products
- Monitoring for continued successful participation in proficiency testing programs such as:
  - National Institute of Standards and Technology Radiochemistry Intercomparison Program
  - Studies that support certification by the State of Nevada or appropriate regulatory authority for analyses performed in support of routine monitoring
- Routine ongoing monitoring of the laboratory's adherence to the quality requirements

14.3.3 Data Evaluation

Data products are routinely evaluated for compliance with contract terms and specifications. This primarily involves review of the laboratory data against the specified analytical method to determine the laboratory's ability to adhere to the QA/QC requirements, as well as an evaluation of the data against the DQOs. This activity is discussed in further detail in Section 14.4. Any discrepancies are documented and resolved with the laboratory, and ongoing assessment tracks the recurrence and efficacy of corrective actions.

14.4 Data Review

A systematic approach to thoroughly evaluating the data products generated from an environmental monitoring effort is essential for understanding and sustaining the quality of data collected under the program. This allows the programs to determine whether the DQOs established in the planning phase were achieved and whether the monitoring design performed as intended or requires review.

Because decisions are based on environmental data, and the effectiveness of operations is measured at least in part by environmental data, reliable, accurate, and defensible records are essential. Detailed records that must be kept include temporal, spatial, numerical, geotechnical, chemical, and radiological data as well as all sampling, analytical, and data review procedures used. Failure to maintain these records in a secure but accessible form may result in exposure to legal challenges and the inability to respond to demands or requests from regulators and other interested organizations.

An electronic data management system is a key tool used by many programs for achieving standardization and integrity in managing environmental data. The primary objective is to store and manage in an easily and efficiently retrievable form unclassified environmental data that are directly or indirectly tied to monitoring events. This may include information on monitoring system construction (groundwater wells, ambient air monitoring), and analytical, geotechnical, and field parameters at the Nevada National Security Site. Database integrity and security are enforced through the assignment of varying database access privileges commensurate with an employee's database responsibilities.

14.4.1 Data Verification

Data verification generally involves a subcontract compliance and completeness review to ensure that all laboratory data and sample documentation are present and complete. Additional critical sampling and analysis process information is also reviewed at this stage, which may include, but is not limited to, sample preservation and temperature, defensible chain-of-custody documentation and integrity, and analytical hold-time compliance. Data verification also ensures that electronic data products correctly represent the sampling and/or analyses performed, and includes evaluation of QC sample results.

14.4.2 Data Validation

Data validation supplements verification and is a more thorough process of analytical data review to better determine if the data meet the analytical and project requirements. Data validation ensures that the reported results correctly represent the sampling and analyses performed, determines the validity of the reported results, and assigns data qualifiers (or "flags"), if required.

14.4.3 Data Quality Assessment (DQA)

DQA is a scientific and statistical evaluation to determine if the data obtained from environmental operations are of the right type, quality, and quantity to support their intended use. The DQA includes reviewing data for accuracy, representativeness, and fit with historical measurements to ensure that the data will support their intended uses.

14.5 Assessments

The overall effectiveness of the environmental program is determined through routine surveillance and assessments of work execution as well as review of program requirements. Deficiencies are identified, causal factors are investigated, corrective actions are developed and implemented, and follow-on monitoring is performed to ensure effective resolution. The assessments discussed below are broken down into general programmatic and focused measurement data areas.

14.5.1 Programmatic

Assessments and audits under this category include evaluations of work planning, execution, and performance activities. Personnel independent of the work activity perform the assessments to evaluate compliance with established requirements and report on deficiencies identified. Organizations responsible for the activity are required to develop and implement corrective actions, with the concurrence of the deficiency originator or recognized subject matter expert. NNSA/NFO contractors maintain companywide issues tracking systems to manage assessments, findings, and corrective actions.

14.5.2 Measurement Data

This type of assessment includes routine evaluation of data generated from analyses of QC and other samples. QC sample data are used to monitor the analytical control on a given batch of samples and are indicators over time of potential biases in laboratory performance. Discussions of the 2020 results for field duplicates, laboratory control samples, blank analyses, matrix spikes, and proficiency testing programs are provided, and summary tables are included below.

14.5.2.1 Field Duplicates

Samples obtained at nearly the same locations and times as initial samples are termed field duplicates. These are used to evaluate the overall precision of the measurement process, including small-scale heterogeneity in the matrix (air, water, or direct radiation) being sampled as well as analytical and sample preparation variation. The absolute relative percent difference (RPD) compares the absolute difference of initial and field duplicate measurements with the average of the two measurements (Table 14-1, footnote c); it is computed only from pairs for which both values are above their respective ***minimum detectable concentrations (MDCs)*** (or MDC + 2σ uncertainty for UGTA water samples). The relative error ratio (RER) compares the absolute difference of initial and field duplicate measurements to the laboratory's reported analytical uncertainty (Table 14-1, footnote d).

The average absolute RPD and average RER values for all 2020 radiological air and water duplicate pairs are shown in Table 14-1. They are similar to those seen in prior years. The higher average absolute RPDs (those greater than ~30) are associated with two types of phenomena. RPDs for ***actinides*** in air, in particular, and consequently for ***gross alpha*** in air, can be elevated when one sampler of a pair intercepts a particle with high americium (Am) or plutonium (Pu), while the other sampler in the pair had a typical ***background*** value. Also, higher average absolute RPDs can be associated with relatively few pairs having both values above their MDCs, as low-level measurements are typically relatively "noisier" than higher-level measurements.

Table 14-1. Summary of field duplicate samples for 2020

Analyte	Matrix	Number of Duplicate Pairs[(a)]	Number of Pairs > MDC[(b)]	Average Absolute RPD[(c)]	Average Absolute RER[(d)]
Environmental Monitoring Samples					
Gross Alpha	Air	52	31	18.0	0.71
Gross Beta	Air	52	52	7.2	1.19
Tritium	Air	53	11	12.5	0.57
^{241}Am	Air	8	0	–	1.03
^{238}Pu	Air	8	1	97.1	0.65
$^{239+240}$Pu	Air	8	1	68.0	1.28
$^{233+234}$U	Air	4	4	4.7	0.34
$^{235+236}$U	Air	4	2	27.6	1.05
^{238}U	Air	4	4	5.1	0.38
^{7}Be[(e)]	Air	8	8	7.8	0.97
^{137}Cs	Air	8	0	–	1.43
^{40}K[(e)]	Air	8	4	30.6	0.94
Gross Alpha	Water	10	9	21.3	1.16
Gross Beta	Water	10	10	16.1	0.90
Tritium (standard)	Water	20	1	5.2	0.63
TLD	Ambient Radiation	440	NA	2.5	0.24
UGTA Samples					
Gross Alpha	Water	3	2	32.7	1.23
Gross Beta	Water	3	3	13.2	0.66
Tritium (standard)	Water	9	6	2.6	0.28
Tritium (low-level)	Water	3	1	23	0.96

(a) Represents the number of field duplicates reported for evaluating precision.

(b) Represents the number of field duplicate–field sample pairs with both values above their MDCs or MDC + 2σ (UGTA). If either the field sample or duplicate was below the MDC (+ 2σ), the RPD was not determined. This does not apply to ***thermoluminescent dosimeter (TLD)*** measurements; because TLDs virtually always detect ambient background radiation, MDCs are not computed.

(c) Represents the average absolute RPD calculated as follows:

$$Absolute\ RPD = \frac{|S - D|}{(D + S)/2} \ X \ 100$$

Where: S = Sample result
D = Duplicate result

(d) Represents the absolute RER, determined by the following equation, which is used to determine whether a sample result and the associated field duplicate result differ significantly when compared to their respective 1 sigma uncertainties (i.e., measurement standard deviation). The RER is calculated for all sample and field duplicate pairs reported, without regard to the MDC.

$$Absolute\ RER = \frac{|S - D|}{\sqrt{(SD_S)^2 + (SD_D)^2}}$$

Where: S = Sample result
D = Duplicate result
SDs Standard deviation of the sample result as reported
SDD = Standard deviation of the duplicate result as reported

(e) ^{7}Be and ^{40}K are naturally occurring analytes included for quality assessment of the gamma ***spectroscopy*** analyses.

14.5.2.2 Laboratory Control Samples (LCSs)

An LCS is prepared from a sample matrix verified to be free from the analytes of interest, and then spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes. The LCS is generally used to establish intra-laboratory or analyst-specific precision and bias or to assess the performance of all or a portion of the measurement system (DOE 2019).

The results are calculated as a percentage of the true value (i.e., percent recovery), and must fall within established control limits to be considered acceptable. If the LCS recovery falls outside control limits, evaluation for potential sample data bias is necessary. The numbers of the 2020 LCSs analyzed and within control limits are summarized in Table 14-2. There were no systemic issues identified in 2020 by LCS recovery data, and no failures that invalidated the associated sample data.

Table 14-2. Summary of laboratory control samples for 2020

Analyte	Matrix	Number of LCS Results Reported	Number Within Control Limits	Control Limits (%)
Environmental Monitoring Samples				
Tritium	Air	102	102	75–125
^{60}Co	Air	5	5	75–125
^{137}Cs	Air	5	5	75–125
$^{239+240}$Pu	Air	9	9	75–125
^{241}Am	Air	13	13	75–125
Gross alpha	Water	12	12	75–125
Gross beta	Water	12	12	75–125
Tritium (standard)	Water	13	13	75–125
^{60}Co	Water	0	0	75–125
^{90}Sr	Water	0	0	75–125
^{137}Cs	Water	0	0	75–125
$^{239+240}$Pu	Water	0	0	75–125
^{241}Am	Water	0	0	75–125
Tritium	Soil	2	2	75–125
^{60}Co	Soil	1	1	75–125
^{90}Sr	Soil	0	0	75–125
^{137}Cs	Soil	1	1	75–125
$^{239+240}$Pu	Soil	1	1	75–125
^{241}Am	Soil	1	1	75–125
^{60}Co	Vegetation	10	10	75–125
^{90}Sr	Vegetation	10	8	75–125
^{137}Cs	Vegetation	10	10	75–125
$^{239+240}$Pu	Vegetation	12	12	75–125
^{241}Am	Vegetation	22	22	75–125
Metals	Water	128	128	80–120
Volatiles	Water	88	86	70–130
Semi volatiles	Water	259	253	Laboratory specific
Miscellaneous	Water	91	91	80–120
Metals	Soil	0	0	80–120
Volatiles	Soil	0	0	70–130

Table 14-2. Summary of laboratory control samples for 2020

Analyte	Matrix	Number of LCS Results Reported	Number Within Control Limits	Control Limits (%)
Semi volatiles	Soil	5	5	Laboratory specific
Miscellaneous	Soil	0	0	80–120
UGTA Samples				
Gross alpha	Water	9	9	80-120
Gross beta	Water	9	9	80-120
Tritium (standard)	Water	7	7	80-120
Tritium (low-level)	Water	3	3	75-125

14.5.2.3 Blank Analysis

In general, a blank is a sample that has not been exposed to the targeted environment and is analyzed in order to monitor "no exposure" analyte levels and contamination that might be introduced during sampling, transport, storage, or analysis. The blank is subjected to the usual analytical and measurement process to establish a baseline or background value, and is sometimes used to adjust or correct routine analytical results (DOE 2019). Blanks are processed simultaneously with and under the same conditions as samples through all steps of the analytical procedures. The following list identifies the blanks routinely used during environmental monitoring activities.

- A trip blank is a sample of analyte-free media taken from the laboratory to the sampling site and returned to the laboratory unopened. A trip blank is used to document contamination attributable to shipping and field handling procedures. This type of blank is useful in documenting contamination of volatile organics samples.
- An equipment blank is a sample of analyte-free media that has been used to rinse common sampling equipment to check effectiveness of decontamination procedures.
- A field blank is prepared in the field by filling a clean container with purified water (appropriate for the target analytes) and appropriate preservative, if any, for the specific sampling activity being undertaken. The field blank is used to indicate the presence of contamination due to sample collection and handling.
- A method blank is a sample of a matrix similar to the associated sample batch in which no target analytes or interferences are present at concentrations that would impact the sample analyses results. Method blank data are summarized in Table 14-3.

There were no systemic issues and no failures that required invalidating the associated sample data identified in 2020 by the blank data.

Table 14-3. Summary of laboratory method blank samples for 2020

Analyte	Matrix	Number of Blank Results Reported	Number of Results < MDC
Environmental Monitoring Samples			
Tritium	Air	75	74
^{7}Be	Air	5	5
^{60}Co	Air	3	3
^{137}Cs	Air	5	5
^{238}Pu	Air	6	6
$^{239+240}$Pu	Air	6	6
^{241}Am	Air	7	7
Gross alpha	Water	12	12
Gross beta	Water	12	12
Tritium (standard)	Water	13	13
^{60}Co	Water	0	0
^{90}Sr	Water	0	0
^{137}Cs	Water	0	0
^{238}Pu	Water	0	0
$^{239+240}$Pu	Water	0	0
^{241}Am	Water	0	0

Table 14-3. Summary of laboratory method blank samples for 2020

Analyte	Matrix	Number of Blank Results Reported	Number of Results < MDC
Tritium	Soil	1	1
^{60}Co	Soil	1	1
^{90}Sr	Soil	0	0
^{137}Cs	Soil	1	1
^{238}Pu	Soil	1	1
$^{239+240}$Pu	Soil	1	1
^{241}Am	Soil	1	1
^{60}Co	Vegetation	9	9
^{90}Sr	Vegetation	8	8
^{137}Cs	Vegetation	10	10
^{238}Pu	Vegetation	9	9
$^{239+240}$Pu	Vegetation	9	8
^{241}Am	Vegetation	18	17
Metals	Water	117	117
Volatiles	Water	57	57
Semi volatiles	Water	155	155
Miscellaneous	Water	258	258
Metals	Soil	0	0
Volatiles	Soil	0	0
Semi volatiles	Soil	3	2
Miscellaneous	Soil	0	0
UGTA Samples			
Gross alpha	Water	3	3
Gross beta	Water	3	3
Tritium (standard)	Water	2	2
Tritium (low-level)	Water	3	3

14.5.2.4 Matrix Spike Analysis

A matrix spike is a sample spiked with a known concentration of analyte. This spiked sample is subjected to the same sample preparation and analysis as the original environmental sample. The matrix spike is used to indicate if the matrix (e.g., soil, water with sediment) interferes with the analytical results. Matrix spike analyses were conducted for samples in 2020, and there were no issues identified by the analysis data (Table 14-4).

Table 14-4. Summary of matrix spike samples for 2020

Analyte	Matrix	Number of Matrix Spikes Reported	Number Within Control Limits	Control Limits[(a)] (%)
Environmental Monitoring Samples				
Tritium	Air	14	14	60–140
Gross alpha	Water	14	13	60–140
Gross beta	Water	14	13	60–140
Tritium	Water	13	11	60–140
UGTA Samples				
Gross alpha	Water	2	2	60–140
Gross beta	Water	2	2	60–140
Tritium (standard)	Water	1	1	60–140
Tritium (low-level)	Water	2	2	60–140

(a) These control limits apply when the sample results are < 4x the amount of spike added.

14.5.2.5 Proficiency Testing Program Participation

All contracted laboratories are required to participate in proficiency testing programs. Laboratory performance supports decisions on work distribution and may also be a basis for state certifications. Table 14-5 presents the 2020 results for the laboratory performance in the March and August studies of the Mixed Analyte Performance

Evaluation Program (MAPEP) (http://www.id.energy.gov/resl/mapep/mapepreports.html) administered by the Radiological and Environmental Sciences Laboratory operated by the DOE Idaho Operations Office. Proficiency testing programs are not available for the low-level tritium analytical method. Low-level tritium proficiency was assessed by comparing commercial laboratory results to data from Lawrence Livermore National Laboratory for the same wells. Evaluations of duplicate samples indicated sufficient control on precision.

Table 14-5. Summary of 2020 Mixed Analyte Performance Evaluation Program reports

Analyte	Matrix	Number of Results Reported	Number within Control Limits(a)
Environmental Monitoring Samples			
^{60}Co	Filter	4	4
^{137}Cs	Filter	4	4
^{238}Pu	Filter	4	4
$^{239+240}$Pu	Filter	4	4
^{241}Am	Filter	4	4
Tritium (standard)	Water	4	3
^{60}Co	Water	4	4
^{90}Sr	Water	4	4
^{137}Cs	Water	4	4
^{238}Pu	Water	4	4
$^{239+240}$Pu	Water	4	4
^{241}Am	Water	4	4
^{60}Co	Vegetation	4	4
^{90}Sr	Vegetation	4	4
^{137}Cs	Vegetation	4	4
^{238}Pu	Vegetation	4	4
$^{239+240}$Pu	Vegetation	4	4
^{60}Co	Soil	4	4
^{90}Sr	Soil	4	4
^{137}Cs	Soil	4	4
^{238}Pu	Soil	4	4
$^{239+240}$Pu	Soil	4	4
^{241}Am	Soil	4	4
Metals	Water	73	72
Metals	Soil	77	74
Gross Alpha	Water	2	2
Gross Beta	Water	2	2

(a) Based upon MAPEP criteria.

Table 14-6 shows the summary of inter-laboratory comparison sample results for the MSTS Radiological Health Dosimetry Group. DOE Standard DOE-STD-1095-2011, "Department of Energy Laboratory Accreditation for External Dosimetry," establishes the methodology for determining acceptable performance testing of dosimeter systems. It also establishes the technical basis for performance testing and the testing categories and performance criteria, which are outlined in American National Standards Institute/Health Physics Society (ANSI/HPS) Standard N13.11-2009, "American National Standard for Dosimetry–Personnel Dosimetry Performance–Criteria for Testing," and in ANSI/HPS N13.32-2008, "An American National Standard, Performance Testing of Extremity Dosimeters." The Dosimetry Group participated in the Battelle Pacific Northwest National Laboratory proficiency-testing program during the course of the year.

Table 14-6. Summary of inter-laboratory comparison TLD samples (UD-802 dosimeters) for 2020

Analysis	Matrix	Number of Results Reported	Number within Control Limits(a)
Gamma Radiation	TLD	23 batches of 5 TLDs	23 batches of 5 TLDs

(a) Based upon ANSI/HPS N13.11-2009 criteria.

ANSI/HSP N13.37-2014, "Environmental Dosimetry – Criteria for System Design and Implementation," contains guidance on conducting "blind spike" quality assurance testing. This process was last followed in 2019 by having 24 Panasonic UD-814AS environmental TLDs exposed to a known radiation level (200 milliroentgens) and placing them with routine monitoring TLDs for analysis. A performance quotient for each ***dosimeter*** was calculated as follows: P = (reported exposure – true value) / true value. According to the standard, the absolute value of the mean performance quotient should not exceed 0.15. The value for the 2019-tested environmental TLDs was 0.10, demonstrating good agreement between the results and the controlled exposure using the blind spike.

14.6 References

DOE, see U.S. Department of Energy.

EPA, see U.S. Environmental Protection Agency

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Chapter 15: Quality Assurance Program for the Community Environmental Monitoring Program

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The Community Environmental Monitoring Program (CEMP) Quality Assurance Management and Assessment Plan (QAMAP) (Desert Research Institute [DRI] 2009) is followed for the collection and analysis of radiological air and water data presented in Chapter 7 of this report. The CEMP QAMAP ensures compliance with U.S. Department of Energy (DOE) Order DOE O 414.1D, "Quality Assurance," which implements a quality management system, ensuring the generation and use of quality data. This QAMAP addresses the following items previously defined in Chapter 14:

- Data Quality Objectives (DQOs)
- Sampling plan development to satisfy the DQOs
- Environmental health and safety
- Sampling plan execution
- Sample analyses
- Data review
- Continuous improvement

15.1 Data Quality Objectives (DQOs)

The DQO process is a strategic planning approach used to plan data collection activities. It provides a systematic process for defining the criteria that a data collection design should satisfy. These criteria include when and where samples should be collected, how many samples to collect, and the tolerable level of decision errors for the study. DQOs are unique to the specific data collection or monitoring activity, and follow similar guidelines for onsite activities where applicable (Chapter 14).

15.2 Measurement Quality Objectives (MQOs)

The MQOs are basically equivalent to DQOs for analytical processes. The MQOs provide direction to the analytical laboratory concerning performance objectives or requirements for specific method performance characteristics. Default MQOs are established in the subcontract with the laboratory, but may be altered in order to satisfy changes in the DQOs. The MQOs for the CEMP project are described in terms of precision, accuracy, representativeness, completeness, and comparability requirements. These terms are defined and discussed in Section 14.1 for onsite activities.

15.3 Sampling Quality Assurance Program

Quality Assurance (QA)[1] in CEMP field operations includes sampling assessment, surveillance, and oversight of the following supporting elements:

- The sampling plan, DQOs, and field data sheets accompanying the sample package
- Database support for field and laboratory results, including systems for long-term storage and retrieval
- A training program to ensure that qualified personnel are available to perform required tasks

Sample packages include the following:

- Station manager checklist confirming all observable information pertinent to sample collection
- An Air Surveillance Network Sample Data Form documenting air sampler parameters, collection dates and times, and total sample volumes collected
- Chain-of-custody forms

This managed approach ensures that the sampling is traceable and enhances the value of the final data. The sample package also ensures that the Community Environmental Monitor (CEM) station manager (Chapter 7 describes CEMs) followed proper procedures for sample collection. The CEMP Project Manager or QA Officer

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

routinely performs assessments of the station managers and field monitors to ensure that standard operating procedures and sampling protocols are followed properly.

Data obtained in the course of executing field operations are entered in the documentation accompanying the sample package during sample collection and in the CEMP database along with analytical results upon their receipt and evaluation.

Completed sample packages are kept as hard copy in file archives at DRI. Analytical reports are kept as hard copy in file archives as well as in electronic form by calendar year. Analytical reports and databases are protected and maintained in accordance with DRI's Computer Protection Program.

15.4 Laboratory QA Oversight

The CEMP QA Officer ensures that DOE O 414.1D requirements are met with respect to laboratory services through review of the vendor laboratory policies formalized in a Laboratory Quality Assurance Plan (LQAP) (Testamerica, Inc., 2017). The CEMP is assured of obtaining quality data from laboratory services through a multifaceted approach involving specific procurement protocols, the conduct of quality assessments, and requirements for selected laboratories to have an acceptable QA program. These elements are discussed below.

15.4.1 Procurement

Laboratory services are procured through subcontracts. The subcontract establishes the technical specifications required of the laboratory and provides the basis for determining compliance with those requirements and evaluating overall performance. The subcontract is awarded on a "best value" basis as determined by pre-award audits. The prospective vendor is required to provide a review package to the CEMP QA Officer that includes the following:

- All procedures pertinent to subcontract scope
- Environment, Safety, and Health Plan
- LQAP
- Example deliverables (hard copy and/or electronic)
- Proficiency testing (PT) results from the previous year from recognized PT programs
- Résumés of laboratory personnel
- All procedures pertinent to subcontract scope
- Facility design/description
- Accreditations and certifications
- Licenses
- Pricing
- Audits performed by an acceptable DOE program covering comparable scope
- Past performance surveys

The CEMP QA Officer evaluates the review package in terms of technical capability. Vendor selection is based solely on these capabilities and not biased by pricing.

15.4.2 Initial and Continuing Assessment

An initial assessment of a laboratory is managed through the procurement process above, including a pre-award audit. Pre-award audits are conducted by the CEMP (usually by the CEMP QA Officer). The CEMP does not initiate work with a laboratory without approval from the CEMP Program Manager.

A continuing assessment of a selected laboratory involves ongoing monitoring of a laboratory's performance against the contract terms and conditions, of which technical specifications are a part. The following tasks support continuing assessment:

- Tracking schedule compliance
- Monitoring the laboratory's adherence to the LQAP
- Reviewing analytical data deliverables
- Conducting regular audits
- Monitoring for continued successful participation in approved PT programs

15.4.3 Laboratory QA Program

The laboratory policy and approach to implement DOE O 414.1D is verified in an LQAP prepared by the laboratory. The required elements of a CEMP LQAP are similar to those required by Mission Support and Test Services, LLC, for onsite monitoring (Section 14.3).

15.5 Data Review

Essential components of process-based QA are data checks, verification, validation, and data quality assessment to evaluate data quality and usability.

Data Checks – Data checks are conducted to ensure accuracy and consistency of field data collection operations prior to and upon data entry into CEMP databases and data management systems.

Data Verification – Data verification is defined as a subcontract compliance and completeness review to ensure that all laboratory data and sample documentation are present and complete. Sample preservation, chain-of-custody, and other field sampling documentation is reviewed during the verification process. Data verification ensures that the reported results entered in CEMP databases correctly represent the sampling and/or analyses performed and includes evaluation of ***quality control (QC)*** sample results.

Data Validation – Data validation is the process of reviewing a body of analytical data to determine if it meets the data quality criteria defined in operating instructions. Data validation ensures that the reported results correctly represent the sampling and/or analyses performed, determines the validity of reported results, and assigns data qualifiers (or "flags"), if required. The process of data validation consists of the following:

- Evaluating the quality of data to ensure all project requirements are met
- Determining the impact on data quality of those requirements if they are not met
- Verifying compliance with QA requirements
- Checking QC values against defined limits
- Applying qualifiers to analytical results in CEMP databases to define the limitations in the use of the reviewed data

Operating instructions, procedures, applicable project-specific work plans, field sampling plans, QA plans, analytical method references, and laboratory statements of work may all be used in the process of data validation. Documentation of data validation includes checklists, qualifier assignments, and summary forms.

Data Quality Assessment (DQA) – DQA is the scientific evaluation of data to determine if the data obtained from environmental data operations are of the right type, quality, and quantity to support their intended use. DQA review is a systematic review against pre-established criteria to verify that the data are valid for their intended use.

15.6 QA Program Assessments

The overall effectiveness of the QA Program is determined through management and independent assessments as defined in the CEMP QAMAP. These assessments evaluate the plan execution workflow (sampling plan development and execution, chain-of-custody, sample receiving, shipping, subcontract laboratory analytical activities, and data review) as well as program requirements as they pertain to the organization.

15.7 Sample QA Results

QA assessments were performed by the CEMP, including the laboratories responsible for sample analyses. These assessments ensure that sample collection procedures, analytical techniques, and data provided by the subcontracted laboratories comply with CEMP requirements. Data were provided by TestAmerica Laboratories, Mirion Technologies (***thermoluminescent dosimeter [TLD]*** data), and the American Radiation Services Laboratory in Port Allen, Louisiana (tritium [^{3}H] data). A brief discussion of the 2020 results for field duplicates, laboratory control samples, blank analyses, and inter-laboratory comparison studies is provided along with summary tables within this section. The 2020 CEMP radiological air and water monitoring data are presented in Chapter 7.

15.7.1 Field Duplicates (Precision)

A field duplicate is a sample collected, handled, and analyzed by the same procedures as the primary sample. The relative percent difference (RPD) between the field duplicate result and the corresponding field sample result is a measure of the variability in the process caused by the sampling uncertainty (matrix heterogeneity, collection variables, etc.) and measurement uncertainty (field and laboratory) used to arrive at a final result. The average absolute RPD, expressed as a percentage, was determined for the calendar year 2020 samples and is listed in Table 15-1. An RPD of zero indicates a perfect duplication of results of the duplicate pair, whereas an RPD greater than 100% generally indicates that a duplicate pair falls beyond QA requirements and is not considered valid for use in data interpretation. These samples are further evaluated to determine the reason for QA failure and if any corrective actions are required. Overall, the RPD values for all analyses indicate very good results.

Table 15-1. Summary of 2020 field duplicate samples for CEMP monitoring

Analysis	Matrix	Number of Samples Reported[(a)]	Number of Samples Reported above MDC[(b)]	Average Absolute RPD of those above MDC (%)[(c)]
Gross Alpha	Air	6	6	24.9
Gross Beta	Air	6	6	6.7
Gamma – Beryllium-7	Air	6	0	NA[(d)]
^{3}H	Water	1	0	NA[(d)]
TLDs	Ambient Radiation	12	NA[(d)]	3.70

(a) Represents the number of field duplicates reported for the purpose of monitoring precision. If an associated field sample was not processed, the field duplicate was not included in this table.
(b) Represents the number of field duplicate–field sample result sets reported above the minimum detectable concentration (MDC) (MDC is not applicable for TLDs). If either the field sample or its duplicate was reported below the detection limit, the precision was not determined.
(c) Reflects the average absolute RPD calculated for those field duplicates reported above the MDC.
(d) Not applicable.

The absolute RPD calculation is as follows:

$$Absolute\ RPD = \frac{|FD - FS|}{(FD + FS)/2} \ X \ 100\%$$

Where: FD = Field duplicate result
FS = Field sample result

15.7.2 Laboratory Control Samples (Accuracy)

Laboratory control samples (LCSs) are performed by the subcontract laboratory to evaluate analytical accuracy, which is the degree of agreement of a measured value with the true or expected value. Samples of known concentration are analyzed using the same methods as employed for the project samples. The results are determined as the measured value divided by the true value, expressed as a percentage. To be considered valid, the results must fall within established control limits (or percentage ranges) for further analyses to be performed. The LCS results obtained for 2020 are summarized in Table 15-2. The LCS results were satisfactory, with all samples falling within control parameters for the air sample matrix.

Table 15-2. Summary of 2020 laboratory control samples for CEMP monitoring

Analysis	Matrix	Number of LCS Results Reported	Number Within Control Limits	Control Limits
Gross Alpha	Air	8	8	75–125%
Gross Beta	Air	8	8	75–125%
Gamma (^{137}Cs, ^{60}Co, ^{241}Am)	Air	8	8	87–117%
^{3}H	Water	2	2	75–125%

15.7.3 Blank Analysis

Laboratory blank analyses are essentially the opposite of LCSs. These samples do not contain any of the ***analyte*** of interest. Results of these analyses are expected to be "zero," or, more accurately, below the MDC of a specific procedure. Blank analysis and control samples are used to evaluate overall laboratory procedures, including sample preparation and instrument performance. The laboratory blank sample results obtained for 2020 are summarized in Table 15-3. The laboratory blank results were satisfactory for all analyses for the air and water sample matrices.

Table 15-3. Summary of 2020 laboratory blank samples for CEMP monitoring

Analysis	Matrix	Number of Blank Results Reported	Number within Control Limits[a]
Gross Alpha	Air	8	8
Gross Beta	Air	8	8
Gamma	Air	8	8
^{3}H	Water	1	1

(a) Control limit is less than the MDC.

15.7.4 Inter-laboratory Comparison Studies

Inter-laboratory comparison studies are conducted by the subcontracted laboratories to evaluate their performance relative to other laboratories providing the same service. These types of samples are commonly known as "blind" samples, in which the expected values are known only to the program conducting the study. The analyses are evaluated and, if found satisfactory, the laboratory is certified that its procedures produce reliable results. The inter-laboratory comparison sample results obtained for 2020 are summarized in Tables 15-4 and 15-5.

Table 15-4 shows the summary of inter-laboratory comparison sample results for the subcontract radiochemistry laboratories. The laboratories participated in either the QA Program administered by Environmental Research Associates (ERA) and/or the Mixed Analyte Performance Evaluation Program (MAPEP) for gross alpha, gross beta, and gamma analyses. The subcontract ^{3}H laboratory also participated in the MAPEP program. Overall, all of the subcontractors performed very well during the year.

Table 15-4. Summary of 2020 inter-laboratory comparison samples of the subcontract radiochemistry and tritium laboratories for CEMP monitoring

		MAPEP and ERA Results	
Analysis	Matrix	Number of Results Reported	Number Within Control Limits[a]
Gross Alpha	Air	2	2
Gross Beta	Air	2	2
Gamma	Air	2	2
^{3}H	Water	2	2

(a) Control limits are determined by the individual inter-laboratory comparison study.

Table 15-5 shows the summary of the in-house performance evaluation results conducted by the subcontract dosimetry group. This internal evaluation is performed in accordance with National Voluntary Laboratory Accreditation Program (NVLAP) tolerance levels and American National Standards Institute (ANSI) Standard ANSI N13.11-2009, *Personal Dosimetry Performance – Criteria for Testing*. For each month of 2020, nine TLD badges were tested and all performed acceptably.

Table 15-5. Summary of 2020 inter-laboratory comparison TLD samples of the subcontract dosimetry group for CEMP monitoring

Analysis	Matrix	Number of Results Reported	Number Within Control Limits[a]
TLDs	Ambient Radiation	12	12

(a) Based upon NVLAP/ANSI criteria; sum of the squares of the bias and standard deviation less than or equal to 0.09.

15.8 References

Desert Research Institute, 2009. *DOE NNSA/NSO Community Environmental Monitoring Program Quality Assurance Management and Assessment Plan*, July 2009. Las Vegas, NV.

Testamerica, Inc., 2017. *Quality Assurance Manual*. Version 8.0, February 2017.

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Appendix A
Las Vegas Area Support Facilities

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FIGURES

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Appendix A: Las Vegas Area Support Facilities

Troy S. Belka, Delane P. Fitzpatrick-Maul, Jennifer M. Larotonda, Xianan Liu, and Nikolas J. Taranik
Mission Support and Test Services, LLC

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) manages two facilities in Clark County, Nevada, that support NNSA/NFO missions on and off the Nevada National Security Site (NNSS). These are the North Las Vegas Facility (NLVF) and the Remote Sensing Laboratory–Nellis (RSL-Nellis) (Figure A-1). This appendix describes environmental monitoring and compliance activities in 2020 at these facilities.

A.1 North Las Vegas Facility

The NLVF is a fenced complex composed of 31 buildings that house much of the NNSS project management, diagnostic development and testing, design, engineering, and procurement personnel. The 32-hectare (80-acre) facility is located along Losee Road, a short distance west of Interstate 15 (Figure A-1). The facility is buffered on the north, south, and east by general industrial zoning. The western border separates the property from fully developed, single-family residential-zoned property. The NLVF is a controlled-access facility. Environmental compliance and monitoring activities associated with this facility in 2020 included the maintenance of one air quality operating permit; one wastewater permit; one National Pollutant Discharge Elimination System (NPDES) permit; one Spill Prevention, Control, and Countermeasure (SPCC) Plan; and one hazardous materials permit (Table 2-2 lists NNSA/NFO permits). NNSA/NFO also monitors ***tritium (^3H)***[1] in air and ambient gamma emissions to comply with federal radiation protection regulations.

A.1.1 Air Quality and Protection

Sources of air pollutants at the NLVF are regulated by the Source 657 Minor Source Permit issued by the Clark County Division of Air Quality (DAQ) for the emission of ***criteria pollutants***. These pollutants include particulate matter (PM), nitrogen oxide (NO_X), carbon monoxide (CO), sulfur dioxide (SO_2), and volatile organic compounds (VOCs). Because the NLVF is considered a true minor source, there is no requirement to report ***hazardous air pollutants (HAPs)***. The regulated sources of emissions at the NLVF include diesel generators, a fire pump, cooling towers, and boilers. The DAQ requires an annual emissions inventory of criteria air pollutants; the 2020 inventory reported the estimated quantities (Table A-1) on March 18, 2021.

Table A-1. Summary of air emissions for the NLVF in 2020

	Criteria Pollutant (tons/yr)[(a)]					
Parameter	**PM10[(b)]**	**PM2.5[(c)]**	**NO_X**	**CO**	**SO_2**	**VOC**
PTE[(d)]	1.16	0.78	19.32	4.35	0.09	0.86
Actual[(e)]	0.06	0.04	0.46	0.20	0.01	0.03
Total Emissions = 0.80 Actual, 26.56 PTE						

(a) 1 ton equals 0.91 metric tons.
(b) Particulate matter equal to or less than 10 microns in diameter.
(c) Particulate matter equal to or less than 2.5 microns in diameter.
(d) ***Potential to emit (PTE)*** is the quantity of criteria air pollutants that facilities/pieces of equipment would emit annually if they were operated for the maximum number of hours at the maximum production rate specified in the air permit.
(e) Emissions based on calculations using actual hours of operation for each piece of equipment.

Clark County air regulations specify that the opacity from any emission unit may not exceed the Clean Air Act National Ambient Air Quality Standards (NAAQS) opacity limit of 20% for more than 6 consecutive minutes. The NLVF air permit requires a visible emissions check be performed from each diesel-fired generator and fire pump when operated for testing and maintenance. If emissions that appear to exceed the opacity limits are observed, then immediate corrective action would be taken. If practical, U.S. Environmental Protection Agency (EPA) Method 9 opacity readings would be recorded by a certified visible-emissions evaluator.

[1] The definition of word(s) in ***bold italics*** may be found by referencing the Glossary, Appendix B.

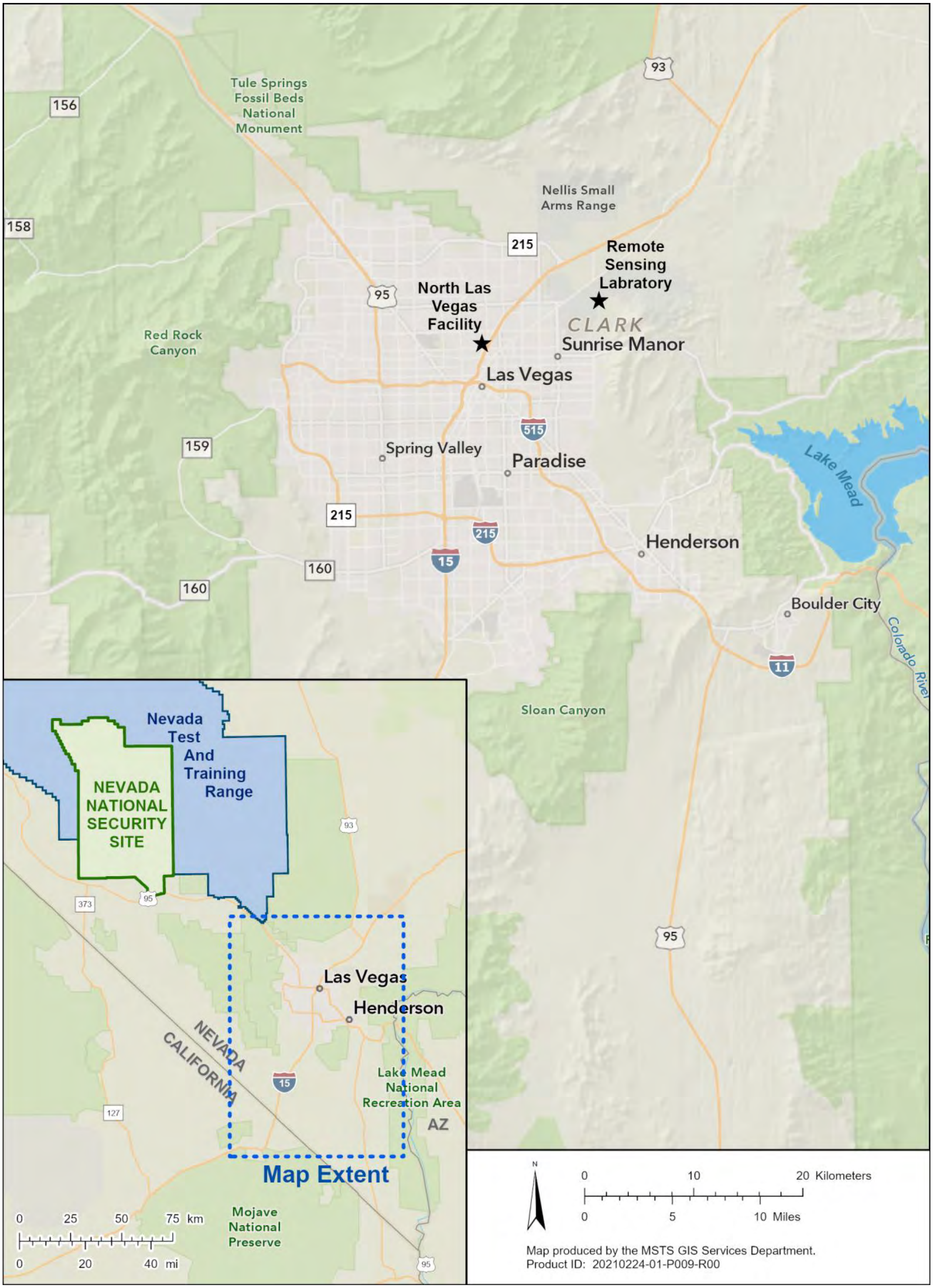

Figure A-1. Location of NNSS offsite facilities in Las Vegas and North Las Vegas

If visible emissions appear to exceed the limit, corrective actions must be taken to minimize emissions. In 2020, two NLVF Maintenance Engineers were recertified. In 2020, observations were taken for diesel-fired generators; emissions were below the NAAQS opacity limit of 20%. One non-emissions deviation report, involving reporting more hours than actual operating hours, was submitted for the NLVF.

At NLVF, a verbal notification to the City of North Las Vegas (CNLV) Fire Department is required before each fire extinguisher training session. In 2020, two hot work live fire extinguisher training sessions were conducted at the NLVF. Quantities of criteria air pollutants produced by the open burns during training are not required to be calculated or reported.

A.1.2 Water Quality and Protection

Water used at the NLVF is supplied by the CNLV and meets or exceeds federal drinking water standards. Water quality permits issued to NNSA/NFO include a Class II Wastewater Control Permit (036555-02) from the CNLV for NLVF sewer discharges and an NPDES DeMinimus (NVG201000) permit from the Nevada Division of Environmental Protection (NDEP) for dewatering operations to control rising groundwater levels at the facility. Discharges of sewage and industrial wastewater from the NLVF must meet permit limits set by the CNLV. These limits support the permit limits for the Publicly Owned Treatment Works operated by the CNLV. The Class II Permit specifies substances prohibited from being discharged at NLVF and requires CNLV be notified of changes in discharge flow rates, spills, or other abnormal events. In 2020, no changes, spills, or abnormal events occurred.

A.1.2.1 Storm Water No Exposure Waiver ISW-40565

This waiver was approved on July 16, 2015, and it provides a conditional exemption from the NPDES Storm Water Program and the State of Nevada Stormwater General Permit. The conditions specify that storm water discharges from the NLVF will not be exposed to industrial activities or materials. In 2020, no storm water exposures to such activities or materials occurred.

A.1.2.2 National Pollutant Discharge Elimination System DeMinimus General Permit

An NPDES DeMinimus general permit covers the dewatering operation at the NLVF (Section A.1.2.3). Dewatering wells (NLVF-13s, -15, -16, -17) and the A-01 Basement Sump Well pump groundwater into a 37,854-liter (L) (10,000-gallon [gal]) storage tank (Figure A-2). The water is then discharged from the storage tank into the Las Vegas Wash via direct discharge (Outfall 002) into the CNLV storm drainage system. Chemical analyses are performed annually on water samples collected from the storage tank. The total quantities of groundwater produced and discharged and the results of chemical analyses are reported annually to NDEP's Bureau of Water Pollution Control.

In 2020, the five dewatering wells at the NLVF produced a total of about 484,514 L (127,995 gal) per month that were directed into the storage tank. Annual water sampling for the presence of 23 analytes (permit NV201000, Section A.10.3.4) was performed on October 6, 2020. All analyte concentrations were below permit limits, and discharge rates (i.e., daily maximum flows) did not exceed the NPDES DeMinimus general permit limits (Table A-2).

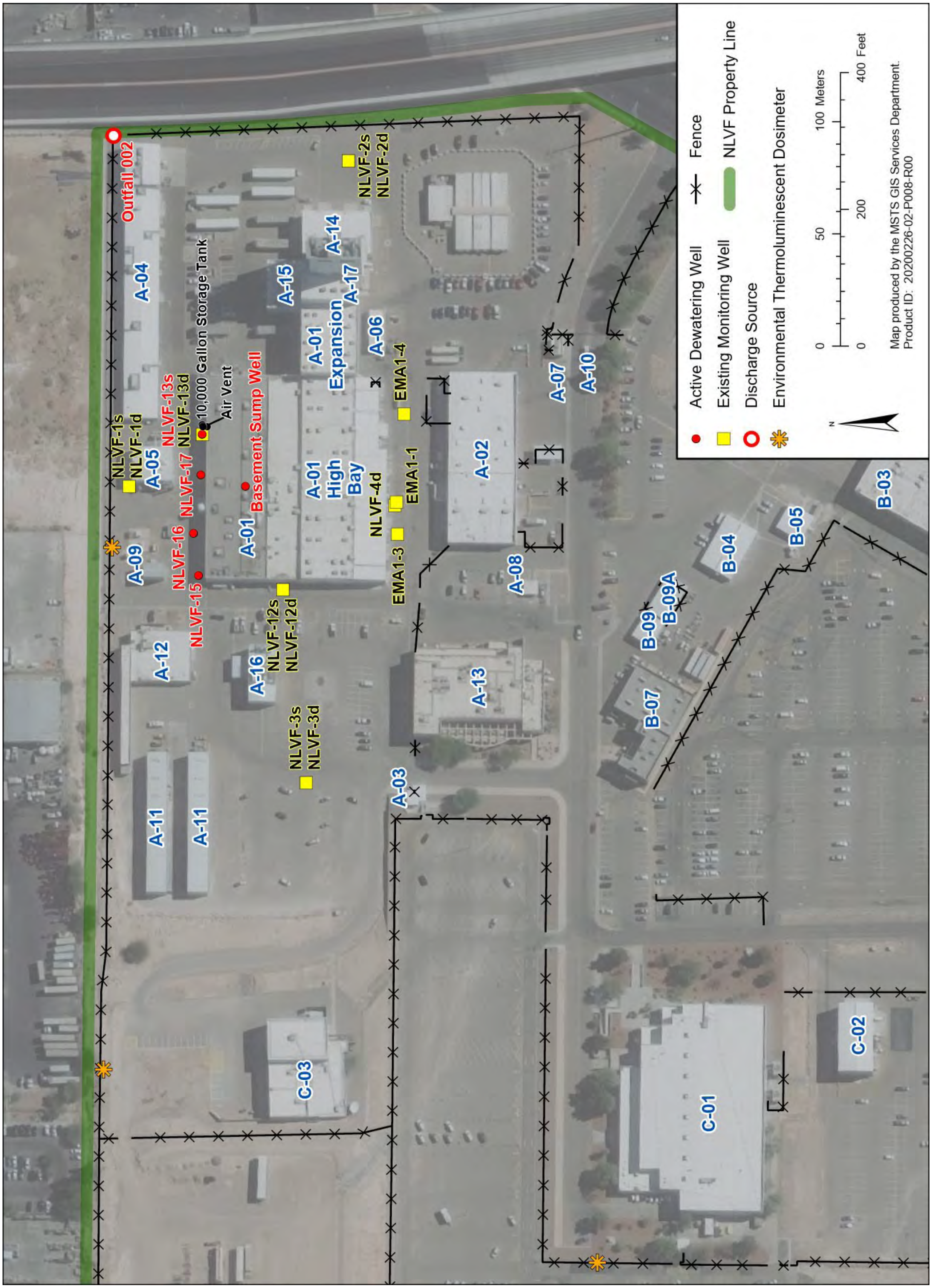

Figure A-2. Location of dewatering and monitoring wells around Building A-1

Table A-2. NLVF NPDES permit 2020 monitoring requirements and analysis results of storage tank water samples

	Monitoring Requirements		Permit Discharge Limits	Sample Results			
Parameter	**Sample Frequency**	**Sample Type**	**Daily Maximum**	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**
Daily Maximum Flow (MGD)[(a)]	Continuous	Flow Meter	0.36	0.004	0.004	0.004	0.004
Total Petroleum Hydrocarbons[(b)] (mg/L)	Annually[(c)]	Discrete	1	NS[(d)]	NS	NS	ND[(e)]
Total Suspended Solids (mg/L)	Annually	Discrete	135	NS	NS	NS	ND
Total Dissolved Solids (mg/L)	Annually	Discrete	1900	NS	NS	NS	1380
Total Inorganic Nitrogen as N (mg/L)	Annually	Discrete	10	NS	NS	NS	1.49
pH (Standard Units)	Annually	Discrete	6.5–9.0	NS	NS	NS	6.85

(a) MGD = million gallons per day.
(b) This parameter includes three analytes, in milligrams per liter (mg/L): diesel range organics, gasoline range organics, and oil range organics.
(c) Sampled in the 4th quarter of the calendar year.
(d) NS = not required to be sampled that quarter.
(e) ND = not detected; values were less than the laboratory detection limits.

A.1.2.3 Groundwater Control and Dewatering Operation

In 2020, the groundwater control and dewatering project at the NLVF continued efforts to reduce the intrusion of groundwater below Building A-01. The project has transitioned from initial groundwater investigations and characterization to a long-term/permanent dewatering operation project. A review of the rising groundwater situation, and past efforts to understand and remediate this, is presented in previous reports (Bechtel Nevada 2003, 2004; National Security Technologies, LLC, 2006). Monitoring for this operation includes periodic measurements of water level at 24 of the 27 NLVF monitoring wells, continuous water level measurements at the A-01 Basement Sump Well, measuring the total volume of discharged groundwater, and conducting groundwater characterization in accordance with the NPDES DeMinimus general permit. Groundwater data are assessed as new data become available. This information is used to help characterize groundwater conditions and evaluate the dewatering operation.

When the A-01 Basement Sump Well pump is active, the water level directly beneath Building A-01 averages 32.3 centimeters (cm) (12.7 inches [in]) below the basement floor, as measured in a monitoring tube installed in a nearby elevator shaft. This average water level is based on daily measurements taken in 2020 and reflects a drop of about 53.8 cm (21.2 in) in the local ***water table*** beneath Building A-01 since full-scale dewatering operations began in 2006. The general trend for the NLVF site-wide monitoring network shows an average rise in the water level of 1.4 meters (4.6 feet) since 2003. Dewatering efforts must continue to counter this rising groundwater trend.

A.1.2.4 Oil Pollution Prevention

The NLVF has an SPCC Plan that was prepared in accordance with the Clean Water Act to minimize the potential discharge of petroleum products, animal fats and vegetable oils, and other non-petroleum oils and greases into waters of the U.S. (i.e., the Las Vegas Wash). The EPA requires SPCC Plans for non-transportation–related facilities having the potential to pollute waters of the U.S. and having an aggregate aboveground oil storage capacity of more than 4,997 L (1,320 gal). Oil storage facilities at the NLVF include 10 aboveground tanks, 18 transformers, 13 pieces of oil-filled machining equipment (e.g., lathes, elevators), and numerous 55-gal drums that are used to store new and used oils. These facilities/pieces of equipment are located within approved spill and storm water runoff containment structures. The SPCC specifies procedures for removing storm water from containment structures and identifies discharge countermeasures, disposal methods for recovered materials, and discharge reporting requirements.

In 2020, quarterly inspections of tanks, transformers, oil-filled equipment, and drums were conducted in March, May, September, and November. Throughout 2020, all NLVF employees who handle oil received their required annual spill prevention and management training. No spills occurred in 2020 that met regulatory agency reporting criteria.

A.1.3 Radiation Protection

A.1.3.1 National Emission Standards for Hazardous Air Pollutants

In compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) of the Clean Air Act, the ***radionuclide*** air emissions from the NLVF and the resultant radiological ***dose*** to the public surrounding the facility were assessed. NESHAP establishes a dose limit for the general public to be no greater than 10 millirems per year (mrem/yr) from all radioactive air emissions (Mission Support and Test Services, LLC [MSTS], 2021). The basement of Building A-01 was contaminated with ^{3}H in 1995 when a container of ^{3}H foils was opened, emitting about 1 curie of ^{3}H (U.S. Department of Energy, Nevada Operations Office 1996). Complete cleanup of the ^{3}H was unsuccessful due to the ^{3}H being absorbed into the building materials. This has resulted in a continuous but decreasing release of ^{3}H into the basement air space, which is ventilated to the outdoors. Since 1995, a dose assessment has been performed every year for this building.

In 2020, no ^{3}H was detected above its analytical method detection limit in groundwater pumped from the sump well in the basement of Building A-01 during dewatering operations. However, there is still an emission from ^{3}H emanating from building materials in the building's basement. This ^{3}H emission was determined by taking two air samples from the basement (on May 19–26 and September 1–8, 2020) in order to compute average ^{3}H emissions. A calculated annual total of 1.59 millicuries were released from the basement air that was vented to the outside. Based on this emission rate, the 2020 calculated radiation dose to the nearest member of the general public from the NLVF was very low: 0.000011 mrem/yr (MSTS 2021). The nearest public place is 100 meters (328 feet) northwest of Building A-01. This annual public dose is well below the regulatory limit of 10 mrem/yr and continues to decrease at a rate of about one-half every 4.75 years (MSTS 2021).

A.1.3.2 U.S. Department of Energy Order 458.1

DOE Order DOE O 458.1, "Radiation Protection of the Public and the Environment," specifies that the radiological dose to a member of the public from radiation from all pathways must not exceed 100 mrem/yr as a result of DOE activities. This dose limit does not include the dose contribution from natural ***background*** radiation. The Atlas A-1 Source Range Laboratory and the Building C-3 High Intensity Source Building are two NLVF facilities that use radioactive sources or where radiation-producing operations are conducted that have the potential to expose the general population or non-project personnel to direct radiation. Direct radiation monitoring is conducted using ***thermoluminescent dosimeters (TLDs)*** to monitor external ***gamma radiation exposure*** near the boundaries of these facilities. The methods of TLD use and data analyses are described in Chapter 6 of this report.

In 2020, radiation exposure was measured at two locations along perimeter fences for Buildings A-01 and C-3 and at one control location along the west fence of Building C-1 (Figure A-2). Annual exposure rates estimated from measurements at those locations are summarized in Table A-3. The radiation exposure in air measured by the TLDs is in the unit of milliroentgens per year (mR/yr), which is considered equivalent to the unit of mrem/yr for tissue. These exposures include contributions from background radiation and are similar to the TLD measurement of 110 mR/yr for total annual exposure reported by the Desert Research Institute from their Las Vegas air monitoring station (Section 7.1.4, Table 7-3). The NLVF TLD results indicate that facility activities do not contribute a radiological dose to the surrounding public that can be distinguished from the dose due to background radiation.

Table A-3. Results of 2020 direct radiation exposure monitoring at the NLVF

Location	Number of Samples	Gamma Exposure (mR/yr)			
		Mean	Median	Minimum	Maximum
West Fence of Building C-1 (Control)	4	93	93	89	96
North Fence of Building A-01	4	63	63	60	65
North Fence of Building C-3	4	63	64	61	65

A.1.4 Hazardous Waste Management

Hazardous wastes (HWs) generated at the NLVF include such items as non-empty aerosol cans, lead debris, and oily rags. HWs are stored temporarily in satellite accumulation areas until they are direct-shipped to approved disposal facilities. The NLVF is a Very Small Quantity Generator; therefore, no HW permit is required by the State of Nevada. However, the Southern Nevada Health District (SNHD) issues the facility an annual permit for restricted waste management. The SNHD normally conducts an annual audit to validate proper handling and storage of restricted wastes; SNHD conducted the audit in 2020 and no issues were identified.

A.1.5 Hazardous Materials Control and Management

The 2020 NLVF chemical inventory was submitted to the state in the Nevada Combined Agency (NCA) Report in February 2021. The inventory data were submitted in accordance with the requirements of the Hazardous Materials Permit 95585. For a description of the content, purpose, and federal regulatory driver behind the NCA Report, see Section 2.4.4.1, "Emergency Planning and Community Right-to-Know Act." No accidental or unplanned release of an extremely hazardous substance (EHS) occurred at the NLVF. Also, the quantities of toxic chemicals kept at the NLVF that are used annually did not exceed the specified reporting thresholds (Chapter 2, Table 2-6 concerning Toxic Chemical Release Inventory, Form R).

A.2 Remote Sensing Laboratory–Nellis

RSL-Nellis is approximately 13.7 kilometers (km) (8.5 miles [mi]) northeast of the Las Vegas city center and approximately 11.3 km (7 mi) northeast of the NLVF. It occupies six facilities on approximately 14 secured hectares (35 acres) at Nellis Air Force Base. A Memorandum of Agreement between the U.S. Air Force (USAF) and NNSA/NFO acknowledges the land belongs to the USAF and is leased to the NNSA/NFO, while the RSL facilities are owned by NNSA/NFO. RSL-Nellis provides emergency response resources for weapons-of-mass-destruction incidents. The laboratory also designs and conducts field tests of counterterrorism/intelligence technologies, and has the capability to assess environmental and facility conditions using complex radiation measurements and multi-spectral imaging technologies.

Environmental compliance and monitoring activities at RSL-Nellis in 2020 included maintenance of an air quality permit, an underground storage tank (UST) permit for one active UST, and a hazardous materials permit (Table 2-2 lists NNSA/NFO permits). Sealed radiation sources are used for calibration at RSL-Nellis, but the public has no access to any area that may have elevated gamma radiation emitted by the sources. Therefore, no environmental TLD monitoring is conducted. However, dosimetry monitoring is performed to ensure worker protection.

A.2.1 Air Quality and Protection

Sources of air pollutants at RSL-Nellis are regulated by the Source 348 Minor Source Permit issued by the Clark County DAQ for the emission of criteria pollutants. Regulated sources of air pollutant emissions at RSL-Nellis include an aluminum sander, an abrasive blaster, spray paint booth, generators, a fire pump, and boilers. The 2020 emissions inventory of criteria air pollutants was submitted to the DAQ on March 18, 2021, and is shown in Table A-4.

Clark County air regulations specify that the opacity from any emission unit may not exceed the NAAQS opacity limit of 20% for more than 6 consecutive minutes. The RSL-Nellis air permit requires a visible emissions check be performed from each diesel-fired generator and fire pump when operated for testing and maintenance. If emissions appear to exceed the opacity limit, then immediate corrective action would be taken. If practical, EPA Method 9 opacity readings would be recorded by a certified visible-emissions evaluator.

Table A-4. Summary of air emissions for RSL-Nellis in 2020

Parameter	Criteria Pollutant (tons/yr)[a]					
	PM10[b]	PM2.5[c]	NO_x	CO	SO_2	VOC
PTE[d]	0.53	0.21	4.44	1.70	0.05	0.39
Actual[e]	0.06	0.03	0.43	0.30	0.01	0.04
Total Emissions = 0.87 Actual, 7.32 PTE						

(a) 1 ton equals 0.91 metric tons.

(b) Particulate matter equal to or less than 10 microns in diameter.

(c) Particulate matter equal to or less than 2.5 microns in diameter.

(d) PTE is the quantity of criteria pollutants that facilities/pieces of equipment would emit annually if they were operated for the maximum number of hours at the maximum production rate specified in the air permit.

(e) Emissions based on calculations using actual hours of operation for each piece of equipment.

A.2.2 Water Quality and Protection

Water used at RSL-Nellis is supplied by the CNLV and meets or exceeds federal drinking water standards. The Clark County Water Reclamation District (CCWRD) determined that a discharge permit is not necessary for RSL-Nellis since no industrial wastewaters are discharged. Instead, an annual submission of a Zero Discharge Form verifying that no industrial wastewater was discharged to the sanitary sewer system is required. A Zero Discharge Certification for 2020 was submitted to CCWRD on January 19, 2021. There were no regulatory inspections of RSL-Nellis by the CCWRD and no findings or corrective actions were identified by internal assessments.

A.2.2.1 Oil Pollution Prevention

An SPCC Plan is in place for RSL-Nellis. Similar to the NLVF (Section A.1.2.4), the SPCC Plan is required because the facility has an aggregate aboveground oil storage capacity of more than 4,997 L (1,320 gal), and spills could potentially enter the Las Vegas Wash. Oil storage facilities at RSL-Nellis include nine aboveground tanks, four transformers, and two pieces of oil-filled machining equipment (e.g., elevators). These facilities and pieces of equipment are within approved spill and storm water runoff containment structures. The SPCC specifies procedures for removing storm water from containment structures and identifies discharge countermeasures, disposal methods for recovered materials, and discharge reporting requirements.

In 2020, quarterly inspections of tanks, transformers, and oil-filled equipment were conducted in March, May, July, and November. All RSL-Nellis employees who handle oil received their required annual spill prevention and management training. No spills occurred in 2020 that met regulatory agency reporting criteria.

A.2.3 Underground Storage Tank Management

The SNHD has oversight authority of USTs in Clark County. On January 1, 2020, the UST program at RSL-Nellis consisted of one fully regulated active tank for diesel fuel and three fully regulated temporarily closed tanks (one for unleaded gasoline, one for diesel fuel, and one for used oil), and three excluded tanks. The fully regulated USTs are operated under the RSL-Nellis UST Permit PR0064276 issued by SNHD. The fully regulated, active, and temporarily closed tanks are inspected annually by SNHD. In December 2020, SNHD inspected the fully regulated USTs at RSL-Nellis. No deficiencies were noted.

A.2.4 Hazardous Materials Control and Management

The chemical inventory at RSL-Nellis was submitted to the state in the NCA Report on February 25, 2021, in accordance with the requirements of the Hazardous Materials Permit 95579 (Section 2.4.4.1 describes the content, purpose, and federal regulatory driver behind the NCA Report). No accidental or unplanned release of an EHS occurred at RSL-Nellis in 2020. Also, no annual usage quantities of toxic chemicals kept at RSL-Nellis exceeded specified thresholds (Chapter 2, Table 2-5 concerning Toxic Chemical Release Inventory, Form R).

A.3 References

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Appendix B: Glossary of Terms

A **Absorbed dose:** the amount of energy absorbed by an object or person per unit mass. It reflects the amount of energy that ionizing radiation sources deposit in materials through which they pass, and is measured in units of radiation-absorbed dose (rad). The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad.

Actinide: any of the series of 15 metallic elements from actinium (atomic number 89) to lawrencium (atomic number 103) in the periodic table. They are all radioactive, the heavier members being extremely unstable and not of natural occurrence. The actinides mentioned in this document include uranium, plutonium, and americium.

Alpha particle: a positively charged particle emitted from the nucleus of an atom having mass and charge equal to those of a helium nucleus (two protons and two neutrons), usually emitted by transuranic elements (elements with atomic numbers greater than 92 [the atomic number of uranium], all of which are unstable and decay radioactively into other elements).

Alpha radioactivity: ionizing radiation consisting of alpha particles, emitted by some substances undergoing radioactive decay.

Analyte: the specific component measured in a chemical analysis.

Aquifer: a saturated layer of rock or soil below the ground surface that can supply usable quantities of groundwater to wells and springs and be a source of water for domestic, agricultural, and industrial uses.

Area 5 Radioactive Waste Management Complex (RWMC): the complex in Area 5 of the Nevada National Security Site at which low-level waste (LLW) and mixed low-level waste (MLLW) may be received, examined, packaged, stored, or disposed. Limited quantities of onsite-generated transuranic waste (TRU) are also stored temporarily at the RWMC. The RWMC is composed of the Area 5 Radioactive Waste Management Site (RWMS) and the Waste Examination Facility (WEF) and supporting administrative buildings, parking areas, and utilities. The operational units of the Area 5 RWMS include active, inactive, and closed LLW and MLLW cells and a Real Time Radiography Building. The operational units of the WEF include the TRU Pad, TRU Pad Cover Building, TRU Loading Operations Area, WEF Yard, WEF Drum Holding Pad, Sprung Instant Structure, and the Visual Examination and Repackaging Building.

As low as reasonably achievable (ALARA): an approach to radiation safety that strives to manage and control doses to the work force and general public.

Atom: the smallest particle of an element capable of entering into a chemical reaction.

B **Background:** as used in this report, background is the term for the amounts of chemical constituents or radioactivity in the environment that are not caused by Nevada National Security Site operations. In the broader context outside this report, background radiation refers to radiation arising from natural sources always present in the environment, including solar and cosmic radiation from outer space and naturally radioactive elements in the atmosphere, the ground, building materials, and the human body.

Becquerel (Bq): the International System of Units unit of activity of a radionuclide, equal to the activity of a radionuclide having one spontaneous nuclear transition per second.

Beta particle: a negatively charged particle emitted from the nucleus of an atom, having charge, mass, and other properties of an electron, emitted from fission products such as cesium-137.

Beta radioactivity: ionizing radiation consisting of beta particles emitted in the radioactive decay of an atomic nucleus.

Biochemical oxygen demand (BOD): a measure of the amount of dissolved oxygen that microorganisms need to break down organic matter in water; used as an indicator of water quality.

Bureau of Land Management (BLM) herd management areas (HMA): the BLM manages wild horses and burros in 177 herd management areas across 10 western states. Each HMA is unique in its terrain features, local climate and natural resources, just as each herd is unique in its history, genetic heritage, coloring and size distribution (source: https://www.blm.gov/programs/wild-horse-and-burro/herd-management/herd-management-areas).

C **Clean Air Package, 1988, (CAP88-PC):** a computer model with a set of computer programs, databases and associated utility programs for estimating dose and risk from radionuclideemissions to air. CAP88 is a regulatory compliance tool under the National Emissions Standard for Hazardous Air Pollutants (NESHAP) (source: https://www.epa.gov/radiation/cap-88-pc).

Closure-in-place: the stabilization or isolation of pollutants, hazardous wastes, and solid wastes, with or without partial treatment, removal activities, and/or post-closure monitoring. Closures-in-place of legacy contamination sites on and off the Nevada National Security Site, which are managed by the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office, are attained in accordance with approved corrective action plans outlined in the 1996 Federal Facility Agreement and Consent Order (as amended) between the U.S. Department of Energy, the U.S. Department of Defense, and the State of Nevada.

Code of Federal Regulations (CFR): a codification of all regulations promulgated by federal government agencies.

Collective population dose: the sum of the total effective dose equivalents of all individuals within a defined population. The unit of collective population dose is person-rem or person-sievert. Collective population dose may also be referred to as "collective effective dose equivalent" or simply "population dose."

Committed effective dose equivalent (CEDE): the sum of the committed dose equivalents to various tissues in the body, each multiplied by an appropriate weighting factor representing the relative vulnerability of different parts of the body to radiation. Committed effective dose equivalent is expressed in units of rem or sievert.

Community water system: as defined in Nevada Revised Statute 445A.808, a public water system that has at least 15 service connections used by year-round residents of the area served by the system; or regularly serves at least 25 year-round residents of the area served by the system.

Composite analysis (CA): an analysis of the risks posed by all wastes disposed in a low-level radioactive waste disposal facility and by all other sources of residual contamination that may interact with the disposal site. CAs, along with performance assessments (PAs), are conducted for the Area 3 and Area 5 Radioactive Waste Management Sites on the Nevada National Security Site to assess and predict their long-term performance.

Concentration Level (CL): the Clean Air Act National Emission Standards for Hazardous Air Pollutants Concentration Level for Environmental Compliance. The CL value represents the annual average concentration that would result in a dose of 10 millirem per year, which is the federal dose limit to the public from all radioactive air emissions.

Confining unit: a geologic unit of relatively low permeability that impedes the vertical movement of groundwater.

Contaminant Boundary: a type of boundary developed for an Underground Test Area (UGTA) corrective action unit (CAU). It is a forecast perimeter and a lower hydrostratigraphic unit boundary that delineates the potential extent of radionuclide-contaminated groundwater from underground testing for 1,000 years. Contaminated groundwater is defined as water exceeding the radiological standards of the Safe Drinking Water Act (SDWA). The forecasted contamination is a volume, which is projected upward to the ground surface to define a two-dimensional contaminant boundary perimeter. Simulation modeling of the transport of radiological contaminants in groundwater is usually used to forecast the locations of the contaminant boundaries within the next 1,000 years. CAU-specific contaminant boundaries are approved by the Nevada Division of Environmental Protection.

Continuous release: defined by the U.S Environmental Protection Agency as a release that occurs without interruption or abatement, or that is routine, anticipated, intermittent, and incidental to normal operation or treatment process.

Criteria pollutants: those air pollutants designated by the U.S. Environmental Protection Agency as potentially harmful and for which National Ambient Air Quality Standards under the Clean Air Act have been established to protect the public health and welfare. These pollutants include sulfur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), ozone, lead, and particulate matter equal to or less than 10 microns in diameter (PM10). The State of Nevada, through an air quality permit, establishes emission limits on the Nevada National Security Site for SO_2, NO_X, CO, PM10, and volatile organic compounds (VOCs). Ozone is not regulated by the permit as an emission, as it is formed in part from NO_X and VOCs. Lead is considered a hazardous air pollutant (HAP) as well as a criteria pollutant, and lead emissions on the Nevada National Security Site are reported as part of the total HAP emissions. Lead emissions above a specified threshold are also reported under Section 313 of the Emergency Planning and Community Right-to-Know Act.

Critical Level (L_C) (also known as decision level): the counts of radioactivity (or concentration level of a radionuclide) in a sample that must be exceeded before there is a specified level of confidence (typically 95 or 99 percent) that the sample contains radioactive material above the background.

Critical receptor sampler: a type of radiological air monitoring station on the NNSS that samples air particulates and water vapor for the purpose of assessing dose to the public from airborne radionuclides originating from past or current NNSS activities and documenting if the assessed dose exceeds the DOE public dose limit of 10 millirems per year from inhalation. The U.S. Environmental Protection Agency has approved a sampling network of six such stations on the NNSS. The critical receptor is assumed to be an individual who resides at the station location. Air sample analysis results for each station identify whether this hypothetical individual would be exposed to airborne radionuclides that would exceed the DOE public dose limit. It is assumed that if air sampling results at these six locations on the NNSS indicate doses below the public limit, then the public who reside off the NNSS at greater distances from the NNSS sources of airborne radionuclides, then the offsite public dose is even less.

Curie (Ci): a unit of measurement of radioactivity, defined as the amount of radioactive material in which the decay rate is 3.7×10^{10} (37 billion) disintegrations per second; one Ci is approximately equal to the decay rate of one gram of pure radium.

D **Daughter nuclide (also known as isotope or product):** a nuclide formed by the radioactive decay of another nuclide, which is called the parent.

Decision level (also known as critical level): the counts of radioactivity (or concentration level of a radionuclide) in a sample that must be exceeded before there is a specified level of confidence (typically 95 or 99 percent) that the sample contains radioactive material above the background...

Depleted uranium (DU): uranium having a lower proportion of the isotope ^{235}U than is found in naturally occurring uranium. The masses of the three uranium isotopes with atomic weights 238, 235, and 234 occur in depleted uranium in the weight-percentages 99.8, 0.2, and 5×10^{-4}, respectively.

Derived Concentration Standard (DCS): concentration of a given radionuclide in either water or air that results in a member of the public receiving 100 millirem (1 millisievert) effective dose following continuous exposure for one year via each of the following pathways: ingestion of water, submersion in air, and inhalation. They replace the Derived Concentration Guides previously published by the U.S. Department of Energy (DOE) in 1993 in DOE Order DOE O 5400.5. Since 1993, the radiation protection framework on which DCSs are based has evolved with more sophisticated biokinetic and dosimetric information provided by the International Commission on Radiological Protection (ICRP), thus enabling consideration of age and gender. DOE-STD-1196-2011 establishes DCS values that reflect the current state of knowledge and practice in radiation protection. These DCSs are based on age-specific effective dose coefficients, revised gender specific physiological parameters for the Reference Man (ICRP 2002), and the latest information on the energies and intensities of radiation emitted by radionuclides (ICRP 2008).

Designated pollutant: any pollutant regulated by the Clean Air Act's New Source Performance Standards that is not a criteria pollutant. Examples of these are acid mist, fluorides, hydrogen sulfide in acid gas, and total reduced sulfur.

Diel: of or relating to a 24-hour period, especially a regular daily cycle, as of the physiology or behavior of an organism.

Diffuse source: an area source from which radioactive air emissions are continuously distributed over a given area or emanate from a number of points randomly distributed over the area (generally, all sources other than point sources). Diffuse sources are not actively ventilated or exhausted. Diffuse sources include: emissions from large areas of contaminated soil, resuspension of dust deposited on open fields, ponds and uncontrolled releases from openings in a structure.

Dose: the energy imparted to matter by ionizing radiation; the unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.

Dosimeter: a portable detection device for measuring the total accumulated exposure to ionizing radiation.

Dosimetry: the theory and application of the principles and techniques of measuring and recording radiation doses.

E **Effective dose equivalent (EDE):** an estimate of the total risk of potential effects from radiation exposure; it is the summation of the products of the dose equivalent and weighting factor for each tissue. The weighting factor is the decimal fraction of the risk arising from irradiation of a selected tissue to the total risk when the whole body is irradiated uniformly to the same dose equivalent. These factors permit dose equivalents from non-uniform exposure of the body to be expressed in terms of an EDE that is numerically equal to the dose from a uniform exposure of the whole body that entails the same risk as the internal exposure. The EDE includes the committed effective dose equivalent from internal deposition of radionuclides and the EDE caused by penetrating radiation from sources external to the body, and is expressed in units of rem or sievert.

Energy Savings Performance Contract (ESPC): a type of Energy Performance Contract (EPC). EPCs are alternative financing mechanisms authorized by the U.S. Congress designed to accelerate investment in cost effective energy conservation measures in existing federal buildings. Another type of EPC is a Utility Energy Service Contract. ESPCs allow federal agencies to accomplish energy savings projects without up-front capital costs and without special Congressional appropriations. The contract is a partnership between a federal agency and an energy service company (ESCO). The ESCO conducts a comprehensive energy audit for the federal facility and identifies improvements to save energy. In consultation with the federal agency, the ESCO designs and constructs a project that meets the agency's needs and arranges the necessary financing. The ESCO guarantees that the improvements will generate energy cost savings sufficient to pay for the project over the term of the contract. After the contract ends, all additional cost savings accrue to the agency. The savings must be guaranteed and the federal agencies may enter into a multiyear contract for a period not to exceed 25 years.

Exposure: the absorption of ionizing radiation or ingestion of a radioisotope. Acute exposure is a large exposure received over a short period. Chronic exposure is exposure received over a long period, such as during a lifetime.

F **Federal citation:** a reference to a federal law identified by its Public Law (Pub. L) or United States Code (USC) abbreviation, or a reference to the implementing regulation of a federal law identified by its Code of Federal Regulations (CFR) abbreviation. CFR citations are used in this report unless none have been written, in which case, USC citations are used. If a public law has yet to be incorporated into the USC, then its public law (Pub. L) citation is used.

When a bill is signed by the President and becomes a new public law, it is assigned a law number, legal statutory citation, and prepared for publication as a slip law. Citations for public laws include the abbreviation, Pub. L., the Congress number, and the number of the law. At the end of each session of Congress, the slip laws are compiled into bound volumes called the Statutes at Large, which present a chronological arrangement of the laws in the order that they have been enacted.

Every 6 years, public laws are incorporated into the USC, which is a codification of all general and permanent laws of the United States. They are assigned a USC number which reflects their relationship to similar laws or laws that govern similar programs. A supplement to the USC is published during each interim year until the next comprehensive volume is published. The USC is arranged by subject matter, and it shows the present status of laws with amendments already incorporated in the text that have been amended on one or more occasions.

Implementing regulations for federal laws are written by the government agencies responsible for the subject matter of the laws and explain in detail how the laws are to be carried out. For example, the United States Environmental Protection Agency writes the regulations concerning water pollution control which are found in Title 40 of the CFR, while the U. S. Fish and Wildlife Service writes the regulations concerning endangered species protection found in Title 50 of the CFR.

G **Gamma radiation:** high-energy, short-wavelength, ionizing, electromagnetic radiation emitted from the nucleus of an atom, frequently accompanying the emission of alpha or beta particles. It consists of photons in the highest observed range of photon energy. Gamma radiation (or gamma rays) easily pass through the human body but can be almost completely blocked by about 40 inches of concrete, 40 feet of water, or a few inches of lead.

Gray (Gy): the International System of Units unit of measure for absorbed dose; the quantity of energy imparted by ionizing radiation to a unit mass of matter, such as tissue. One gray equals 100 rads, or 1 joule per kilogram.

Gross alpha: the measure of radioactivity caused by all radionuclides present in a sample that emit alpha particles. Gross alpha measurements reflect alpha activity from all sources, including those that occur naturally. Gross measurements are used as a method to screen samples for relative levels of radioactivity.

Gross beta: the measure of radioactivity caused by all radionuclides present in a sample that emit beta particles. Gross beta measurements reflect beta activity from all sources, including those that occur naturally. Gross measurements are used as a method to screen samples for relative levels of radioactivity.

H **Half-life:** the time required for one-half of the radioactive atoms in a given amount of material to decay; for example, after one half-life, half of the atoms will have decayed; after two half-lives, three-fourths; after three half-lives, seven-eighths; and so on, exponentially.

Hazardous air pollutant (HAP): a toxic air pollutant that is known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. The U.S. Environmental Protection Agency has set emission standards for 22 of the 187 designated HAPs. Examples of toxic air pollutants include benzene, which is found in gasoline; perchloroethylene, which is emitted from some dry cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper by a number of industries. Examples of other listed HAPs include dioxin, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds.

Hazardous waste (HW): hazardous wastes exhibit any of the following characteristics: ignitability, corrosivity, reactivity, or Extraction Procedure toxicity (yielding excessive levels of toxic constituents in a leaching test), but other wastes that do not necessarily exhibit these characteristics have been determined to be hazardous by the U.S. Environmental Protection Agency (EPA). Although the legal definition of hazardous waste is complex, according to the EPA, the term generally refers to any waste that, if managed improperly, could pose a threat to human health and the environment.

High-efficiency particulate air (HEPA) filter: a disposable, extended-media, dry-type filter used to capture particulates in an air stream; HEPA collection efficiencies are at least 99.97 percent for 0.3-micrometer diameter particles.

I **Incidental take:** as per the Endangered Species Act (ESA), 'take' means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct of a listed species under the ESA. An incidental take is a take that results from activities that are otherwise lawful.

International System of Units (SI): an international system of physical units that includes meter (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent). The abbreviation, SI, comes from the French term Système International d'Unités.

Ionizing radiation: a form of radiation, which includes alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Compared to non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light, ionizing radiation is considerably more energetic. When ionizing radiation passes through material such as air, water, or living tissue, it deposits enough energy to produce ions by breaking molecular bonds and displace (or remove) electrons from atoms or molecules. This electron displacement may lead to changes in living cells. Given this ability, ionizing radiation has a number of beneficial uses, including treating cancer or sterilizing medical equipment. However, ionizing radiation is potentially harmful if not used correctly, and high doses may result in severe skin or tissue damage.

Isotope (also known as daughter nuclide or product): each of two or more forms of the same element that contain equal numbers of protons but different numbers of neutrons in their nuclei, and hence differ in relative atomic mass but not in chemical properties; in particular, a radioactive form of an element. For example, carbon-12 (^{12}C), the most common form of carbon, has six protons and six neutrons, whereas carbon-14 (^{14}C), the radioactive isotope of carbon, has six protons and eight neutrons.

L **L_C:** see Critical Level (L_C).

Low-level waste (LLW): defined by U.S. Department of Energy Manual DOE M 435.1-1, "Radioactive Waste Management Manual," as radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in section 11e.(2) of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material.

M **Maximally exposed individual (MEI):** a hypothetical member of the public at a fixed location who, over an entire year, receives the maximum effective dose equivalent (summed over all pathways) from a given source of radionuclide releases to air. Generally, the MEI is different for each source at a site.

Maximum contaminant level (MCL): the highest level of a contaminant in drinking water that is allowed by U.S. Environmental Protection Agency regulation.

Minimum detectable concentration (MDC): also known as the lower limit of detection, the smallest amount of radioactive material in a sample that can be quantitatively distinguished from background radiation in the sample with 95 percent confidence.

Mixed low-level waste (MLLW): waste containing both radioactive and hazardous components. It is defined by U.S. Department of Energy Manual DOE M 435.1-1, "Radioactive Waste Management Manual," as low-level waste determined to contain both source, special nuclear, or byproduct material subject to the Atomic

Energy Act of 1954, as amended, and a hazardous component subject to the Resource Conservation and Recovery Act (RCRA), as amended.

N **Non-community water system:** as defined in Nevada Revised Statute 445A.828, it is a public water system that is not a community water system.

O **Ozone Depleting Substances (ODS):** substances regulated by the EPA in the U.S. as Class I or Class II controlled substances. Class I substances have a higher ozone depletion potential (0.2 or higher) and have been completely phased out in the U.S. With a few exceptions, this means no one can produce or import Class I substances. Class I ODS include halons, chlorofluorocarbons (CFCs), methyl chloroform, carbon tetrachloride, and methyl bromide. Class II substances have an ozone depletion potential less than 0.2 and are all hydrochlorofluorocarbons (HCFCs). HCFCs were developed as transitional substitutes for many Class I substances. New production and import of most HCFCs will be phased out by 2020. The most common HCFC in use today is HCFC-22 or R-22, a refrigerant still used in existing air conditioners and refrigeration equipment.

P **Performance assessment (PA):** a systematic analysis of the potential risks posed by a waste disposal facility to the public and to the environment from disposed low-level radioactive waste. PAs are conducted, along with composite analyses (CAs), for the Area 3 and Area 5 Radioactive Waste Management Sites on the Nevada National Security Site to assess and predict their long-term performance.

Piezometer: an instrument for measuring the pressure of a liquid or gas, or something related to pressure (such as the compressibility of liquid). Piezometers are often placed in boreholes to monitor the pressure or depth of groundwater.

Plowshare Program: the program established by the United States Atomic Energy Commission (AEC), now the Department of Energy (DOE), as a research and development activity to explore the technical and economic feasibility of using nuclear explosives for industrial applications. The reasoning was that the relatively inexpensive energy available from nuclear explosions could prove useful for a wide variety of peaceful purposes. The Plowshare Program began in 1958 and continued through 1975. Between December 1961 and May 1973, the U.S. conducted 27 Plowshare nuclear explosive tests comprising 35 individual detonations. (source: https://www.osti.gov/opennet/reports/plowshar.pdf)

Point source: a single well-defined point (origin) of an airborne release, such as a stack or vent or other functionally equivalent structure. Point sources are actively ventilated or exhausted. Point source monitoring is monitoring emissions from a stack or vent.

Polychlorinated biphenyls (PCBs): a chemical belonging to the broad family of man-made organic chemicals known as chlorinated hydrocarbons. PCBs were domestically manufactured from 1929 until their manufacture was banned by the U.S. Congress in 1979. They have a range of toxicity and vary in consistency from thin, light-colored liquids to yellow or black waxy solids. Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics, and rubber products; in pigments, dyes, and carbonless copy paper; and many other industrial applications. PCBs can persist in the environment and accumulate in the food chain. PCBs' are classified as persistent organic pollutants. Their production was banned by the Stockholm Convention on Persistent Organic Pollutants in 2001. The International Research Agency on Cancer (IRAC) rendered PCBs as definite carcinogens in humans. According to the U.S. Environmental Protection Agency, PCBs cause cancer in animals and are probable human carcinogens.

Polychlorinated biphenyl (PCB) bulk waste: building material (i.e., substrate) “coated or serviced” with PCB bulk product waste (e.g., caulk, paint, mastics, sealants) at the time of disposal are managed as a PCB bulk product waste, even if the PCBs have migrated from the overlying bulk product waste into the substrate (source: https://www.epa.gov/pcbs/polychlorinated-biphenyl-pcb-guidance-reinterpretation).

Potential to emit (PTE): the quantity of a criteria air pollutant that each facility/piece of equipment would emit annually if it were operated for the maximum number of hours at the maximum production rate specified under its applicable air permit.

Private water system: a water system that is not a public water system, as defined in Nevada Revised Statute 445A.235, and is not regulated under State of Nevada permits.

Product (also known as daughter nuclide or isotope): each of two or more forms of the same element that contain equal numbers of protons but different numbers of neutrons in their nuclei, and hence differ in relative atomic mass but not in chemical properties; in particular, a radioactive form of an element. For example, carbon-12 (^{12}C), the most common form of carbon, has six protons and six neutrons, whereas carbon-14 (^{14}C), the radioactive isotope of carbon, has six protons and eight neutrons.

Public water system (PWS): as defined in Nevada Revised Statute 445A.235, it is a system, regardless of ownership, that provides the public with water for human consumption through pipes or other constructed conveyances, if the system has 15 or more service connections, as defined in NRS 445A.843, or regularly serves 25 or more persons. The three PWSs on the NNSS are permitted by the State of Nevada as non-community water systems.

Q **Quality assurance (QA):** a system of activities whose purpose is to provide the assurance that standards of quality are attained with a stated level of confidence.

Quality control (QC): procedures used to verify that prescribed standards of performance are attained.

R **Rad:** one of the two units used to measure the amount of radiation absorbed by an object or person, known as the "absorbed dose," which reflects the amount of energy that radioactive sources deposit in materials through which they pass. The radiation-absorbed dose (rad) is the amount of energy (from any type of ionizing radiation) deposited in any medium (e.g., water, tissue, air). An absorbed dose of 1 rad means that 1 gram of material absorbed 100 ergs of energy (a small but measurable amount) as a result of exposure to radiation. The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad.

Radioactive decay: the spontaneous transformation of one radionuclide into a different nuclide (which may or may not be radioactive), or de-excitation to a lower energy state of the nucleus by emission of nuclear radiation, primarily alpha or beta particles, or gamma rays (photons).

Radioactivity: the spontaneous emission of nuclear radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope.

Radioisotope: same as radionuclide.

Radionuclide: may also be called a radioactive nuclide, radioisotope, or radioactive isotope. It is an atom that has excess nuclear energy, making it unstable. This excess energy can either create and emit from the nucleus new radiation (gamma radiation) or a new particle (alpha particle or beta particle), or transfer this excess energy to one of its electrons, causing it to be ejected (conversion electron). During this process, the radionuclide is said to undergo radioactive decay.

Radon progeny: When radon in air decays, it forms a number of short-lived radioactive decay products (radon progeny), which include polonium-218, lead-214, bismuth-214 and polonium-214. All are radioactive isotopes of heavy metal elements and all have half-lives that are much less than that of radon.

Regulatory Boundary: a type of boundary developed for an Underground Test Area (UGTA) corrective action unit (CAU). It is established by negotiation between the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) and the Nevada Division of Environmental Protection (NDEP) during the CAU closure process based upon negotiated CAU-specific objectives to provide protection for the public and the environment from the effects of migration of radioactive contaminants. If radionuclides above the agreed-upon levels reach this boundary, NNSA/NFO is required to submit a plan for NDEP approval that will identify how the CAU-specific regulatory boundary objectives will be met.

Rem: one of the two standard units used to measure the dose equivalent (or effective dose), which combines the amount of energy (from any type of ionizing radiation that is deposited in human tissue), along with the medical effects of the given type of radiation. For beta and gamma radiation, the dose equivalent is the same as the absorbed dose. By contrast, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Thus, the dose equivalent (in rems) is equal to the absorbed dose (in rads) multiplied by the quality factor of the type of radiation [see Title 10, Section 20.1004, of the *Code of Federal Regulations* (10 CFR 20.1004), "Units of Radiation Dose"]. The related international system unit is the sievert (Sv), where 100 rem is equivalent to 1 Sv.

Roentgen (R): a unit of measurement used to express radiation exposure in terms of the amount of ionization produced in a volume of air. It is the amount of gamma or x-rays required to produce ions resulting in a charge of 0.000258 coulombs/kilogram of air under standard conditions. Named after Wilhelm Roentgen, the German scientist who discovered x-rays in 1895.

S

Saturated zone: a zone below the earth's surface below which all pore spaces between rocks or soil are completely filled with water.

Section 106: Section 106 of the National Historic Preservation Act requires federal agencies to take into account the effects of their undertakings on historic properties and afford the Council a reasonable opportunity to comment on such undertakings (source: https://www.achp.gov/protecting-historic-properties).

Sievert (Sv): the International System of Units unit of radiation dose equivalent and effective dose equivalent, that is the product of the absorbed dose (gray), quality factor, distribution factor, and other necessary modifying factors; 1 Sv equals 100 rem.

Solid waste: most simply, waste generated by routine operations that is not regulated as hazardous or radioactive by state or federal agencies.

Source term: the amount of a specific pollutant emitted or discharged to a particular medium, such as the air or water, from a particular source.

Spectroscopy: the study of the interaction between matter and electromagnetic radiation.

Subcritical experiment: an experiment using high explosives and nuclear weapon materials (including special nuclear materials like plutonium) to gain data used to maintain the nuclear stockpile without conducting nuclear explosions banned by the Comprehensive Nuclear Test Ban Treaty.

Subsidence crater: a hole or depression left on the surface of an area which has had an underground (usually nuclear) explosion.

T

Thermoluminescent dosimeter (TLD): a device used to measure external beta or gamma radiation levels, and which contains a material that, after exposure to beta or gamma radiation, emits light when processed and heated.

Total effective dose equivalent (TEDE): The sum of the external exposures and the committed effective dose equivalent (CEDE) for internal exposures.

Transuranic (TRU) waste: material contaminated with alpha-emitting transuranium nuclides, which have an atomic number greater than 92 (e.g., ^{239}Pu), half-lives longer than 20 years, and are present in concentrations greater than 100 nanocuries per gram of waste. Mixed TRU waste contains hazardous waste also.

Tritium (^{3}H): a radioactive form of hydrogen that is produced naturally in the upper atmosphere when cosmic rays strike nitrogen molecules in the air. Although tritium can be a gas, its most common form is in water, because, like non-radioactive hydrogen, tritium reacts with oxygen to form water. Tritium replaces one of the stable hydrogens in the water molecule, H_2O, and is called tritiated water (HTO). Like H_2O, tritiated water is colorless and odorless. Naturally-occurring tritium is found in very small or trace amounts in the environment as HTO, which easily disperses in the atmosphere, water bodies, soil, and rock. Tritium is also produced during nuclear weapons explosions, as a by-product in nuclear reactors producing electricity, and in special production reactors, where the isotope lithium-6 is bombarded to produce tritium. In the mid-1950s and early 1960s, tritium was widely dispersed during the above-ground testing of nuclear weapons. The quantity of tritium in the atmosphere from weapons testing peaked in 1963 and has been decreasing ever since. Tritium is a contaminant of groundwater in select areas of the NNSS as a result of historical underground nuclear testing and is the contaminant of concern being monitored in NNSS groundwater samples. Tritium decays at a half-life of 12.3 years by emitting a low-energy beta particle. In 1976, EPA established a dose-based drinking water standard of 4 mrem per year and set a maximum contaminant level for drinking water of 20,000 picocuries per liter (pCi/L) for tritium, the level assumed to yield a dose of 4 mrem per year. One year of drinking water with this amount of contamination would produce approximately the same dose of radiation you would get during a single commercial flight between Los Angeles and New York City.

U **Uncertainty:** the parameter associated with a sample measurement that characterizes the range of the measurement that could reasonably be attributed to the sample. Used in this report, the uncertainty value is established at ± 2 standard deviations.

United States Code (USC): a codification of all general and permanent laws of the United States. Laws in the USC are grouped into various Titles, Chapters, and Sections by topic. For example, the citation 16 USC 1531-1544 is for Title 16 (Conservation), Sections 1531-1544 (in Chapter 35) which comprise the law called the Endangered Species Act.

Unsaturated zone: that portion of the subsurface in which the pores are only partially filled with water and the direction of water flow is vertical; also referred to as the vadose zone.

Use-Restriction (UR) Boundary: a type of boundary developed for an Underground Test Area (UGTA) corrective action unit (CAU). It delineates an area expected to require institutional controls to restrict access to potentially contaminated groundwater. A UR boundary is established by negotiation between the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) and the Nevada Division of Environmental Protection. It is based primarily on ***contaminant boundary*** (see Glossary definition) forecasts. A UR boundary is established to protect site workers from inadvertently contacting, or site activities from affecting, the flow paths of contaminated groundwater. NNSA/NFO, and any future land manager, must maintain all official CAU-specific UR boundary records.

V **Vadose zone:** the partially saturated or unsaturated region above the water table that does not yield water to wells; also referred to as the unsaturated zone.

W **Water table:** the underground boundary between saturated and unsaturated soils or rock. It is the point beneath the surface of the ground at which natural groundwater is found. It is the upper surface of a saturation zone where the body of groundwater (i.e., aquifer) is not confined by an overlying impermeable formation. In the situation where an aquifer does have an overlying confining formation, the aquifer has no water table.

Appendix C: Acronyms and Abbreviations

ac	acre(s)
Ac	actinium
ACHP	Advisory Council on Historic Preservation
ACM	asbestos-containing material
AEC	Atomic Energy Commission
AFV	alternative fuel vehicle
AICP	American Indian Consultation Program
ALARA	as low as reasonably achievable
Am	americium
ANSI	American National Standards Institute
ANSI/HPS	American National Standards Institute/Health Physics Society
AP	Accreditation Program
APE	area of potential effects
ARL	Army Research Laboratory
ARL/SORD	Air Resources Laboratory, Special Operations and Research Division
ASN	Air Surveillance Network
B	Background
BCG	Biota Concentration Guide
Be	beryllium
BEEF	Big Explosives Experimental Facility
BH	Bloomington Hills
BLM	Bureau of Land Management
BN	Bechtel Nevada
BOD_5	5-day biochemical oxygen demand
Bq	Becquerel(s)
Bq/m^3	Becquerels per cubic meter
BREN	Bare Reactor Experiment–Nevada
BSDW	Bureau of Safe Drinking Water
BTU	British thermal unit
C	carbon (except in Chapter 6, where it denotes “control”)
°C	degrees Centigrade
CA	Composite Analysis
CAA	Clean Air Act
CAPP	Chemical Accident Prevention Program
CAS	Corrective Action Site
CAU	Corrective Action Unit
CCDAQ	Clark County Department of Air Quality
CCWRD	Clark County Water Reclamation District
CEDE	committed effective dose equivalent
CEI	Compliance Evaluation Inspection
CEM	Community Environmental Monitor
CEMP	Community Environmental Monitoring Program
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	curie(s)
CL	concentration level (used in text for the Clean Air Act National Emission Standards for Hazardous Pollutants Concentration Level for Environmental Compliance)
cm	centimeter(s)
cm^2	square centimeter(s)
CNLV	City of North Las Vegas
CNR	Classified Non-Radiological
CNRH	Classified Non-Radiological Hazardous
Co	cobalt
CO	carbon monoxide
COVID-19	coronavirus disease 2019
cpm	counts per minute
CRMP	Cultural Resources Management Program
Cs	cesium
CV	coefficient of variation
CY	calendar year
d	day(s)
DAF	Device Assembly Facility
DAQ	Division of Air Quality (Clark County)
DCS	Derived Concentration Standard
D&D	decontamination and decommissioning
DEAR	U.S. Department of Energy Acquisition Regulation

DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOECAP	U.S. Department of Energy Consolidated Audit Program
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DOI	U.S. Department of Interior
DPF	Dense Plasma Focus
dpm	disintegrations per minute
DQA	Data Quality Assessment
DQO	Data Quality Objective
DRI	Desert Research Institute
DSA	Documented Safety Analysis
DU	depleted uranium
E1	Environmental 1
E2	Environmental 2
EDE	effective dose equivalent
EHS	extremely hazardous substance
EH&S	Environmental, Safety and Health
EM	Environmental Management
EMAC	Ecological Monitoring and Compliance
E-MAD	Engine Maintenance and Disassembly
EMS	Environmental Management System
E.O.	Executive Order
EODU	Explosive Ordnance Disposal Unit
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ER	Environmental Restoration
ERA	Environmental Research Associates
ESPC	Energy Savings Performance Contract
ETDS	E-Tunnel Waste Water Disposal System
Eu	europium
EWDP	Early Warning Drill Program
°F	degrees Fahrenheit
FD	field duplicate
FFACO	Federal Facility Agreement and Consent Order
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FOAV	Finding of Alleged Violation
ft	foot or feet
ft^2	square feet
ft^3	cubic feet
FS	field sample
FWS	U.S. Fish and Wildlife Service
FY	fiscal year
g	gram(s)
gal	gallon(s)
gal/ft^2	gallons used per square foot
GHG	greenhouse gas
GIS	Geographic Information System
GPD	gallon(s) per day
GPS	global positioning system
gsf	gross square feet
Gy	gray(s)
Gy/d	gray(s) per day
h	hour(s)
^3H	tritium
ha	hectare(s)
HAP	hazardous air pollutant
HENRE	High-Energy Neutron Reactions Experiment
HEPA	high-efficiency particulate air
HEST	High Explosives Simulation Test
HPSB	High Performance Sustainable Building
hr	hour(s)
HW	hazardous waste
HWAA	Hazardous Waste Accumulation Area
HWSU	Hazardous Waste Storage Unit
I	iodine
ICRP	International Comission on Radiological Protection
ID	identification number
IEC	International Electrotechnical Commission
IL	investigation level
ILA	industrial, landscaping, and agricultural
in.	inch(es)
IOC	inorganic chemical
ISO	International Organization for Standardization
JASPER	Joint Actinide Shock Physics Experimental Research
K	potassium
kg	kilogram(s)

kg/d	kilogram(s) per day
km	kilometer(s)
km^2	square kilometer(s)
kV	kilovolt(s)
L	liter(s)
LANL	Los Alamos National Laboratory
lb	pound(s)
L_C	Critical Level (synonymous with Decision Level)
LCA	lower carbonate aquifer
LCS	laboratory control sample
L/d	liter(s) per day
LEPC	Local Emergency Planning Commission
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LM	Legacy Management
log	logarithmic
LQAP	Laboratory Quality Assurance Plan
M	mega-
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
M&O	Management and Operating
MAPEP	Mixed Analyte Performance Evaluation Program
MBTA	Migratory Bird Treaty Act
mCi	millicurie(s)
MCL	maximum contaminant level
MDC	minimum detectable concentration
MDL	Method Detection Limit
MEI	maximally exposed individual
MET	meteorological
MGD	million gallons per day
mg/L	milligram(s) per liter
MHD	Mercury Historic District
mi	mile(s)
mi^2	square mile(s)
min	minute(s)
mL	milliliter
MLLW	mixed low-level waste
mm	millimeter(s)
mmhos/cm	millimhos per centimeter
MOA	memorandum of agreement
MQO	Measurement Quality Objectives
MR	monitor and report
mR	milliroentgen(s)
mR/d	milliroentgen(s) per day
mR/yr	milliroentgen(s) per year
mrad	millirad(s)
mrem	millirem(s)
mrem/yr	millirem(s) per year
MSTS	Mission Support and Test Services, LLC
mSv	millisievert(s)
mSv/yr	millisievert(s) per year
$MtCO_2e$	metric ton(s) of carbon dioxide equivalent
mton	metric ton(s)
MTRU	mixed transuranic
MWDU	Mixed Waste Disposal Unit
MWh	megawatt hour(s)
MWSU	Mixed Waste Storage Unit
µ	micro-
µCi	microcurie(s)
µCi/mL	microcurie(s) per milliliter
µg/L	microgram(s) per liter
µm	micrometer(s)
µR	microroentgen(s)
µR/hr	microroentgen(s) per hour
µS/cm	microseimen(s) per centimeter
N	nitrogen
n	nano-
NA	not applicable
NAAQS	National Ambient Air Quality Standards
NAC	Nevada Administrative Code
NATM	National Atomic Testing Museum
NCA	Nevada Combined Agency
NCERC	National Criticality Experiments Research Center
NC-GWE	Nye County Groundwater Evaluation
nCi	nanocurie(s)
ND	not detected
NDA	Nevada Department of Agriculture
NDEP	Nevada Division of Environmental Protection
NDOF	Nevada Department of Forestry
NDOW	Nevada Department of Wildlife
NELAC	National Environmental Laboratory Accreditation Conference

NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NLVF	North Las Vegas Facility
NNSA	U.S. Department of Energy, National Nuclear Security Administration
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSS	Nevada National Security Site
NNSSER	Nevada National Security Site Environmental Report
NOV	Notice of Violation
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPTEC	Nonproliferation Test and Evaluation Complex
NRDS	Nuclear Rocket Development Station
NRHP	National Register of Historic Places
NRS	Nevada Revised Statutes
NS	not required to be sampled
NSHPO	Nevada State Historic Preservation Office
NSPS	New Source Performance Standards
NSSAB	Nevada Site Specific Advisory Board
NSTec	National Security Technologies, LLC
NTA	Nuclear Testing Archive
NTS	Nevada Test Site
NTTR	Nevada Test and Training Range
NV	Nevada
NVLAP	National Voluntary Laboratory Accreditation Program
ODS	ozone-depleting substance
OSHA	Occupational Safety and Health Administration
OSTI	Office of Scientific and Technical Information
oz	ounce(s)
p	pico-
P2/WM	pollution prevention/waste minimization
PA	Performance Assessment
PAC	polycyclic aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
pCi	picocurie(s)
pCi/g	picocurie(s) per gram
pCi/L	picocurie(s) per liter
pCi/mL	picocurie(s) per milliliter
PFAS	per- and polyfluoroalkyl substances
PI	prediction interval
PIC	pressurized ion chamber
PM	particulate matter
PM10	particulate matter equal to or less than 10 microns in diameter
POE	point of entry
PSU	Portland State University
PT	proficiency testing
PTE	potential to emit
Pu	plutonium
PUE	Power Utilization Effectiveness
PV	photovoltaic
PVC	polyvinyl chloride
PWS	public water system
QA	quality assurance
QAMAP	Quality Assurance Management and Assessment Plan
QAP	Quality Assurance Program (or Plan)
QC	quality control
QSM	Quality Systems Manual
R	roentgen(s)
Ra	radium
rad	radiation absorbed dose (a unit of measure)
rad/d	rad(s) per day
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RER	relative error ratio
RFP	request for proposal
RIDP	Radionuclide Inventory and Distribution Program
RL	Reporting Limit
RNCTEC	Radiological/Nuclear Countermeasures Test and Evaluation Complex
ROTC	Record of Technical Change
RPD	relative percent difference

RREMP	Routine Radiological Environmental Monitoring Plan
RSL	Remote Sensing Laboratory
RTR	Real-Time Radiography
RWAP	Radioactive Waste Acceptance Program
RWMC	Radioactive Waste Management Complex
RWMS	Radioactive Waste Management Site
s	second(s)
SAA	Satellite Accumulation Area
SAD	surface area disturbance
SAP	Sampling and Analysis Plan
SC	specific conductance
SD	standard deviation
SDWA	Safe Drinking Water Act
SE	standard error of the mean
SER	Safety Evaluation Report
SERC	State Emergency Response Commissioner
SHPO	State Historic Preservation Office
SI	International System of Units
SIS	Sprung Instant Structure
SLEIS	State and Local Emissions Inventory System
SNHD	Southern Nevada Health District
SNL	Sandia National Laboratories
SOC	synthetic organic chemical
SOI	Secretary of the Interior
SO_2	sulfur dioxide
SPCC	Spill Prevention, Control, and Countermeasure
Sr	strontium
SRIP	Sustainability Report and Implementation Plan
SSP	Site Sustainability Plan
S.U.	standard unit(s) (for measuring pH)
Sv	sievert(s)
SWEIS	Site-Wide Environmental Impact Statement
Tc	technetium
TEDE	total effective dose equivalent
Th	thorium
TLD	thermoluminescent dosimeter
TPC	Tribal Planning Committee
TPCB	Transuranic Pad Cover Building
TRC	Tribal Revegetation Committee
TRI	Toxic Release Inventory
TRU	transuranic
TSaMP	Tritium Sampling and Monitoring Program
TSCA	Toxic Substances Control Act
TSR	Technical Safety Requirements
TSS	total suspended solids
TTR	Tonopah Test Range
TUM	Tribal Update Meeting
U	uranium
UGT	underground test
UGTA	Underground Test Area
U.S.	United States
USAF	U.S. Air Force
USC	United States Code
USGS	U.S. Geological Survey
UST	underground storage tank
VERB	Visual Examination and Repackaging Building
VOC	volatile organic compound
VZM	vadose zone monitoring
WAC	Waste Acceptance Criteria
WDP	water delivery point
WEF	Waste Examination Facility
WIPP	Waste Isolation Pilot Plant
WO	Waste Operations
WW	water well
WWII	World War II
Y-12	Y-12 National Security Complex
yd	yard(s)
yd^3	cubic yard(s)
YOY	year over year
yr	year(s)

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NNSA
National Nuclear Security Administration

NEVADA NATIONAL
NNSS
SECURITY SITE

06210002

DOE/NV/03624--1210-ATT A

September 2021

2020

Environmental Report

Attachment A: Site Description

DOE/NV/03624--1210-ATT A

NEVADA NATIONAL NNSS SECURITY SITE

2020 Environmental Report

Attachment A: Site Description

This report was prepared for:

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Acronyms and Abbreviations

AA	alluvial aquifer
AEC	Atomic Energy Commission
a.k.a.	also known as
ARL/SORD	Air Resources Laboratory, Special Operations and Research Division
ATCU	argillic tuff confining unit
ATICU	Ammonia Tanks intrusive confining unit
BA	Benham aquifer
BFCU	Bullfrog confining unit
BLM	Bureau of Land Management
BMICU	Black Mountain intrusive confining unit
BN	Bechtel Nevada
BRA	Belted Range aquifer
BRCU	Belted Range confining unit
°C	degree Celsius
ca.	*circa,* meaning "approximately"
CA	carbonate aquifer
CAS	corrective action site
CAU	corrective action unit
CCICU	Claim Canyon intrusive confining unit
CCU	clastic confining unit
CFCM	Crater Flat composite unit
CFCU	Crater Flat confining unit
CG	cloud-to-ground
CHCU	Calico Hills confining unit
CHICU	Calico Hills intrusive confining unit
CHVCM	Calico Hills vitric composite unit
CHVTA	Calico Hills vitric-tuff aquifer
CHZCM	Calico Hills zeolitized composite unit
cm	centimeter(s)
CP	Control Point
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
dT/dz	change in temperature with height
DVCM	detached volcanics composite unit
ESA	Endangered Species Act
°F	degree Fahrenheit
FCCM	Fortymile Canyon composite unit
FCCU	Fluorspar Canyon confining unit
FFACO	Federal Facility Agreement and Consent Order
ft	foot or feet
GCU	granite confining unit

GPS	Global Positioning System
HGU	hydrogeologic unit
HSA	Hydrological Services America
HSU	hydrostratigraphic unit
IA	inlet aquifer
IICU	intracaldera intrusive confining unit
in.	inch(es)
IT	International Technology Corporation
KA	Kearsarge aquifer
km	kilometer(s)
kph	kilometer(s) per hour
kt	kiloton(s)
LCA	lower carbonate aquifer
LCA3	lower carbonate aquifer - upper thrust plate
LCCU	lower clastic confining unit
LCCU1	lower clastic confining unit - upper thrust plate
LFA	lava-flow aquifer
LPCU	lower Paintbrush confining unit
LTCU	lower tuff confining unit
LTCU1	lower tuff confining unit 1
LVTA	lower vitric-tuff aquifer
LVTA1	lower vitric-tuff aquifer 1
LVTA2	lower vitric-tuff aquifer 2
m	meter(s)
Ma	million years ago
mb	millibar(s)
MEDA	Meteorological Data Acquisition
MGCU	Mesozoic granite confining unit
mi	mile(s)
mph	mile(s) per hour
NASA	National Aeronautics and Space Administration
NDNH	Nevada Division of Natural Heritage
NNES	Navarro Nevada Environmental Services, LLC
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSS	Nevada National Security Site
NOAA	National Oceanic and Atmospheric Administration
NRDS	Nuclear Rocket Development Station
NSTec	National Security Technologies, LLC
NTS	Nevada Test Site
NV	Nevada
OSBCU	Oak Spring Butte confining unit
PBRCM	Pre-Belted Range composite unit
PCM	Paintbrush composite unit
PCU	playa confining unit

PDT	Pacific Daylight Time
PLFA	Paintbrush lava-flow aquifer
PM-OV	Pahute Mesa–Oasis Valley
PST	Pacific Standard Time
PVTA	Paintbrush vitric-tuff aquifer
RMBCU	Rainier Mesa breccia confining unit
RMICU	Rainier Mesa intrusive confining unit
RM-SM	Rainier Mesa–Shoshone Mountain
RVA	Redrock Valley Aquifer
RVBCU	Redrock Valley Breccia Confining Unit
RVICU	Redrock Valley intrusive confining unit
SCCC	Silent Canyon caldera complex
SCICU	Silent Canyon intrusive confining unit
SCVCU	subcaldera volcanic confining unit
SNJV	Stoller-Navarro Joint Venture
SWA	Stockade Wash aquifer
SWL	static water level
SWNVF	Southwestern Nevada Volcanic Field
TCA	Tiva Canyon Aquifer
TCU	tuff confining unit
TCVA	Thirsty Canyon volcanic aquifer
THCM	Tannenbaum Hill composite unit
THLFA	Tannenbaum Hill lava-flow aquifer
TMA	Timber Mountain aquifer
TMCC	Timber Mountain caldera complex
TMCM	Timber Mountain composite unit
TMLVTA	Timber Mountain lower vitric-tuff aquifer
TMUVTA	Timber Mountain upper vitric-tuff aquifer
TMWTA	Timber Mountain welded-tuff aquifer
TPA	Twin Peaks aquifer
TSA	Topopah Spring aquifer
TUBA	Tub Spring aquifer
UCA	upper carbonate aquifer
UCCU	upper clastic confining unit
UGTA	Underground Test Area
UPCU	upper Paintbrush confining unit
USFS	U.S. Forestry Service
UTCU	upper tuff confining unit
UTCU1	upper tuff confining unit 1
UTCU2	upper tuff confining unit 2
VCU	volcaniclastic confining unit
VTA	vitric-tuff aquifer
WCU	Wahmonie confining unit
WTA	welded-tuff aquifer
WWA	Windy Wash aquifer

YMCFCM	Yucca Mountain Crater Flat composite unit
YMCHLFA	Yucca Mountain Calico Hills lava-flow aquifer
YVCM	younger volcanic composite unit

Attachment A: Nevada National Security Site Description

This attachment expands on the general description of the Nevada National Security Site (NNSS) presented in the Chapter 1 Introduction to the *Nevada National Security Site Environmental Report 2020*. Included are subsections that summarize the site's geological, hydrological, climatological, and ecological settings and the cultural resources of the NNSS. The subsections are meant to aid the reader in understanding the complex physical and biological environment of the NNSS. An adequate knowledge of the site's environment is necessary to assess the environmental impacts of new projects, design and implement environmental monitoring activities for current site operations, and assess the impacts of site operations on the public residing in the vicinity of the NNSS. The NNSS environment contributes to several key features of the site that afford protection to the inhabitants of adjacent areas from potential exposure to radioactivity or other contaminants resulting from NNSS operations. These key features include the general remote location of the NNSS, restricted access, extended wind transport times, the great depths to slow-moving groundwater, little or no surface water, and low population density. This attachment complements the annual summary of monitoring program activities and dose assessments presented in the main body of this report.

A summary of information about historic NNSS underground nuclear explosive tests, including their locations and geologic setting, is provided in Table A-1.

A.1 Geology

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A.1.1 Physiographic/Geologic Setting

The NNSS is located in the southern part of the Great Basin, the northern-most subprovince of the Basin and Range Physiographic Province (Figure A-1). The NNSS terrain is typical of much of the Basin and Range Physiographic Province, characterized by mostly tilted, fault-bounded blocks that are as much as 80 kilometers (km) (50 miles [mi]) long and 24 km (15 mi) wide. These features are modified locally by the Las Vegas Shear Zone (a component of the Walker Lane regional structural belt) in the southern part of the NNSS, and by resurgent calderas of the Southwestern Nevada Volcanic Field (SWNVF). The land forms and topography of the NNSS area reflect the complex geology and its location in the arid Mojave Desert.

The NNSS area is geologically complex, with at least seven Tertiary-age calderas nearby, many relatively young basin-and-range-style normal faults (due to extensional forces), Mesozoic-age thrust faults (due to compressional forces), and igneous intrusive bodies, all superimposed on a basement complex of highly deformed Proterozoic- and Paleozoic-age sedimentary and metasedimentary rocks. Geologic units exposed at the surface in the NNSS area can be categorized as approximately 40% alluvium-filled basins and 20% Paleozoic and uppermost Precambrian sedimentary rocks, the remainder being Tertiary-age volcanic rocks with a few intrusive masses (Orkild 1983; Slate et al. 1999). A generalized geologic map of the NNSS area is given in Figure A-2.

The NNSS area is dominated by Tertiary-age volcanic rocks formed from materials that were erupted from various vents in the SWNVF, located on and adjacent to the northwestern part of the NNSS (Figure A-2). At least seven major calderas have been identified in this multi-caldera silicic volcanic field (Byers et al. 1976; National Security Technologies, LLC [NSTec] 2007). The calderas were formed by the voluminous eruption of zoned ash-flow tuffs between 16 and 7.5 million years ago (Ma) (Sawyer et al. 1994). From oldest to youngest, the calderas are Redrock Valley, Grouse Canyon, Area 20, Claim Canyon, Rainier Mesa, Ammonia Tanks, and Black Mountain calderas. A comprehensive review of past studies and the evolution of concepts on calderas of the SWNVF during the period from 1960 to 1988 is presented in Byers et al. (1989).

The volcanic rocks are covered in many areas by a variety of late Tertiary and Quaternary surficial deposits. These younger deposits consist of alluvium, colluvium, eolian (wind-blown sand) deposits, spring deposits, basalt lavas, lacustrine (fresh-water lake) deposits, and playa deposits.

Table A-1. Information summary of NNSS underground nuclear tests

Physiographic Area NNSS Area(s)	Total Underground[a] Tests	Total Underground[a] Detonations	Test Dates[a]	Depth of Burial Range	Overburden Media	Comments
Yucca Flat 1, 2, 3, 4, 6, 7, 8, 9, 10	659	747	1951–1992	27–1,219 m (89–3,999 ft)	Alluvium/playa, Volcanic tuff	Various test types and yields; almost all were vertical emplacements above and below static water level; includes four high-yield[b] detonations.
Pahute Mesa 19, 20	85	85	1965–1992	31–1,452 m (100–4,765 ft)	Alluvium (thin), volcanic tuffs and lavas	Almost all were large-diameter vertical emplacements above and below static water level; includes 18 high-yield detonations.
Rainier/Aqueduct Mesa 12	61	62	1957–1992	61–640 m (200–2,100 ft)	Tuffs with welded tuff caprock (little or no alluvium)	Two vertical emplacements; all others were horizontal tunnel emplacements above static water level; mostly low-yield[c] U.S. Department of Defense weapons effects tests.
Frenchman Flat 5, 11	10	10	1965–1971	179–296 m (587–971 ft)	Mostly alluvium, minor volcanic tuff	Various emplacement configurations, both above and below static water level.
Shoshone Mountain 16	6	6	1962–1971	244–640 m (800–2,100 ft)	Bedded tuff, ash-flow tuff	Tunnel-based low-yield weapons effects and Vela Uniform[d] tests.
Oak Spring Butte (Climax Area) 15	3	3	1962–1966	229–351 m (750–1,150 ft)	Granite	Three tests above static water level. (Hard Hat, Tiny Tot, and Pile Driver).
Buckboard Mesa 18	3	3	1962–1964	≤ 27 m (90 ft)	Basaltic lavas	Shallow, low-yield experiments (Sulky, Johnnie Boy[e], and Danny Boy); all were above static water level.
Dome Mountain 30	1	5	03/12/1968	50 m (165 ft)	Mafic lava	Buggy (A, B, C, D, and E); Plowshare cratering test using a 5-detonation-horizontal salvo; all above static water level.

Source: Allen et al. (1997)

(a) Source: U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) (2015a).
(b) High-yield detonations – detonations more than 200 kt.
(c) Low-yield detonations – detonations less than 20 kt.
(d) Vela Uniform was a Department of Defense program designed to improve the capability to detect, identify, and locate underground nuclear explosions (according to NNSA/NFO 2015a).
(e) Johnnie Boy was detonated at a depth of 23 ft (NNSA/NFO 2015a; essentially a surface burst) approximately 1 mi east of Buckboard Mesa.

Note: ft = foot/feet; kt = kiloton(s); m = meter(s).

Figure A-1. Basin and Range Province and Great Basin Province (Fiero 1986)

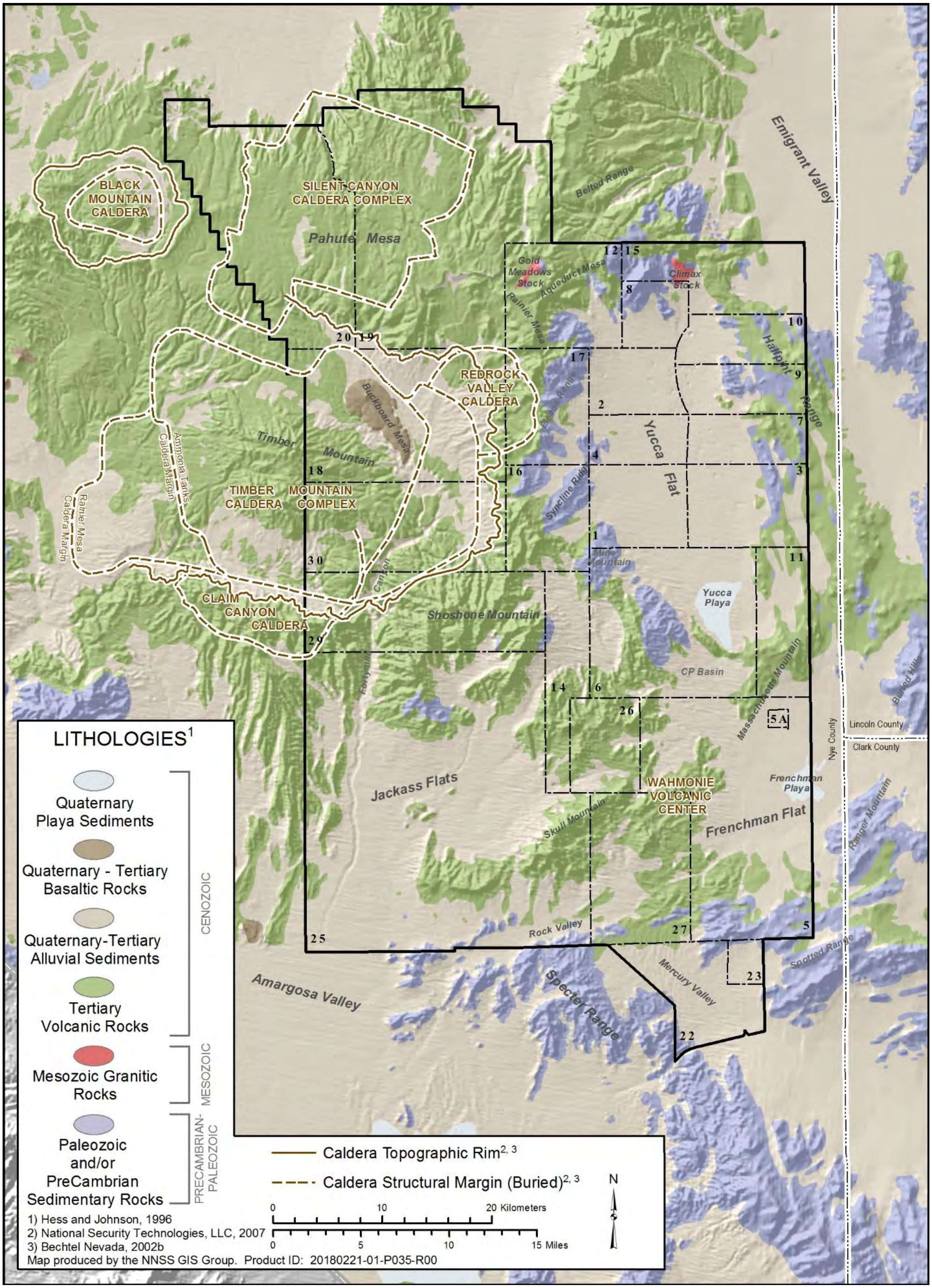

Figure A-2. Generalized geologic map of the NNSS and vicinity

The area includes more than 300 described Tertiary-age volcanic units (Warren et al. 2000a, 2003). As a matter of practicality, some units are grouped together, especially those of limited areal extent or thickness. Table A-2 presents most of the Tertiary volcanic units useful in characterizing the subsurface at the NNSS.

Table A-2. Quaternary and Tertiary stratigraphic units of the NNSS and vicinity

Stratigraphic Assemblages and Major Units[a, b]	Volcanic Sources[c]
Quaternary and Tertiary Sediments Young alluvium (Qay) Playa (Qp) Quaternary - Tertiary colluvium (QTc) Middle alluvium (Qam) Eolian sand (QTe) Quaternary-Tertiary alluvium (QTa)	Not applicable
Quaternary Basalts (Qby)	Several discrete sources
Pliocene Basalts (Typ)	Several discrete sources
Tertiary alluvium (Tgy)	Not applicable
Miocene Basalt and Rhyolite Thirsty Canyon and Younger Basalts (Tyb) Rhyolite of Obsidian Butte (Tyr)	Several discrete sources
Tertiary Sediments Late synvolcanic sedimentary rocks (Tgm) Caldera moat-filling sedimentary deposits (Tgc) Younger landslide and sedimentary breccia (Tgyx)	Not applicable
Thirsty Canyon Group (Tt) Gold Flat Tuff (Ttg) Trachyte of Hidden Cliff (Tth) Trachytic rocks of Pillar Spring and Yellow Cleft (Tts) Trail Ridge Tuff (Ttt) Pahute Mesa and Rocket Wash Tuffs (Ttp) Comendite of Ribbon Cliff (Ttc)	Black Mountain Caldera (9.1–9.4 Ma)
Volcanics of Fortymile Canyon (Tf) Rhyolite of Boundary Butte (Tfu) Post-Timber Mountain Basaltic Rocks (Tft) Trachyte of Donovan Mountain (Tfn) Rhyolite of Shoshone Mountain (Tfs) Lavas of Dome Mountain (Tfd) Younger intrusive rocks (Tiy) Rhyolite of Rainbow Mountain (Tfr) Beatty Wash Formation (Tfb) Tuff of Leadfield Road (Tfl) Rhyolite of Fleur-de-lis Ranch (Tff)	Several discrete vent areas in and around the Timber Mountain Caldera Complex
Timber Mountain Group (Tm) Trachyte of East Cat Canyon (Tmay) Tuff of Buttonhook Wash (Tmaw) Ammonia Tanks Tuff (Tma) Bedded Ammonia Tanks Tuff (Tmab) Timber Mountain landslide breccia (Tmx) Rhyolite of Tannenbaum Hill (Tmat) Basalt of Tierra (Tmt) Rainier Mesa Tuff (Tmr) Rhyolite of Fluorspar Canyon (Tmrf) Tuff of Holmes Road (Tmrh) Landslide or eruptive breccia (Tmrx) Rhyolite of Windy Wash (Tmw) Transitional Timber Mountain rhyolites (Tmn)	**Timber Mountain Caldera Complex:** Ammonia Tanks Caldera (11.45 Ma) Rainier Mesa Caldera (11.6 Ma)
Paintbrush Group (Tp) Rhyolite of Benham (Tpb) Post-Tiva Canyon rhyolites (Tpu) Rhyolite of Scrugham Peak (Tps) Paintbrush caldera-collapse breccias (Tpx)	

Table A-2. Quaternary and Tertiary stratigraphic units of the NNSS and vicinity

Stratigraphic Assemblages and Major Units[a, b]	Volcanic Sources[c]
Tiva Canyon Tuff (Tpc)	Claim Canyon Caldera (12.65 Ma)
Yucca Mountain Tuff (Tpy) Rhyolite of Delirium Canyon (Tpd) Rhyolite of Echo Peak (Tpe) Middle Paintbrush Group rhyolites (Tpm) Pah Canyon Tuff (Tpp) Rhyolite of Silent Canyon (Tpr) Topopah Spring Tuff (Tpt) Calico Hills Formation (Th; formerly Tac)	Unknown (12.8 Ma)
Wahmonie Formation (Tw)	Wahmonie Volcanic Center (13.0 Ma)
Crater Flat Group (Tc) Rhyolite of Inlet (Tci) Prow Pass Tuff (Tcp) Rhyolite of Kearsarage (Tcpk) Andesite of Grimy Gulch (Tcg) Bullfrog Tuff (Tcb) Rhyolites in the Crater Flat Group (Tcr) Tram Tuff (Tct) Belted Range Group (Tb) Deadhorse Flat Formation (Tbd) Grouse Canyon Tuff (Tbg) Comendite of Split Range (Tbgs) Comendite of Quartet Dome (Tbq)	**Silent Canyon Caldera Complex:** Area 20 Caldera (13.1 Ma) Grouse Canyon Caldera (13.6 Ma)
Tram Ridge Group (Tr) Lithic Ridge Tuff (Trl) Dikes of Tram Ridge (Trd) Rhyolite of Picture Rock (Trr)	Uncertain
Tunnel Formation (Tn) Tunnel 4 Member (Tn4) Tunnel 3 Member (Tn3)	Uncertain
Volcanics of Quartz Mountain (Tq) Tuff of Sleeping Butte (Tqs) Hornblende-bearing rhyolite of Quartz Mountain(Tqh) Tuff of Tolicha Peak (Tqt) Early rhyolite of Quartz Mountain (Tqe) Dacite of Mount Helen (Tqm)	Uncertain
Volcanics of Big Dome (Tu) Comendite of Ochre Ridge (Tuo) Tub Spring Tuff (Tub) Comendite of Emigrant Valley (Tue)	Unknown (14.9 Ma)
Volcanics of Oak Spring Butte (To) Tunnel bed 2 (Ton2) Yucca Flat Tuff (Toy) Tunnel bed 1 (Ton1) Redrock Valley Tuff (Tor) Tuff of Twin Peaks (Tot)	Unknown (15.1 Ma) Redrock Valley Caldera (15.4 Ma) Unknown (15.5 Ma)
Older Volcanics (Tqo)	Unknown
Paleocolluvium (Tl)	Not applicable

(a) Compiled from Slate et al. (1999) and Ferguson et al. (1994).
(b) Letters in parentheses are stratigraphic unit map symbols.
(c) Sources and ages, where known, from Sawyer et al. (1994). Sources for Redrock Valley caldera from NSTec (2007).
Refer to Table A-3 for lists of Mesozoic, Paleozoic, and Precambrian sedimentary rock formations.

Underlying the Tertiary volcanic rocks are Paleozoic and Proterozoic sedimentary rocks including dolomite, limestone, quartzite, and argillite, some of which form the primary regional aquifer and the regional hydrologic "basement" (Table A-3). In Precambrian and Paleozoic time, as much as 10,000 m (32,800 ft) of marine sediments were deposited in the NNSS region (Cole 1997). The only surface exposure of Mesozoic-age rocks in the NNSS area are granitic intrusive masses, the Gold Meadows Stock north of Rainier Mesa (Gibbons et al.

1963; Snyder 1977), and the Climax Stock located at the extreme north end of Yucca Flat (Barnes et al. 1963; Maldonado 1977) (Figure A-2).

Table A-3. Pre-Tertiary stratigraphic units of the NNSS and vicinity

Map Unit	Stratigraphic Unit Map Symbol	Stratigraphic Thickness		Dominant Lithology
		Feet	Meters	
Gold Meadows Stock Climax Stock	Kgg Kgc	N/A	N/A	Quartz monzonite Granodiorite
Tippipah Limestone (correlative with the Bird Spring Formation)	PPt	3,500	1,070	Limestone
Chainman Shale and Eleana Formation	Mc MDe	4,000	1,220	Shale, argillite, and quartzite
Guilmette Formation	Dg	1,400	430	Limestone
Simonson Dolomite	Ds	1,100	330	Dolomite
Sevy Dolomite	DSs	690	210	Dolomite
Laketown Dolomite	Sl	650	200	Dolomite
Ely Spring Dolomite	Oes	340	105	Dolomite
Eureka Quartzite	Oe	400	125	Quartzite
Antelope Valley Limestone	Oa	1,530	466	Limestone
Ninemile Formation	On	335	102	Limestone
Goodwin Limestone	Og	685	209	Limestone
Nopah Formation	Cn	2,050	620	Limestone
Bonanza King Formation	Cb	4,350	1,330	Limestone/dolomite
Carrara Formation (upper)	Cc	925	280	Limestone
Carrara Formation (lower)	Cc	925	280	Shale/Siltstone
Zabriskie Quartzite	Cz	200	60	Quartzite
Wood Canyon Formation	CZw	2,300	700	Micaceous quartzite
Stirling Quartzite	Zs	2,900	890	Quartzite
Johnnie Formation	Zj	3,000	914	Quartzite/siltstone/limestone

(Stratigraphic units and lithologies adapted from Cole [1992])

A.1.2 Stratigraphy

In order to confidently characterize the geology at the NNSS, geoscientists must start from a well-understood stratigraphic system. Refinement of the stratigraphy of the area was a continuous process during the decades in which geoscientists associated with the Weapons Testing Program worked to understand the complex volcanic setting (documented by Byers et al. 1989). The need to develop detailed geologic models in support of the Underground Test Area (UGTA) activity (Chapter 11 of the main report) intensified this process, and the recognition of smaller and smaller distinct volcanic units permitted a greater understanding of the three-dimensional configuration of the various types of rocks, which has been incorporated into the geologic framework. Efforts to understand the structure and stratigraphy of the non-volcanic rocks (pre-Tertiary) have also continued to a lesser degree (Cashman and Trexler 1991; Cole 1997; Cole and Cashman 1999; Trexler et al. 2003). The most widespread and significant Quaternary and Tertiary (mainly volcanic) units of the NNSS area are listed in Table A-2. Refer to Table A-3 for a list of Mesozoic (granitic), Paleozoic (sedimentary), and Precambrian (sedimentary and metamorphic) stratigraphic units.

A.1.3 Structural Controls

Geologic structures define the geometric configuration of the area, including the distribution, thickness, and orientation of units. Synvolcanic structures, including caldera faults and some normal faults, had a strong influence on depositional patterns of many of the units. Geologic structures are an important component of the hydrogeology of the area. The juxtaposition of units with different hydrologic properties across faults may have significant hydrogeologic consequences. Also, faults may act as either conduits or barriers to groundwater flow, depending on the difference in permeability between a fault zone and the surrounding rocks and the fault orientation within the present stress field. This is partially determined by whether the fault zone is characterized by open fractures, or if it is associated with fine-grained gouge or increased alteration, which can reduce permeability.

Five main types of structural features exist in the area:

- Thrust faults (e.g., Belted Range and Control Point [CP] thrusts)
- Normal faults (e.g., Yucca and West Greeley faults)
- Transverse faults and structural zones (e.g., Rock Valley and Cane Spring faults)
- Calderas (e.g., Timber Mountain and Silent Canyon caldera complexes)
- Detachment faults (e.g., Fluorspar Canyon–Bullfrog Hills detachment fault)

The Belted Range thrust fault is the principal pre-Tertiary structure in the NNSS region and, thus, controls the distribution of pre-Tertiary rocks in the area. The fault can be traced or inferred from Bare Mountain, just south of the southwest corner of the NNSS area, to the northern Belted Range, just north of the NNSS, a distance of more than 130 km (81 mi). It is an eastward-directed thrust fault that generally places late Proterozoic to early Cambrian rocks over rocks as young as Mississippian. Several imbricate thrust faults occur east of the main thrust fault. Deformation related to the Belted Range thrust fault occurred sometime between 100 and 250 Ma. Lesser thrusts of similar age are also mapped in the area (e.g., the CP and Spotted Range thrusts).

Normal faults in the area are related mainly to basin-and-range extension (e.g., Yucca fault in Yucca Flat and West Greeley fault on Pahute Mesa). Most of these faults likely developed during and after the main phase of volcanic activity of the SWNVF (Sawyer et al. 1994). The majority of these faults are northwest- to northeast-striking, high-angle faults. However, the exact locations, amount of offset along the faults, and character of the faults become increasingly uncertain with depth.

Calderas are probably the most hydrogeologically important features in the NNSS area. Volcano-tectonic and geomorphic processes related to caldera development resulted in abrupt and dramatic lithologic and thickness changes across caldera margins. Consequently, caldera margins (i.e., faults) separate regions with considerably different hydrogeologic character.

A.2 Hydrology

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The hydrologic character of the NNSS and vicinity reflects the region's arid climatic conditions and complex geology (D'Agnese et al. 1997). The hydrology of the NNSS has been extensively studied for over 60 years (U.S. Department of Energy, Nevada Operations Office [DOE/NV] 1996); numerous scientific reports and large databases are available (refer to cited references for more detailed information). The following subsections present an overview of the hydrologic setting of the NNSS and vicinity, including summary descriptions of surface water and groundwater, hydrogeologic framework, and brief descriptions of the hydrogeology for each of the idle underground test areas on the NNSS. The reader is directed to Chapter 11 of the main report for a discussion of the hydrogeologic modeling efforts conducted through the UGTA activity.

A.2.1 Surface Water

The NNSS is located within the Great Basin, a closed hydrographic province that comprises numerous closed (no outlet for surface water) hydrographic subbasins (Figure A-3). The closed hydrographic basins of the NNSS (most notably Yucca and Frenchman Flats) are subbasins of the Great Basin. Streams in the region are ephemeral, flowing only in response to precipitation events or snowmelt. Runoff is conveyed through normally dry washes toward the lowest areas of the closed hydrographic subbasins, and collects on playas. There are two playas (seasonally dry lakes) on the NNSS: Frenchman Lake and Yucca Lake, which lie in Frenchman and Yucca Flats, respectively. While water may stand on the playas for a few weeks before evaporating, the playas are dry most of the year. Surface water may leave the NNSS in only a few places, such as Fortymile Canyon in the southwestern NNSS.

Springs that emanate from local perched groundwater systems are the only natural sources of perennial surface water in the region. There are 28 known springs and seeps on the NNSS (Hall and Perry 2020) (Figure A-4). Spring discharge rates are low, ranging from 0.014 to 2.2 liters/second (0.22 to 35 gallons/minute) (International Technology Corporation [IT] 1997; Thordarson and Robinson 1971). Most water discharged from springs travels only a short distance from the source before evaporating or infiltrating into the ground. The springs are important sources of water for wildlife, but they are too small to be of use as a public water supply source.

Other surface waters on the NNSS include man-made impoundments constructed at several locations throughout the NNSS to support various operations. These are numerous and include open industrial reservoirs, containment ponds, and sewage lagoons. Surface water is not a source of drinking water on the NNSS.

A.2.2 Groundwater

The NNSS is located within the Death Valley regional groundwater flow system, one of the major hydrologic subdivisions of the southern Great Basin (Waddell et al. 1984; Laczniak et al. 1996). Groundwater in southern Nevada is conveyed within several flow-system subbasins in the Death Valley regional flow system (a subbasin is defined as the area that contributes water to a major surface discharge area [Laczniak et al. 1996]). Three principal groundwater subbasins, named for their down-gradient discharge areas, have been identified within the NNSS region: the Ash Meadows, Oasis Valley, and Alkali Flat-Furnace Creek Ranch subbasins (Waddell et al. 1984; Fenelon et al. 2010) (Figure A-5).

The groundwater-bearing rocks at the NNSS have been classified into several hydrogeologic units (HGUs) (Section A.2.3), of which the most important is the lower carbonate aquifer, a thick sequence of Paleozoic-age carbonate rock. This unit extends throughout the subsurface of central and southeastern Nevada, and is considered to be a regional aquifer (Winograd and Thordarson 1975; Laczniak et al. 1996; IT 1996a). Various volcanic and alluvial aquifers are also locally important as water sources.

In general, the static water level across the NNSS is deep, but measured depths vary depending on the land elevation from which each well was drilled. The depth to groundwater in wells at the NNSS varies from about 210 m (690 ft) below the land surface under the Frenchman Flat playa in the southeastern NNSS, to more than 610 m (2,000 ft) below the land surface in the northwestern NNSS beneath Pahute Mesa (Reiner et al. 1995; Robie et al. 1995; IT 1996b; O'Hagan and Laczniak 1996; Bright et al. 2001; Locke and La Camera 2003; Fenelon 2005, 2007; Fenelon et al. 2010; Elliott and Fenelon 2013). Perched groundwater (isolated lenses of water lying above the regional groundwater level) occurs locally throughout the NNSS, mainly within the volcanic rocks.

Recharge areas for the Death Valley groundwater system are the higher mountain ranges of central and southern Nevada, where there can be significant precipitation and snowmelt. Groundwater flow is generally from these upland areas to natural discharge areas in the south and southwest. Groundwater at the NNSS is also derived from underflow from basins up-gradient of the area (Harrill et al. 1988). The direction of groundwater flow may locally be influenced by structure, rock type, or other geologic conditions. Based on existing water-level data (Hale et al. 1995; Reiner et al. 1995; IT 1996b; Fenelon et al. 2010; Elliott and Fenelon 2013) and flow models (IT 1996a; D'Agnese et al. 1997; Stoller-Navarro Joint Venture [SNJV] 2006a, 2006b, 2007; Navarro Nevada Environmental Services, LLC [NNES], 2010a, 2010b; Belcher et al. 2017), the general groundwater flow direction within major water-bearing units beneath the NNSS is to the south and southwest (Figure A-6).

Most of the natural discharge from the Death Valley flow system is via transpiration by plants or evaporation from soil and playas in the Amargosa Desert and Death Valley (Laczniak et al., 1996). Groundwater discharge at the NNSS is minor, consisting of small springs that drain perched water lenses and artificial discharge at a limited number of water supply wells.

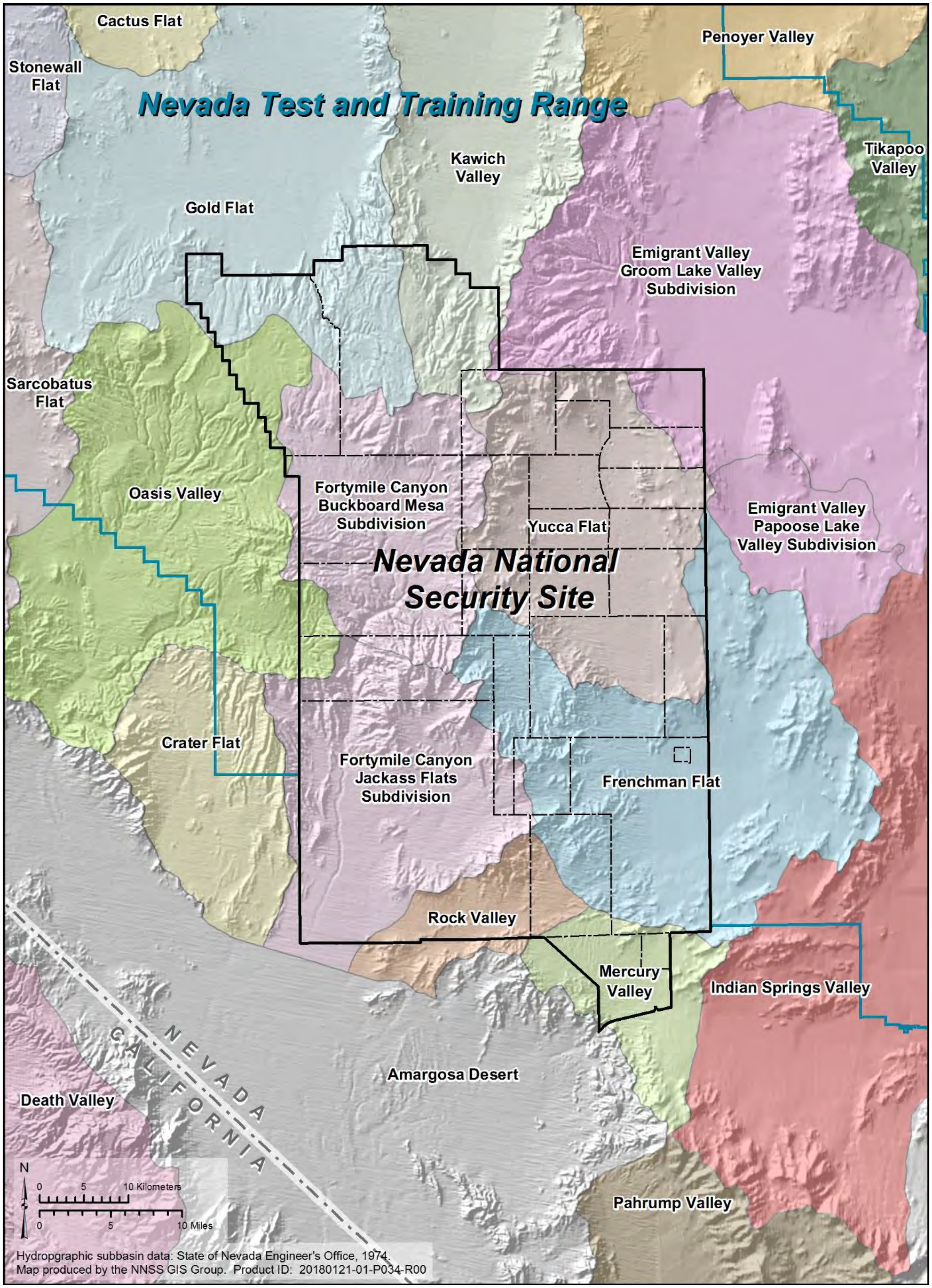

Figure A-3. Hydrographic subbasins on the NNSS (from State of Nevada Engineers Office 1974)

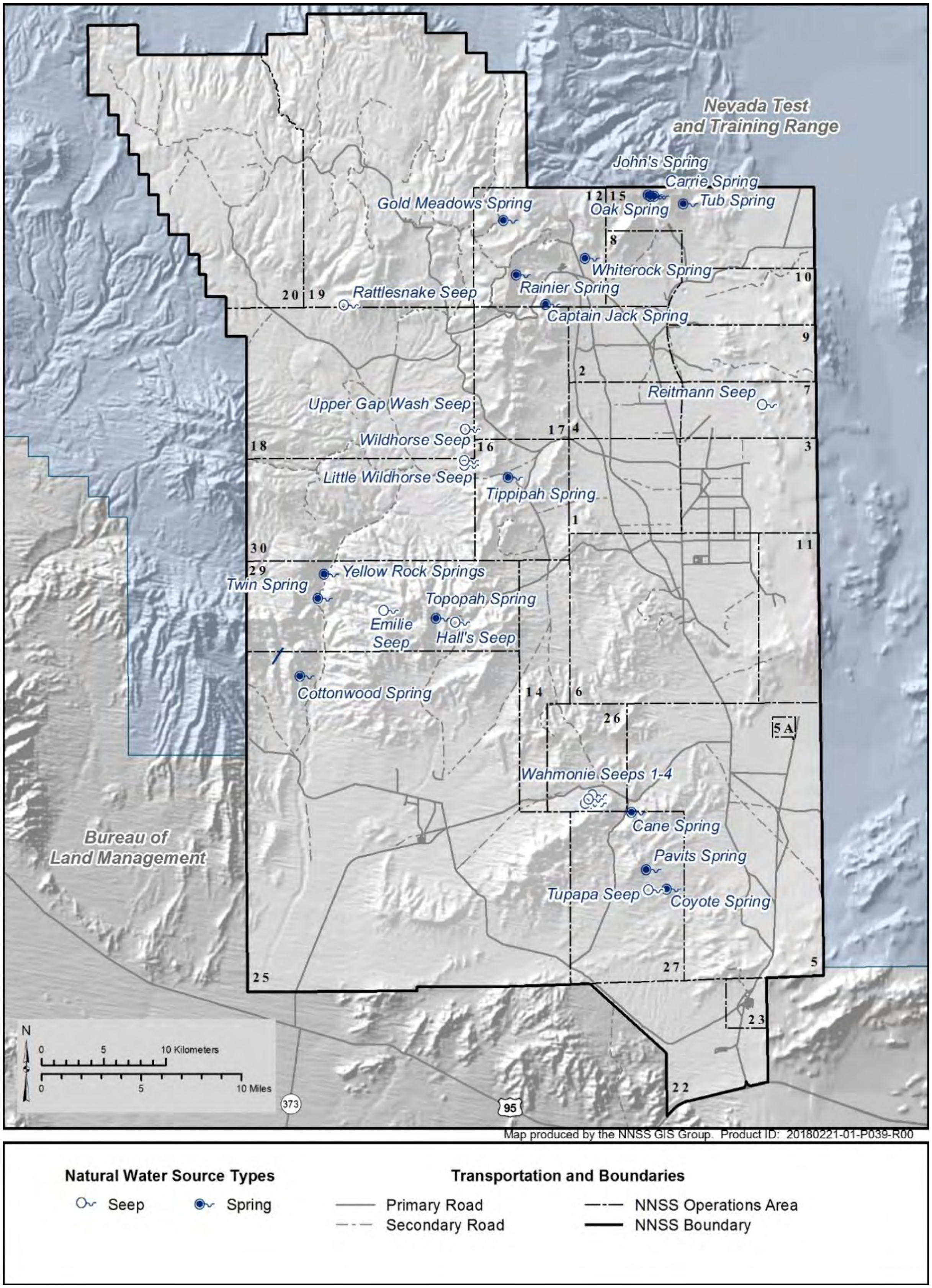

Figure A-4. Natural springs and seeps on the NNSS (adapted from Hall and Perry 2020)

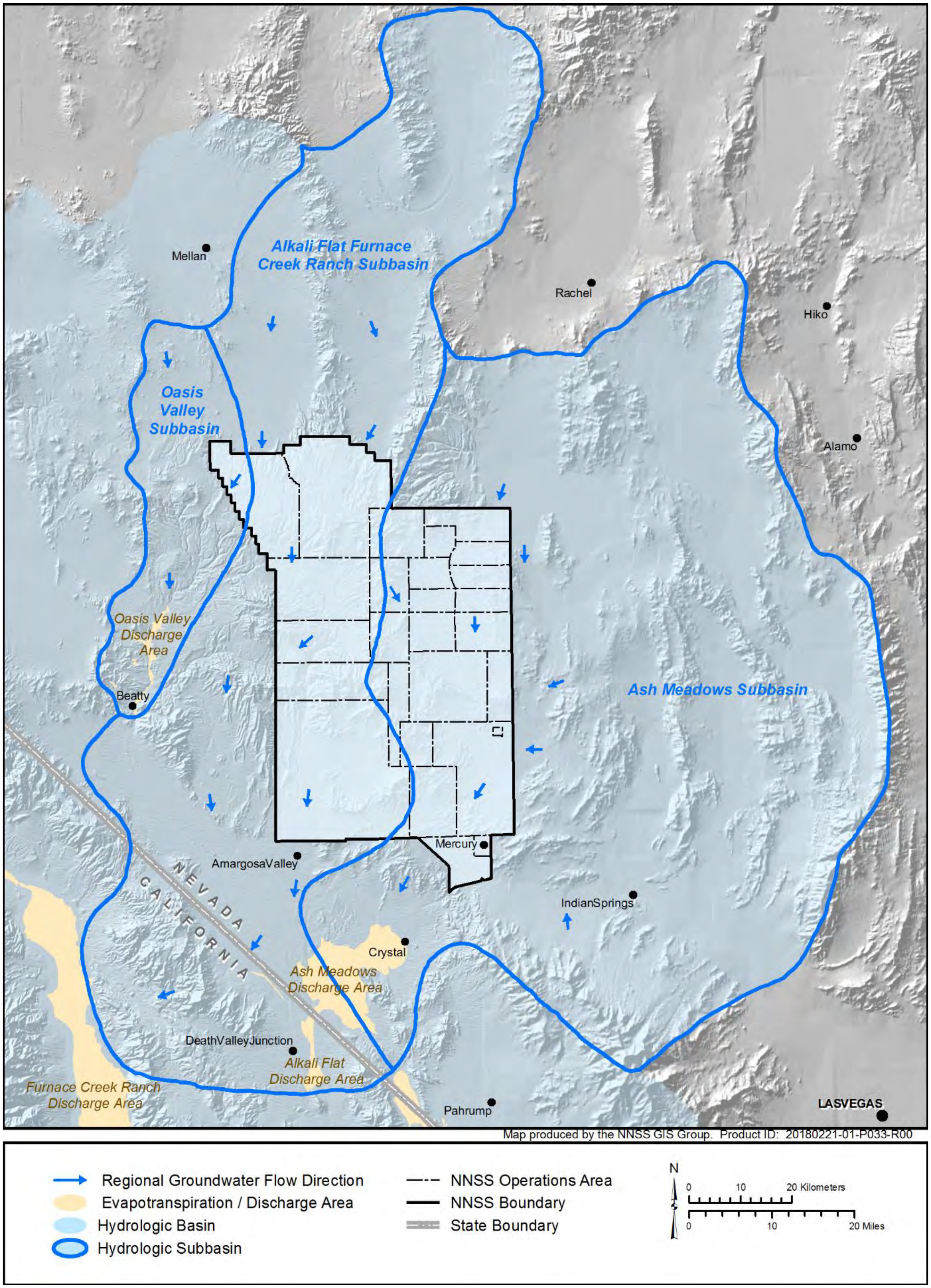

Figure A-5. Groundwater subbasins of the NNSS and vicinity (modified from Waddell et al. 1984; Laczniak et al. 1996, 2001)

Groundwater is the only local source of potable water on the NNSS. The supply wells that make up the NNSS water system (Gillespie et al. 1996; U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office [NNSA/NSO] 2008) and the other supply wells for the various water systems in the area (town of Beatty, small mines, and local ranches) produce water for human and industrial use from the carbonate, volcanic, and alluvial aquifers. Water chemistry varies from a sodium-potassium-bicarbonate type to a calcium-magnesium-carbonate type, depending on the mineralogical composition of the aquifer source. Groundwater quality within aquifers of the NNSS is generally acceptable for drinking water and industrial and agricultural uses (Chapman 1994) and meets Safe Drinking Water Act standards (Chapman and Lyles 1993; Rose et al. 1997; MSTS 2020).

A.2.3 Hydrogeologic Framework for the NNSS and Vicinity

When the need for testing nuclear devices underground was recognized in the 1950s, among the first concerns was the effect testing would have on the groundwater of the area. One of the earliest nuclear tests conducted below the groundwater table (the Bilby test conducted in 1963) was designed in part to study explosion effects on groundwater and the movement in groundwater of radioactive byproducts from the explosion (Hale et al. 1963; Garber 1971). Since that time, additional studies at various scales have been conducted to aid in the understanding of groundwater flow at the NNSS. The current understanding of the regional groundwater flow at the NNSS is derived from work by Winograd and Thordarson (1975), which was summarized and updated by Laczniak et al. (1996), and has further been developed by the UGTA activity hydrogeologic modeling team (IT 1996a; Bechtel Nevada [BN] 2002a, 2005, 2006a; NSTec 2007, 2009a) (Chapter 11 of the main report).

Winograd and Thordarson (1975) established a hydrogeologic framework, incorporating the work of Blankennagel and Weir (1973), who defined the first HGUs to address the complex hydraulic properties of volcanic rocks. HGUs are used to categorize lithologic units according to their ability to transmit groundwater, which is mainly a function of their primary lithologic properties, degree of fracturing, and secondary mineral alteration. Hydrostratigraphic units (HSUs) for the NNSS volcanic rocks were first defined during the UGTA modeling initiative (IT 1996a). HSUs are groupings of contiguous stratigraphic units that have a particular hydrogeologic character, such as an aquifer (unit through which water moves readily) or confining unit (unit that generally is impermeable to water movement). The concept of HSUs is very useful in volcanic terrains where stratigraphic units can vary greatly in hydrologic character both laterally and vertically.

The rocks of the NNSS have been classified for hydrologic modeling using this two-level classification scheme in which HGUs are grouped to form HSUs (IT 1996a; NSTec 2009a). An HSU may consist of several HGUs, but is defined so that a single general type of HGU dominates (for example, mostly welded-tuff and vitric-tuff aquifers or mostly tuff confining units).

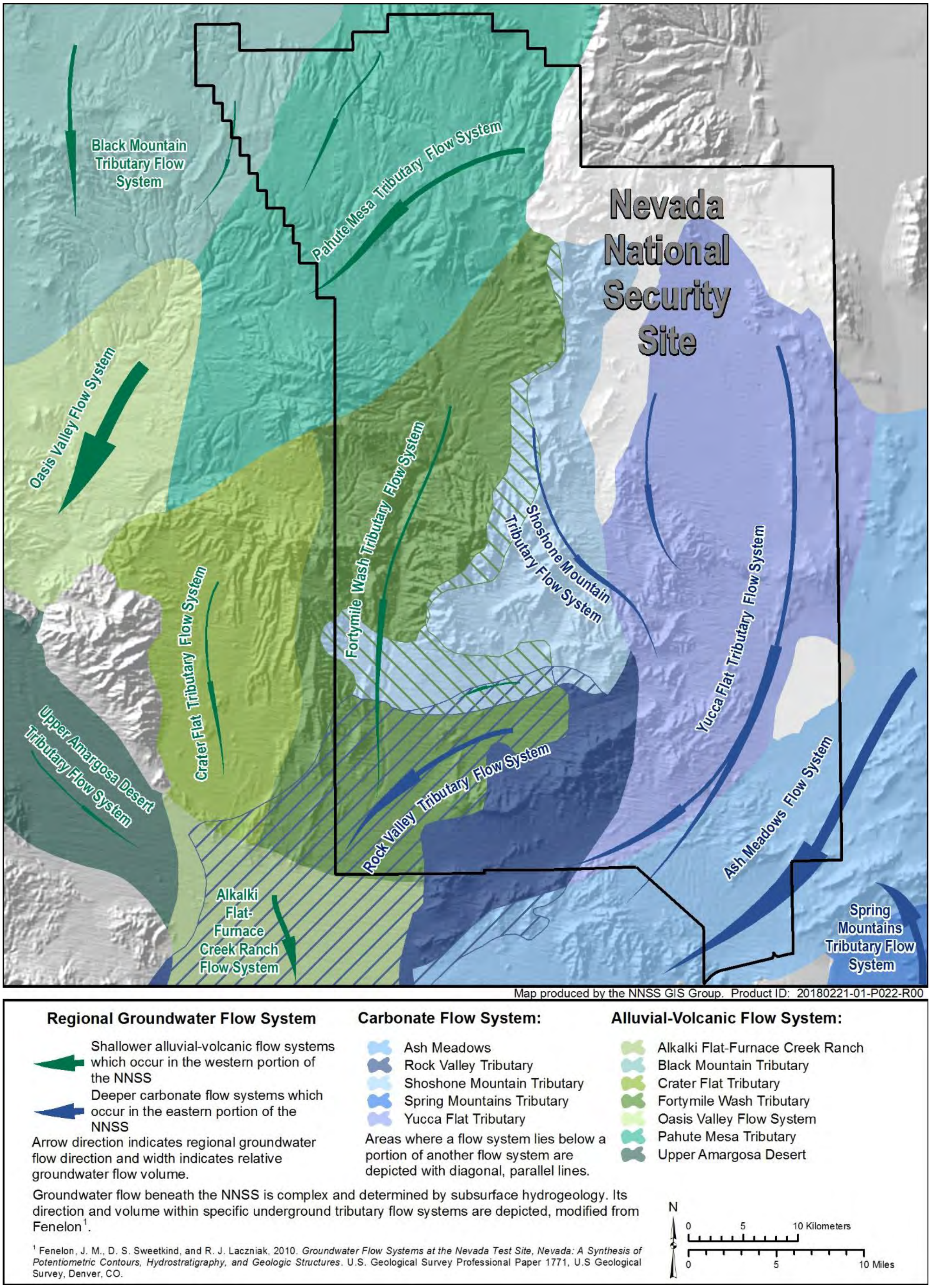

Figure A-6. Groundwater flow systems on the NNSS

A.2.3.1 Hydrogeologic Units

All the rocks of the NNSS and vicinity can be classified as one of ten HGUs, which include the alluvial aquifer, a playa confining unit, four volcanic HGUs, two intrusive units, and two HGUs that represent the pre-Tertiary rocks (Table A-4).

The deposits of alluvium (alluvial aquifer) fill the main basins of the NNSS, and generally consist of a consolidated mixture of boulders, gravel, and sand derived from volcanic and Paleozoic sedimentary rocks (Slate et al. 1999). The finest sediments can be deposited as playa deposits (or dry lake beds) in some closed basins (e.g., Yucca and Frenchman Flats). Because of their silty/clayey nature, these fine-grained units tend to behave hydrologically as confining units (restrictive of groundwater flow).

Table A-4. Hydrogeologic units of the NNSS area

Hydrogeologic Unit (Symbol)	Typical Lithologies	Hydrologic Significance
Alluvial Aquifer (AA)	Unconsolidated to partially consolidated gravelly sand, eolian sand, and colluvium	Has characteristics of a highly conductive aquifer, but less so where lenses of clay-rich paleocolluvium or zeolitic alteration are present at depth.
Playa Confining Unit (PCU)	Clayey silt, sandy silt	Surface and near-surface confining unit at Yucca and Frenchman Lakes and within the lower portion of the alluvial section in the deepest portions of Frenchman Flat.
Welded-Tuff Aquifer (WTA)	Welded ash-flow tuff; vitric to devitrified	Degree of welding greatly affects interstitial porosity (less porosity as degree of welding increases) and permeability (greater fracture permeability as degree of welding increases).
Vitric-Tuff Aquifer (VTA)	Bedded tuff; ash-fall and reworked tuff; vitric	Constitutes a volumetrically minor hydrogeologic unit. Generally does not extend far below the static water level due to tendency to become zeolitized (which drastically reduces permeability) under saturated conditions. Significant interstitial porosity (20% to 40%). Generally insignificant fracture permeability.
Lava-Flow Aquifer (LFA)	Rhyolite, basalt, and dacite lava flows; includes flow breccias (commonly at base) and pumiceous zones (commonly at top)	Generally occurs as small, moderately thick (rhyolite) to thin (basalt) local flows. Hydrologically complex; wide range of transmissivities; fracture density and interstitial porosity differ with lithologic variations.
Tuff Confining Unit (TCU)	Zeolitic bedded tuff with interbedded, but less significant, zeolitic, nonwelded to partially welded ash-flow tuff	May be saturated but measured transmissivities are very low. May cause accumulation of perched and/or semi-perched water in overlying units.
Intracaldera Intrusive Confining Unit (IICU)	Highly altered, highly injected/intruded country rock and granitic material	Assumed to be impermeable. Conceptually underlies each of the SWNVF calderas and Calico Hills.
Granite Confining Unit (GCU)	Granodiorite, quartz monzonite	Relatively impermeable; forms local bulbous stocks, north of Rainier Mesa and Yucca Flat; may contain perched water.
Clastic Confining Unit (CCU)	Argillite, siltstone, quartzite	Clay-rich rocks are relatively impermeable; more siliceous rocks are fractured, but with fracture porosity generally sealed due to secondary mineralization.
Carbonate Aquifer (CA)	Dolomite, limestone	Transmissivity values differ greatly and are directly dependent on fracture frequency.

Note: Adapted from NSTec (2009a).

The volcanic rocks of the NNSS and vicinity can be categorized into four HGUs based on primary lithologic properties, degree of fracturing, and secondary mineral alteration (Table A-4). In general, the altered (typically zeolitized but hydrothermally altered near caldera margins) volcanic rocks act as confining units (tuff confining unit), and the unaltered rocks form aquifers. The volcanic aquifer units can be further divided into welded-tuff aquifers or vitric-tuff aquifers (depending upon the degree of welding) and lava-flow aquifers. The denser rocks (welded ash-flow tuffs and lava flows) tend to fracture more readily and therefore have relatively high permeability (Blankennagel and Weir 1973; Winograd and Thordarson 1975; Laczniak et al. 1996; IT 1996c, 1997; Prothro and Drellack 1997).

The pre-Tertiary sedimentary rocks at the NNSS and vicinity are also categorized as aquifer or confining unit HGUs based on lithology. The silicic clastic rocks (quartzite, siltstone, shale) tend to be aquitards or confining units, while the carbonates (limestone and dolomite) tend to be aquifers (Winograd and Thordarson 1975; Laczniak et al. 1996). The granite confining unit is considered to behave as a confining unit due to low primary porosity and low permeability, and because most fractures tend to be filled with secondary minerals (Walker 1962).

A.2.3.2 Hydrostratigraphic Units

The rocks at the NNSS and vicinity are grouped into more than 76 HSUs (NSTec 2009a). The more important and widespread HSUs in the area are discussed separately below, from oldest to youngest. Additional information regarding other HSUs is summarized in Section A.2.5, and can be found in the documentation packages for the UGTA corrective action unit (CAU)-scale hydrogeologic models (BN 2002a, 2005, 2006a; NSTec 2007).

Lower Clastic Confining Unit (LCCU) – The Proterozoic to Middle-Cambrian-age rocks are largely quartzite and silica-cemented siltstone. Although these rocks are brittle and commonly fractured, secondary mineralization has apparently greatly reduced formation permeability (Winograd and Thordarson 1975). These units make up the LCCU, which is considered to be the regional hydrologic basement (IT 1996a). The LCCU is interpreted to underlie the entire region, except at the calderas. Where it is in a structurally high position, the LCCU may act as a barrier to deep regional groundwater flow.

Lower Carbonate Aquifer (LCA) – The LCA consists of thick sequences of Middle Cambrian through Upper Devonian carbonate rocks. This HSU serves as the regional aquifer for most of southern Nevada and, locally, may be as thick as 5,000 m (16,400 ft) (Cole 1997; Cole and Cashman 1999). The LCA is present under most of the area, except where the LCCU is structurally high and at the calderas. Measured transmissivities of these rocks differ from place to place, apparently reflecting the observed differences in fracture and fault densities and characteristics (Winograd and Thordarson 1975; NSTec 2009b).

Upper Clastic Confining Unit (UCCU) – Upper Devonian and Mississippian silicic clastic rocks in the NNSS vicinity are assigned to the Eleana Formation and the Chainman Shale (Trexler et al. 1996, 2003; Cashman and Trexler 1991). Both formations are grouped into the UCCU. At the NNSS, this HSU is found mainly within a north-south band along the western portion of Yucca Flat. It is a significant confining unit and in many places forms the footwall of the Belted Range and CP thrust faults.

Lower Carbonate Aquifer - Upper Thrust Plate (LCA3) – Cambrian through Devonian, mostly carbonate rocks that occur in the hanging walls of the Belted Range and CP thrust faults are designated as LCA3. These rocks are equivalent stratigraphically to the LCA but are structurally separated from the LCA by the Belted Range thrust fault. The LCA3 is patchily distributed as remnant thrust blocks, particularly along the western and southern sides of Yucca Flat (at Mine Mountain and the CP Hills), at Calico Hills, and at Bare Mountain.

Mesozoic Granite Confining Unit (MGCU) – The Mesozoic era is represented at the NNSS only by intrusive igneous rocks. Cretaceous-age granitic rocks are exposed at two locations: in northern Yucca Flat at the Climax Stock, and the Gold Meadows Stock, which lies 12.9 km (8 mi) west of the Climax Stock, just north of Rainier Mesa (Snyder 1977; Bath et al. 1983) (Figure A-2). The two are probably related in both source and time and are believed to be connected at depth (Jachens 1999; Phelps et al. 2004). Because of its low intergranular porosity and permeability, and the lack of inter-connecting fractures (Walker 1962), the MGCU is considered a confining unit. The Climax and Gold Meadows intrusives are grouped into the MGCU HSU.

Tertiary and Quaternary Hydrostratigraphic Units – Tertiary- and Quaternary-age strata at the NNSS are organized into dozens of HSUs. Nearly all are of volcanic origin, except the alluvial aquifer and playa confining unit, which are the uppermost HSUs. These rocks are important because (1) most of the underground nuclear tests at the NNSS were conducted in these units, (2) they constitute a large percentage of the rocks in the area, and (3) they are inherently complex and heterogeneous. As pointed out in Section A.2.3.1, the volcanic rocks are divided into aquifer or confining units according to lithology and secondary alteration. More detailed information can be found in the documentation packages for the UGTA CAU-scale hydrogeologic models (BN 2002a, 2005, 2006a; NSTec 2007, 2009b).

Alluvial Aquifer (AA) – The alluvium throughout most of the NNSS is a consolidated mixture of detritus derived from silicic volcanic and Paleozoic-age sedimentary rocks, ranging in particle size from clay to boulders. Sediment deposition is largely in the form of alluvial fans (debris flows, sheet wash, and braided streams), which coalesce to form discontinuous, gradational, and poorly sorted deposits. Eolian sand, playa deposits, and rare basalt flows are also present within the alluvial section of some valleys. The alluvium thickness in major valleys (e.g., Frenchman Flat and Yucca Flat) generally ranges from about 30 m (100 ft) to more than 1,128 m (3,700 ft) in the deepest subbasins. The AA HSU is restricted primarily to the basins of the NNSS. However, because the water table in the vicinity is moderately deep, the alluvium is generally unsaturated, except in the deep subbasins of some valleys. These sediments are porous and, thus, have high storage coefficients. Hydraulic conductivity may also be high, particularly in the coarser, gravelly beds.

A.2.4 General Hydraulic Characteristics of NNSS Rocks

Volcanic rocks typically are extremely variable in lithologic character both laterally and vertically. The rock characteristics that control the density and character of fractures are the primary determinants of their hydraulic properties, and most hydraulic heterogeneity ultimately is related to fracture characteristics such as fracture density, openness, orientation, and other properties. Secondary fracture-filling minerals can drastically obstruct the flow through or effectively seal an otherwise transmissive formation (IT 1996c; Drellack et al. 1997). Fracture density typically increases with proximity to faults, potentially increasing the hydraulic conductivity of the formation; however, the hydrologic properties of faults, per se, are not well known. Limited data suggest that the full spectrum of hydraulic properties, from barrier to conduit, may be possible (Blankennagel and Weir 1973; Faunt 1998).

Table A-5 presents a brief summary of the hydrologic properties of NNSS HGUs. The lowest transmissivity values in volcanic rocks at the NNSS are typically associated with nonwelded ash-flow tuff and bedded tuff (ash-fall and reworked tuffs). Although interstitial porosity may be high, the interconnectivity of the pore space is limited, and these relatively incompetent rocks tend not to support open fractures. Secondary alteration of these tuffs (most commonly, zeolitization) ultimately produces a very impermeable unit. As described in Section A.2.3.1 and in NSTec (2009a), these zeolitized tuffs are considered to be confining units (aquicludes and aquitards). The equivalent unaltered bedded and nonwelded tuffs are considered to be vitric-tuff aquifers, and have intermediate transmissivities.

In general, the most transmissive rocks tend to be moderately to densely welded ash-flow tuffs (welded-tuff aquifer), rhyolite lava flows (lava-flow aquifer), and carbonate rocks (limestone and dolomite). Although their interstitial porosity is low, these competent lithologies tend to be highly fractured, and groundwater flow through these rocks is largely through an interconnected network of fractures (Blankennagel and Weir 1973; GeoTrans, Inc. 1995).

Underground nuclear explosions affect hydraulic properties of the geologic medium, creating both long-term and short-term effects. Effects include enhanced permeability from shock-induced fractures, the formation of vertical conduits (e.g., collapse chimneys), and elevated water levels (mounding and over-pressurization of saturated low-permeability units). However, these effects tend to be localized (Borg et al. 1976; Brikowski 1991; Allen et al. 1997).

Table A-5. Summary of hydrologic properties for hydrogeologic units at the NNSS

Hydrogeologic Unit[(a)]			Fracture Density[(b, c)]	Relative Hydraulic Conductivity[(c)]
Alluvial Aquifer			Very low	Moderate to very high
Vitric-Tuff Aquifer			Low	Low to moderate
Welded-Tuff Aquifer			Moderate to high	Moderate to very high
Lava-Flow Aquifer[(d)]	Pumiceous Lava	Vitric	Low	Low to moderate
		Zeolitic	Low	Very low
	Stoney Lava and Vitrophyre		Moderate to high	Moderate to very high
	Flow Breccia		Low to moderate	Low to moderate
Tuff Confining Unit			Low	Very low
Intrusive Confining Unit			Low to moderate	Very low
Granite Confining Unit			Low to moderate	Very low
Carbonate Aquifer			Low to high (variable)	Low to very high
Clastic Confining Unit			Moderate	Very low to low[(e)]

(a) Refer to Table A-4 for hydrogeologic nomenclature.
(b) Including primary (cooling joints in tuffs) and secondary (tectonic) fractures.
(c) The values presented are from BN (2002a).
(d) Abstracted from Prothro and Drellack (1997).
(e) Fractures tend to be sealed by the presence of secondary minerals.
Note: Adapted from BN (2002a).

A.2.5 Hydrogeology of the NNSS Underground Test Areas

Most NNSS underground nuclear detonations were conducted in three main UGTAs (Figure A-7; NNSA/NFO 2015a): (1) Yucca Flat, (2) Pahute Mesa, and (3) Rainier Mesa (including Aqueduct Mesa). Underground tests in Yucca Flat and Pahute Mesa typically were conducted in vertical drill holes, whereas almost all tests conducted in Rainier Mesa were tunnel emplacements. A total of 85 underground tests (85 detonations) were conducted on Pahute Mesa, including 18 high-yield detonations (more than 200 kt). Rainier Mesa hosted 61 underground tests (62 detonations), almost all of which were relatively low-yield (less than 20 kt), tunnel-based weapons-effects tests. Yucca Flat was the most extensively used UGTA, hosting 659 underground tests (747 detonations), 4 of which were high-yield detonations (Allen et al. 1997; NNSA/NFO 2015a).

In addition to the three main UGTAs, underground nuclear tests were conducted in Frenchman Flat (ten tests), Shoshone Mountain (six tests), the Oak Spring Butte/Climax Mine area (three tests), the Buckboard Mesa area (three tests), and Dome Mountain (one test with five detonations) (Allen et al. 1997; NNSA/NFO 2015a). It should be noted that these totals include nine cratering tests (13 total detonations) conducted in various areas of the NNSS. Table A-1 is a synopsis of information about the locations of UGTAs at the NNSS, and Figure A-7 shows the areal distribution of underground nuclear tests conducted at the NNSS.

The location of each underground nuclear test is classified as a corrective action site (CAS). These in turn have been grouped into five CAUs, according to the Federal Facility Agreement and Consent Order (FFACO; as amended), between the U.S. Department of Energy (DOE), the State of Nevada, and the U.S. Department of Defense. In general, the CAUs relate to the geographical UGTAs on the NNSS (Figure A-7).

The hydrogeology of the four main NNSS UGTAs is summarized in the following subsections. For detailed stratigraphic descriptions of geologic units at the NNSS (including each of the UGTAs), see Sawyer et al. (1994) and Slate et al. (1999).

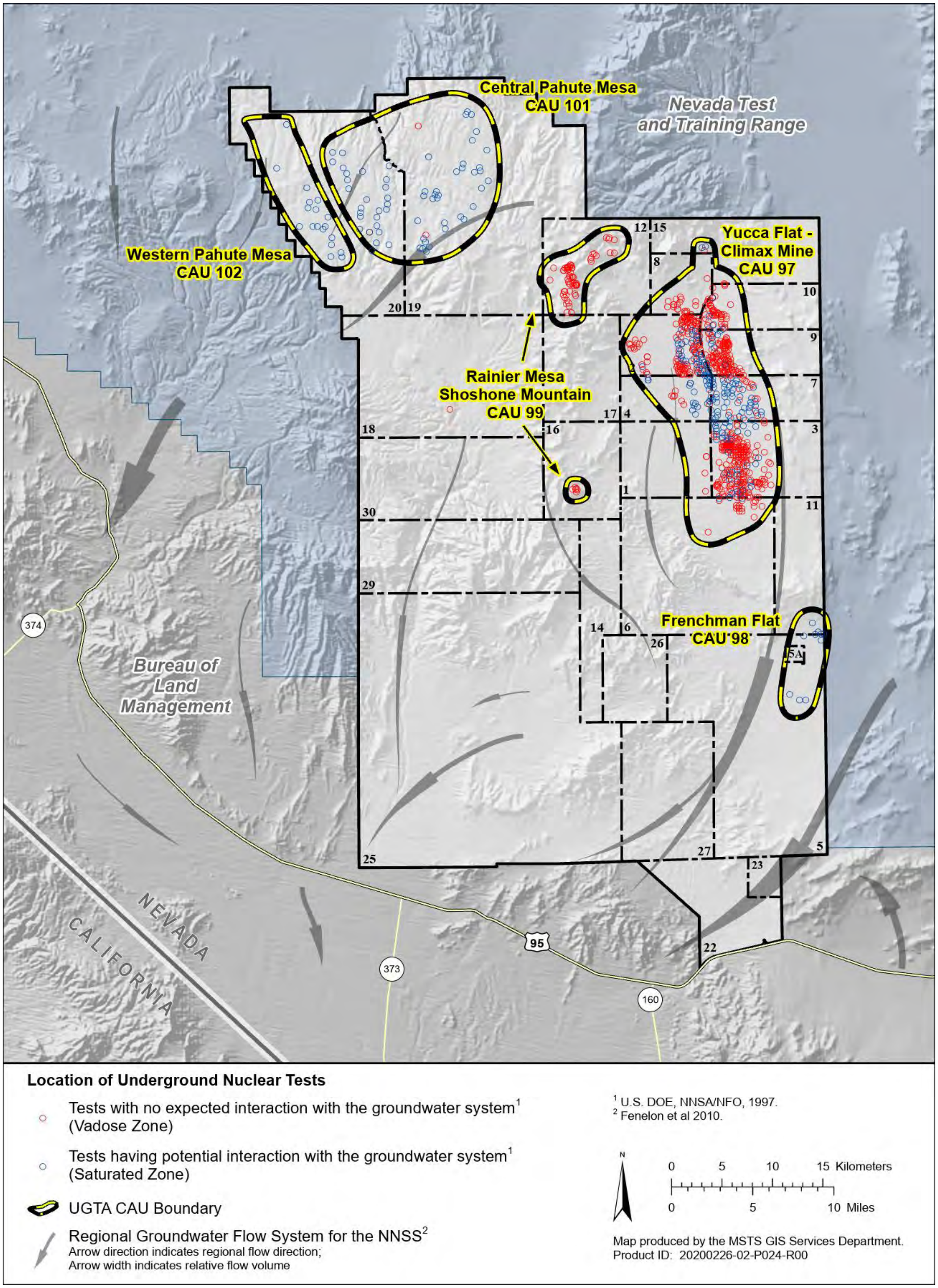

Figure A-7. Locations of UGTA CAUs and historical underground nuclear tests

A.2.5.1 Frenchman Flat Underground Test Area

The Frenchman Flat CAU consists of ten CASs located in the northern part of NNSS Area 5 and southern part of Area 11 (Figure A-7). The detonations were conducted in vertical emplacement holes and two mined shafts. Most of the tests were conducted in alluvium above the water table (BN 2005).

Physiography – Frenchman Flat is a closed intermontane basin located in the southeastern portion of the NNSS. It is bounded on the north by Massachusetts Mountain and the Halfpint Range, on the east by the Buried Hills, on the south by the Spotted Range, and on the west by the Wahmonie volcanic center (Figure A-2). The sparsely vegetated valley floor slopes gently toward a central playa lakebed. Ground-level elevations range from 938 m (3,078 ft) above sea level at the playa, to over 1,463 m (4,800 ft) in the nearby surrounding mountains.

Geology Overview – The stratigraphic section for Frenchman Flat consists of (from oldest to youngest) Proterozoic and Paleozoic clastic and carbonate rocks, Tertiary sedimentary and tuffaceous sedimentary rocks, Tertiary volcanic rocks, and Quaternary and Tertiary alluvium (Slate et al. 1999). In the northernmost portion of Frenchman Flat, the middle to upper Miocene volcanic rocks that are derived from calderas located to the northwest of Frenchman Flat unconformably overlie Ordovician-age carbonate and clastic rocks. To the south, these volcanic units, including the Ammonia Tanks Tuff, Rainier Mesa Tuff, Topopah Spring Tuff, and Crater Flat Group, either thin considerably, interfinger with coeval sedimentary rocks, or pinch out together (BN 2005). Upper-middle Miocene tuffs, lavas, and debris flows from the Wahmonie volcanic center located just west of Frenchman Flat dominate the volcanic section beneath the western portion of the valley. To the south and southeast, most of the volcanic units are absent, and Oligocene to middle Miocene sedimentary and tuffaceous sedimentary rocks, which unconformably overlie the Paleozoic rocks in the southern portion of Frenchman Flat, dominate the Tertiary section (Prothro and Drellack 1997). In most of the Frenchman Flat area, upper Miocene to Holocene alluvium covers the older sedimentary and volcanic rocks (Slate et al. 1999). Alluvium thicknesses range from a thin veneer along the valley edges to perhaps as much as 1,158 m (3,800 ft) in north central Frenchman Flat (BN 2005).

Structural Setting – The structural geology of Frenchman Flat is complex. In the late Mesozoic era, the region was subjected to compressional deformation, which resulted in folding, thrusting, uplift, and erosion of the pre-Tertiary rocks (Barnes et al. 1982). Approximately 11 Ma, the region underwent extensional deformation, during which the present basin-and-range topography was developed, and the Frenchman Flat basin was formed (Ekren et al. 1968; BN 2005). In the immediate vicinity of Frenchman Flat, extensional deformation has produced northeast-trending, left-lateral strike-slip faults and generally north-trending normal faults that displace the Tertiary and pre-Tertiary rocks. Beneath Frenchman Flat, major west-dipping normal faults merge and are probably contemporaneous with strike-slip faults beneath the southern portion of the basin (Grauch and Hudson 1995). Movement along the faults has created a relatively deep, east-dipping, half-graben basin elongated in a northeasterly direction (Figure A-8).

Hydrogeology Overview – The hydrogeology of Frenchman Flat is fairly complex but is typical of the NNSS area. Many of the HGU and HSU building blocks developed for models of the NNSS vicinity are applicable to the Frenchman Flat basin. The strata in the Frenchman Flat area have been subdivided into four Quaternary/Tertiary alluvium and playa HSUs, nine Tertiary-age volcanic HSUs, and three pre-Tertiary HSUs to serve as layers for the UGTA Frenchman Flat CAU groundwater model (BN 2005). The dominant units are, in descending order, the AA, the Timber Mountain welded-tuff aquifer (TMWTA), the Timber Mountain lower vitric-tuff aquifer (TMLVTA), the Topopah Spring aquifer (TSA), the Wahmonie confining unit (WCU), the lower tuff confining unit (LTCU), the volcaniclastic confining unit (VCU), the LCA, and the LCCU (Table A-6).

Water-Level Elevation and Groundwater Flow Direction – The depth to the static water level (SWL) in Frenchman Flat ranges from 210 m (690 ft) near the central playa to more than 350 m (1,150 ft) at the northern end of the valley (SNJV 2004a, 2006a). The SWL is generally located within the AA, TMWTA, TSA, WCU, or LTCU. In the deeper, central portions of the basin, more than half of the alluvium section is saturated. Water-level elevation data in the AA indicate a very flat water table (Blout et al. 1994; SNJV 2004a, 2006a; NNES 2010a).

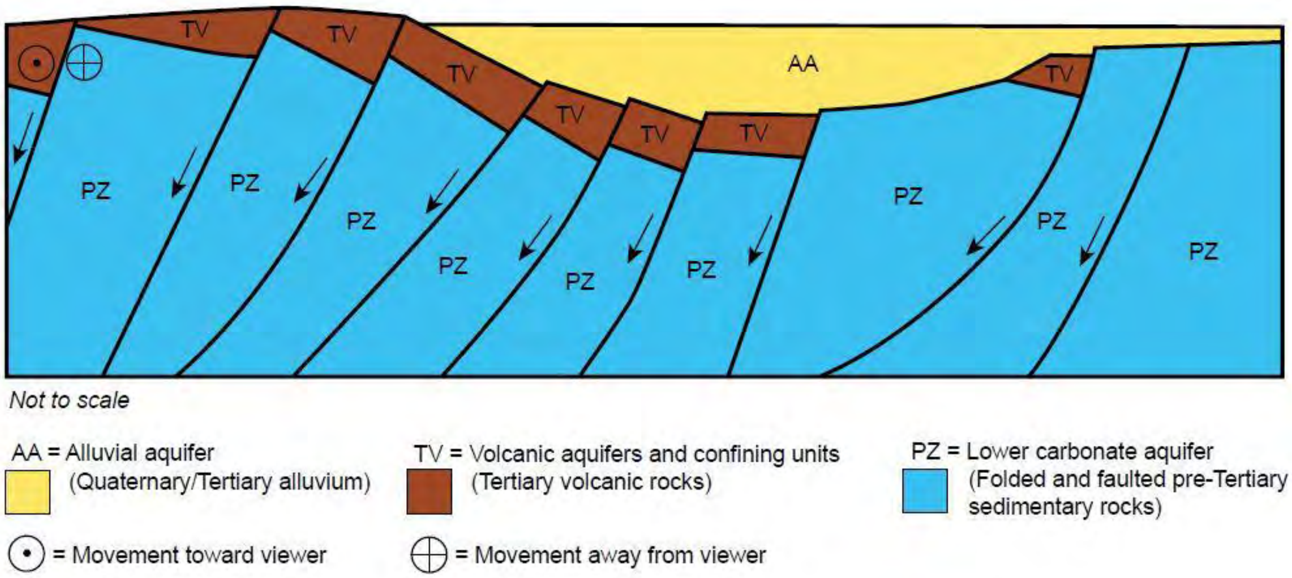

Figure A-8. Conceptual east-west cross section through Frenchman Flat

Table A-6. Dominant hydrostratigraphic units of the Frenchman Flat underground test area

Hydrostratigraphic Unit (Symbol)	Dominant Hydrogeologic Unit[a]	Typical Lithologies
Alluvial Aquifer (AA)	AA	Consists mainly of alluvium (gravelly sand) that fills extensional basins. Lower permeability layers, such as the older, altered alluvium and playa deposits, are differentiated as separate HSUs in the hydrogeologic models.
Timber Mountain Welded-Tuff Aquifer (TMWTA)	WTA, minor VTA	Welded ash-flow tuff and related nonwelded and ash-fall tuffs; vitric to devitrified
Timber Mountain Lower Vitric-Tuff Aquifer (TMLVTA)	VTA	Nonwelded ash-flow and bedded tuffs; vitric (unaltered)
Topopah Spring Aquifer (TSA)	WTA	Welded ash-flow tuff; vitric to devitrified
Wahmonie Confining Unit (WCU)	TCU, minor LFA	Ash-fall and reworked tuffs; debris and breccia flows; minor intercalated lava flows. Typically altered: zeolitic to argillic
Lower Tuff Confining Unit (LTCU and LTCU1)	TCU	Zeolitic bedded tuffs, with interbedded but less significant zeolitic, nonwelded to partially welded ash-flow tuffs
Volcaniclastic Confining Unit (VCU)	TCU, minor AA	Diverse assemblage of interbedded volcanic and sedimentary rocks including tuffs, shale, tuffaceous and argillaceous sandstones, conglomerates, minor limestones
Upper Clastic Confining Unit (UCCU)	CCU	Argillite, quartzite; present only in northwest portion of model in the CP Basin
Lower Carbonate Aquifer (LCA)	CA	Dolomite and limestone; the “regional aquifer”
Lower Clastic Confining Unit (LCCU)	CCU	Quartzites and siltstones; the “hydrologic basement”

(a) See Table A-4 for descriptions of HGUs
Note: Adapted from BN (2005).

Water-level data for the LCA in the southern part of the NNSS are limited, but indicate a fairly low gradient in the Yucca Flat, Frenchman Flat, and Jackass Flats areas. This gentle gradient implies a high degree of hydraulic continuity within the aquifer, presumably due to high fracture permeability (Laczniak et al. 1996). Furthermore, the similarity of the water levels measured in Paleozoic rocks (LCA) in Yucca Flat and Frenchman Flat implies that, at least for deep interbasin flow, there is no groundwater barrier between the two basins. Inferred regional groundwater flow through Frenchman Flat is to the south-southwest toward discharge areas in Ash Meadows (Figure A-5). An increasing westward flow vector in southern NNSS may be due to preferential flow paths subparallel to the northeast-trending Rock Valley fault (Grauch and Hudson 1995) and/or a northward gradient from the Spring Mountain recharge area (IT 1996a, 1996b).

Groundwater elevation measurements for wells completed in the AA and the volcanic aquifers (e.g., TMWTA, TSA) are higher than those in the underlying LCA (IT 1996b; BN 2005; SNJV 2006a). This implies a downward gradient. This apparent semi-perched condition is believed to be due to the presence of intervening LTCU and VCU.

A.2.5.2 Yucca Flat/Climax Mine Underground Test Area

The Yucca Flat/Climax Mine CAU consists of several hundred CASs located in NNSS Areas 1, 2, 3, 4, 6, 7, 8, 9, and 10, and three CASs located in Area 15 (Figure A-7). These tests were typically conducted in vertical emplacement holes and a few related tunnels (Table A-1).

The Yucca Flat and Climax Mine UGTAs were originally defined as two separate CAUs (CAU 97 and CAU 100) in the FFACO because the geologic frameworks of the two areas are distinctly different. The Yucca Flat underground nuclear tests were conducted in alluvial, volcanic, and carbonate rocks, whereas the Climax Mine tests were conducted in an igneous intrusion (granite) in northern Yucca Flat. However, particle-tracking simulations performed during the regional evaluation (IT 1997) indicated that the local Climax Mine groundwater flow system merges into the much larger Yucca Flat groundwater flow system during the 1,000-year time period of interest, so the two areas were combined into the single CAU 97.

Yucca Flat was the most heavily used UGTA on the NNSS (Figure A-7). The alluvium and tuff formations provide many characteristics advantageous to the containment of nuclear explosions. They are easily mined or drilled. The high-porosity overburden (alluvium and vitric tuffs) will accept and depressurize any gas that might escape the blast cavity. The deeper tuffs are zeolitized, which creates a nearly impermeable confining unit. The zeolites also have absorptive and "molecular sieve" attributes that severely restrict or prevent the migration of radionuclides (Carle et al. 2008). The deep water table (greater than 503 m [1,650 ft] depth) provides additional operational and environmental benefits.

This section provides brief descriptions of the geologic and hydrogeologic setting of the Yucca Flat/Climax Mine UGTA, as well as a discussion of the hydrostratigraphic framework. This summary was compiled from various sources, including Winograd and Thordarson (1975), Byers et al. (1989), Laczniak et al. (1996), Cole (1997), IT (2002), and BN (2006a), where additional information can be found.

Physiography – Yucca Flat is a topographically closed basin with a playa at its southern end. The geomorphology of Yucca Flat is typical of the arid, inter-mountain basins found throughout the Basin and Range province of Nevada and adjoining states. Faulted and tilted blocks of Tertiary-age volcanic rocks and underlying Precambrian and Paleozoic sedimentary rocks form low ranges around the basin (Figure A-2). These rocks also compose the "basement" of the basin, which is now covered by alluvium.

Ground elevation in the Yucca Flat area ranges from about 1,195 m (3,920 ft) above mean sea level at Yucca Lake (playa) in southern Yucca Flat to about 1,463 m (4,800 ft) in the northern portion of the valley. The highest regions of the surrounding mountains and hills range from less than 1,500 m (5,000 ft) in the south to over 2,316 m (7,600 ft) at Rainier Mesa in the northwest corner of the area. Yucca Flat is bounded by the Halfpint Range to the east, by Rainier Mesa and the Belted Range to the north, by the Eleana Range and Mine Mountain to the west, and by the CP Hills, CP Hogback, and Massachusetts Mountain to the south.

Geology Overview – The Precambrian and Paleozoic rocks of the NNSS area consist of approximately 11,300 m (37,000 ft) of carbonate and silicic clastic rocks (Cole 1997). These rocks were severely deformed by compressional movements during Mesozoic time, which resulted in the formation of folds and thrust faults (e.g., Belted Range and CP thrust faults). In the middle Late Cretaceous, granitic bodies (such as the Climax Stock in northern Yucca Flat) intruded these deformed rocks (Houser and Poole 1960; Maldonado 1977).

A total of 22 pre-Tertiary formations (including the Mesozoic granitic intrusives) has been recognized in the Yucca Flat region (Table A-3). These rocks range in age from Precambrian to Cretaceous and are the result of primarily carbonate and silicic shallow- to deep-water sedimentation near a continental margin. Some of these units are widespread throughout southern Nevada and California, though complex structural deformation has created many uncertainties in determining the geometric relationships of these units around Yucca Flat.

In Cenozoic time, the sedimentary and intrusive rocks were buried by thick sections of volcanic material deposited in several eruptive cycles from source areas in the SWNVF. The Cenozoic stratigraphy of the Yucca Flat area, though not structurally complicated, is very complex. Most of the volcanic rocks of the Yucca Flat area were deposited during many eruptive cycles of the SWNVF (Section A.1.1). The source areas of most units (Volcanics of Oak Spring Butte, Tunnel Formation, Belted Range Group, Crater Flat Group, Calico Hills Formation, Paintbrush Group, and Timber Mountain Group) are located to the west and northwest of Yucca Flat; the Wahmonie source area is located southwest of Yucca Flat. Table A-2 includes the Tertiary stratigraphic units common to the Yucca Flat basin.

The volcanic rocks include primarily ash-flow tuffs, ash-fall tuffs, and reworked tuffs, whose thicknesses and extents vary partly due to the irregularity of the underlying depositional surface, and partly due to the presence of topographic barriers and windows between Yucca Flat and the source areas to the north and west.

Over the last several million years, gradual erosion of the highlands that surround Yucca Flat has deposited a thick blanket of alluvium on the tuff section. The alluvium in Yucca Flat, and throughout most of the NNSS, is a consolidated mixture of detritus derived from silicic volcanic and Paleozoic sedimentary rocks, ranging in particle size from clay to boulders. Sediment deposition is largely in the form of alluvial fans (debris flows, sheet wash, and braided streams) that coalesce to form discontinuous, gradational, and poorly sorted deposits. Eolian sand, playa deposits, and rare basalt flows are also present within the alluvium section of Yucca Flat. The alluvium thickness in Yucca Flat generally ranges from about 30 m (100 ft) to over 914 m (3,000 ft) (Drellack and Thompson 1990).

Structural Setting – The structure of the pre-Tertiary rocks in Yucca Flat is complex and poorly known (Cole 1997), but it is important because the pre-Tertiary section is very thick and extensive and includes units that form regional aquifers. The main pre-Tertiary structures in the Yucca Flat area are related to the east-vergent Belted Range thrust fault, which has placed Late Proterozoic to Cambrian-age rocks over rocks as young as Late Mississippian (Cole 1997; Cole and Cashman 1999). In several places along the western and southern portions of Yucca Flat, east-vergent structures related to the Belted Range thrust were deformed by younger west-vergent structural activity (Cole and Cashman 1999). This west-vergent deformation is related to the CP thrust fault, which also placed Cambrian and Ordovician rocks over Mississippian and Pennsylvanian-age rocks beneath western Yucca Flat (Caskey and Schweickert 1992).

Large-scale normal faulting began in Yucca Flat in response to regional extensional movements near the end of this period of volcanism. This faulting formed the Yucca Flat basin. As fault movement continued, blocks between faults were down-dropped and tilted, creating subbasins within the Yucca Flat basin.

The major basin-forming faults generally strike in a northerly direction, and relative offset is typically down to the east (e.g., Yucca, Topgallant, and Carpetbag faults). Movement along the Yucca fault in central Yucca Flat indicates deformation in the area has continued into the Holocene (Hudson 1992). Specific details regarding these faults are lacking because of the program's preference to avoid known and inferred faults during drilling of emplacement holes for underground nuclear tests.

The configuration of the Yucca Flat basin is illustrated on the generalized west-east cross section shown in Figure A-9. The cross section is simplified to show the positions of only the primary lithostratigraphic units in the region. This cross section provides a conceptual illustration of the irregular Precambrian and Paleozoic rocks overlain by the Tertiary volcanic units, and the basin-filling alluvium at the surface. The main Tertiary-age, basin-forming large-scale normal faults are also shown.

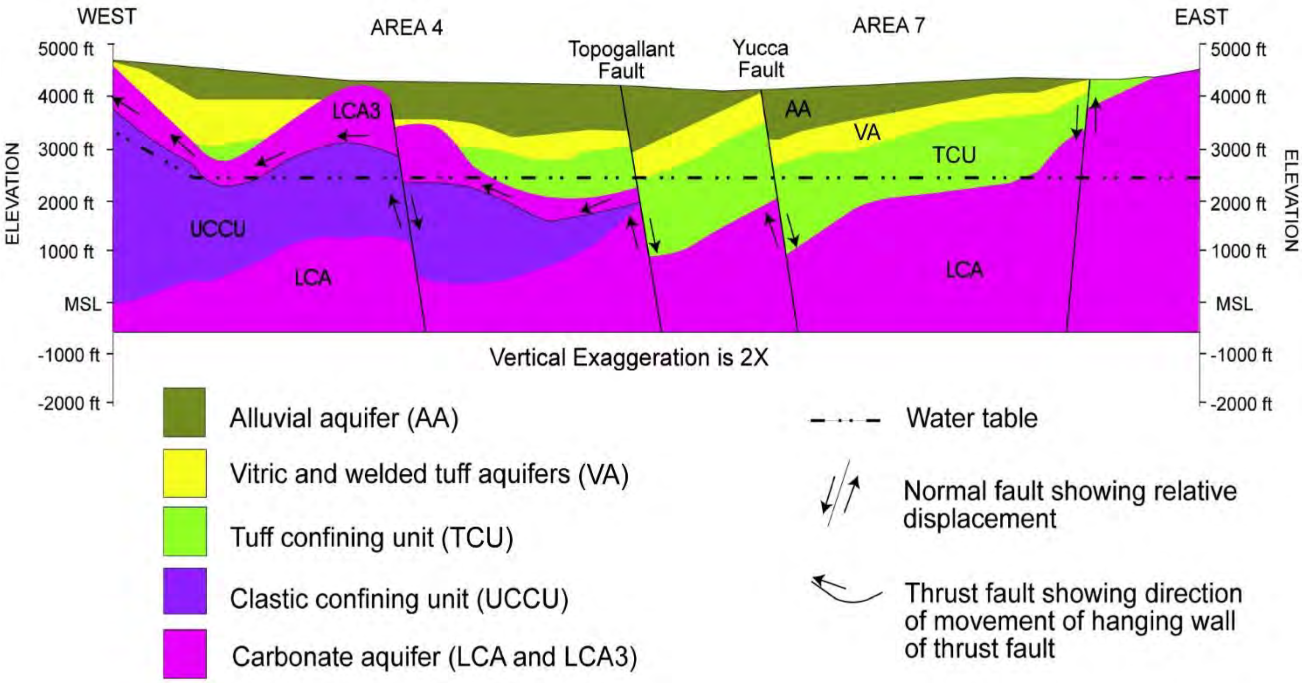

Figure A-9. Generalized west-east hydrogeologic cross section through central Yucca Flat
MSL=mean surface level

Hydrogeologic Overview – All the rocks of the Yucca Flat underground test area can be classified as one of eight HGUs (Table A-4), which include the AA, four volcanic HGUs, an intrusive unit, and two HGUs that represent the pre-Tertiary rocks.

The strata in Yucca Flat have been subdivided into 11 Tertiary-age HSUs (including the Tertiary/Quaternary alluvium), 1 Mesozoic intrusive HSU, and 6 Paleozoic HSUs (BN 2006a). These units are listed in Table A-7, and several of the more important HSUs are discussed in the following paragraphs. The alluvium and pre-Tertiary HSUs in Yucca Flat are as defined in Section A.2.3.2.

The hydrostratigraphy for the Tertiary-age volcanic rocks in Yucca Flat can be simplified into two categories: zeolitic tuff confining units and (nonzeolitic) volcanic aquifers.

The zeolitic TCUs in Yucca Flat have been grouped into three HSUs: the upper tuff confining unit (UTCU), the lower tuff confining unit (LTCU), and the Oak Spring Butte confining unit (OSBCU) (Table A-7). The LTCU and OSBCU are important HSUs in the Yucca Flat region (stratigraphically similar to the LTCU in Frenchman Flat) because they separate the volcanic aquifer units from the underlying regional LCA. Almost all zeolitized tuff units in Yucca Flat are grouped within the LTCU and OSBCU, which comprises mainly zeolitized bedded tuff (ash-fall tuff, with minor reworked tuff). The LTCU and OSBCU are saturated in much of Yucca Flat; however, measured transmissivities are very low.

The LTCU and OSBCU are generally present in the eastern two-thirds of Yucca Flat. They are absent over the major structural highs, where the volcanic rocks have been removed by erosion. Areas where the LTCU and OSBCU are absent include the "Paleozoic bench" in the western portion of the basin. In northern Yucca Flat, the LTCU and OSBCU tend to be confined to the structural subbasins. Outside the subbasins and around the edges of Yucca Flat, the volcanic rocks are thinner and are not zeolitized.

The unaltered volcanic rocks of Yucca Flat are divided into three Timber Mountain HSUs. The hydrogeology of this part of the geologic section is complicated by the presence of one or more ash-flow tuff units that are quite variable in properties both vertically and laterally.

Table A-7. Hydrostratigraphic units of the Yucca Flat underground test area

Hydrostratigraphic Unit (Symbol)	Dominant Hydrogeologic Units[(a)]	Typical Lithologies
Alluvial Aquifer (AA)	AA, minor LFA	Alluvium (gravelly sand); also includes one or more thin basalt flows, playa deposits and eolian sands
Timber Mountain Upper Vitric-Tuff Aquifer (TMUVTA)	WTA, VTA	Includes vitric nonwelded ash-flow and bedded tuff
Timber Mountain Welded-Tuff Aquifer (TMWTA)	WTA	Partially to densely welded ash-flow tuff; vitric to devitrified
Timber Mountain Lower Vitric-Tuff Aquifer (TMLVTA)	VTA	Nonwelded ash-flow and bedded tuff; vitric
Upper Tuff Confining Unit (UTCU)	TCU	Zeolitic bedded tuff
Topopah Spring Aquifer (TSA)	WTA	Welded ash-flow tuff; present only in extreme southern Yucca Flat
Belted Range Aquifer (BRA)	WTA	Welded ash-flow tuff
Belted Range Confining Unit (BRCU)	TCU	Zeolitic bedded tuffs
Pre-Grouse Canyon Tuff Lava-Flow Aquifer (Pre-Tbg-LFA)	LFA	Lava flow
Lower Tuff Confining Unit (LTCU)	TCU	Zeolitic bedded tuffs with interbedded but less significant zeolitic, nonwelded to partially welded ash-flow tuffs
Tub Spring Aquifer (TUBA)	WTA	Welded ash-flow tuff
Oak Spring Butte Confining Unit (OSBCU)	TCU	Zeolitic bedded tuffs with interbedded but less significant zeolitic, nonwelded to partially welded ash-flow tuffs
Argillic Tuff Confining Unit (ATCU)	TCU	Includes the argillic, lowermost Tertiary volcanic units and paleocolluvium that immediately overlie the pre-Tertiary rocks
Mesozoic Granite Confining Unit (MGCU)	GCU	Granodiorite and quartz monzonite
Upper Carbonate Aquifer (UCA)	CA	Limestone
Lower Carbonate Aquifer - Yucca Flat Upper Thrust Plate (LCA3)	CA	Limestone and dolomite
Lower Clastic Confining Unit - Yucca Flat Upper Plate (LCCU1)	CCU	Quartzite and siltstone
Upper Clastic Confining Unit (UCCU)	CCU	Argillite and quartzite
Lower Carbonate Aquifer (LCA)	CA	Dolomite and limestone; "regional aquifer"
Lower Clastic Confining Unit (LCCU)	CCU	Quartzite and siltstone; "hydrologic basement"

(a) See Table A-4 for description of HGUs.
Note: Adapted from BN (2006a).

The Timber Mountain Group includes ash-flow tuffs that can be either WTAs or VTAs, depending on the degree of welding (refer to Sections A.2.3.1 and A.2.3.2). In Yucca Flat, these units are generally present in the central portions of the basin. They can be saturated in the deepest structural subbasins.

The AA is confined primarily to the basins of the NNSS. However, because the water table in the vicinity is moderately deep, the alluvium is generally unsaturated, except in the deep subbasins of some valleys. These sediments are porous and, thus, have high storage coefficients. Transmissivities may also be high, particularly in the coarser, gravelly beds.

The more recent large-scale extensional faulting in the Yucca Flat area is significant from a hydrologic perspective because the faults have profoundly affected the hydrogeology of the Tertiary volcanic units by controlling to a large extent their alteration potential and final geometry. In addition, the faults themselves may facilitate migration of potentially contaminated groundwater from sources in the younger (volcanic) rocks into the underlying regional aquifers. Final geometry of formations may be such that rocks of very different properties are now juxtaposed (e.g., altered volcanic rocks against a Paleozoic carbonate scarp).

Water-Level Elevation and Groundwater Flow Direction – Water-level data are abundant for Yucca Flat, as a result of more than 60 years of drilling in the area in support of the weapons testing program. However, water-level data for the surrounding areas are scarce. These data are listed in the potentiometric data package prepared for the UGTA regional-scale groundwater model (Hale et al. 1995; IT 1996b) and in the more recent Yucca Flat-CAU–specific data reports (Fenelon 2005; SNJV 2006b; Navarro-Intera [NI] 2013).

The SWL in the Yucca Flat basin is relatively deep, ranging in depth from about 183 m (600 ft) in extreme western Yucca Flat to more than 580 m (1,900 ft) in north-central Yucca Flat (Hale et al. 1995; Laczniak et al. 1996). Elevation of the water table within Yucca Flat proper is relatively flat and varies from 773 m (2,535 ft) in the north to 730 m (2,400 ft) at the southern end of Yucca Flat (Hale et al. 1995; Laczniak et al. 1996; Fenelon 2005; SNJV 2006b; Fenelon et al. 2012; NI 2013). Throughout much of the Yucca Flat area, the SWL typically is located within the lower portion of the volcanic section, in the LTCU and OSBCU. Beneath the hills surrounding Yucca Flat, the SWL can be within the Paleozoic-age units, while in the deeper structural subbasins of Yucca Flat, the Timber Mountain Tuff and the lower portion of the alluvium are also saturated. It is interesting to note that the water level just north of Yucca Flat in western Emigrant Valley is at an elevation of 1,340 m (4,400 ft), about 305 m (2,000 ft) higher than in Yucca Flat. This is due to a hydrologic barrier around the north end of Yucca Flat formed by the LCCU in the Halfpint Range and the Climax granite stock.

Water levels measured in wells completed in the AA and volcanic units in the eastern two-thirds of Yucca Flat are typically about 20 m (70 ft) higher than in wells completed in the LCA (Winograd and Thordarson 1975; IT 1996b; Fenelon 2005; SNJV 2006b). The hydrogeology of these units suggests that the higher elevation of the water table in the overlying Tertiary rocks is related to the presence of low permeability zeolitized tuffs of the LTCU and OSBCU (aquitards) between the Paleozoic and Tertiary aquifers (SNJV 2006b). Detailed water-level data indicate the existence of a groundwater trough along the axis of the valley. The semi-perched water within the AA and volcanic aquifers eventually moves downward to the carbonate aquifer in the central portion of the valley. Water-level elevations in western Yucca Flat are also well above the regional water level. The hydrology of western Yucca Flat is influenced by the presence of the Mississippian clastic rocks, which directly underlie the carbonate aquifer of the upper plate of the CP thrust (locally present), AA, and volcanic rocks west of the Topgallant fault. This geometry is a contributing factor in the development of higher (semi-perched) water levels in this area. The Climax Stock also bears perched water (Walker 1962; Laczniak et al. 1996) well above the regional water level.

The present structural interpretation for Yucca Flat depicts the LCCU at great depth, except in the northeast corner of the study area. The Zabriskie Quartzite and Wood Canyon Formation, which are both classified as clastic confining units, are exposed in the northern portion of the Halfpint Range. The high structural position of the LCCU there (and in combination with the Climax Stock) may be responsible for the steep hydrologic gradient observed between western Emigrant Valley and Yucca Flat.

Based on the existing data as interpreted from the UGTA regional-scale groundwater flow model (DOE/NV 1997) and the CAU-scale flow and transport model for Yucca Flat (NNES 2010a; NI 2013), the overall groundwater flow direction in Yucca Flat is to the south and southwest (Hershey and Acheampong 1997; Figure A-6). Groundwater ultimately discharges at Ash Meadows and Alkali Flat to the south and Death Valley to the southwest.

A.2.5.3 Pahute Mesa Underground Test Area

This section provides descriptions of the geologic and hydrologic settings of the Pahute Mesa UGTA. This summary was compiled from various sources, including Winograd and Thordarson (1975), Byers et al. (1976, 1989), Laczniak et al. (1996), Cole (1997), and BN (2002a). Additional information can be found in these documents. For detailed stratigraphic descriptions, see Sawyer et al. (1994) and Slate et al. (1999).

The Western and Central Pahute Mesa CAUs, encompassing Areas 19 and 20 of the NNSS, were the site of 85 underground nuclear tests (NNSA/NFO 2015a) (Figure A-7). These detonations were all conducted in vertical emplacement holes (Table A-1). The Western Pahute Mesa CAU is separated from the Central Pahute Mesa CAU by the Boxcar fault and is distinguished by a relative abundance of tritium (DOE/NV 1999). For hydrogeologic studies and modeling purposes, these two CAUs are treated together.

Hydrogeologically, these CAUs are considered to be part of a larger region that includes areas both within and outside the boundaries of the NNSS, designated as the Pahute Mesa–Oasis Valley (PM-OV) study area. Because most of the underground nuclear tests at Pahute Mesa were conducted near or below the SWL, test-related contaminants are available for transport via a groundwater flow system that may extend to discharge areas in Oasis Valley. Similar to the UGTAs of Frenchman Flat and Yucca Flat, a CAU-scale hydrostratigraphic framework model (BN 2002a) has been developed for the PM-OV study area to support modeling of groundwater flow and contaminant transport for the UGTA activity (SNJV 2006c, 2009; Jackson and Fenelon 2018).

Physiography – Pahute Mesa is a structurally high volcanic plateau in the northwest corner of the NNSS (Figure A-2). Ground-level elevations in the area range from below 1,650 m (5,400 ft) off the mesa to the north and south, to over 2,135 m (7,000 ft) on eastern Pahute Mesa. Pahute Mesa proper is composed of flat-topped buttes and mesas separated by deep canyons. This physiographic feature covers most of NNSS Areas 19 and 20, which are the second-most used testing real estate at the NNSS. Consequently, there are numerous drill holes that provide a substantial amount of subsurface geologic and hydrologic information (Warren et al. 2000a, 2000b; BN 2002a).

Geology Overview – Borehole and geophysical data from Pahute Mesa indicate the presence of several nested calderas (Figure A-2) that produced thick sequences of rhyolite tuffs and lavas. The older calderas are buried by ash-flow units produced from younger calderas. Most of eastern Pahute Mesa is capped by the voluminous Ammonia Tanks and Rainier Mesa ash-flow tuff units, which erupted from the Timber Mountain Caldera, located immediately to the south of Pahute Mesa (Byers et al. 1976). The western portion is capped by ash-flows of the Thirsty Canyon Group from the Black Mountain caldera (9.4 Ma). A typical geologic cross section for Pahute Mesa is presented in Figure A-10. For a more detailed geologic summary, see Ferguson et al. (1994), Sawyer et al. (1994), Warren et al. (2000b), and BN (2002a).

The most widespread and significant Quaternary and Tertiary (mainly volcanic) units of the Pahute Mesa area are included in Table A-2. Refer to Table A-3 for a list of Mesozoic (granitic), Paleozoic (sedimentary), and Precambrian (sedimentary and metamorphic) stratigraphic units.

Underlying the Tertiary-age volcanic rocks (exclusive of the caldera complexes) are Paleozoic and Proterozoic sedimentary rocks consisting of dolomite, limestone, quartzite, and argillite. In Precambrian and Paleozoic time, as much as 10,000 m (32,800 ft) of these marine sediments were deposited in the NNSS region (Cole 1997). For detailed stratigraphic descriptions of these rocks, see Slate et al. (1999). The only occurrence of Mesozoic age rocks in the Pahute Mesa area is the Gold Meadows Stock, a granitic intrusive mass located at the eastern edge of Pahute Mesa, north of Rainier Mesa (Gibbons et al. 1963; Snyder 1977).

The Silent Canyon caldera complex (SCCC) lies beneath Pahute Mesa. This complex contains two of the older known calderas within the SWNVF, and is completely buried by volcanic rocks erupted from younger nearby calderas. It was first identified from gravity observations that indicated a deep basin below the topographically high Pahute Mesa. Subsequent drilling on Pahute Mesa indicated that the complex consists of at least two nested calderas, the Grouse Canyon caldera and younger Area 20 caldera (13.6 and 13.1 Ma, respectively) (Sawyer et al. 1994). For more information on the SCCC, see Ferguson et al. (1994), which is a comprehensive study of the caldera complex based on analysis of gravity, seismic refraction, drill hole, and surface geologic data.

Like the SCCC, the Timber Mountain caldera complex (TMCC) consists of two nested calderas: the Rainier Mesa caldera and the younger Ammonia Tanks caldera, 11.6 and 11.45 Ma, respectively (Sawyer et al. 1994). However, unlike the SCCC, the TMCC has exceptional topographic expression, consisting of an exposed topographic margin for more than half its circumference and a well-exposed central resurgent dome (Timber Mountain, the most conspicuous geologic feature in the western part of the NNSS). The complex truncates the older Claim Canyon caldera (12.65 Ma) (Sawyer et al. 1994), which is farther to the south. The calderas of the TMCC are the sources of the Rainier Mesa and Ammonia Tanks Tuffs, which form important and extensive stratigraphic units at the NNSS and vicinity.

The Black Mountain caldera is a relatively small caldera in the northwest portion of the Pahute Mesa area. It is the youngest caldera in the area, formed as a result of the eruption, 9.4 Ma, of tuffs assigned to the Thirsty Canyon Group (Sawyer et al. 1994).

Deep gravity lows and the demonstrated great thickness of tuffs in the Pahute Mesa area suggest the presence of older buried calderas. These calderas would pre-date the Grouse Canyon caldera and, thus, could be the source of some of the pre-Belted Range units.

Structural Setting – The structural setting of the Pahute Mesa area is dominated by the calderas described in the previous paragraphs. Several other structural features are considered to be significant factors in the hydrology, including the Belted Range thrust fault (Section A.1.3), numerous normal faults related mainly to basin-and-range extension, and transverse faults and structural zones. However, many of these features are buried, and their presence is inferred from drilling and geophysical data. A typical geologic cross section for Pahute Mesa is presented in Figure A-10. For a more detailed geologic summary, see Ferguson et al. (1994), Sawyer et al. (1994), and BN (2002a).

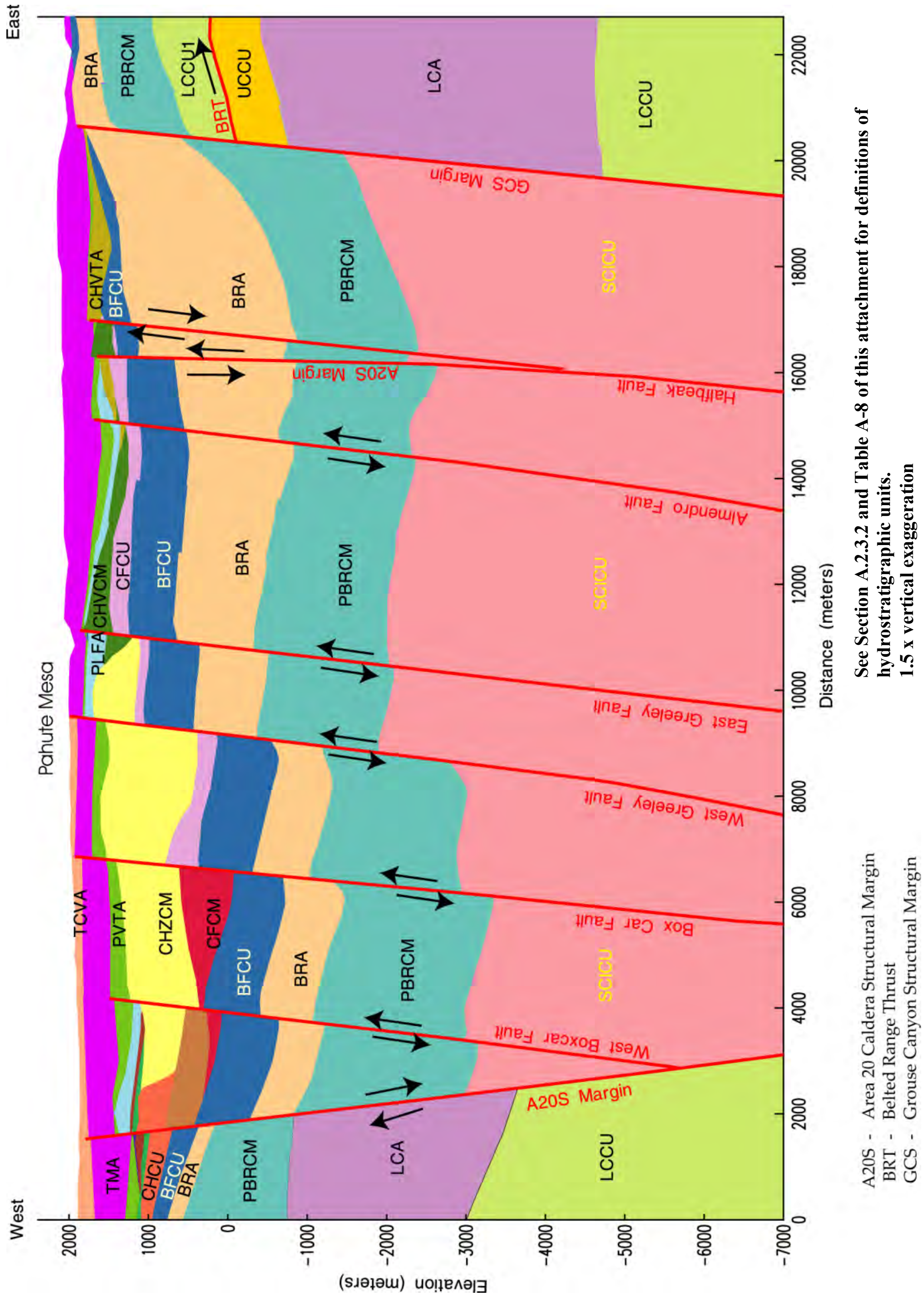

Figure A-10. Generalized hydrostratigraphic cross section through the Silent Canyon complex, Pahute Mesa

Hydrogeology Overview – The hydrogeology of Pahute Mesa is complex. The thick section of volcanic rocks comprises a wide variety of lithologies that range in hydraulic character from aquifer to aquitard. The presence of several calderas and tectonic faulting further complicate the area, placing the various lithologic units in juxtaposition and blocking or enhancing the flow of groundwater in a variety of ways.

The general hydrogeologic framework for Pahute Mesa and vicinity was established in the early 1970s by U.S. Geological Survey geoscientists (Blankennagel and Weir 1973; Winograd and Thordarson 1975). As described in Section A.2.3, their work has provided the foundation for most subsequent hydrogeologic studies at the NNSS (IT 1996a; BN 2002a; NSTec 2009b; Jackson and Fenelon 2018).

All the rocks in the PM-OV study area can be classified as one of nine HGUs, which include the AA, four volcanic HGUs, two intrusive units, and two HGUs that represent the pre-Tertiary rocks (Table A-3).

The rocks within the PM-OV study area are grouped into 44 HSUs for the UGTA CAU-scale hydrogeology framework model (Table A-8; BN 2002a). The volcanic units are organized into 37 HSUs that include 13 aquifers, 13 confining units, and 11 composite units (comprising a mixture of hydraulically variable units). The underlying pre-Tertiary rocks are divided into six HSUs, including two aquifers and four confining units. HSUs that are common to several CAUs at the NNSS are briefly discussed in Section A.2.3.2.

Table A-8. Hydrostratigraphic units of the Pahute Mesa-Oasis Valley area

Hydrostratigraphic Unit (Symbol)	Dominant Hydrogeologic Unit(s)[(a)]	Typical Lithologies
Alluvial Aquifer (AA)	AA	Alluvium (gravelly sand); also includes eolian sand
Younger Volcanic Composite Unit (YVCM)	LFA, WTA, VTA	Basalt, welded and nonwelded ash-flow tuff
Thirsty Canyon Volcanic Aquifer (TCVA)	WTA, LFA, lesser VTA	Partially to densely welded ash-flow tuff; vitric to devitrified
Detached Volcanics Composite Unit (DVCM)	WTA, LFA, TCU	Complex distribution of welded ash-flow tuff, lava, and zeolitic bedded tuff
Fortymile Canyon Composite Unit (FCCM)	LFA, TCU, lesser WTA	Lava flows and associated tuffs
Timber Mountain Composite Unit (TMCM)	TCU (altered tuffs, lavas) and unaltered WTA and lesser LFA	Densely welded ash-flow tuff; includes lava flows, and minor debris flows
Tannenbaum Hill Lava-Flow Aquifer (THLFA)	LFA	Rhyolitic lava
Tannenbaum Hill Composite Unit (THCM)	Mostly TCU lesser WTA	Zeolitic tuff and vitric, nonwelded to welded ash-flow tuffs
Timber Mountain Aquifer (TMA)	Mostly WTA, minor VTA	Partially to densely welded ash-flow tuff; vitric to devitrified
Subcaldera Volcanic Confining Unit (SCVCU)	TCU	Probably highly altered volcanic rocks and intruded sedimentary rocks beneath each caldera
Fluorspar Canyon Confining Unit (FCCU)	TCU	Zeolitic bedded tuff
Windy Wash Aquifer (WWA)	LFA	Rhyolitic lava
Paintbrush Composite Unit (PCM)	WTA, LFA, TCU	Welded ash-flow tuffs, rhyolitic lava and minor associated bedded tuffs
Paintbrush Vitric-tuff Aquifer (PVTA)	VTA	Vitric, nonwelded and bedded tuff
Benham Aquifer (BA)	LFA	Rhyolitic lava
Upper Paintbrush Confining Unit (UPCU)	TCU	Zeolitic, nonwelded and bedded tuff
Tiva Canyon Aquifer (TCA)	WTA	Welded ash-flow tuff
Paintbrush Lava-Flow Aquifer (PLFA)	LFA	Lava; lesser moderately to densely welded ash-flow tuff
Lower Paintbrush Confining Unit (LPCU)	TCU	Zeolitic nonwelded and bedded tuff
Topopah Spring Aquifer (TSA)	WTA	Welded ash-flow tuff

Table A-8. Hydrostratigraphic units of the Pahute Mesa-Oasis Valley area

Hydrostratigraphic Unit (Symbol)	Dominant Hydrogeologic Unit(s)[(a)]	Typical Lithologies
Yucca Mountain Crater Flat Composite Unit (YMCFCM)	LFA, WTA, TCU	Lava; welded ash-flow tuff; zeolitic, bedded tuff
Calico Hills Vitric-Tuff Aquifer (CHVTA)	VTA	Vitric, nonwelded tuff
Calico Hills Vitric Composite Unit (CHVCM)	VTA, LFA	Partially to densely welded ash-flow tuff; vitric to devitrified
Calico Hills Zeolitized Composite Unit (CHZCM)	LFA, TCU	Rhyolitic lava and zeolitic nonwelded tuff
Calico Hills Confining Unit (CHCU)	Mostly TCU, minor LFA	Zeolitic nonwelded tuff; minor lava
Inlet Aquifer (IA)	LFA	Lava
Crater Flat Composite Unit (CFCM)	Mostly LFA, intercalated with TCU	Lava and welded ash-flow tuff
Crater Flat Confining Unit (CFCU)	TCU	Zeolitic nonwelded and bedded tuff
Kearsarge Aquifer (KA)	LFA	Lava
Bullfrog Confining Unit (BFCU)	TCU	Zeolitic, nonwelded tuff
Belted Range Aquifer (BRA)	LFA and WTA, with lesser TCU	Lava and welded ash-flow tuff
Pre-Belted Range Composite Unit (PBRCM)	TCU, WTA , LFA	Zeolitic bedded tuffs with interbedded but less significant zeolitic, nonwelded to partially welded ash-flow tuffs
Black Mountain Intrusive Confining Unit (BMICU)	IICU	These units are presumed to be present beneath the calderas of the SWNVF. Their actual character is unknown, but they may be igneous intrusive rocks or older volcanic and pre-Tertiary sedimentary rocks intruded to varying degrees by igneous rocks.
Ammonia Tanks Intrusive Confining Unit (ATICU)	IICU	
Rainier Mesa Intrusive Confining Unit (RMICU)	IICU	
Claim Canyon Intrusive Confining Unit (CCICU)	IICU	
Calico Hills Intrusive Confining Unit (CHICU)	IICU	
Silent Canyon Intrusive Confining Unit (SCICU)	IICU	
Mesozoic Granite Confining Unit (MGCU)	GCU	Granodiorite and quartz monzonite; Gold Meadows Stock
Lower Carbonate Aquifer-Thrust Plate (LCA3)	CA	Limestone and dolomite
Lower Clastic Confining Unit-Thrust Plate (LCCU1)	CCU	Quartzite and siltstone
Upper Clastic Confining Unit (UCCU)	CCU	Argillite and quartzite
Lower Carbonate Aquifer (LCA)	CA	Dolomite and limestone; “regional aquifer”
Lower Clastic Confining Unit (LCCU)	CCU	Quartzite and siltstone; “hydrologic basement”

(a) See Table A-4 for definitions of HGUs
Note: Adapted from BN (2002b).

Water-Level Elevation and Groundwater Flow Direction – Water-level data are relatively abundant for the Pahute Mesa UGTA as a result of more than 30 years of drilling in the area in support of the Weapons Testing Program. However, water-level data for the outlying areas to the west and south are sparse. These data are listed in the potentiometric data package prepared for the UGTA regional-scale groundwater flow model (IT 1996b), the Pahute Mesa water table map (O’Hagan and Laczniak 1996), and recent work in support of flow modeling (SNJV 2004b, 2006c).

The SWL at Pahute Mesa is relatively deep, at about 640 m (2,100 ft) below the ground surface. Groundwater flow at Pahute Mesa is driven by recharge in the east and subsurface inflow from the north. Local groundwater flow is influenced by the discontinuous nature of the volcanic aquifers and the resultant geometry created by overlapping caldera complexes and high-angle basin-and-range faults (Laczniak et al. 1996). Potentiometric data indicate that groundwater flow direction is to the southwest toward discharge areas in Oasis Valley and, ultimately, Death Valley (see Figures A-5 and A-6).

A.2.5.4 Rainier Mesa/Shoshone Mountain

The Rainier Mesa/Shoshone Mountain CAU consists of 61 CASs on Rainier Mesa and 6 CASs on Shoshone Mountain, which are located in NNSS Areas 12 and 16, respectively (see Figure A-7). Together, these two mesas constitute the third major area used for underground nuclear explosive testing at the NNSS between 1957 and 1992. Underground nuclear tests were conducted in horizontal, mined tunnels within these mesas, and two tests were conducted in vertical drill holes. All tests were conducted above the regional water table. Underground geologic mapping data from the six large and several smaller tunnel complexes, and lithologic and geophysical data from dozens of exploratory drill holes, provide a wealth of geologic and hydrologic information for this relatively small underground test area.

Physiography – The Rainier Mesa UGTA includes Rainier Mesa proper and the contiguous Aqueduct Mesa. Rainier Mesa and Aqueduct Mesa form the southern extension of the northeast trending Belted Range (see Figure A-2). This high volcanic plateau cuts diagonally across Area 12 in the north-central portion of the NNSS. Ground-level elevations on Rainier Mesa are generally over 2,225 m (7,300 ft). The highest point on the NNSS, 2,341 m (7,679 ft), is on Rainier Mesa. Aqueduct Mesa has slightly rougher and lower terrain, generally above 1,920 m (6,300 ft) in elevation. The edges of the mesas drop off quite spectacularly on the west, south, and east sides.

Shoshone Mountain is located in the middle of the NNSS, southwest of Syncline Ridge and about 20 km (12 mi) south of Rainier Mesa (see Figures A-2 and A-7). Ground-level elevations range from 1,707 to 2,012 m (5,600 to 6,600 ft) but are generally above 1,830 m (6,000 ft). Tippipah Point, above the old Area 16 tunnels, has an elevation of 2,015 m (6,612 ft).

Geology Overview – Both Rainier Mesa and Aqueduct Mesa are composed of Miocene-age ash-fall and ash-flow tuffs that erupted from nearby calderas to the west and southwest (NSTec 2007). As in Yucca Flat, these silicic volcanic tuffs were deposited unconformably on an irregular pre-Tertiary (upper Precambrian and Paleozoic age) surface of sedimentary rocks (Gibbons et al. 1963; Orkild 1963) and Mesozoic granitic rocks (at Rainier Mesa only). The stratigraphic units and lithologies are similar to those present in the subsurface of Yucca Flat (see Section A.2.5.2). The tunnel complexes used for underground nuclear testing at Rainier Mesa and Shoshone Mountain were excavated in zeolitized bedded tuff, though the upper part of this section is unaltered (vitric) in some areas. At both locations, the bedded tuffs are capped by a thick layer of welded ash-flow tuff. The Tertiary stratigraphic units and lithologies are similar to those present in the subsurface of Yucca Flat (see Section A.2.5.2).

Structural Setting – The geologic structure of the volcanic rocks of the Rainier Mesa is well documented. Several high-angle, normal faults have been mapped in the volcanic rocks. Faults with greater than about 30 m (100 ft) of displacement are notably absent in the volcanic rocks of Rainier Mesa. The Rainier and Aqueduct Mesa area was minimally extended during Basin and Range tectonism, thus accounting for the absence of larger faults and its relatively high elevation (NSTec 2007). At Shoshone Mountain, several faults have been mapped, but in general the structure is less well known there than at Rainier Mesa. The structure of the pre-Tertiary section at both locations is poorly known, though most workers agree on the framework in general, and that the trace of the Belted Range thrust fault is present in the pre-Tertiary rocks beneath Rainier Mesa. A broad synclinal feature mapped at the surface and in the tuffs of Rainier Mesa and Aqueduct Mesa roughly overlies the postulated location of the Belted Range thrust fault. It may reflect a paleo-topographic low or valley beneath the tuffs (Figure A-11), but the exact character of this feature is unknown.

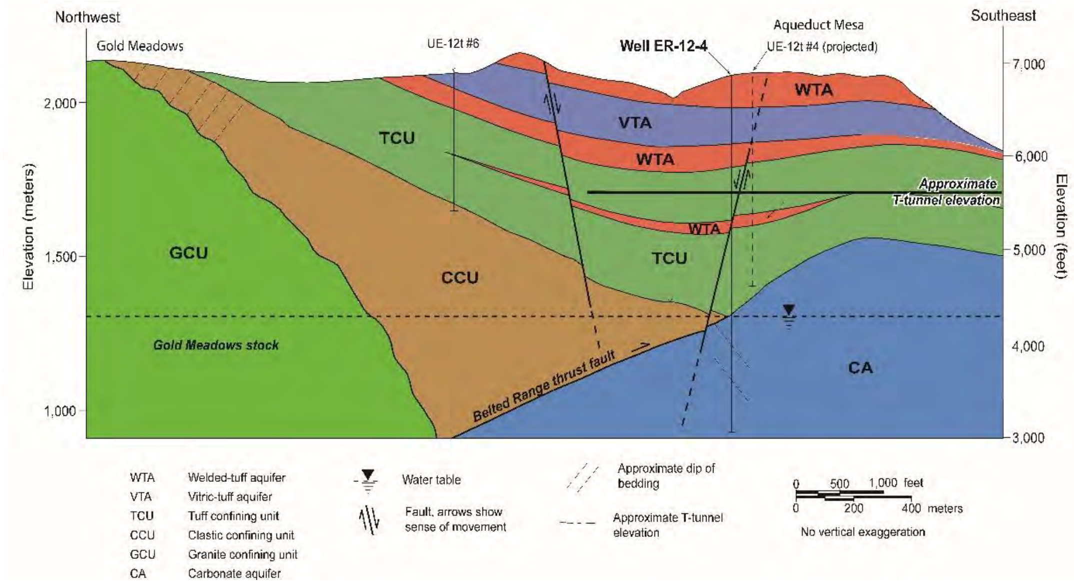

Figure A-11. Generalized hydrostratigraphic cross section through Aqueduct Mesa

Hydrogeology Overview – Construction of a UGTA CAU-scale hydrogeology model for the Rainier Mesa and Shoshone Mountain UGTAs was completed in 2007 (NSTec 2007). All the rocks in the Rainier Mesa–Shoshone Mountain (RM-SM) study area can be classified as one of nine HGUs, which include the AA, four volcanic HGUs, two intrusive units, and two HGUs that represent the pre-Tertiary rocks (see Table A-4). The geologic units within the RM-SM model area are grouped into 44 HSUs (NSTec 2007). Thirty Tertiary-age HSUs, including the Tertiary/Quaternary alluvium, older paleocolluvium, two caldera-related collapse breccias, five caldera-related intrusives, one Mesozoic intrusive HSU, and six Paleozoic/Precambrian HSUs, have been identified in the RM-SM CAU (Table A-9).

The hydrostratigraphy for the Tertiary-age volcanic rocks in the former UGTAs (Rainier Mesa, Aqueduct Mesa, and Shoshone Mountain) can be simplified into two categories: zeolitic, tuff confining units and (nonzeolitic) volcanic aquifers. Except for a few nomenclature complications due to embedded welded tuff aquifers, the TCUs belong to either the LTCU or the OSBCU HSU (similar to the hydrostratigraphic section in Yucca Flat; see Subsection A.2.5.2). The LTCU and OSBCU are important HSUs, as they separate the UGTAs from the underlying regional aquifer.

The hydrostratigraphy of the pre-Tertiary section at Shoshone Mountain is surmised from a single deep drill hole, Well ER-16-1 (NNSA/NSO 2006), and from surficial geology (Orkild 1963). From oldest to youngest, the hydrogeologic section for the Shoshone Mountain UGTA consists of the regional carbonate aquifer, the upper clastic confining unit, tuff confining units, vitric-tuff aquifers, and welded-tuff aquifers at the surface (Figure A-12). At Rainier Mesa, granitic rocks (GCU), related to the nearby Gold Meadows Stock), carbonate rocks (CA), silicic sedimentary rocks such as siltstone, and metamorphic rocks such as quartzite and schist (CCUs) have been encountered beneath the tuff section in the few existing drill holes that penetrate through the tuff section. This variability is indicative of the complex geology of the pre-Tertiary section, which is a consequence of the Gold Meadows intrusive and the Belted Range thrust fault.

Most of the tests in Shoshone Mountain and Rainier Mesa tunnels were conducted in the TCU, though a few were conducted in vitric bedded tuff higher in the stratigraphic section.

Table A-9. Hydrostratigraphic units of the Rainier Mesa-Shoshone Mountain area

Hydrostratigraphic Unit (Symbol)	Dominant Hydrogeologic Units[(a)]	Typical Lithologies
Alluvial aquifer (AA)	AA	Alluvium: Gravelly sand; also includes colluvium and older moat-filling sediments around the Timber Mountain caldera
Fortymile Canyon Composite Unit (FCCM)	LFA, TCU, lesser WTA	Lava flows, lesser ash-flow and bedded tuffs
Timber Mountain Upper Vitric-Tuff Aquifer (TMUVTA)	VTA, minor WTA	Includes vitric nonwelded to partially welded ash-flow and bedded tuff
Timber Mountain Welded-Tuff Aquifer (TMWTA)	WTA minor VTA	Partially to densely welded ash-flow tuff; vitric to devitrified, minor nonwelded tuff
Timber Mountain Lower Vitric-Tuff Aquifer (TMLVTA)	VTA	Nonwelded ash-flow and bedded tuff; vitric
Timber Mountain Composite Unit (TMCM)	TCU (altered tuffs, lavas) and unaltered WTA and lesser LFA	Welded ash-flow tuffs, lava flows
Rainier Mesa Breccia Confining Unit (RMBCU)	TCU/AA	Landslide breccias
Subcaldera Volcanic Confining Unit (SCVCU)	TCU	Highly altered pre-Tm volcanic units
Tiva Canyon Aquifer (TCA)	WTA	Welded ash-flow tuff
Paintbrush Vitric-Tuff Aquifer (PVTA)	VTA	Bedded tuff, vitric
Upper Tuff Confining Unit (UTCU)	TCU	Zeolitized bedded tuff
Topopah Spring Aquifer (TSA)	WTA minor VTA	Welded ash-flow tuff
Lower Vitric-Tuff Aquifer (LVTA)	VTA	Nonwelded and bedded tuff; vitric
Calico Hills Vitric-Tuff Aquifer (CHVTA)	VTA	Nonwelded and bedded tuff; vitric
Yucca Mountain Calico Hills Lava-Flow Aquifer (YMCHLFA)	LFA	Lava flow
Kearsarge Aquifer (KA)	LFA	Lava flow
Upper Tuff Confining Unit 2 (UTCU2)	TCU	Zeolitized bedded tuff
Stockade Wash Aquifer (SWA)	WTA minor VTA	Weakly welded ash-flow tuff
Lower Vitric-Tuff Aquifer 2 (LVTA2)	VTA	Nonwelded and bedded tuff; vitric
Bullfrog Confining Unit (BFCU)	TCU	Zeolitic nonwelded tuff
Upper Tuff Confining Unit 1 (UTCU1)	TCU	Zeolitized bedded tuff
Belted Range Aquifer (BRA)	LFA and WTA	Lava and welded ash-flow tuff
Lower Vitric-Tuff Aquifer 1 (LVTA1)	VTA	Bedded tuff; vitric
Belted Range Confining Unit (BRCU)	TCU	Zeolitized bedded tuff
Tub Spring Aquifer (TUBA)	WTA	Welded ash-flow tuff
Lower Tuff Confining Unit (LTCU)	TCU	Zeolitized bedded tuffs with interbedded but less significant zeolitized, nonwelded to partially welded ash-flow tuffs
Oak Spring Butte Confining Unit (OSBCU)	TCU	Devitrified to zeolitic nonwelded to partially welded tuffs and intervening bedded tuffs
Redrock Valley Aquifer (RVA)	WTA	Welded ash-flow tuff, devitrified
Redrock Valley Breccia Confining Unit (RVBCU)	TCU/AA	Landslide breccias
Lower Tuff Confining Unit 1 (LTCU1)	TCU	Zeolitized bedded tuffs
Twin Peaks Aquifer (TPA)	WTA	Welded ash-flow tuff
Argillic Tuff Confining Unit (ATCU)	TCU	Argillic bedded tuffs, minor paleocolluvium
Ammonia Tanks Intrusive Confining Unit (ATICU)	IICU	Intrusive (granite?) and altered, older host rocks
Rainier Mesa Intrusive Confining Unit (RMICU)	IICU	Intrusive (granite?) and altered, older host rocks
Calico Hills Intrusive Confining Unit (CHICU)	IICU	Intrusive (granite?) and altered, older host rocks

Table A-9. Hydrostratigraphic units of the Rainier Mesa-Shoshone Mountain area

Hydrostratigraphic Unit (Symbol)	Dominant Hydrogeologic Units[(a)]	Typical Lithologies
Silent Canyon Intrusive Confining Unit (SCICU)	IICU	Highly altered older volcanic rocks and pre-Tertiary sedimentary rocks and granitic intrusive masses.
Redrock Valley Intrusive Confining Unit (RVICU)	IICU	Highly altered injected/intruded country rock and granitic material
Mesozoic Granite Confining Unit (MGCU)	GCU	Granodiorite and quartz monzonite
Lower Clastic Confining Unit - Upper Thrust Plate (LCCU1)	CCU	Quartzite and siltstone
Lower Carbonate Aquifer - Upper Thrust Plate (LCA3)	CA	Limestone and dolomite
Upper Carbonate Aquifer (UCA)	CA	Limestone
Upper Clastic Confining Unit (UCCU)	CCU	Argillite and quartzite
Lower Carbonate Aquifer (LCA)	CA	Dolomite and limestone; "regional aquifer"
Lower Clastic Confining Unit (LCCU)	CCU	Quartzite and siltstone; "hydrologic basement"

(a) See Table A-4 for definitions of hydrogeologic units.
Note: Adapted from NSTec (2007).

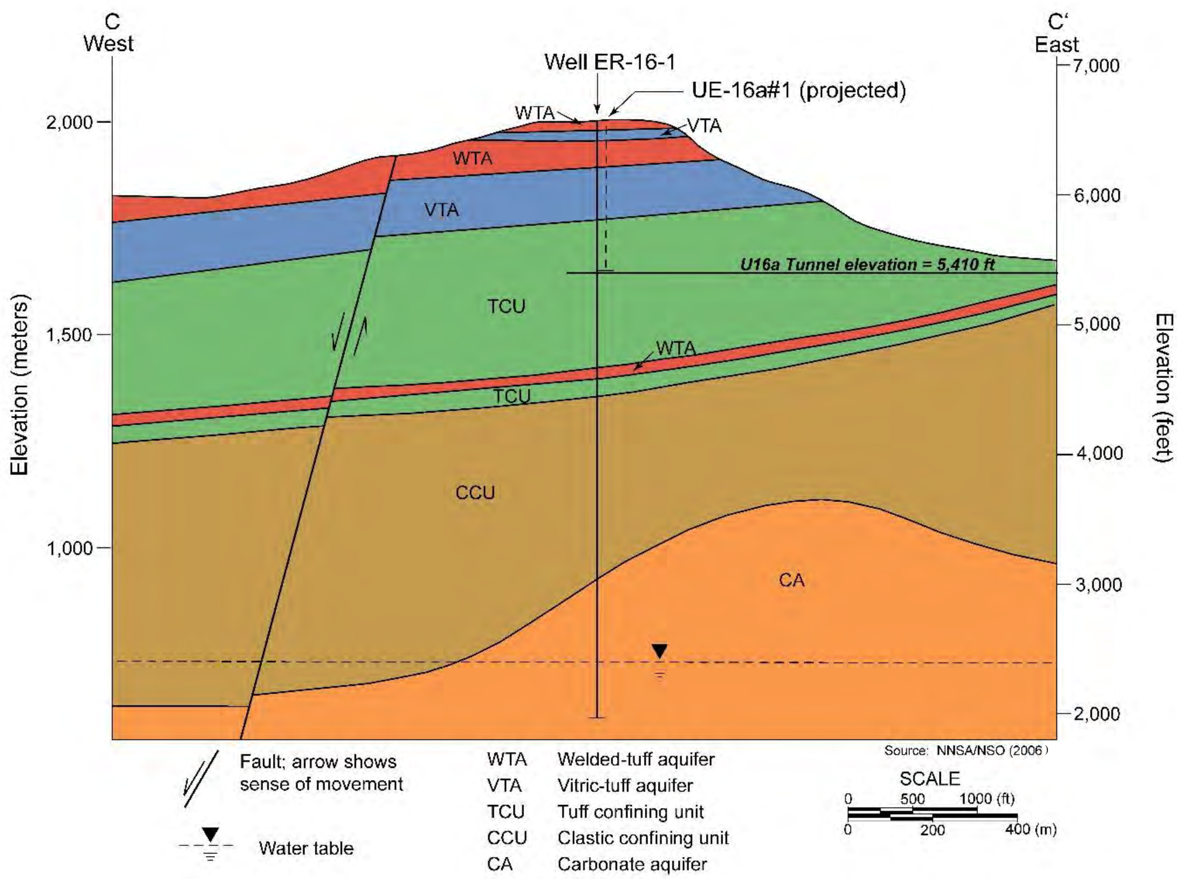

Figure A-12. West-east hydrogeologic cross section through Well ER-16-1

Water-level Elevation and Groundwater Flow Direction – Only a few boreholes on or in the vicinity of Rainier Mesa are deep enough to tag the regional water table. Most notable are UGTA Wells ER-12-3 (BN 2006b) and ER-12-4 (NNSA/NSO 2006 and BN 2006) located on Rainier Mesa and Aqueduct Mesa, respectively. The water levels in these wells are 949 m (3,114 ft) at ER-12-3 and 786 m (2,580 ft) at ER-12-4, or 1,302 m (4,271 ft) and 1,312 m (4,304 ft) elevation, respectively, in the thrusted Paleozoic-age carbonate rocks (LCA3) that underlie the volcanic section (Fenelon 2007). This is approximately 300 m (1,000 ft) below the average elevation of test locations in Rainier Mesa. The SWL, where measured in volcanic units at Rainier Mesa, is at an elevation of about 1,847 m (6,060 ft). This anomalously high water level relative to the regional water level reflects the presence of water perched above the regional aquifer within the tuff confining unit (Walker 1962; Laczniak et al. 1996; Fenelon et al. 2008). Water is present in the fracture systems of some of the tunnel complexes at Rainier Mesa. This water currently is permitted to flow from U12e Tunnel (also known as E-Tunnel); however, water has filled the open drifts behind barriers built near the portals of U12n and U12t Tunnels.

The water level at Shoshone Mountain was measured at 1,248 m (4,093 ft) true vertical depth from the mesa surface, or 761.7 m (2,499 ft) elevation, at UGTA Well ER-16-1 (NNSA/NSO 2006) in the Paleozoic-age carbonate rocks (LCA). This is the deepest water-level tag at the NNSS. No water was encountered during mining at Shoshone Mountain.

Regional groundwater flow from Rainier Mesa may be directed either toward Yucca Flat or, because of the intervening UCCU, to the south toward the Alkali Flat discharge area (Fenelon et al. 2008; see Figures A-5 and A-6). The groundwater flow direction beneath Shoshone Mountain is probably southward.

A.2.6 Conclusion

The hydrogeology of the NNSS and vicinity is complex and varied. Yet, the remote location, alluvial and volcanic geology, and deep water table of the NNSS provided a favorable setting for conducting underground nuclear explosive tests and containing radionuclides produced by the tests. Its arid climate and its setting in a region of closed hydrographic basins also are factors in stabilizing residual surficial contamination from atmospheric testing, and are considered positive environmental attributes for existing radioactive waste management sites.

Average groundwater flow velocities at the NNSS are generally slow, and flow paths to discharge areas or potential receptors (domestic and public water supply wells) are long. The water tables within local aquifers in the valleys and the underlying regional carbonate aquifer are relatively flat (low gradient). The zeolitic volcanic rocks (TCU) separating the shallower alluvial and volcanic aquifers and the regional carbonate aquifer (LCA) appear to form a viable aquitard (non-aquifer). Consequently, both vertical and horizontal flow velocities are low. Additionally, carbon-14 dates for water from NNSS aquifers are on the order of 10,000 to 40,000 years old (Rose et al. 1997). This indicates that there is considerable residence time in the aquifers, allowing contaminant attenuating processes such as matrix diffusion, sorption, and natural decay of radioactive isotopes to operate.

A.3 Climatology

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The NNSS is located in the extreme southwestern corner of the Great Basin. Consequently, the climate is arid, with limited precipitation, low humidity, intense sunlight, and large daily temperature ranges. The climatological data presented here were developed from the NNSS monitoring networks described below.

A.3.1 Monitoring Networks

Meteorological and climatological data are collected on the NNSS by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory, Special Operations and Research Division (ARL/SORD). Data are collected through the Meteorological Data Acquisition (MEDA) system, a network of 23 mobile meteorological towers that became operational in 1981. The network was updated in 2005, and was totally replaced and expanded in 2016 and 2018. A standard MEDA station consists of a portable 10-m (32.8-ft) tower, meteorological instrumentation, a micro-processor/datalogger, and a UHF radio transmitter, all powered by a battery and solar recharging system (Figure A-13). Locations of the MEDA stations are shown in Figure A-14. All towers were sited according to standards set by the Federal Meteorological Handbook No. 1 (NOAA 2005) and the World Meteorological Organization (2008) so as not to be influenced by natural or man-made obstructions or by heat dissipation and generation systems. The selection of MEDA station locations is based on effective site weather characterization, site safety, project support, physical accessibility, and line-of-sight radio availability.

Figure A-13. Example of a typical MEDA station with a 10-meter tower

MEDA station instrumentation is located on top of the tower and on booms oriented into the prevailing wind direction at a minimum distance of two tower widths from the tower. The station configuration measures three-dimensional winds, two levels of temperature and relative humidity, atmospheric pressure, incoming solar radiation, Global Positioning System (GPS) data, and precipitation. Wind direction and speed are measured at the 10-m (32.8-ft) level, in accordance with the specifications of the American National Standard for Determining Meteorological Information at Nuclear Facilities (ANSI/ANS-3.11-2015, American Nuclear Society 2015). Ambient temperature and relative humidity measurements are taken at the approximate heights of 8.7 m (28.5 ft) and 2 m (6.6 ft) to be within the surface boundary layer.

Atmospheric pressure, solar radiation measurements, and GPS measurements are also taken in the surface boundary layer at a height of approximately 2 m (6.6 ft). In addition to the direct measured parameters, the datalogger calculates dew-point temperature, dT/dz (change in temperature with height), and total daily solar radiation. Wind data are 15-minute averages of speed and direction. The maximum and minimum wind speeds are the fastest and slowest, respectively, 3-second moving averages calculated within the 15-minute time interval. Temperature, relative humidity, solar radiation, and pressure are 15-minute averages. All observed and calculated parameters are collected and transmitted every 15 minutes on the quarter hours.

NOAA ARL/SORD also operates and maintains a climatological rain gauge network on the NNSS (Figure A-15). In 2020, the network consisted of 3 Belford Series 5-780 Universal Precipitation Gauges and 23 Hydrological Services America (HSA) TB3 Tipping Bucket Precipitation Gauges. The three Belford gauges are strip chart recorders that are manually read about once every 30 days. The HSA gauges are part of the MEDA network that report data every 15 minutes and are included in the ARL/SORD real-time weather database. Once read and certified, the strip chart

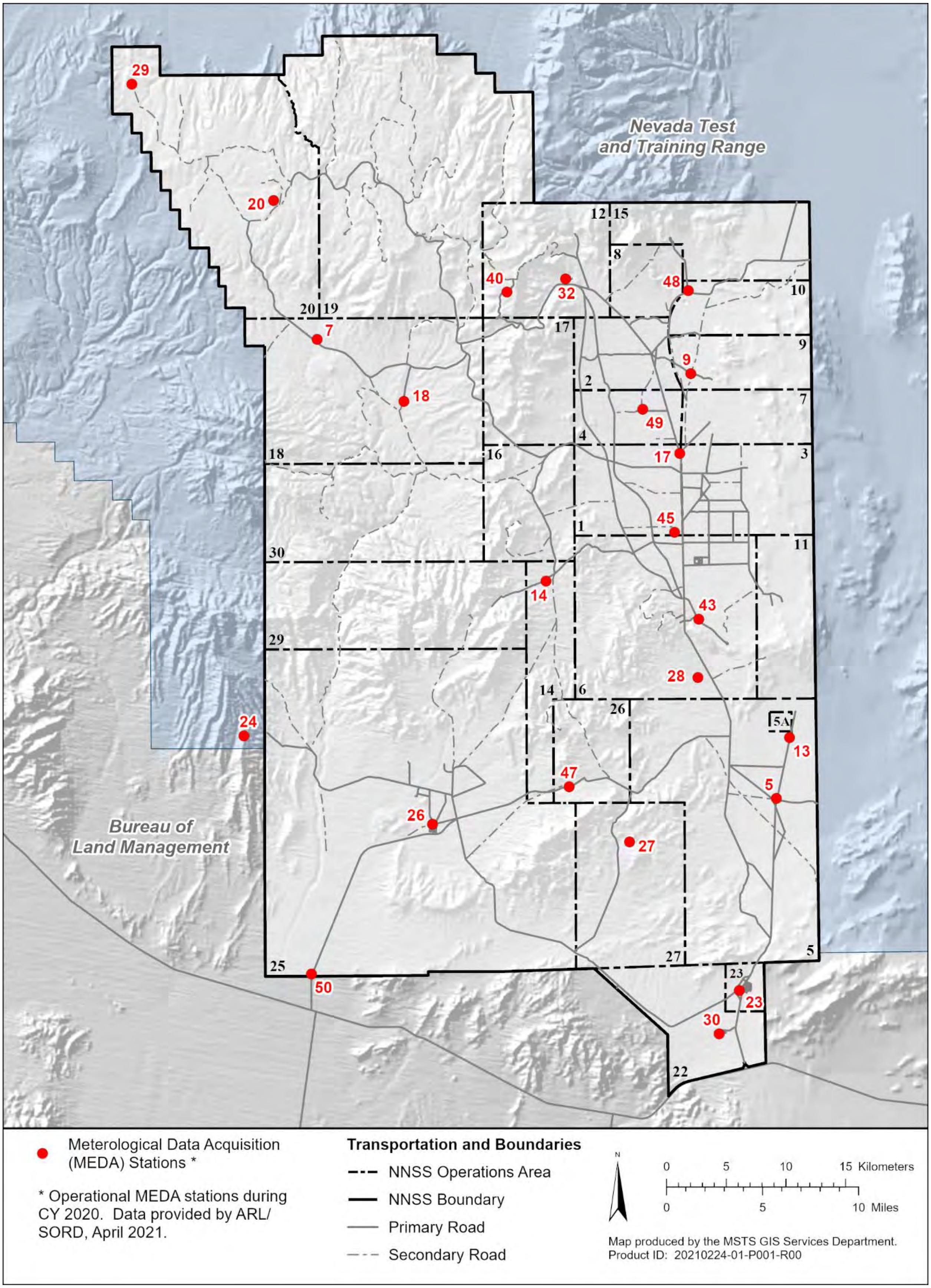

Figure A-14. MEDA station locations on the NNSS

data are entered into the SORD precipitation climatological database. Data are recorded as daily totals. Under special circumstances, 1- to 3-hour totals can be obtained.

MEDA data are used daily for operational support to a wide variety of projects on the NNSS and form the climatological database for the NNSS. The data are used in safety analysis reports, emergency response activities, radioactive waste remediation projects, environmental reports, and compliance assessments. For new NNSS projects and facility modifications that may produce radiological emissions, wind data from the MEDA stations are used to calculate potential radiological doses to members of the public. MEDA data are processed and archived in the NOAA ARL/SORD climatological database. An NNSS Climatological Report is posted on the NOAA ARL/SORD website, http://www.sord.nv.doe.gov, under the Climate section.

A.3.2 Precipitation

Two fundamental physical processes drive precipitation events on the NNSS: those resulting from cool-season, mid-tropospheric cyclones and those resulting from summertime convection. Cool-season precipitation is usually light and can consist of rain or snow. Although light, winter precipitation events can last for several days and result in significant precipitation totals per winter storm, especially in January and February. Summer is thunderstorm season. Precipitation from thunderstorms is usually light; however, some storms produce very heavy rain, flash floods, intense cloud-to-ground lightning, and strong surface winds. Thunderstorms generally occur in July and August when moist tropical air flows from the southeastern North Pacific Ocean and spreads over the desert southwest. This seasonal event is referred to as the southwestern U.S. monsoon.

Distinct winter and summer precipitation mechanisms produce a bimodal monthly precipitation cycle. Figure A-16 shows patterns of mean monthly precipitation recorded from 6 of the 25 climatological stations on the NNSS over the past 35+ years. Mean annual precipitation totals on the NNSS range from over 30 centimeters (cm) (12.13 inches [in.]) over the high terrain in the northwestern part of the NNSS to about 12 cm (4.83 in.) in Frenchman Flat. However, inter-annual variations can be significant. For example, annual totals of less than 2.54 cm (1.0 in., nearly a quarter of the average) have been measured on the lower elevations of the NNSS, but 24.6 cm (9.67 in., nearly double the average) occurred in Frenchman Flat in 1998, and 68.2 cm (26.87 in., over double the average) fell on Rainier Mesa in 1983. Daily precipitation totals can also be large and range from 5 to just over 9 cm (2 to over 3.5 in.). A storm-total precipitation amount of 8.9 cm (3.5 in.) is considered a 100-year, 24-hour, extreme precipitation event. Daily totals of 5.1 to 7.6 cm (2 to 3 in.) have been measured at several sites on the NNSS (Randerson 1997). The greatest daily precipitation event on the NNSS was 11.89 cm (4.68 in), which was measured in Jackass Flats on September 26–27, 2007.

Snow can fall on the NNSS any time between October and May. On Yucca Flat, the greatest daily snow depth measured was 25.4 cm (10 in.) in January 1974. The greatest daily depth measured at Desert Rock was 15.2 cm (6 in.) in February 1987. Maximum daily totals of 38 to 50 cm (15 to 20 in.) or more can occur on Pahute and Rainier Mesas. Hail, sleet, freezing rain, and fog are rare on the NNSS, but can cover the ground briefly during intense thunderstorms. Only 24 hailstorms have been observed on Yucca Flat between 1957 and 1978 (an average of about 1 event per year) and 9 at Desert Rock from 1978 to 2010 (an average of 1 event every 3 to 4 years). Manned observations ended on the NNSS in 2010.

A.3.3 Temperature

As is typical of an arid climate, the NNSS experiences large daily and annual ranges in temperature. In addition, temperatures vary with elevation. Sites above 1,524 m (5,000 ft) mean sea level can be quite cold in the winter and fairly mild during the summer months. At lower elevations, summertime temperatures frequently exceed 37.7 degrees Celsius (°C) (100 degrees Fahrenheit [°F]). On the dry lakebeds, average normal daily low and high temperatures can vary by as much as 22°C (40°F), with very cold morning temperatures in the winter and very hot afternoon temperatures in the summer. These temperature characteristics are shown in Figure A-17. These annual temperature plots describe the temperature extremes and average maximums and minimums throughout the year at six locations on the NNSS.

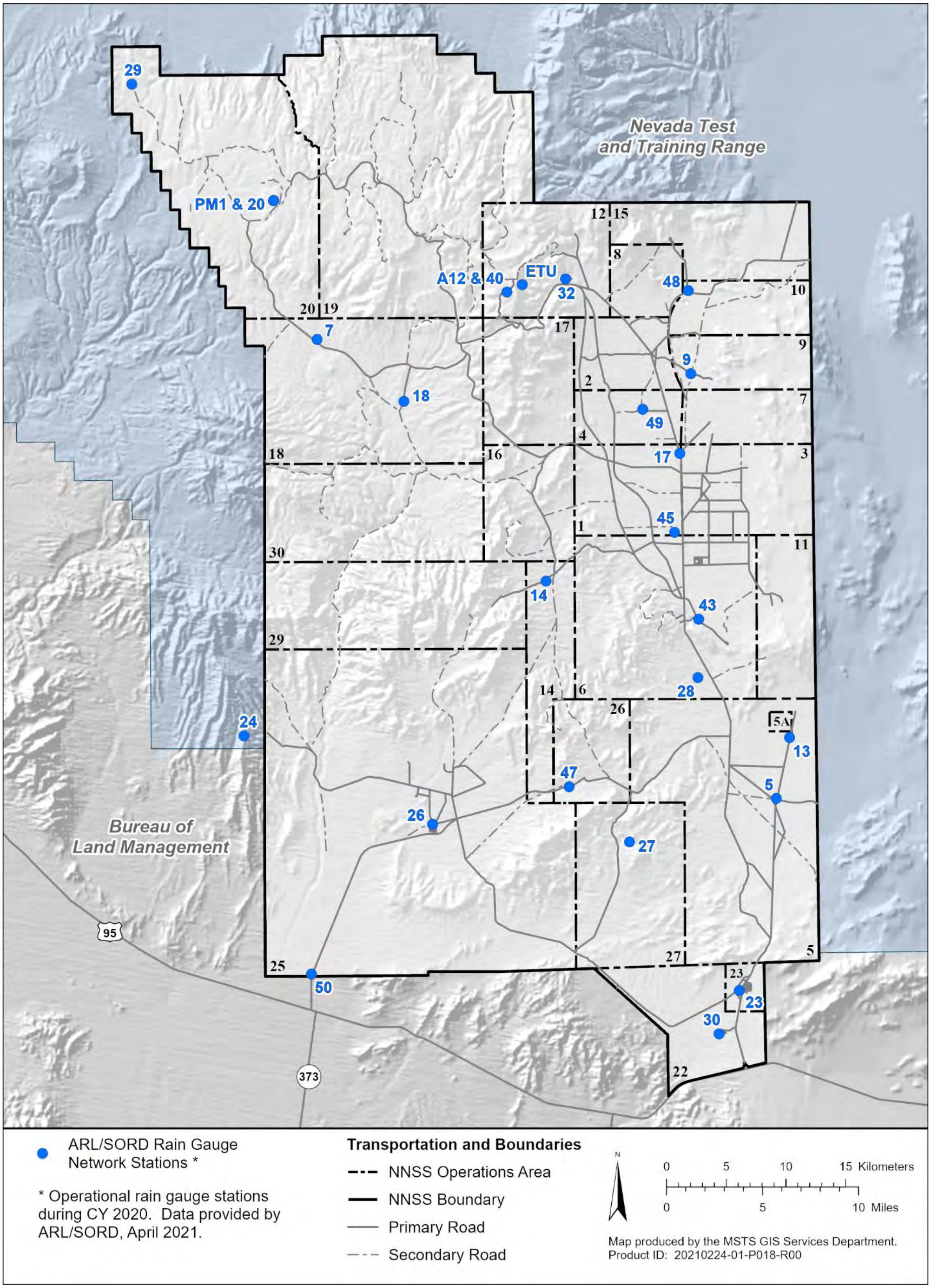

Figure A-15. Climatological rain gauge network on the NNSS

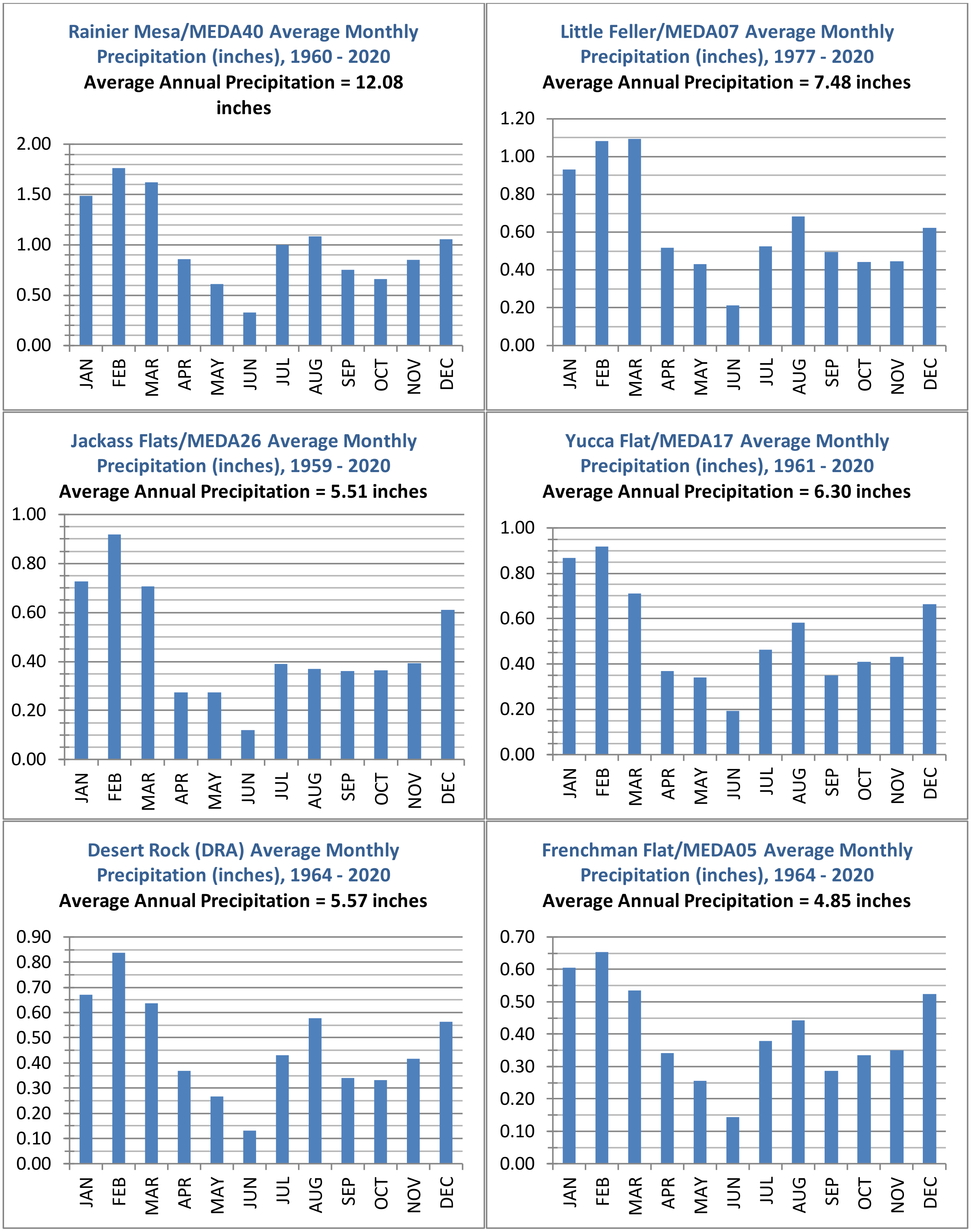

Figure A-16. Mean monthly precipitation at six NNSS rain gauge stations (locations of numbered stations are shown in Figure A-14)

In Frenchman Flat (MEDA 5), the average daily temperature minimum and maximum for January are −4.5°C and 13.8°C (24°F and 57°F), while in July they are 17.3°C and 38.6°C (63°F and 101°F). By contrast, on Rainier Mesa (MEDA 12/40), the minimum and maximum temperature for January are −3.7°C and 4.0°C (25°F and 39°F) and for July are 15.4°C and 26.7°C (60°F and 80°F). The highest maximum temperature measured on the NNSS is 46.1°C (115°F) in Frenchman Flat near Well 5B in July 1998 and in Jackass Flats near Lathrop Gate in July 2002. The coldest minimum temperature measured on the NNSS is −28.9°C (−20°F) in Area 19 in January 1970. The temperature extremes at Mercury are −12.2°C to 45°C (10°F to 113°F).

A.3.4 Wind

Complex topography, such as that on the NNSS, can influence wind speeds and directions. Furthermore, there is a seasonal as well as strong daily periodicity to local wind conditions. For example, in Yucca Flat, in the summer months, the wind direction is usually northerly (from the north) from 10 p.m. Pacific Daylight Time (PDT) to 8 a.m. PDT, and southerly from 10 a.m. PDT to 8 p.m. PDT. However, in January, the winds are generally from the north from 6 p.m. Pacific Standard Time (PST) to 11 a.m. PST, with some southerly winds developing between 11 a.m. PST and 5 p.m. PST. March through June tend to experience the fastest average wind speeds, 13 to 19 kilometers per hour (kph) (7 to 10 knots or 8 to 12 miles per hour [mph]), with the faster speeds occurring at the higher elevations. Peak wind gusts of 80 to 113 kph (43 to 61 knots or 50 to 70 mph) have occurred throughout the NNSS. Peak winds at Mercury have been as high as 135 kph (73 knots or 84 mph) during a spring wind storm. During the same windstorm, Frenchman Flat experienced wind gusts to 113 kph (61 knots or 70 mph). The peak wind speeds measured on the NNSS are above 145 kph (78 knots or 90 mph) on the high terrain with maximums of 204 kph (110 knots or 127 mph) at the Yucca Mountain Ridge-top (MEDA Station 24), and 185 kph (100 knots or 115 mph) on Tippipah Point in south-central Area 16 (former MEDA Station 19, which is no longer in service) during a wind event on February 13, 2008.

Wind speed and direction data have been summarized for all the meteorological sites (MEDAs) on the NNSS. These climatological summaries are referred to as wind roses. Annual wind roses for 16 stations on the NNSS for the years 2005 through 2020 are shown in Figure A-18. These wind roses describe the strong seasonal and diurnal effects on the surface air flow pattern across the NNSS as described above. In general, winter and pre-sunrise winds tend to be northerly, while summer and afternoon flow tends to be southerly.

A.3.5 Relative Humidity

The air over the NNSS tends to be dry. On average, June is the driest month, with the humidity ranging from 10% to 35%. Humidity readings of 35% to 70% are common in the winter. The reason for this variability is that relative humidity is temperature dependent. The relative humidity tends to be higher with cold temperatures and lower with hot temperatures. Consequently, there is not only a seasonal variation but also a marked diurnal rhythm. Early in the morning the humidity ranges from 25% to 70%, and in mid-afternoon it ranges from 10% to 40%, with the larger readings occurring in winter. Humidity readings of more than 75% are observed during thunderstorms and frontal passages with precipitation, but are not otherwise common on the NNSS.

A.3.6 Atmospheric Pressure

Atmospheric pressure is measured at all the MEDA stations on the NNSS (Figure A-14). These measurements show that atmospheric pressure has marked annual and diurnal cycles. In addition, pressure decreases with elevation. Consequently, stations at high elevations have lower atmospheric pressures than do stations at lower elevations. Moreover, because pressure depends on temperature, the larger pressure readings occur during the winter months and the smaller readings in the summer months. The diurnal cycle is bimodal; it is driven by the diurnal tide of the entire atmosphere and by the diurnal heating/cooling cycle. In general, maximum daily surface pressure on the NNSS occurs between 8 and 10 a.m. PST (later in winter, earlier in summer), and minimum pressure tends to occur between 2 and 6 p.m. PST (earlier in winter, later in summer). Weaker secondary maxima occur at approximately midnight PST and minima near 3 a.m. PST. In Yucca Flat (elevation 1,195 m [3,920 ft]), the atmospheric pressure varies from 857 to 908 millibars (mb) annually; however, the daily variation is only approximately 3.4 mb in summer and 2.7 mb in winter.

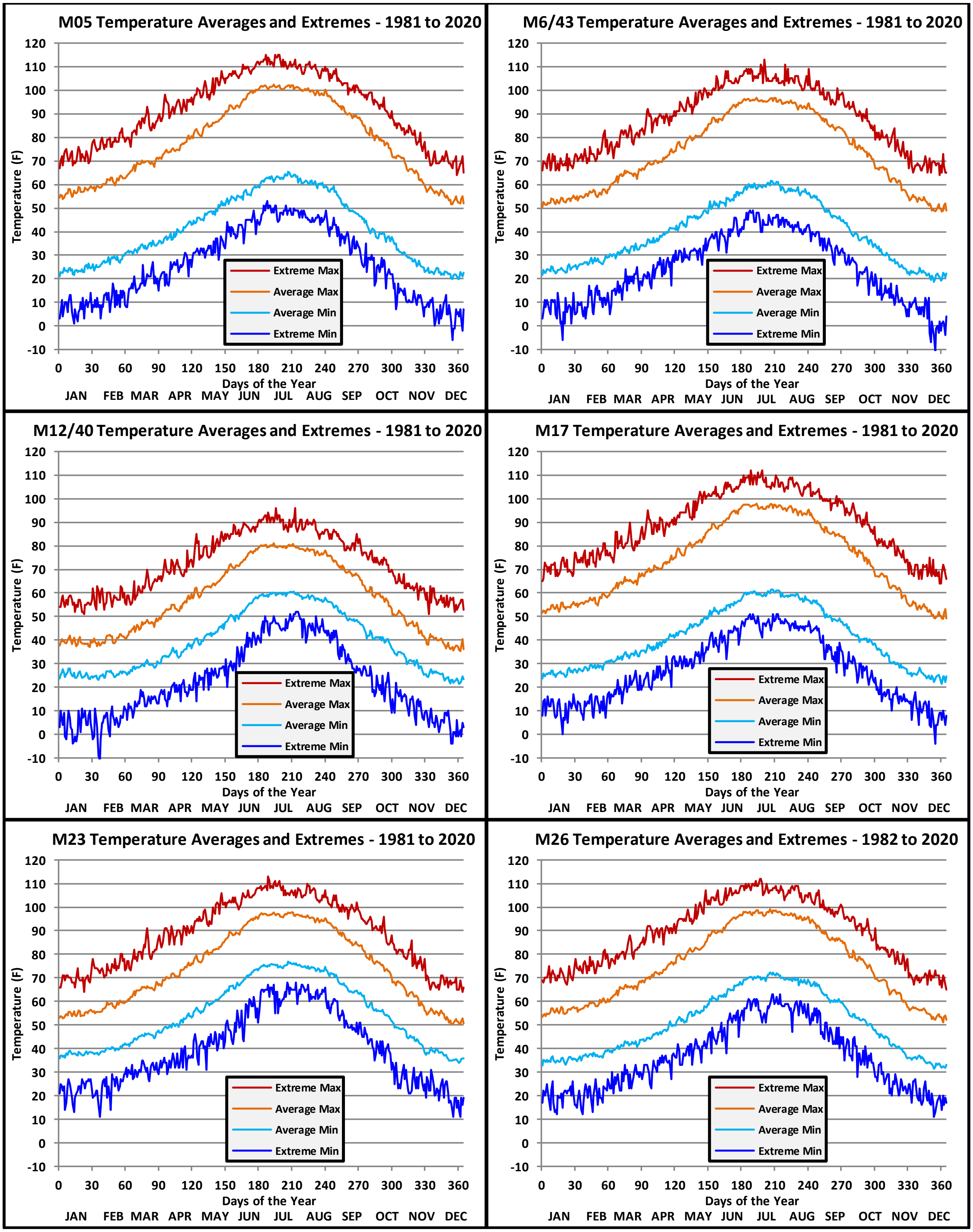

Figure A-17. Temperature extremes and average maximums and minimums at six NNSS MEDA stations (locations of numbered stations are shown in Figure A-14)

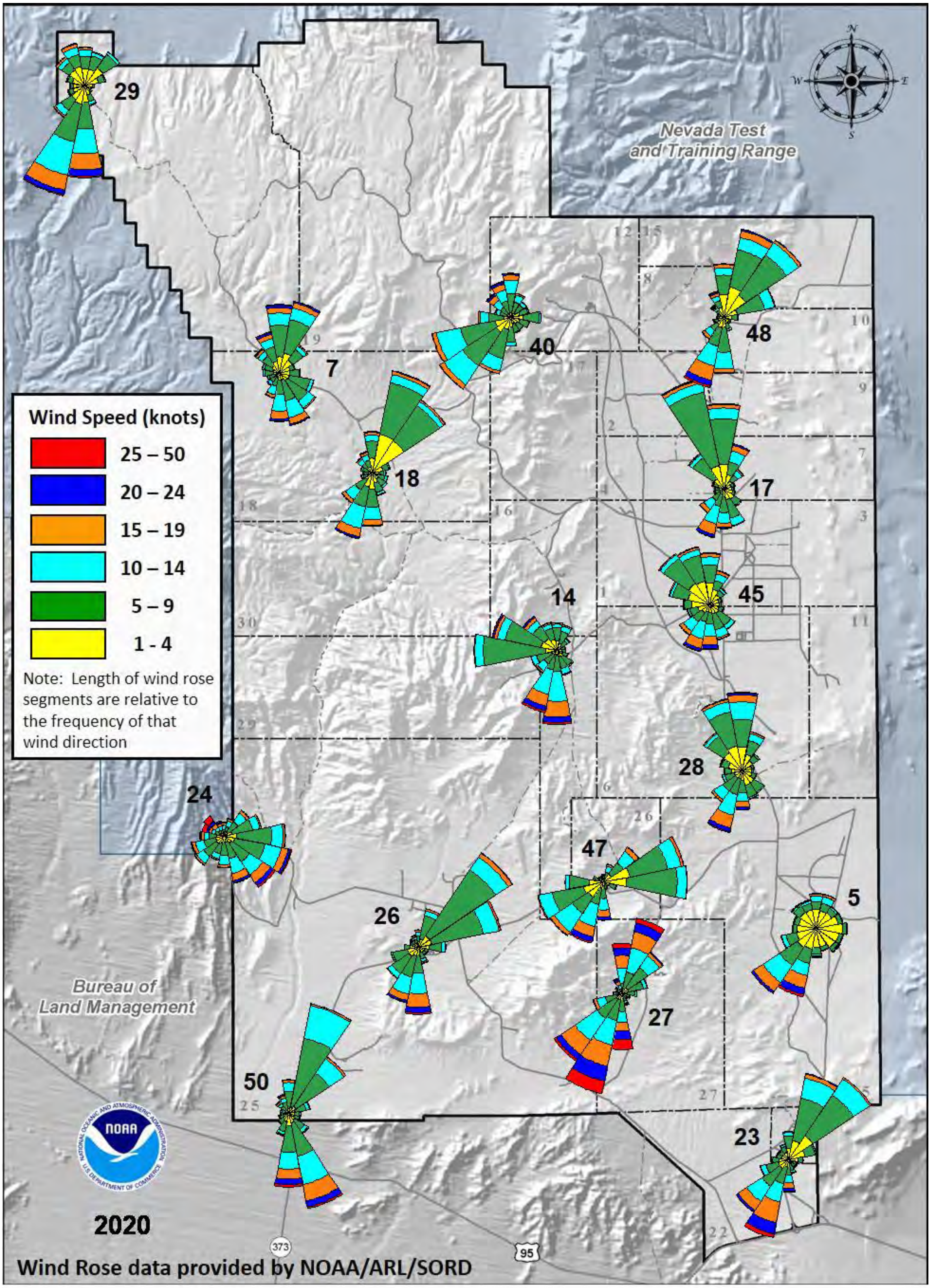

Figure A-18. Annual wind rose climatology for the NNSS (2005–2020)

A phenomenon referred to as atmospheric or barometric pumping can occur as atmospheric pressure decreases. When this happens, gases trapped below ground can seep upward through the soil and enter the atmosphere. Barometric pumping was observed on the NNSS following some underground nuclear tests, and small concentrations of noble gases from the tests were detected for several months afterwards. Barometric pumping also contributes to the release of naturally occurring radionuclides (e.g., radon) from terrestrial sources.

A.3.7 Dispersion Stability Categories

Determination of the stability of the atmosphere near the ground is a key input requirement for atmospheric dispersion models. Such models are used to estimate the impacts of hazardous materials that might be accidentally released into the atmosphere or become airborne from radioactively contaminated soil sites on the NNSS. The dispersion models commonly used for this purpose are Gaussian plume models that require the specification of stability categories to account for effects of atmospheric turbulence on the dispersion process. The mountain-valley topography on the NNSS makes it impossible to calculate a single set of values that characterizes atmospheric turbulent mixing on the NNSS. Consequently, the stability categories for the NNSS are calculated from the average hourly wind speeds for each MEDA station, the solar angle, and the hourly cloud-cover observations reported at the Desert Rock Meteorological Observatory. This procedure follows regulatory guidance provided by the U.S. Environmental Protection Agency (2000) and the American Nuclear Society (2015). The stability category concept makes use of the letters “A” through “F” to define different turbulence regimes. Category “A” specifies free convection in statistically unstable air, “D” represents neutral stability, and “F” is very stable (dispersion suppressed) with little turbulent mixing. In Yucca and Frenchman Flats, in winter, F-stability tends to persist from 4 p.m. PST until 8 a.m. PST the next morning, with an abrupt transition to C- or B-stability near 9 a.m. PST, followed by C- or B-stability during the afternoon. In summer, E- or F-stabilities occur between 7 p.m. PST and 6 a.m. the next morning, with a rapid change to B-stability at 7 a.m. PST and, generally, C- or B-stabilities and some D-stability in late afternoon.

A.3.8 Other Natural Phenomena

Wind speeds in excess of 97 kph (60 mph) occur annually. Additional severe weather in the region includes occasional severe thunderstorms, lightning, hail, and dust storms. Severe thunderstorms may produce high precipitation rates that may create localized flash flooding. Few tornadoes have been observed in the region and are not considered a significant threat.

Cloud-to-Ground (CG) lightning can occur throughout the year but occurs primarily between June and September. Maximum CG lightning activity on the NNSS occurs between 11 a.m. and 5 p.m. PST, while minimum activity occurs between 11 p.m. and 1 a.m. PST. For safety analyses, the mean annual flash density on the NNSS is 0.4 flashes per square km. Randerson and Sanders (2002) have characterized CG lightning activity on the NNSS.

Much of the information presented here can be reviewed on the SORD website, www.sord.nv.doe.gov.

A.4 Ecology

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The NNSS lies on the transition between the Mojave and Great Basin deserts. As a result, elements of both deserts are found in a diverse and complex assemblage of flora and fauna (Ostler et al. 2000; Wills and Ostler 2001).

A.4.1 Flora

Biologists have identified over 800 species of vascular plants in ten major vegetation alliances and twenty associations (Figure A-19). Distributions of the Mojave Desert, transition zone, and Great Basin Desert ecoregions are linked to elevation, temperature extremes, precipitation, and soil conditions.

Mojave Desert vegetation associations dominate about a third of the NNSS in the south, on hillsides and mountain ranges at elevations below about 1,200 m (4,000 ft). Creosote bush (*Larrea tridentata*) is the dominant shrub within these associations except where the mean temperature is below −1.9°C (28.5°F) and average rainfall is 18.3 cm (7.2 in.) or less (Beatley 1974). Between elevations of about 1,200 to 1,500 m (4,000 to 5,000 ft), dominant vegetation shifts in the transition zone (22% of the NNSS) and is a blackbrush-Nevada jointfir (*Coleogyne ramosissima-Ephedra nevadensis*) shrubland (Ostler et al. 2000). Above about 1,500 m (5,000 ft), the vegetation is characteristic of the Great Basin Desert. Dominant shrub species are basin big sagebrush (*Artemisia tridentata*) and black sagebrush (*A. nova*). Distribution of Great Basin Desert associations appears to be limited by mean maximum temperature and by minimum rainfall tolerances of cold desert species (Beatley 1975).

Above about 1,800 m (6,000 ft), singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) mix with the sagebrush association where suitable moisture is present. Tree densities on the NNSS are often not high enough to create closed canopies but, rather, form an open woodland with a mix of shrub and tree cover.

A characterization of vegetation communities was established in the late 1950s, but botanical efforts began in earnest in the 1970s with the passing of the U.S. Department of the Interior, Endangered Species Act (ESA). Although none of the known plant species on the NNSS are listed as threatened or endangered under the ESA, numerous plants on the NNSS are considered sensitive by the Nevada Division of Natural Heritage (NDNH) and are included in the NDNH At-Risk Plant and Animal Tracking List, summarized in Table A-10. Sensitive species are those whose long-term viability is a concern to natural resource experts. Populations of sensitive plant species are well documented on the NNSS (Figure A-20) and the condition of those populations are monitored under the Ecological Monitoring and Compliance Program (Chapter 13 of the main report).

A.4.2 Fauna

At least 1,163 species of invertebrates within the phylum Arthropoda have been identified on the NNSS. Of the known arthropods, 78 % are insects. Ants, termites, and ground-dwelling beetles are probably the most important groups of insects in regard to distribution, abundance, and functional roles. No native fish or amphibians are known to occur on the NNSS.

Among reptiles, the desert tortoise (*Gopherus agassizii*), 16 lizard species, and 17 snake species are known to occur on the NNSS (Wills and Ostler 2001). The rich reptile fauna is partly due to the overlapping ranges of plant species characteristic of the Mojave and Great Basin deserts. The most abundant, widely distributed lizards include the side-blotched lizard (*Uta stansburiana*), western whiptail (*Cnemidophorus tigris*), and desert horned lizard (*Phrynosoma platyrhinos*). The western shovel-nosed snake (*Chionactis occipitalis*) is the most common snake on the NNSS. There are four species of poisonous snakes: the Mohave Desert sidewinder (*Crotalus cerastes*), speckled rattlesnake (*Crotalus mitchellii*), night snake (*Hypsiglena torquata*), and Sonoran lyre snake (*Trimorphodon biscutatus*).

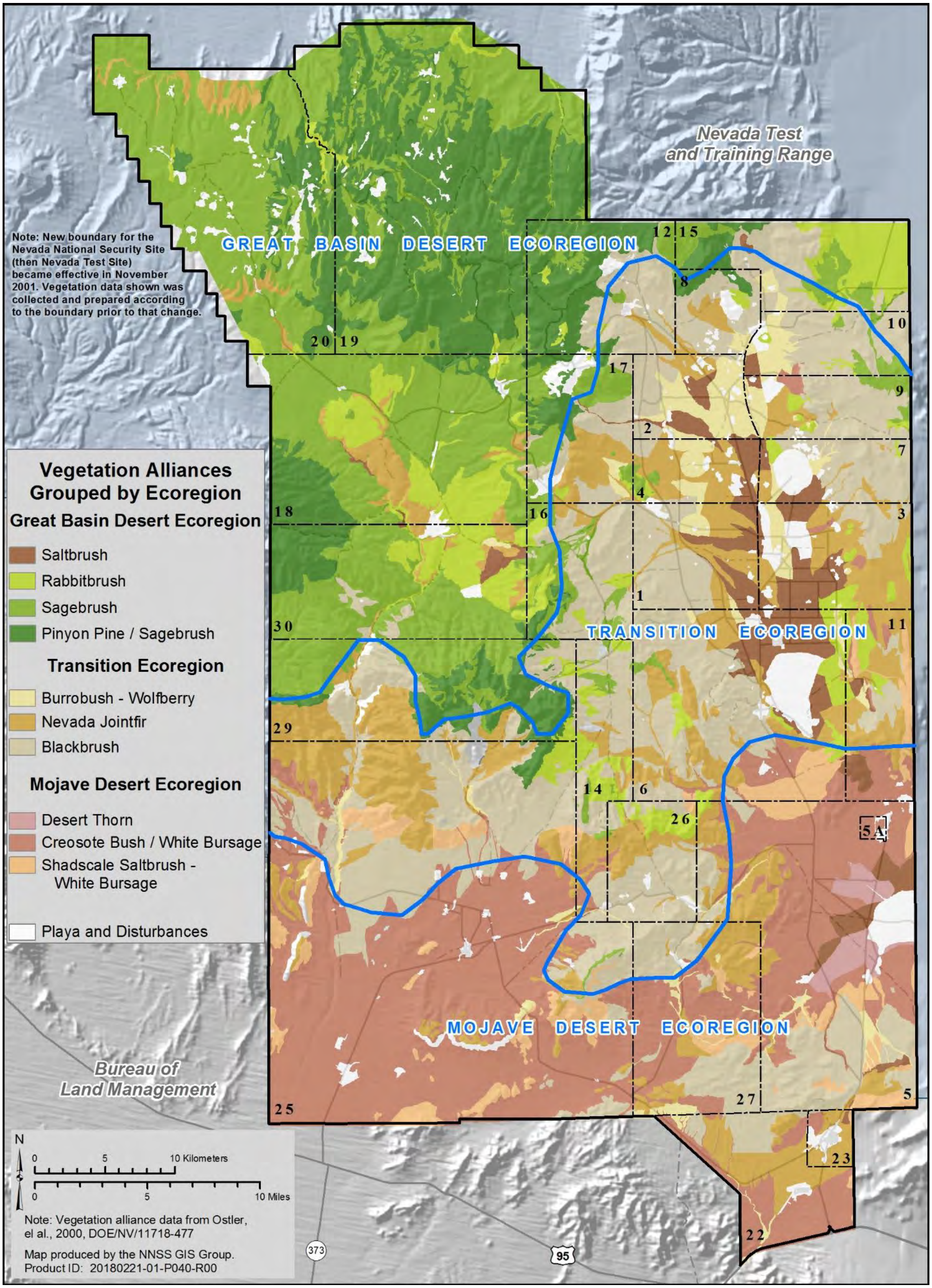

Figure A-19. Distribution of plant alliances on the NNSS

Table A-10. List of sensitive and protected/regulated plant and animal species known to occur on the NNSS

Plant Species	Common Names	Status[a]
Moss Species		
Entosthodon planoconvexus	Planoconvex cordmoss	S, H
Flowering Plant Species		
Arctomecon merriamii	White bearpoppy	S, M
Astragalus beatleyae	Beatley's milkvetch	S, H
Astragalus funereus	Black woollypod	S, H
Astragalus oophorus var. *clokeyanus*	Clokey eggvetch	S, W
Chylismia megalantha	Cane Spring suncup	S, M
Cryptantha clokeyi	Clokey's cryptantha	S, E
Cymopterus ripleyi var. *saniculoides*	Sanicle biscuitroot	S, W
Eriogonum concinnum	Darin buckwheat	S, M
Eriogonum heermannii var. *clokeyi*	Clokey buckwheat	S, W
Frasera pahutensis	Pahute green gentian	S, M
Galium hilendiae ssp. *kingstonense*	Kingston Mountains bedstraw	S, H
Hulsea vestita ssp. *inyoensis*	Inyo hulsea	S, W
Ivesia arizonica var. *saxosa*	Rock purpusia	S, H
Penstemon fruticiformis ssp. *amargosae*	Death Valley beardtongue	S, M
Penstemon pahutensis	Pahute Mesa beardtongue	S, W
Penstemon palmeri var. macranthus	Lahontan beardtongue	S, E
Phacelia beatleyae	Beatley scorpionflower	S, M
Phacelia filiae	Clarke phacelia	S, W
Phacelia mustelina	Weasel phacelia	S, W
Agavaceae	Yucca (3 species), Agave (1 species)	CY
Cactaceae	Cacti (17 species)	CY
Juniperus osteosperma	Utah juniper	CY
Pinus monophylla	Single-leaf pinyon	CY

Table A-10. List of sensitive and protected/regulated plant and animal species known to occur on the NNSS (continued).

Animal Species	Common Name	Status[a]
Mollusk Species		
Pyrgulopsis turbatrix	Southwest Nevada pyrg	S, A
Reptile Species		
Plestiodon gilberti rubricaudatus	Western red-tailed skink	S, IA
Gopherus agassizii	Desert tortoise	LT, S, NPT, A
Bird Species[b]		
Accipiter gentilis	Northern goshawk	S, NPS, A
Alectoris chukar	Chukar	G, IA
Aquila chrysaetos	Golden eagle	EA, NP, A
Asio flammeus	Short-eared owl	S, A
Asio otus	Long-eared owl	S, A
Callipepla gambelii	Gambel's quail	G, IA
Coccyzus americanus	Western yellow-billed cuckoo	LT, S, NPS, IA
Corvus brachyrhynchos	American crow	G, IA
Falco peregrinus	Peregrine falcon	S, NPE, A
Gymnorhinus cyanocephalus	Pinyon jay	S, NP, IA
Haliaeetus leucocephalus	Bald eagle	EA, S, NPE, A
Ixobrychus exillis hesperis	Western least bittern	S, NP, IA
Lanius ludovicianus	Loggerhead shrike	NPS, A
Melanerpes lewis	Lewis woodpecker	S, IA
Oreoscoptes montanus		NPS, IA
Riparia riparia	Bank swallow	S, IA
Spinus pinus	Pine siskin	S, IA
Spizella breweri	Brewer's sparrow	NPS, IA
Toxostoma lecontei	LeConte's thrasher	S, NP, IA
Mammal Species		
Antilocapra americana	Pronghorn antelope	G, A
Antrozous pallidus	Pallid bat	NP, A
Cervus elaphus	Rocky Mountain elk	G, IA
Corynorhinus townsendii	Townsend's big-eared bat	S, NPS, A

Table A-10. List of sensitive and protected/regulated plant and animal species known to occur on the NNSS (continued).

Animal Species	Common Name	Status[a]
Equus asinus	Burro	H&B, A
Equus caballus	Horse	H&B, A
Euderma maculatum	Spotted bat	S, NPT, A
Lasionycteris noctivagans	Silver-haired bat	S, A
Lasiurus blossevillii	Western red bat	S, NPS, A
Lasiurus cinereus	Hoary bat	S, A
Lynx rufus	Bobcat	F, IA
Microdipodops megacephalus	Dark kangaroo mouse	NP, A
Microdipodops pallidus	Pale kangaroo mouse	S, NP, A
Myotis thysanodes	Fringed myotis	S, NP, A
Ovis canadensis nelson	Desert bighorn sheep	G, A
Odocoileus hemionus	Mule deer	G, A
Puma concolor	Mountain lion	G, A
Sorex tenellus	Inyo shrew	S, IA
Sylvilagus audubonii	Audubon's cottontail	G, IA
Sylvilagus nuttallii	Nuttall's cottontail	G, IA
Tadarida brasiliensis	Brazilian free-tailed bat	NP, A
Urocyon cinereoargenteus	Gray fox	F, IA
Vulpes macrotis	Kit fox	F, IA

[a] **Status Codes for Column 3**

Endangered Species Act, U.S. Fish and Wildlife Service

LT	Listed Threatened

U.S. Department of Interior

H&B	Protected under *Wild Free-Roaming Horses and Burros Act*
EA	Protected under *Bald and Golden Eagle Act*

State of Nevada – Animals

S	Nevada Division of Natural Heritage – At-Risk Plant and Animal Tracking List
NPE	Nevada Protected-Endangered, species protected under Nevada Administrative Code (NAC) 503
NPT	Nevada Protected-Threatened, species protected under NAC 503
NPS	Nevada Protected-Sensitive, species protected under NAC 503
NP	Nevada Protected, species protected under NAC 503
G	Regulated as game species under NAC 503

F	Regulated as fur bearer species under NAC 503

State of Nevada – Plants

S	Nevada Division of Natural Heritage – At-Risk Plant and Animal Tracking List
CY	Protected as a cactus, yucca, or Christmas tree from unauthorized collection on public lands

NNSS Sensitive Plant Ranking

E	Evaluate
H	High
M	Moderate
W	Watch

Long-term Animal Monitoring Status for the NNSS

A	Active
IA	Inactive

[b] All bird species on the NNSS are protected by the *Migratory Bird Treaty Act* except for chukar, Gambel's quail, English house sparrow, rock dove, Eurasian collared dove and European starling. Most bird species are also protected under NAC 503.

Sources used: NDNH 2021, NAC 2021, U.S. Fish and Wildlife Service (FWS) 2021

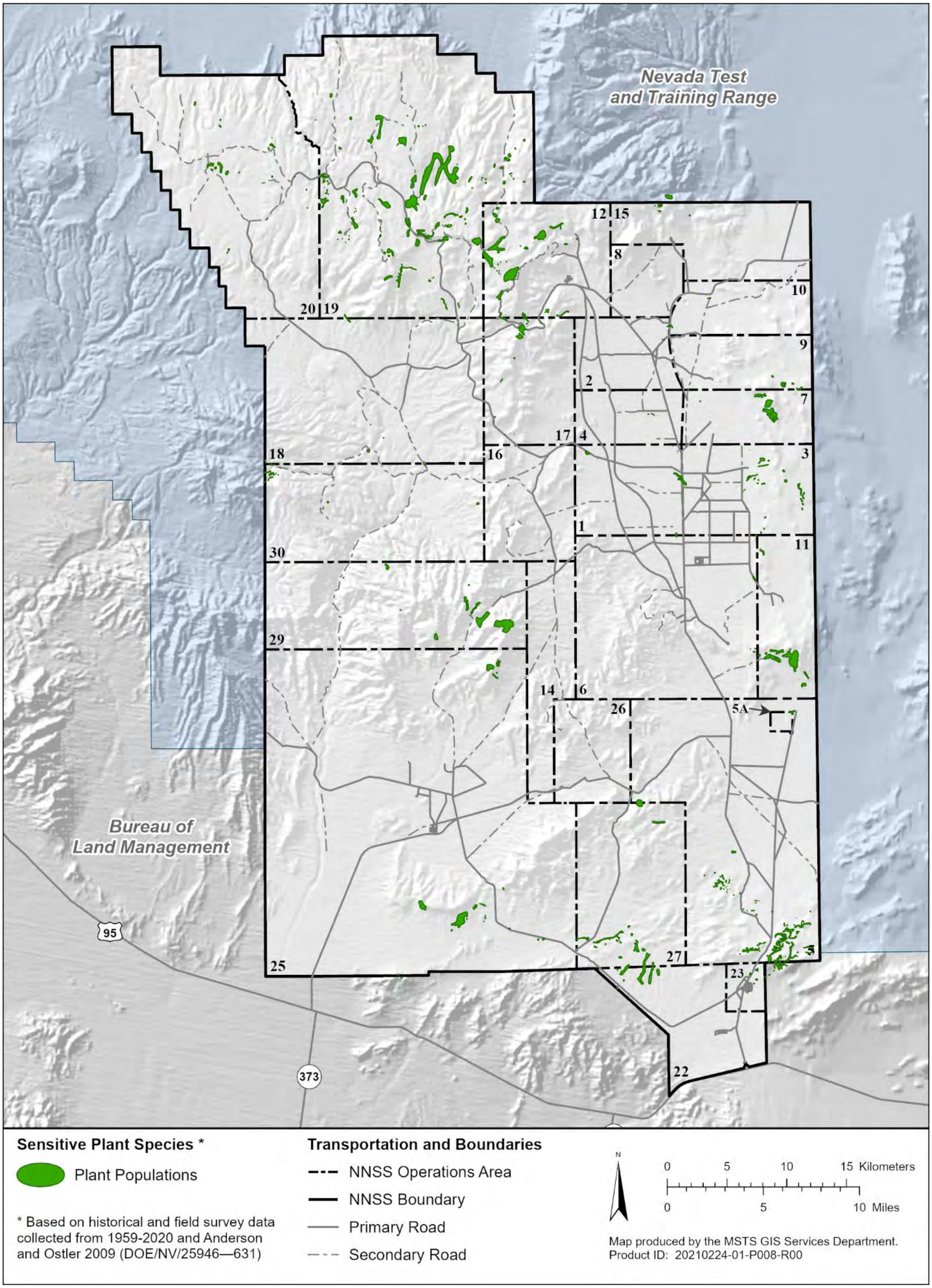

Figure A-20. Known locations of sensitive plant species on the NNSS

There are records of 245 species of birds observed on the NNSS (Hall and Perry 2019). Approximately 80% of the bird species are migrants or seasonal residents. To date, 26 species, including 9 raptor species (birds of prey), are known to breed on the NNSS. Raptors that breed on the NNSS include the golden eagle (*Aquila chrysaetos*), long-eared owl (*Asia otus*), red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*), prairie falcon (*Falco mexicanus*), American kestrel (*Falco sparverius*), western burrowing owl (*Athene cunicularia hypugaea*), barn owl (*Tyto alba*), and great-horned owl (*Bubo virginianus*) (BN 2002b).

There are 44 terrestrial mammals and 15 bat species known to occur on the NNSS. Rodents account for about 40% of known mammals and, in terms of distribution and relative abundance, are the most important group of mammals on the NNSS (Wills and Ostler 2001). An apparent correlation exists between production by winter annual plants and reproduction in desert rodents on the NNSS. Larger mammals on the site include black-tailed jackrabbit (*Lepus californicus*), desert cottontail (*Sylvilagus audubonii*), feral horse (*Equus caballus*), mule deer (*Odocoileus hemionus*), pronghorn antelope (*Antilocapra americana*), Rocky Mountain elk (*Cervus elaphus*), coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), grey fox (*Urocyon cinereoargenteus*), badger (*Taxidea taxus*), bobcat (*Lynx rufus*), mountain lion (*Puma concolor*), feral burro (*Equus asinus*), and desert bighorn sheep (*Ovis canadensis nelson*). Mule deer herds occur mainly on the high mesas and surrounding bajadas. Small numbers of feral horses and pronghorn antelope range over small areas of the NNSS, and a reproducing population of desert bighorn sheep occur in the Yucca Mountain/Fortymile Canyon area of the NNSS. A small number of burros are resident in Yucca Flat, Frenchman Flat, Jackass Flats, and Fortymile Canyon/Yucca Mountain areas. Elk are thought to be rare visitors to the high mesas.

The desert tortoise is the only resident species on the NNSS listed as threatened under the ESA. Habitat of the desert tortoise is in the southern third of the NNSS (Chapter 13). No other federally threatened or endangered animal is known to occur routinely on the NNSS. All wild bird species on the NNSS are protected by the Migratory Bird Treaty Act except for six species: English house sparrow (*Passer domesticus*), European starling (*Sturnus vulgaris*), Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), Eurasian collared dove (*Streptopelia decaocto*), and rock dove (*Columba livia*). Most non-rodent mammals of the NNSS are protected by the State of Nevada and managed as either game or furbearing mammals, and eight bats on the NNSS are considered sensitive species. Table A-10 identifies the important animal species on the NNSS that are either classified as sensitive, protected, and/or regulated by state or federal agencies. They are the species commonly evaluated for inclusion in long-term monitoring activities on the NNSS.

A.4.3 Natural Water Sources

Important biological communities on the NNSS are those associated with springs or other natural sources of water. They are rare, localized habitats that are important to regional wildlife and to isolated populations of water-loving plants and aquatic organisms. They include 16 springs and 12 seeps. In addition, there are 14 tank sites (natural rock depressions that catch and hold surface runoff), and 15 ephemeral ponds (Hall and Perry 2020) (Figure A-21). The ephemeral ponds occur in low elevation areas on playas or within natural drainages that may have been modified during historical NNSS operations (e.g., road construction, excavation), resulting in well-defined catchments for surface water runoff. Twelve of these occur on Frenchman Flat Playa and are referred to as earthen sumps.

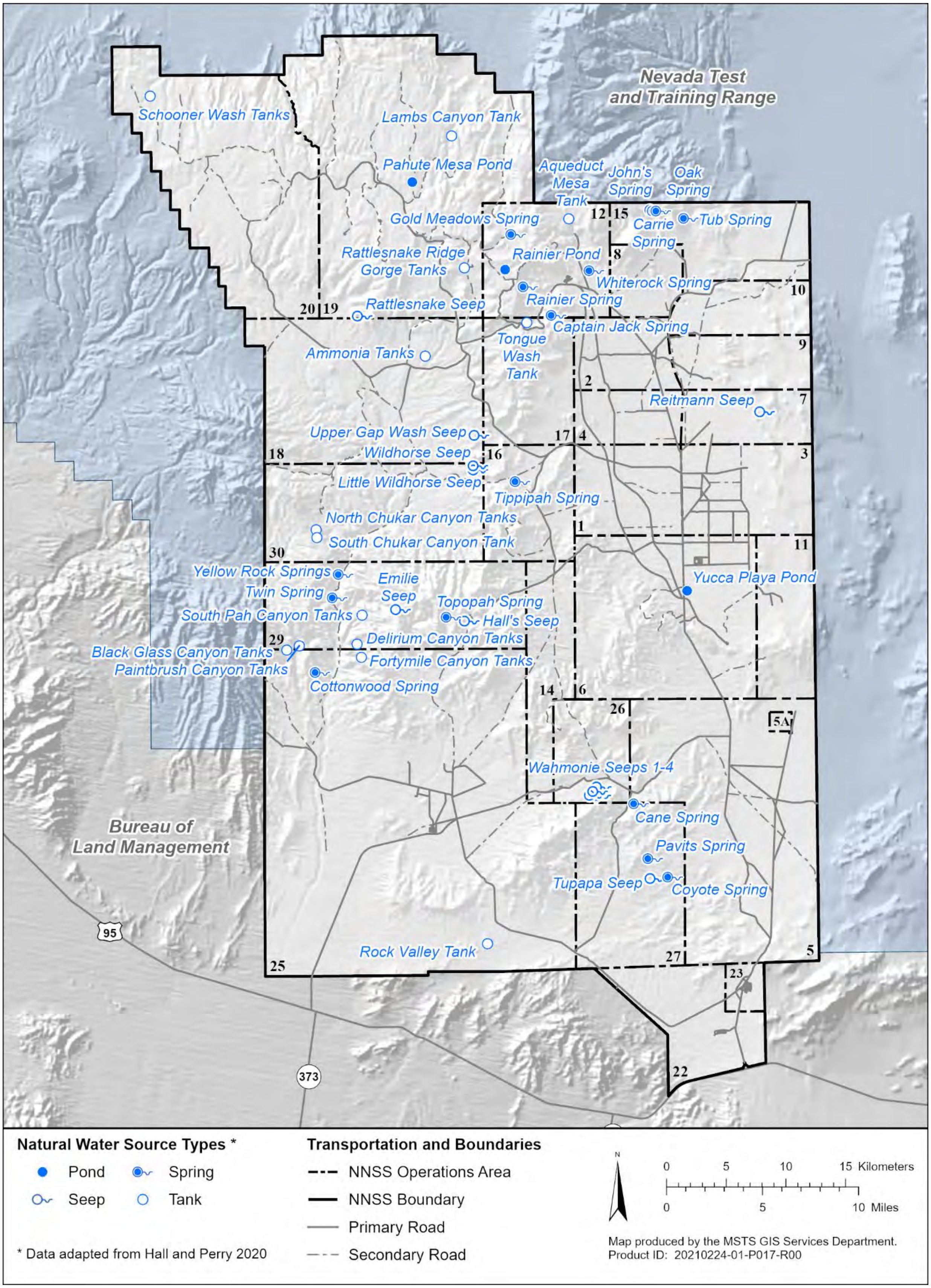

Figure A-21. Natural water sources on the NNSS (Hall and Perry 2020)

A.5 Cultural Resources

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A.5.1 Cultural Resources Investigations on the NNSS

Archaeological and cultural research pertaining to the NNSS region has been conducted since at least the 1930s. The most notable are reconnaissance surveys of the area by S. M. Wheeler in 1940 and Richard Shutler in 1955, and the extensive early studies conducted by Frederick Worman for the Atomic Energy Commission (AEC) (Shutler 1961; Worman 1969). In the late 1970s, with strengthened federal laws and regulations supporting historic preservation, systematic cultural resources investigations on the NNSS were carried out on a regular basis. The Desert Research Institute (DRI) became the cultural resources support contractor at that time, and DRI has continued to perform many archaeological and historical surveys and data recovery efforts ever since, as well as records management and curation of artifacts. Documentation and protection of Cold War-era structures and buildings on the NNSS have become a key part of the cultural resources program since the 1990s, with the increased recognition that Cold War-era nuclear testing and other activities carried out on the NNSS comprise a historic period of major national and international importance (Fehner and Gosling 2002, 2006; Titus 1986), (Figure A-24).

Cultural resources on the NNSS range from the earliest known prehistoric societies in North America ca. 13,000 years ago, through the millennia to historic times including Native American occupations, early Euroamerican exploration and emigration, mining booms and busts, ranching, military training, and AEC and DOE nuclear weapons testing.

A.5.2 Prehistory

The oldest cultural remains discovered on the NNSS come from what is generically called the Paleoamerican period, about 13,000–10,000 years ago (Graf et al. 2013). In the Great Basin, this period is commonly called the Paleoindian or the Paleoarchaic, depending on how evidence for early subsistence activities is interpreted (Graf and Schmitt 2007; Davis et al. 2012). Archaeological sites dating to this period contain two major distinctive types of stone tool weaponry: first, fluted lanceolate bifacial spear points that are clearly related to the Clovis points of the Southwest and eastern North America, and secondly, a variety of spear point and knife forms having long stems for hafting that are collectively known as Western Stemmed points (Beck and Jones 1997). The two point types apparently represent different methods of stone tool production, and they may represent two different groups of early occupants in the region (Beck and Jones 2010, 2012; Davis et al. 2012). Only a few Clovis-like point fragments have been found on the NNSS, along the alluvial terraces of Fortymile Canyon in Area 25, and in the upper reaches of the Fortymile drainage system between Timber Mountain and Rainier Mesa (Jones and Edwards 1994; Reno 1985; Worman 1969). Western Stemmed points and sites are much more common in the region, occurring especially along Fortymile Wash (Haynes 1996; Buck et al. 1998).

The basic economic strategy during this period was a wide-ranging hunting and gathering orientation, generalized in the collection of an array of animal and plant food resources and a common focus on the exploitation of resource-rich habitats such as shallow lakes, deltas, and marshes (Grayson 2011; Madsen 2002; Madsen et al. 2015; Warren and Crabtree 1986). No evidence indicates that the basins on the NNSS supported pluvial lakes (Grayson 2011; Mifflin and Wheat 1979), but they could have been filled with small seasonal wetlands. The Fortymile Wash drainage, where Paleoamerican sites are most common, may have been used as a travel route between lowland marshy areas near Ash Meadows and highlands such as Pahute and Rainier Mesas where deer and elk could be procured (Pippin 1998). Archaeological sites dating to this time period often contain artifacts made of obsidian and other raw materials that were transported from very distant source areas, indicating people traveled very widely in their migrations (Jones et al. 2003). In the Paleoamerican period and unlike later periods, small seeds do not appear to have been a major part of subsistence pursuits, as very few seed-grinding tools such as grinding slabs (metates) and handstones (manos) have been found at archaeological sites dating to this time period; such implements only become common after the Paleoindian interval comes to a close (Rhode et al. 2006).

After ca. 10,000 years ago, the climate became significantly warmer and dryer, with long periods of drought (Grayson 2011; Lachniet et al. 2017). Many regional wetlands dried up (Grayson 2011). Woodlands began to retreat upslope and were replaced in the lowlands by creosote bush and saltbush desert scrub (Rhode and Adams 2016; Spaulding 1990; Thompson 1990), and desert-adapted fauna replaced animals more suited to cooler climes (Grayson 2011; Hockett 2000). The middle Holocene period from ca. 8,000–4,500 years ago was marked by continued aridity (Antevs 1948; Grayson 2011; Lachniet et al. 2017; Wigand and Rhode 2002). As environmental conditions changed in the Great Basin, human population numbers appear to have declined in several areas, and some evidence suggests that entire areas were abandoned (Grayson 2011; Louderback et al. 2011; Warren and Crabtree 1986). The people in this period may have aggregated at springs and other dependable water sources, and only briefly entered more arid locales during times of greater effective moisture. In the NNSS area, higher elevation zones became an important part of the subsistence base. People expanded their food resource base to incorporate more abundant but more costly to process plant food resources such as small seeds (Rhode et al. 2006). This general trend appears to have occurred on the NNSS (Pippin 1998), but intensification of food-getting pursuits and expansion of the range of habitats exploited did not translate into permanent residential bases in the uplands. The small populations of people roaming the arid landscape apparently continued to be highly mobile, though likely tethered to the scattered springs throughout the region (Warren and Crabtree 1986).

The late Holocene period from ca. 4,500–1,900 years ago was cooler and wetter than the middle Holocene in the region (Wigand and Rhode 2002; Lachniet et al. 2017). Subsequent periods in the late Holocene fluctuated between dry and wet episodes, with notable arid episodes from 1,900–1,000 and 700–500 years ago (Wigand and Rhode 2002). Culturally, the late Holocene is marked by an increase in the number of people as indicated by the abundance of archaeological sites, and an even greater range of food resources exploited (Bettinger 1999; Grayson 2011). In some areas of the southern Great Basin, people began to inhabit large, semi-sedentary communities on valley floors with frequent seasonal use of the highlands (Pippin 1998). An increase in the frequency of grinding implements indicates a greater reliance on seeds than previously practiced (Warren and Crabtree 1986). Rock features interpreted as pine nut caches begin to appear in higher elevation woodlands on the NNSS (Pippin 1998), exhibiting a greater expenditure of effort and permanence in these sites than had occurred previously. This late Holocene intensification of the use of pinyon pine nuts has also been observed elsewhere in the southern Great Basin, notably Owens Valley to the west (Bettinger 1976, 1989; Madsen 1986a). One of the most conspicuous technological changes is the introduction of the bow and arrow, ca. 1,500 years ago (Bettinger 2013; Bettinger and Eerkens 1999). Examples of projectile points from the late Holocene period found on the NNSS are shown in Figure A-23. Another important technological introduction was brownware pottery (Figure-A-24), ca. 700 to 1,000 before present (Lockett and Pippin 1990; Madsen 1986b; Pippin 1986; Rhode 1994), indicating a change in the way food was prepared and stored. Eerkens (2005) notes that pots were conducive to boiling over a fire and, based on residues found adhering to pot interiors, were used to boil seeds. They also served as private storage vessels for family groups, which may have resulted in greater private ownership of food stores and a stronger family-group economic orientation of the kind noted in historic times (Steward 1938), rather than a larger communal group pattern of sharing of public goods that might have prevailed in earlier times (Bettinger 1994, 1999).

A.5.3 Ethnohistoric American Indian

Early explorers and immigrants in the southern Great Basin during the nineteenth century encountered widely scattered groups of Numic-speaking hunters and gatherers currently known as Southern Paiute (Kelly and Fowler 1986) and Western Shoshone (Thomas et al. 1986). The areas traditionally claimed by these tribal entities encompassed a large region and were bound in territories of ethnic or political groups (Inter-Tribal Council of Nevada 1976; Stoffle et al. 1990, 2001). These territorial boundaries, even between subgroups, were stronger, with less mixing or movement between them prior to Euroamerican intrusion into the region and its deleterious effects on the local native peoples. Subsistence strategies mainly revolved around movements between environmental zones (e.g., highlands and lowlands) within their territories according to seasonal availability of food resources (Steward 1938; Wheat 1967). The normal range of travel for resources was up to 32 km (20 mi) of the primary residential base camp, but most could be found within a short distance of the camp. Criteria for the location of the primary residential base camp was proximity to stored or cached foods, availability of water, wood for fuel and house construction, and relatively warm winter temperatures like that found in canyon mouths or in the woodlands (Steward 1938).

The communal Western Shoshone group around Rainier Mesa and the southern end of the Belted Range ca. 1875–1880 was known as *Ĕso* (little hill). The *Ĕso* were closely linked linguistically with people to the east, but maintained close relationships with groups all around them, particularly to the north and west. They established winter residential camps at Captain Jack Spring, Oak Springs, Tippipah Springs (Figure A-25), Topopah Spring, White Rock Springs, and on Pahute and Rainier Mesas (Pippin 1997). Captain Jack Spring is named after One-eyed Captain Jack, who resided there at various times with his wives in the late 1800s and early 1900s (Steward 1938; Stoffle et al. 1990). At White Rock Springs lived *Wandagwana,* headman for the *Ĕso*. He directed the annual fall rabbit drive in Yucca Flat, in which various camps from around the region gathered and interacted. Sweat houses, also serving as gathering places for local groups, were located at White Rock Springs and at Oak Springs. They were used by both women and men for smoking, gambling, sweating, and as dormitories.

Another Western Shoshone group, the *Ogwe'pi* (creek), lived primarily based in Oasis Valley to the west (Pippin 1997; Steward 1938; Stoffle et al. 1990). Most of their winter camps and residential bases were located north of Beatty, but their territory or use area extended eastward and included Pahute Mesa and Fortymile Canyon, with the latter forming the boundary abutting the territory of the *Ĕso* to the east and the Southern Paiute to the south. The *Ogwe'pi* had strong ties to the Timbisha people in Death Valley, and they traveled to the Grapevine and Funeral Mountains and valleys to the west and south for certain resources or when areas to the east were less productive.

A fandango, or group gathering festival, was usually held by the *Ĕso* at the winter camp of *Wungiakuda* off the southeast edge of Pahute Mesa near Landmark Rock (Johnson et al. 1999; Steward 1938). The *Ogwe'pi* also hosted an annual regional fandango, alternating with the *Ĕso*. This fandango was held in Oasis Valley instead of at *Wungiakuda*. The fandango lasted about 5 days, and provided opportunity for the exchange of goods and information, as well as courtship and merry-making.

The southern portion of the NNSS, southward from Yucca and Shoshone Mountains, including the Cane Spring site, was part of the territory occupied by mixed Western Shoshone and Southern Paiute people centered on Ash Meadows (*Toi'oits*) (Kelly and Fowler 1986; Stoffle et al. 1990). The Ash Meadows group interacted with both Southern Paiutes to the south and east as well as Western Shoshone to the north and west. The Ash Meadows group practiced some horticulture at the spring sites to supplement their primary subsistence base of hunting and gathering; crops included maize, squash, bean, and sunflower (Steward 1938). At Cane Spring, the stubble of a corn field and a cache of squash were found by immigrants traveling through Death Valley in 1849 (Manly 1927). The only standing structure at the spring at that time was a wickiup. Steward (1938) documents a small family of five people living at Cane Spring ca. 1880. Today, there are remnants of two cabins and a corral at the spring (Jones 2001).

A.5.4 Euroamerican Emigration, Exploration, and Settlement

Euroamerican explorers and emigrants began entering the NNSS area by the late 1840s. A stone block with the name "R. J. BYOR" and the date "1847" carved in it was found and used in the fireplace of a stone cabin at Cane Spring. The name on the stone remains a mystery, but may have been a member of the Mormon Battalion traveling from San Diego to Salt Lake City in that year.

More concrete evidence of Euroamerican travelers passing through the NNSS are the diaries and publications of the famed Death Valley Expedition of 1849 (Long 1950; Manly 1927). Part of that expedition, deciding to follow a rumor of a shorter route than the Old Spanish Trail to southern California, found themselves in unknown territory of the NNSS. The group split in two at Papoose Lake, north of Indian Springs. One party, the Bennett-Arcanes, went southwest toward Skull Mountain, stopped at Cane Spring, and then continued south to Ash

Meadows. The other party, the Jayhawkers, headed west from Papoose Lake to Tippipah Spring, then split up again and followed two separate routes, one proceeding south between Skull Mountain and Fortymile Canyon and then on to the Amargosa Valley. The other offshoot (Reverend James Brier and family) traveled west of Tippipah Spring down Fortymile Canyon where the Briers had to abandon their wagons; they ultimately walked on foot down the canyon, found the trail of their fellow Jayhawkers, and all three parties ultimately reunited to follow Furnace Creek Canyon into Death Valley and endure many further tribulations (Long 1950; Manly 1927). Remains of the Brier's old abandoned wagons have been found in Fortymile Canyon (Worman 1969).

The great topographic and exploring surveys of the American West conducted by George Wheeler, John Wesley Powell, and others after the Civil War skirted the margins of the NNSS in southern Nevada (Winslow 1996). Subsequent Euroamerican settlement in the NNSS area during the nineteenth and early twentieth century was scanty and involved ranching, wild horse hunting, mining, and relay stations for stage and freight lines. Initially ranching operations were small-scale individual settlements centered on the few springs in the region, but in the early twentieth century these were taken over by larger entities such as the Clay Spring Cattle Company and its successor the Naquinta Cattle Company. Ultimately, however, the poor quality of the rangeland prevented these larger operations from being profitable and ranching languished. Most of the springs bear remains of ranching operations and spring improvements.

A.5.5 Historic Mining On and Near the NNSS

Around the beginning of the twentieth century, substantial gold and silver deposits were discovered in southwestern Nevada, with major strikes at Tonopah, Goldfield, and Rhyolite (Elliott 1966, 1973; McCracken 1992; Zanjani 1992). The overall population of Nevada doubled as a consequence. Within the confines of the NNSS no permanent settlement appeared, just marginal ranching and mining operations (Ball 1907). The great mining boom was short-lived, however, and quickly entered the bust phase. The Las Vegas and Tonopah rail line, constructed in 1906, lasted until 1918. The rails were removed in 1919, and the line was sold to the Nevada Department of Transportation for use as a highway (Myrick 1963). Still evident on the NNSS today are some of the abandoned ties reused for corrals and other structures at a number of the springs. Around the Beatty area, the ties were used in some of the later mining operations for shoring tunnels (McCracken 1992).

As mining explorations continued in the region, fanning out from the earlier strikes, small mining districts were founded (Cornwall 1972; Lincoln 1923; Tingley 1984). The mining town of Wahmonie around Mine and Skull Mountains was founded in 1928 (Jones et al. 1996; McLane 1995; Quade and Tingley 1984). It grew into a small town with boarding houses, tent stores, and cafes. The Silver Dollar Saloon and the Northern Club were but two of the enterprises (Long 1950). Most of the miners lived in small tents. George Wingfield, a well-known mine owner and banker in Nevada, became interested and incorporated the Wahmonie Mining Company. However, the strike was apparently not as rich as had first been thought, and by early 1929 optimism faded and people began leaving. Small amounts of prospecting in the district continued into the 1930s and 1940s, but few ore deposits were ever discovered.

The Oak Spring mining district was located at the north edge of the NNSS (Drollinger 2003). Documents at the Recorder's Office in Tonopah indicate the first claims were by Antonio Aguayo and W.S. Bennett dating to 1886. Most of the early mining activity in the district, however, is from the early twentieth century and coincides with the Tonopah-Goldfield-Rhyolite mining boom (Ball 1907; Lincoln 1923; McLane 1995; Quade and Tingley 1984; Stager and Tingley 1988). Like other similar mining districts in the region during this time, the main objectives were gold and silver. Overall, the early Oak Spring mining district was not very productive and not rich enough to offset shipping costs to process the ores (Hall 1981).

B. M. Bower (a.k.a. Bertha Muzzy Sinclair), a noted author, with husband (Bud Cowan) and family, moved to Nevada from Los Angeles, California, in 1920 and took up residence at an abandoned silver mine near Oak Spring (Drollinger 2003; Engen 1973; McLane 1996). An accomplished and prolific writer, B. M. Bower published 57 novels as well as short stories and screenplays over a 40-year career, with many becoming the basis for early western-themed movies in Hollywood. While living at the camp (Figure A-26), Bower wrote 11 novels, incorporating some of the surrounding geographic features, such as Oak Butte and the camp itself, into a few of the stories. The family formed the El Picacho Mining Company, with B. M. Bower serving as president, and filed assessment work for the claims from 1922 to 1928. The family moved to Las Vegas around 1926 and still worked the mining claims sporadically over the next couple years, but eventually the Great Depression forced them to move to Oregon. Fittingly, in keeping with the theme for some of the novels, the abandoned camp was used in the early 1930s by outlaws from Utah and Arizona whose escapades were later featured in a Death Valley Days radio episode narrated by Ronald W. Reagan. B. M. Bower died in Los Angeles 1940 and was inducted into the Western Writers of America Hall of Fame in 1994.

In 1937, a source of tungsten was discovered in the Oak Spring district (Kral 1951; Quade and Tingley 1984; Stager and Tingley 1988). Workings of the Climax tungsten mine included several mines, shafts, adits, trenches, an open pit, roads, and a processing mill. These operations ended when the area was closed with the founding of the bombing and gunnery range by the Federal government. The last known mining operation was from December 1956 to May 1957 involving a co-use agreement between the owners of the Climax Tungsten Corporation and the AEC, who now had control of the area for nuclear testing (Drollinger 2003; Quade and Tingley 1984).

A.5.6 The Cold War, Nuclear Testing, and Nuclear Research on the NNSS

A.5.6.1 The Cold War

The Cold War was a global conflict pivoting around themes of ideology, imperialism, strategic issues, and the nuclear arms race (Puzio 2013). It was a war fought via economic and cultural means, as well as a series of proxy wars by the United States and the former Soviet Union and their allies from 1947 to 1991 (Walker 1995; Gaddis 2005). After World War II, the U.S. and the former Soviet Union emerged as the only superpowers possessing intact heavy industry, large populations, and low international debt, as well as conflicting ideological outlooks (Gaddis 2005; Fink 2014). However, the U.S. was the only nuclear power in the world. This changed in August 1949 when the Soviets tested their first fission bomb. The U.S. response to the perceived Soviet threat was to expand production facilities and accelerate the development of nuclear weapons. On June 29, 1950, President Truman approved the development of a thermonuclear weapon, and then a plan for a test series in the Pacific (named Greenhouse) was initiated. However, while this plan was underway, the onset of the conflict in the Korean Peninsula began.

U.S. military involvement in Korea created technical and logistical problems for continuing with the Pacific test location. This led the AEC Chair Gordon Dean to declare that it was “wise to reexamine the question of a continental site with the objective of having available a definite and specific site which could be recommended for use” (Fehner and Gosling 2002). In December 1950, the U.S. Air Force approved a plan to allow the AEC to use the Las Vegas Bombing and Gunnery Range, a federal facility established in 1940 by President Roosevelt, for a proposed series of continental tests named Ranger (NNSA/NFO 2013). On December 18, 1950, President Truman approved the choice and construction began the following month. Camp Mercury, located at the southern end of the test area, was established as the main support, housing, and administrative base (Figure A-27). The new facility went through a series of name changes: Las Vegas Test Site in spring 1951; Nevada Test Site (NTS) on June 22, 1951; Nevada Proving Ground on February 25, 1952; and, finally reverting to the NTS on January 1, 1955. It remained the NTS throughout the rest of the Cold War. Additional land parcels were obtained under public orders and memorandums of agreement. A critical acquisition was made in August 1965, when Mercury and the nearby Camp Desert Rock were finally included in the NTS. Until then, they were still technically on land borrowed from the U.S. Air Force. This acquisition accounts for the southeastern boundary of the site, which extends out just enough to include these two facilities that were essential for site operations.

A.5.6.2 Nuclear Testing, Nuclear Research, and the Continental Test Site

The NNSS played a crucial role in the U.S. nuclear testing program during the Cold War with the former Soviet Union. An escalating arms race for nuclear weapons superiority led to numerous nuclear explosions worldwide by the U.S., the former Soviet Union, and other foreign nuclear powers. The AEC and the U.S. Department of Defense conducted these tests for the U.S. Most of the tests occurred at the NNSS, where the operations included both atmospheric and underground tests. The major purposes of nuclear testing were weapons related (testing a device intended for a specific weapon system); weapons effects (evaluating the civil or military effects of a detonation); safety experiments (confirming a nuclear detonation would not occur from an accidental detonation of the high explosive associated with the device); joint U.S.–United Kingdom testing (storage-transportation); and Vela Uniform (improving the ability to detect, identify, and locate underground nuclear detonations) (NNSA/NFO 2015b). In all, a total of 928 nuclear tests were conducted at the site, with 120 performed in the 1950s, and 808 after 1961 following a short moratorium between 1958 and 1961 agreed to by both the U.S. and the former Soviet Union (Friesen 1995). On August 5, 1963, the U.S. and former Soviet Union signed the Limited Test Ban Treaty. This treaty effectively banned testing of nuclear weapons in the atmosphere, ocean, or space, and atmospheric testing drew to an end, although there is evidence that some Soviet testing actually occurred after the treaty. In 1992, the U.S. established a second self-imposed moratorium on nuclear testing. In 1995, President Clinton announced a total ban on all critical U.S. nuclear weapons testing. In September 1996, the United Nations approved the Comprehensive Nuclear-Test-Ban Treaty, which prohibited any nuclear explosion. However, the U.S. Senate failed to ratify this treaty.

In addition to weapons testing, the NNSS served as the location for an array of notable non-defense related nuclear research and development programs. This other type of Cold War-era research ran the gamut from nuclear-powered space vehicles to experimental civil works projects to radiation dosimetry studies. In the mid-1950s, the AEC and the National Aeronautics and Space Administration (NASA) selected Jackass Flat as the site of the Nevada Rocket Development Station (NRDS) (Figure A-28) constructing a network of cutting-edge facilities interconnected by rail lines to develop and test nuclear thermal propulsion systems for missions to Mars and beyond (Dewar 2004). During the same period, the NNSS became a key component of the Eisenhower Administration’s Plowshare Program. The concept focused on using nuclear explosives for peaceful purposes such as nuclear excavation for massive civil engineering projects (dam, harbor, road cut, and waterway construction) and industrial applications (oil and gas stimulation, geothermal power, underground storage/waste disposal cavities) (Beck et al. 2011). The Nevada facility was also the site of several landmark dosimetry studies focused on determining radiation dose rates and allowing more accurate risk assessments and health monitoring of the survivors of the Hiroshima and Nagasaki bombings. The data gleaned from all of these programs continue to inform contemporary research studies providing a foundation for future investigations (Bennett 2018; Cullings et al. 2006; Kerr et al. 2015; Short 2004; Williams 2017).

Figure A-22. Prehistoric projectile points from the NNSS (photo taken by DRI 1992)

Figure A-23. Brownware bowl recovered from archaeological excavations on Pahute Mesa (photo taken by DRI 1992)

Figure A-24. Overview of the Tippipah Spring area (photo taken by DRI 2004)

Figure A-25. Bower cabin on the NNSS (photo taken by DRI 2001)

Figure A-26. The town of Mercury, Nevada (photo taken by REECo May 1965)

Figure A-27. The NRDS Engine Maintenance and Disassembly Building (photo taken by Remote Sensing Laboratory 2013)

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