DOE/NV/03624--0521

National Emission Standards for Hazardous Air Pollutants – Radionuclide Emissions Calendar Year 2018

June 2019

Nevada National Security Site
&
North Las Vegas Facility

Prepared for

U.S. Department of Energy,
National Nuclear Security Administration
Nevada Field Office
Under Contract Number
DE-NA0003624

Prepared by

Mission Support and Test Services, LLC
P.O. Box 98521
Las Vegas, Nevada 89193-8521

NEVADA NATIONAL NNSS SECURITY SITE
Managed and operated by Mission Support and Test Services LLC

National Nuclear Security Administration

DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312
Phone: (800) 553-6847
Fax: (703) 605-6880
E-mail: info@ntis.gov; customerservice@ntis.gov
Downloadable (no charge) at: https://classic.ntis.gov/search/

Available electronically (no charge) at: http://www.osti.gov
and http://www.nnss.gov/pages/resources/library/NESHAP.html

Available, in paper, for a processing fee to the U.S. Department of Energy and its contractors from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
Telephone: 865-576-8401
Fax: 865-576-5728
E-mail: reports@osti.gov

DOE/NV/03624--0521

National Emission Standards for Hazardous Air Pollutants – Radionuclide Emissions Calendar Year 2018

June 2019

Work Performed Under
Contract No. DE-NA0003624

Prepared for:
U.S. Department of Energy
National Nuclear Security Administration
Nevada Field Office

Prepared by:
Mission Support and Test Services, LLC
P.O. Box 98521
Las Vegas, Nevada 89193-8521

This page intentionally left blank

Certification

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fine and imprisonment. See 18 U.S.C. 1001.

Name: Steven J. Lawrence,
Manager, NNSA/NFO

Signature: Steven J. Lawrence Date: 6.17.19

This page intentionally left blank

EXECUTIVE SUMMARY

2018 RADIOLOGICAL DOSE TO THE PUBLIC BELOW FEDERAL STANDARD

The U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) operates the Nevada National Security Site (NNSS) and the North Las Vegas Facility (NLVF). From 1951 through 1992, the NNSS was the continental testing location for U.S. nuclear weapons. The release of radionuclides from NNSS activities has been monitored since the initiation of atmospheric testing. After 1962, testing was limited to underground detonations, which greatly reduced radiation exposure to the public. Since the end of nuclear testing in 1992, radiation monitoring has focused on detecting airborne radionuclides from historically contaminated soils. These radionuclides are derived from re-suspension of soil (primarily by wind) and emission of tritium-contaminated soil moisture through evapotranspiration. Low amounts of legacy-related tritium are also emitted to air at the NLVF, an NNSS support complex in North Las Vegas.

To protect the public from harmful levels of man-made radiation, the Clean Air Act, National Emission Standards for Hazardous Air Pollutants (NESHAP) (Title 40 Code of Federal Regulations [CFR] Part 61 Subpart H) (CFR 2010a) limits the release of radioactivity from a U.S. Department of Energy (DOE) facility to that which would cause 10 millirem per year (mrem/y) effective dose equivalent to any member of the public. This limit does not include radiation unrelated to NNSS activities. Unrelated doses could come from naturally occurring radioactive elements, from sources such as medically or commercially used radionuclides, or from sources outside of the United States, such as Japan's Fukushima nuclear power plant, which was damaged in 2011.

NNSA/NFO demonstrates compliance with the NESHAP limit by reporting environmental measurements of radionuclide air concentrations at critical receptor locations on the NNSS (U.S. Environmental Protection Agency [EPA] and DOE 1995). This method was approved by the EPA in 2001 (EPA 2001a) and has been the method used to demonstrate compliance with the 40 CFR 61.92 dose standard since 2005. Six locations on the NNSS have been established to act as critical receptor locations to demonstrate compliance with the NESHAP limit. These locations are actually pseudo-critical receptor stations because no member of the public resides at these onsite locations. Compliance is demonstrated if the measured annual average concentration is less than the NESHAP Concentration Level (CL) for Environmental Compliance listed in 40 CFR 61, Appendix E, Table 2 (CFR 2010a). For multiple radionuclides, compliance 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.

In 2018, the potential dose from radiological emissions to air from both current and past NNSS activities was well below the 10 mrem/y dose limit. This is demonstrated by air sampling data collected at the critical receptor air monitoring stations which had average concentrations of radioactivity that were a fraction of the CL values. Concentrations ranged from 0.1% to a maximum of 5.2% of the allowed NESHAP limit. Clean Air Package 1988 (CAP88-PC) was used to model dose to the offsite public from all 2018 NNSS radionuclide emissions. The model showed the maximally exposed individual to be on the northern end of Amargosa Valley; this individual received a potential dose of 0.07 mrem/y. The potential dose to the public from NLVF emissions was also very low at 0.000008 mrem/y, over six orders of magnitude lower than the 10 mrem/y limit.

NESHAP Compliance for 2018

NNSS: Compliance Demonstrated by the Sum of Fractions at Each Critical Receptor Sampler Being Less Than 1.0

Radionuclides Included: ^{3}H, ^{137}Cs, ^{238}Pu, $^{239+240}Pu$, ^{241}Am

NNSS Operations Area	Critical Receptor Location	Sum of Fractions of CLs
6	Yucca	0.0058
10	Gate 700 S	0.014
16	3545 Substation	0.0047
20	Schooner	0.052
23	Mercury	0.0031
25	Gate 510	0.0014

NLVF: Compliance Demonstrated by the Highest Potential Offsite Dose Being Less Than 10 mrem/y

Estimated offsite dose from NLVF = 0.000008 mrem/y

This page intentionally left blank

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Am	americium
Ar	argon
ARL/SORD	Air Resources Laboratory, Special Operations and Research Division
Ba	barium
BEEF	Big Explosives Experimental Facility
Br	bromine
°C	degrees Celsius
CAP88-PC	Clean Air Package 1988 (EPA software program for estimating doses)
Ce	Cerium
CFR	Code of Federal Regulations
Ci	curie(s)
CL	Concentration Level
cm	centimeter(s)
Co	cobalt
Cs	cesium
CY	calendar year
d	day(s)
DAF	Device Assembly Facility
DOE	U.S. Department of Energy
DPFF	Dense Plasma Focus Facility
DRA	Desert Rock Meteorological Observatory
E	east
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
Eu	europium
ft^3/min	cubic feet per minute
h	hour(s)
^3H	tritium
HEPA	high efficiency particulate air
HTO	tritiated water in the form of $^3H^3HO$ or ^3HHO
I	iodine if with atomic mass superscript
JASPER	Joint Actinide Shock Physics Experimental Research
K	potassium
km	kilometer(s)
km^2	square kilometer(s)
Kr	krypton
L	liter(s)
La	Lanthanum
LLW	low-level waste
m	meter(s)
mCi	millicurie(s)
mCi/y	millicurie(s)/year
MEDA	Meteorological Data Acquisition
MEI	maximally exposed individual
MIDNET	Meteorological Integrated Data Network
min	minute(s)
mrem/y	millirem per year

List of Acronyms and Abbreviations (continued)

µrem/y	microrem per year
m/s	meter(s) per second
N	north or nitrogen (nitrogen if with atomic mass superscript)
NCERC	National Criticality Experiments Research Center
NESHAP	National Emission Standards for Hazardous Air Pollutants
NLVF	North Las Vegas Facility
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NOAA	National Oceanic and Atmospheric Administration
NPTEC	Nonproliferation Test and Evaluation Complex
NTTR	Nevada Test and Training Range
O	oxygen
pCi	picocurie(s)
pCi/L	picocurie(s) per liter
pCi/m^3	picocurie(s) per cubic meter
Pu	plutonium
RIDP	Radionuclide Inventory and Distribution Program
rem	roentgen equivalent man
RNCTEC	Radiological/Nuclear Countermeasures Test and Evaluation Complex
RWMC	Radioactive Waste Management Complex
RWMS	Radioactive Waste Management Site
s	second(s)
S	south
Sb	antimony
Sm	samarium
Sr	strontium
STAR	Stability Array (grouping of meteorological data)
Te	tellurium
TRU	transuranic (nuclides with atomic numbers greater than uranium)
UCC	Yucca Flat Meteorological Observatory
UGTA	Underground Test Area
UNESE	Underground Nuclear Explosion Signatures Experiment
W	west
Xe	xenon
y	year(s)

Report Information

U.S. Department of Energy
National Nuclear Security Administration
Nevada Field Office
Air Emissions Annual Report
(under Subpart H, Title 40 Code of Federal Regulations [CFR] 61.94)
Calendar Year (CY) 2018

Site Name: Nevada National Security Site

Office Information

Office: U.S. Department of Energy, National Nuclear Security Administration
Nevada Field Office

Address: P.O. Box 98518

Las Vegas, NV 89193-8518

Contact: Betty L. Huck Phone: (702) 295-4825

Assistant Manager for Operations and Safety

Site Information

Operator: Mission Support and Test Services, LLC

Address: P.O. Box 98521

Las Vegas, NV 89193-8521

Contact: Stacey L. Alderson Phone: (702) 295-5283

Director, Environmental, Safety and Health

This page intentionally left blank

SECTION I
FACILITY INFORMATION

SITE DESCRIPTION

The Nevada National Security Site (NNSS) is operated by the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) as the site for maintaining and enhancing the safety, security, reliability, and performance of the U.S. nuclear weapons stockpile; reducing global danger from weapons of mass destruction; and responding to nuclear and radiological emergencies in the U.S. and abroad. The NNSS is also an operational site for environmental restoration, low-level radioactive waste management, and groundwater characterization activities. Located in Nye County, Nevada, the site's southeast corner is about 105 kilometers (km) northwest of the major population center, Las Vegas, Nevada. The NNSS covers about 3,523 square kilometers (km^2) and is 46 to 56 km east to west and 64 to 88 km north to south. The NNSS is surrounded, except on the south side, by the Nevada Test and Training Range (NTTR), a public exclusion area that provides another 24 to 104 km between the NNSS and publicly accessible land (Figure 1).

The NNSS is characterized by desert valley and Great Basin mountain topography, with climate, flora, and fauna typical of the southwest deserts. Based on the most recent population estimates (Clark County Department of Comprehensive Planning 2018; Nye County Planning Department 2015) there were 503,300 people residing within 80 km of the NNSS boundary. The distribution of this population is concentrated in the metropolitan areas of Las Vegas and North Las Vegas (89 %) to the southeast and in the town of Pahrump (8%) to the south (Figure 1). These more populated areas drive the overall average population density up to about 11.2 person/km^2, but the vast majority of the area within 80 km of the NNSS is uninhabited. The nearest populated location to the NNSS boundary is the north end of Amargosa Valley, which extends to within 3.4 km of the southwest corner of the NNSS. Two mines are also relatively near the boundaries of the NNSS: the American Silica mine, 2.7 km east from the southeast edge of the NNSS, and the Cinder Cone Pit mine, 5.5 km west of the southwest corner of the NNSS. The American Silica mine was not in operation in 2018 but is still identified on maps for reference.

One dairy operated within 80 km of the NNSS in 2018. It is located in Amargosa Valley at a distance of about 16.1 km from the NNSS boundary. Agriculture around the NNSS is sparse and consists primarily of alfalfa fields, which are found mainly in Amargosa Valley, Pahrump, Penoyer Farm, Reed's Ranch, and locations between Alamo and Hiko. There were also one honey production and two winery businesses operating in Pahrump in 2018. These are about 44 km south of the NNSS boundary. One 60-acre farm in Las Vegas, 73.3 km east-southeast of the NNSS, operated in 2018. This farm sells produce directly to the public. Sparse livestock production may occur throughout the area around the NNSS on a relatively small scale.

The NLVF is an 80-acre complex composed of buildings that house much of the NNSS project management; diagnostic development; and testing, design, engineering, and procurement operations. This facility is located along Losee Road in the city of North Las Vegas and is surrounded on the north, south, and east by general industrial zoning. The western border separates the property from fully developed, single-family residential-zoned property.

SOURCE DESCRIPTION

In 1950, the now-named NNSS was established as the primary location for testing the nation's nuclear explosive devices. Such testing took place from 1951 to 1992. Historical testing included (1) atmospheric testing in the 1950s and early 1960s, (2) underground testing between 1951 and 1992, and (3) open-air nuclear reactor and rocket engine testing between 1959 and 1973. No nuclear tests have been conducted since September 23, 1992 (U.S. Department of Energy [DOE] 2013). The environmental legacy of nuclear weapons and other testing on the NNSS is a major source of radionuclides that are released into the air. They are characterized as non-point (diffuse) sources and include (1) areas of radioactively contaminated surface soils, (2) contaminated groundwater

that is pumped or flows naturally to the surface, (3) radioactive waste storage and burial sites, and (4) radiologically contaminated structures and materials being decommissioned, demolished, and/or managed.

Surfaces contaminated with plutonium (Pu), americium (Am), tritium (^{3}H), and fission and activation products from past nuclear device safety, atmospheric, or cratering test activities could become sources of radionuclide exposure to the public if the radionuclides were to be re-suspended, for example, through evaporation or transpiration of ^{3}H in water, by windy conditions, surface cleanup, construction, vehicular travel, or similar activities for radionuclides associated with particulates. In 1981, DOE began a project known as the Radionuclide Inventory and Distribution Program (RIDP). After five years of field work and three years of data analysis, the result was a report that identified the inventory and described the distribution of radionuclides in the soil in parts of the NNSS affected by NNSS operations (DOE 1991) (Table 1). The inventory includes an estimate of the curies (Ci) of the manmade radionuclides detected and reported by the RIDP. Though the inventory includes cobalt-60 (^{60}Co), strontium-90 (^{90}Sr), cesium-137 (^{137}Cs), and the europium (Eu) isotopes ^{152}Eu, ^{154}Eu, and ^{155}Eu, their concentrations in air samples are generally below detection levels and collectively contribute less than 10% to total dose, which is the threshold for required measurement per 40 CFR 61.93. Figure 2 shows areas of elevated exposure rates due to radionuclides in NNSS soils as measured by an aerial survey conducted in 1994 (Hendricks and Riedhauser 1999).

Table 1. Inventory of Manmade Radionuclides in NNSS Surface Soil[(a)]

	Radionuclide inventory (Ci)[(b)]								
Area	**^{60}Co**	**^{90}Sr**	**^{137}Cs**	**^{152}Eu**	**^{154}Eu**	**^{155}Eu**	**^{238}Pu**	**$^{239+240}Pu$**	**^{241}Am**
1	0.03	7.55	4.57	3.48	0.01	0.01	5.19	23.98	6.04
2	0.03	23.15	12.46	3.25	0.00	0.01	6.86	21.98	4.63
3	0.02	16.61	6.23	4.18	0.01	0.01	2.47	36.97	7.52
4	0.04	6.54	6.23	2.11	0.00	0.00	10.38	39.97	9.69
5	0.01	0.45	0.21	2.32	0.02	0.00	0.08	4.80	0.98
6	0.00	1.76	1.45	0.00	0.00	0.00	2.63	8.39	2.33
7	0.02	4.63	2.70	5.11	0.02	0.00	0.48	15.99	3.45
8	0.13	12.58	21.81	1.02	0.00	0.01	6.39	109.91	25.54
9	0.02	6.54	4.52	5.34	0.02	0.00	1.76	88.93	11.53
10	0.23	27.68	43.62	0.51	0.03	0.08	15.17	109.91	27.45
11	0.00	0.15	0.26	0.00	0.00	0.00	0.40	28.98	5.60
12	0.03	8.56	10.39	0.00	0.00	0.00	6.78	38.97	8.74
15	0.01	11.07	9.87	0.00	0.00	0.00	6.23	62.95	12.97
16	0.00	1.86	1.51	0.00	0.00	0.00	1.20	3.70	0.98
17	0.02	9.56	7.79	0.00	0.00	0.00	3.59	17.99	4.20
18	0.02	8.56	5.19	0.26	0.01	0.01	4.47	99.92	26.60
19	0.03	15.60	18.69	0.00	0.00	0.00	25.54	139.89	31.89
20	0.19	2.16	2.86	3.02	0.16	0.08	23.95	40.97	25.44
25	0.00	0.05	0.10	0.09	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.02	0.65	0.78	0.16	0.01	0.00	3.59	13.99	4.24

(a) Source of inventory from DOE (1991) and includes radionuclides in soil within 0–30 centimeters (cm) of the surface with most activity in the top 5 cm.
(b) Decay corrected to the middle of calendar year 2018 (July 2, 2018), with ingrowth of ^{241}Am from ^{241}Pu included.

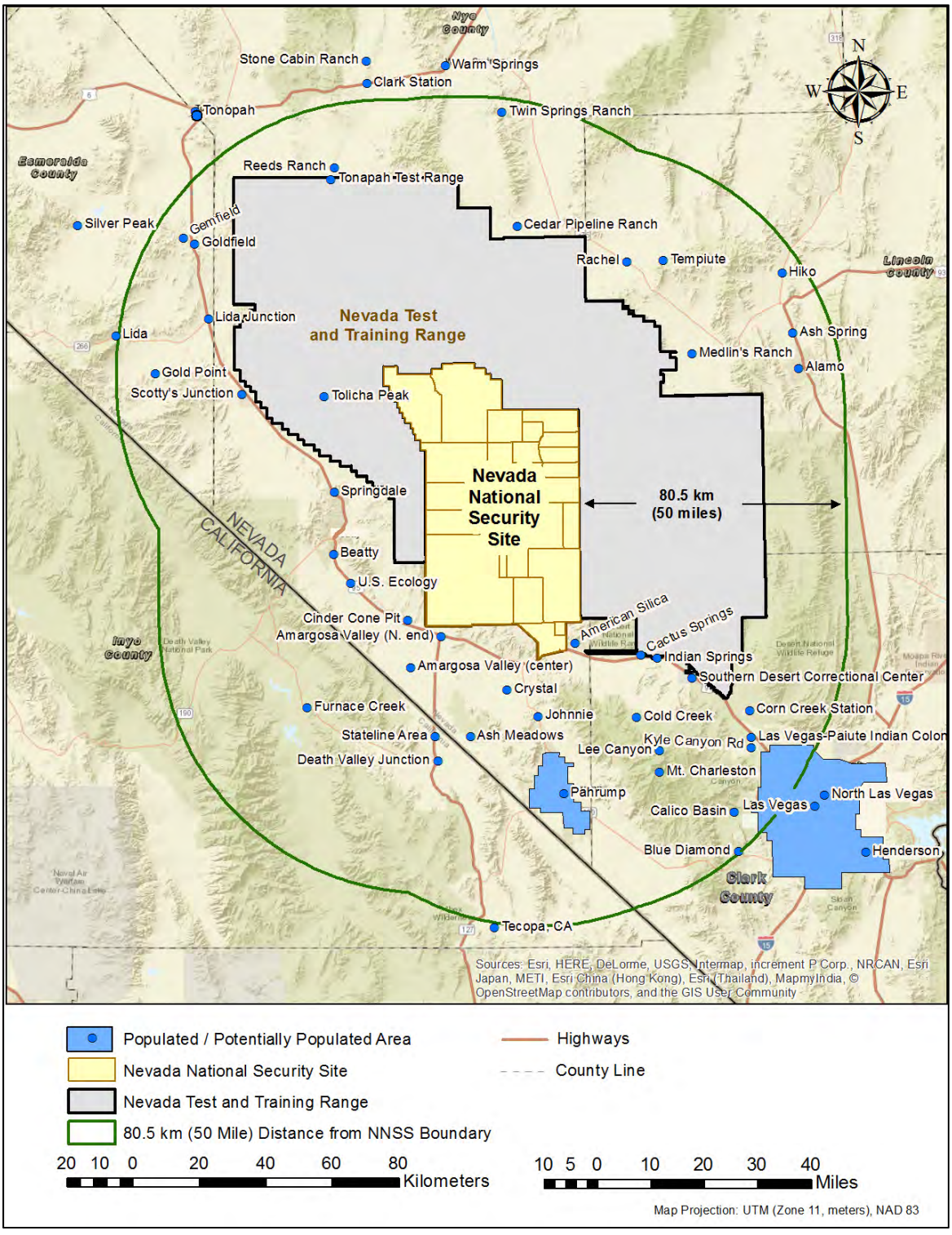

Figure 1. NNSS and Surrounding Populated Area

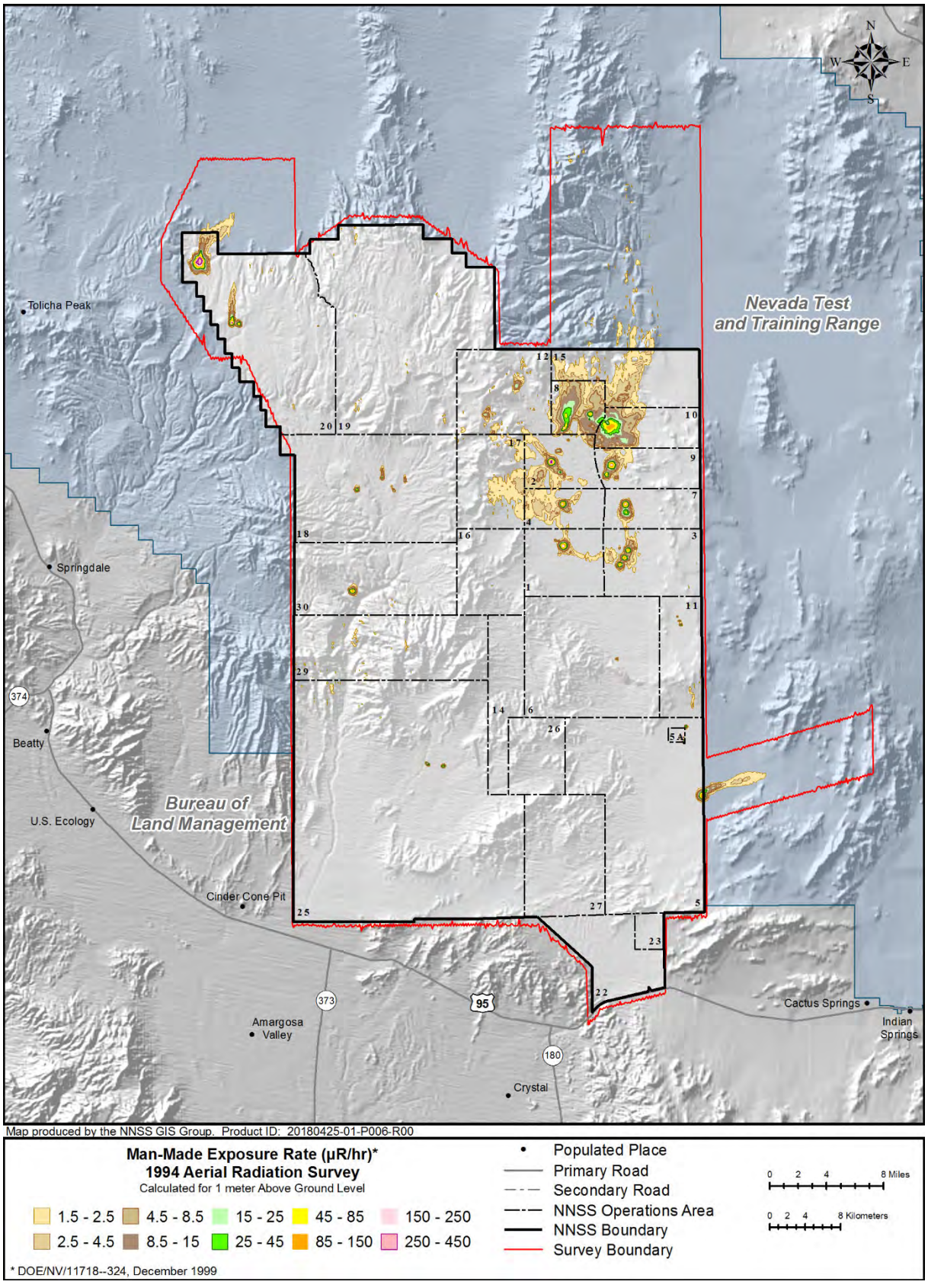

Figure 2. Distribution of Elevated Exposure Rates from Radionuclides in NNSS Soils

Current missions of the NNSS are to help ensure the security of the United States and its allies by supporting the stewardship of the nuclear deterrent stockpile, providing emergency response capability and training, and contributing to key nonproliferation and arms control initiatives. Activities include (1) conducting high-hazard operations in support of defense-related nuclear and national security experiments; (2) providing support for homeland security activities, national security, and nonproliferation technology development and research; (3) characterizing and remediating the environmental legacy of past nuclear testing; and (4) managing and disposing of radioactive wastes. A few programs and experiments at the NNSS use or handle radioactive materials in specific facilities. In all such facilities, radioactive materials are controlled in accordance with Title 10 Code of Federal Regulations (CFR) Part 835, "Occupational Radiation Protection" (CFR 2010b). The primary facilities that have key NNSA/NFO missions that have unsealed radioactive material and are potential sources for radiological air emissions are shown in Figure 3. Radionuclides potentially present at these facilities include various isotopes of Pu, Am, and U, as well as ^{3}H, ^{60}Co, ^{137}Cs, and various short-lived activation and fission products. Radioactive emissions are not necessarily produced from these facilities in a given year, but all have the potential for radioactive emissions. The key facilities and programs that are potential NNSS sources are listed by general organization category below.

- Stockpile Stewardship, Science, and Experimentation
    - Device Assembly Facility (DAF)
        - National Criticality Experiments Research Center (NCERC)
    - Dense Plasma Focus Facility (DPFF)
    - High Explosive Facilities
        - Big Explosives Experimental Facility (BEEF)
    - Joint Actinide Shock Physics Experimental Research (JASPER)
    - U1a Complex
- Nonproliferation, Counterterrorism, and Incident Response
    - Nonproliferation Test and Evaluation Complex (NPTEC)
    - Radiological/Nuclear Countermeasures Test and Evaluation Complex (RNCTEC)
    - T1 Training and Exercise Area
    - Tumbleweed Test Range
    - Underground Nuclear Explosion Signatures Experiment (UNESE)
- Environmental Restoration and Waste Operations
    - Environmental Restoration
    - Radioactive Waste Management Complex (RWMC)
        - Area 3 Radioactive Waste Management Site (RWMS)
        - Area 5 RWMC
    - Underground Test Area (UGTA) Activity
- Mission Support
    - Buildings housing support activities where radioactive material may be surveyed, processed, and/or analyzed include 23-180, 23-600, 23-650, 23-652, and 23-703. All of these are in Mercury in Area 23 (Figure 3). Handling of radioactive material in these buildings is limited and consists primarily of handling environmental samples and laboratory standards containing radioactive material. Although the amounts of radioactive material in the environmental samples and laboratory standards are low, and therefore the potential emissions from them are also very low, they are still included as sources.

All facilities and activities from which radionuclides were known to be released to air in calendar year (CY) 2018 are listed in Section II, Table 2, and their source information is listed in Appendix A, Table A.1.

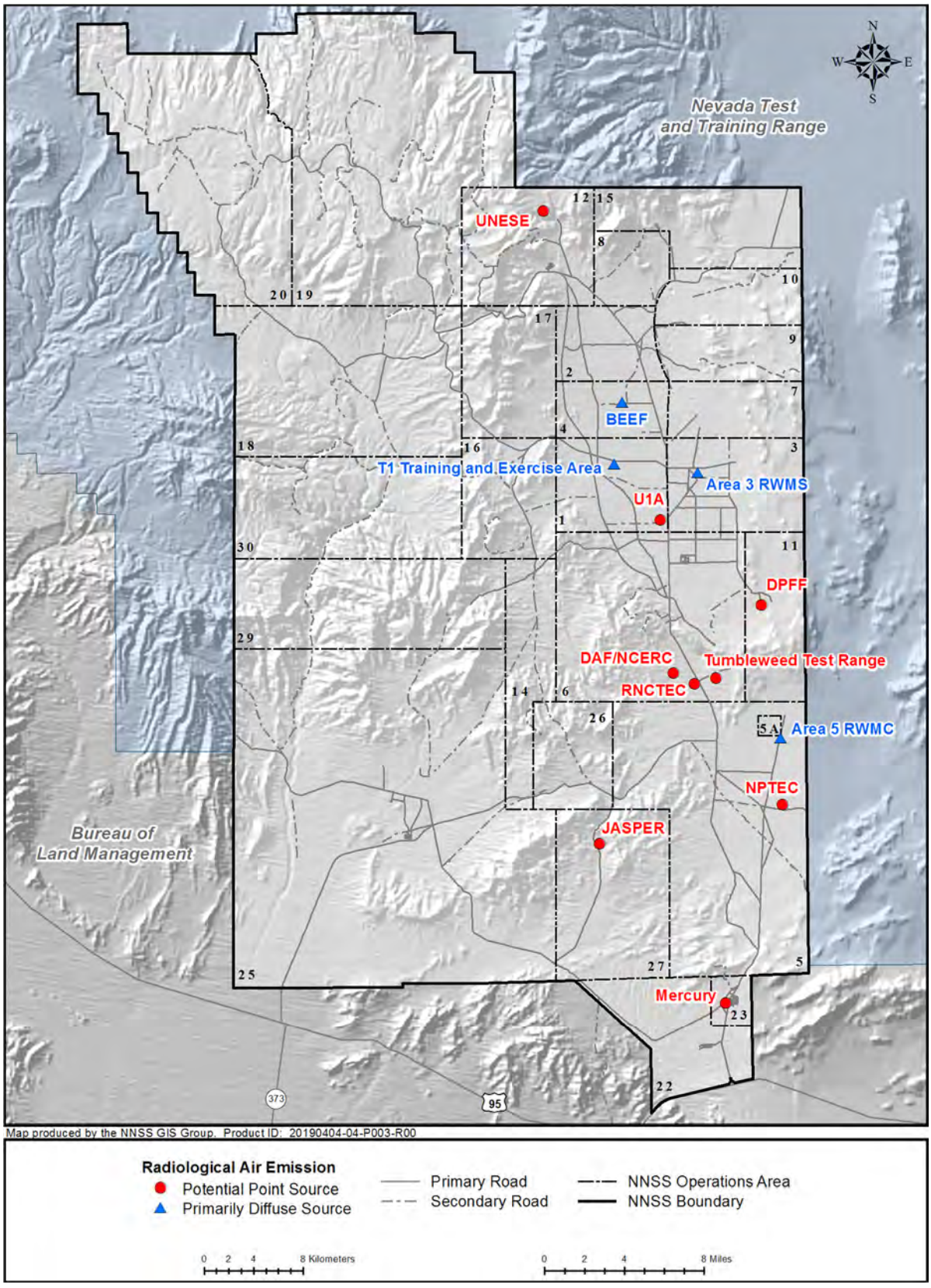

Figure 3. Primary Facilities or Projects with Potential to Release Radionuclides to Air

SECTION II
AIR EMISSIONS DATA

Facilities and operations from which radionuclides were released to the atmosphere during CY 2018 are listed in Table 2, and their source information is listed in Appendix A. Their locations are displayed in Figure 4. Releases for the year are grouped into five general source categories: (1) Legacy Contamination Sites; (2) Stockpile Stewardship, Science, and Experimentation; (3) Nonproliferation, Counterterrorism, and Incident Response; (4) Environmental Restoration and Waste Operations; and (5) Mission Support. CY 2018 emission sources by category are described below.

Legacy Contamination Sites

The environmental legacy of nuclear weapons and other testing on the NNSS is a major source of radionuclides that are released into the air. They are generally characterized as non-point (diffuse) sources and include:

Weapon Test and Plowshare Soil Contamination Sites

Three general soil contamination locations are listed for emission sources in this category. Two of them, Sedan and Schooner, are craters from the Plowshare program, which used nuclear devices to demonstrate their ability to excavate large amounts of earth. They are specifically listed separately from other test locations because they dominate the legacy contamination sites for ^{3}H emissions. The derivation of ^{3}H emission estimates from these locations is described in Appendix B. The third general location, referred to as "Grouped Area Sources," is a grouping of all large areas impacted by past nuclear testing on the NNSS. This grouping is used to report emissions of radionuclides in particulate form due to soil resuspension caused by wind. The derivation of this emission is described in Appendix C.

Emanation from Building Materials

At the NLVF, parts of the Building A-01 basement were contaminated with ^{3}H in 1995. Emanation of tritiated water in the form of $^{3}H^{3}HO$ or ^{3}HHO (collectively referred to as HTO) from these building materials has persisted at continually decreasing levels. These emissions are exhausted from the building through the ventilation system. A description of the incident and the potential effective dose equivalent (EDE) for offsite exposure during CY 2018 are presented in Appendix D.

The 1995 ^{3}H contamination of the NLVF Building A-01 basement also affected an inactive radiation source well that had since been filling with water due to the soil bottom in the well and a rise in groundwater. This source well was sealed in 2001 and a pump was installed to remove the residual ^{3}H contaminated water. After more than 15 years of pumping, average tritium concentrations are not detectable with standard analyses. The State of Nevada approved disposing of this water through discharges under the NLVF DeMinimis General Permit. Therefore, there were no tritium emissions from this source for CY 2018.

Stockpile Stewardship, Science, and Experimentation

The NNSS provides unique resources to maintain the integrity of the United States' nuclear weapons stockpile through weapons testing without nuclear detonation. Nuclear Asset Operations supports this mission through its nuclear and high-hazard facility management.

Certain experiments have the potential for radioactive emissions. Primary facilities for such emissions are DAF in Area 6, NCERC (located within the DAF) in Area 6, DPFF in Area 11, U1a in Area 1, BEEF in Area 4, and JASPER in Area 27.

During CY 2018 the DPFF was the only facility known to have radioactive emissions. Also, conservatively calculated potential air emissions from the NCERC are included as a source for CY 2018.

Nonproliferation, Counterterrorism, and Incident Response

This category can be generally described as global security activities conducted to strengthen national security by providing real-world testing, evaluation, and training venues. Certain activities have the potential for radioactive emissions. The primary facilities for this are the T1 Training and Exercise Area in Area 1, RNCTEC in Area 6, NPTEC in Area 5, the Tumbleweed Test Range in Area 6, and tunnel facilities primarily in Area 12. Certain experiments using radioactive materials may also be conducted in remote locations of the NNSS.

The only facility in this category from which radionuclides were released during CY 2018 was the UNESE in Area 12.

Environmental Restoration and Waste Operations

Environmental Restoration

Environmental Restoration Corrective Action Site 12-59-01, E-Tunnels, has a component consisting of water contaminated from historical nuclear weapons testing flowing into collection ponds (E-Tunnel Ponds) in Area 12. The only radiological contaminant that produces a measurable air emission is ^{3}H evaporating as HTO. Calculation of this emission source for CY 2018 is described in Appendix E.

An Environmental Restoration cleanup project was started during CY 2017 at the Clean Slate site on the Tonopah Test Range. This work continued through CY 2018. Environmental monitoring / reporting is conducted by Sandia National Laboratories (http://www.sandia.gov/news/publications/environmental_reports/).

There were no Environmental Restoration demolitions or cleanup projects conducted on the NNSS during CY 2018 that had a potential for radionuclide emissions to air.

Underground Test Area (UGTA) Activity

UGTA activities include the task of characterizing the aquifers at sites of past underground nuclear tests. To characterize the groundwater regime, suitable wells are drilled and existing wells re-completed and sampled as determined by hydrologists. During these drilling and sampling operations, water is pumped to the surface. This water is then available for evaporation. Again, the only contaminant producing a measurable air emission from this evaporating water is ^{3}H as HTO. During CY 2018, water containing ^{3}H was pumped from the following wells:

- ER-4-1
- RNM #2s
- UE-5n
- WW C-1
- WW-3
- ER-7-1
- PM-3

These well locations are displayed in Figure 4. Calculation of the ^{3}H emission from water pumped from them is described in Appendix E.

Waste Operations

The Area 3 RWMS and the Area 5 RWMC are used for the disposal of packaged, dry, low-level waste in pits and trenches. The Area 5 RWMC also has facilities for waste examination and repackaging activities,

the accumulation of mixed waste, and the storage of transuranic (TRU) and mixed TRU wastes. Concrete pads are used for temporary storage of these wastes. The only radioactive emission detected by the various types of samplers located downwind of these sites and attributed to waste operations was ^{3}H as HTO in atmospheric moisture. The calculation of the ^{3}H source term for these emissions in CY 2018 is described in Appendix B.

Mission Support

Facilities with laboratories as described in Section I have the potential to emit low quantities of radionuclides from handling or processing contaminated material (primarily samples) or from the preparation of ^{3}H standards that are used for quality assurance purposes. Also, the Radiological Control Department has the responsibility of conducting receipt surveys of any radioactive materials arriving at the NNSS. If packaging is damaged, materials must be handled during repackaging, which creates the potential for low-level air emissions. These activities generally take place at Radioactive Materials Control, Building 23-180. Of these support facilities, only operations in Building 23-652 were known to use unsealed radioactive materials in CY 2018; therefore, it was the only facility in this category listed as being an emission source in CY 2018.

Radionuclide emissions from each CY 2018 source were characterized by one of the following methods:

- Facility- or project-reported radionuclide emissions based on operations
- Identifying the radionuclide inventory and determining losses of radionuclides that were released to the environment using 40 CFR 61 Appendix D emission factors
- Measuring the HTO concentrations in liquid effluents discharged and proceeding as if all the effluent evaporates over the course of the year to become an air emission
- Using re-suspension calculations
- Using a combination of environmental measurements and the Clean Air Package 1988 (CAP88-PC) air dispersion model (EPA 2014) to calculate the emissions

Distances and directions from all CY 2018 emission sources to the nearest offsite locations of interest are listed in Table 2. Distances ranged from 20 to 72 km from NNSS emission sources and from 0.1 to 0.85 km from the NLVF emission source.

Total CY 2018 emissions, by radionuclide, are shown in Table 3 for the NNSS and in Table 4 for the NLVF. Radionuclide emissions by source are shown in Table 5. The source type, emission control (for example, high efficiency particulate air [HEPA] filters), and description of the nature of each emission are listed in Table A.1 of Appendix A. Appendices B through E describe the methods used to determine the CY 2018 emissions.

Radionuclides making up about 84% of the total activity emitted from the NNSS in CY 2018 have very short half-lives. These range from seven seconds for nitrogen-16 to 15.3 minutes for metastable xenon-135. Due to these short half-lives, almost all of the activity is lost due to physical decay over the time it takes to travel the long distances to offsite receptors (Table 2).

Table 2. CY 2018 Radionuclide Emission Sources and Distance to Offsite Locations

Emission Source		Distance[a] and Direction[b] to Nearest Offsite Locations		
		Offsite Residence	Offsite Business/Office	Offsite School
Legacy Contamination Sites	Sedan	51 km ENE (Medlin's Ranch)	58 km NNE (Rachel)	72 km WSW (Beatty)
	Schooner	36 km WSW (Sarcobatus Flat)	20 km WSW (Tolicha Peak)	55 km SSW (Beatty)
	Grouped Area Sources – All NNSS Areas	Various locations ranging from 20 to 74 km		
	Building A-01, basement, NLVF	0.6 km W (N Las Vegas)[c]	0.1 km (at north fence of NLVF)	0.85 km W (N Las Vegas)[c]
Stockpile Stewardship, Science, and Experimentation	DPFF	35 km NNE (NTTR)	35 km NNE (NTTR)	49 km SSE (Indian Springs)
	NCERC	42 km SW (Amargosa Valley)	42 km SW (Amargosa Valley)	49 km SE (Indian Springs)
Nonproliferation, Counterterrorism, and Incident Response	UNESE	31 km E (NTTR)	31 km E (NTTR)	67 km SW (Beatty)
Environmental Restoration and Waste Operations	E-Tunnel Ponds	53 km WSW (Springdale)	55 km WNW (Tolicha Peak)	62 km SW (Beatty)
	UGTA Wells	21 km WNW (Tolicha Peak)	21 km WNW (Tolicha Peak)	38 km SE (Indian Springs)
	Area 3 RWMS	56 km SW (Amargosa Valley)	56 km SW (Amargosa Valley)	61 km SSE (Indian Springs)
	Area 5 RWMC	36 km SE (Cactus Springs)	40 km SE (Indian Springs)	40 km SE (Indian Springs)
Mission Support	Building 23-652	24 km SW (Crystal)	24 km SW (Crystal)	30 km (Indian Springs)

(a) Distance is shown in km. For miles, multiply by 0.62.
(b) N=north, S=south, E=east, W=west in all direction combinations shown.
(c) City of North Las Vegas

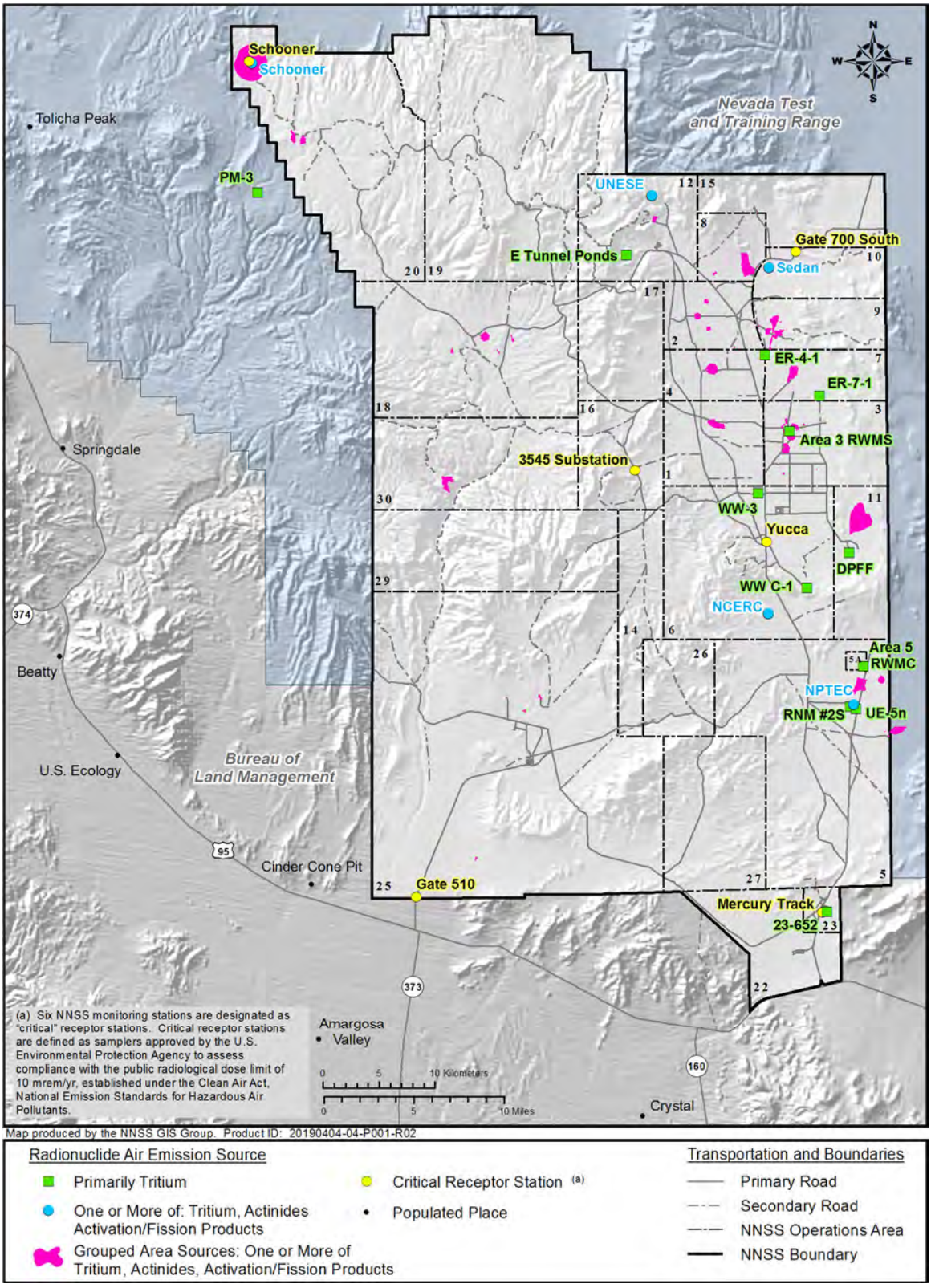

Figure 4. Sources of Radiological Air Emissions and Critical Receptor Air Monitoring Stations on the NNSS in CY 2018

Table 3. Total Estimated NNSS Emissions for CY 2018

Radionuclide[(a)]	Symbol	Half-life	Total Quantity (Ci)
Tritium	^{3}H	12.32 years (y)	1260
Nitrogen-16	^{16}N	7.13 seconds (s)	15
Oxygen-19	^{19}O	26.46 s	0.026
Argon-37	^{37}Ar	35.04 days (d)	0.65
Argon-41	^{41}Ar	109.61 minutes (min)	5.66
Cobalt-60	^{60}Co	5.27 y	0.00027
Bromine-85	^{85}Br	2.90 min	9260
Krypton-85	^{85}Kr	10.76 y	0.0011
metastable Krypton-85	^{85m}Kr	4.48 hours (h)	106
Strontium-90	^{90}Sr	28.79 y	0.061
Antimony-125	^{125}Sb	2.76 y	0.0010
Tellurium-132	^{132}Te	3.20 d	22
Iodine-131	^{131}I	8.02 d	6.37
Iodine-133	^{133}I	20.80 h	116
Iodine-135	^{135}I	6.57 h	354
Xenon-127	^{127}Xe	36.345 d	0.56
metastable Xenon-131	^{131m}Xe	11.84 d	0.047
Xenon-133	^{133}Xe	5.24 d	19.04
metastable Xenon-133	^{133m}Xe	2.19 d	1.32
Xenon-135	^{135}Xe	9.14 h	263
metastable Xenon-135	^{135m}Xe	15.29 m	1740
Cesium-137	^{137}Cs	30.17 y	0.059
Barium-140	^{140}Ba	12.75 d	7.51
Lanthanum-140	^{140}La	1.68 d	0.00000057
Cerium-141	^{141}Ce	32.50 d	0.0027
Samarium-153	^{153}Sm	46.5 h	1.18
Europium-152	^{152}Eu	13.54 y	0.0097
Europium-154	^{154}Eu	8.59 y	0.000091
Europium-155	^{155}Eu	4.76 y	0.00045
Plutonium-238	^{238}Pu	87.7 y	0.040
Plutonium-239+240	$^{239+240}Pu$	24,110 y	0.29
Americium-241	^{241}Am	432 y	0.069

Note: This table includes conservative point and diffuse source release estimates.

(a) Includes all radionuclides with reasonable emission estimates available. Not all of these radionuclides would contribute ≥ 10% of the potential EDE (threshold for required measurement per 40 CFR 61.93).

Table 4. Total Estimated NLVF Emissions for CY 2018

Radionuclide	Total Quantity (Ci)
^{3}H	0.0016

Table 5. Summary of CY 2018 Air Emissions Data by Source

Emission Source[a]		Emissions Control	Radionuclide	Quantity (Ci/y)
Legacy Contamination Sites	Sedan[b]	None	^{3}H	6
	Schooner[b]	None	^{3}H	10
	Grouped Area Sources – All NNSS Areas[c]	None	^{60}Co	0.00027
			^{90}Sr	0.052
			^{137}Cs	0.050
			^{152}Eu	0.0097
			^{154}Eu	0.000092
			^{155}Eu	0.000067
			^{238}Pu	0.040
			$^{239+240}$Pu	0.29
			^{241}Am	0.069
	Building A-01, NLVF[d]	None	^{3}H	0.0016
Stockpile Stewardship, Science, and Experimentation	DPFF[e]	None	^{3}H	1233
			^{16}N	0.00016
			^{19}O	0.00000021
			^{41}Ar	0.00000026
	NCERC[e]	HEPA filter	^{3}H	0.000036
			^{16}N	15
			^{19}O	0.026
			^{41}Ar	5.66
			^{85}Kr	0.0011
			^{85m}Kr	106
			^{85}Br	9260
			^{90}Sr	0.0083
			^{125}Sb	0.0010
			^{132}Te	22
			^{131}I	6.37
			^{133}I	116
			^{135}I	354
			^{131m}Xe	0.047
			^{133}Xe	19
			^{133m}Xe	1.32
			^{135}Xe	263
			^{135m}Xe	1740
			^{137}Cs	0.0086
			^{140}Ba	7.51
			^{140}La	0.00000057
			^{141}Ce	0.0027
			^{153}Sm	1.18
			^{155}Eu	0.00038
Nonproliferation, Counterterrorism, and Incident Response	UNESE[e]	Underground	^{37}Ar	0.65
			^{127}Xe	0.56
			^{133}Xe	0.04
Environmental Restoration and Waste Operations	E-Tunnel Ponds[f]	None	^{3}H	4
	UGTA Wells[f]	None	^{3}H	0.04
	Area 3 RWMS[b]	Soil cover over waste	^{3}H	6
	Area 5 RWMC[b]	Soil cover over waste	^{3}H	1
Mission Support	Building 23-652[g]	None	^{3}H	0.0000069

(a) All locations are on the NNSS except for Building A-01.
(b) Emission based on samples and CAP88-PC; see Appendix B.
(c) Emissions from soil re-suspension model; see Table C.1.
(d) Based on air concentrations and ventilation system; see Appendix D.
(e) Emission based on potential release reported by project personnel.
(f) Emission based on HTO discharged into containment pond(s) or onto the ground; see Appendix E.
(g) Based on concentrations used in Building 23-652 lab during 2017 - the most recent year an emission estimate is available.

This page intentionally left blank

SECTION III
DOSE ASSESSMENTS

CRITICAL RECEPTOR AIR MONITORING

The NNSS demonstrates compliance with dose limits by reporting 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 approved by EPA Region 9 for use on the NNSS in 2001 (EPA 2001a) and has been used to demonstrate compliance with the 40 CFR 61.92 dose standard since 2002. The six approved critical receptor locations are listed below and displayed in Figure 4 with NNSS emission locations and in Figure 5 along with the entire NNSS air sampling network.

- Area 6, Yucca
- Area 10, Gate 700 S
- Area 16, 3545 Substation
- Area 20, Schooner
- Area 23, Mercury Track
- Area 25, Gate 510

No changes to the critical receptor air monitoring locations occurred during CY 2018 but one station (Pu Valley AMS) was installed and began sampling on December 19, 2017 (Figure 5). Both air particulates and atmospheric moisture are sampled at this new station.

The six critical receptor locations can be thought of as worst case for an offsite receptor because these samplers are much closer to emissions sources. Table 6 displays the distances and direction between the critical receptor monitoring stations and offsite locations where members of the public potentially live, work, and/or go to school. The distance and direction between emission sources and the critical receptor sampling locations are listed in Table 7. The shortest distance between where a member of the public resides and a critical receptor monitoring station is 4 km. This is between the Gate 510 sampler, in the SW corner of the NNSS, and the northern edge of the community of Amargosa Valley. The shortest distance between an NNSS radionuclide emission source and a critical receptor monitoring station is 0.3 km. This is between the Schooner sampler, in the NW corner of the NNSS, and Schooner Crater. Because this sampler is actually within the area physically affected by the nuclear test, it generally has the highest radionuclide concentrations of the six critical receptor stations. The distance from the Schooner sampler to the closest member of the public (Tolicha Peak) is 20 km, which is 100 times farther than it is from the emission source.

Compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) public air pathway dose limit of 10 mrem/y is demonstrated if the measured annual average concentration of each detected radionuclide at each of the six critical receptor locations is less than the NESHAP Concentration Level (CL) for Environmental Compliance (40 CFR 61, Appendix E, Table 2). The CL represents the annual average concentration of each radionuclide that would result in an EDE of 10 mrem/y (see Table 8). For multiple radionuclides, 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 CY 2018 air sampling results from the six compliance stations are presented in Table 8. Concentration ratios for all NNSS air samplers are listed in Table 9. Presentation of air monitoring results in relation to the CL for non-critical receptor locations in Table 9 is provided as information only. These stations are not used to demonstrate compliance.

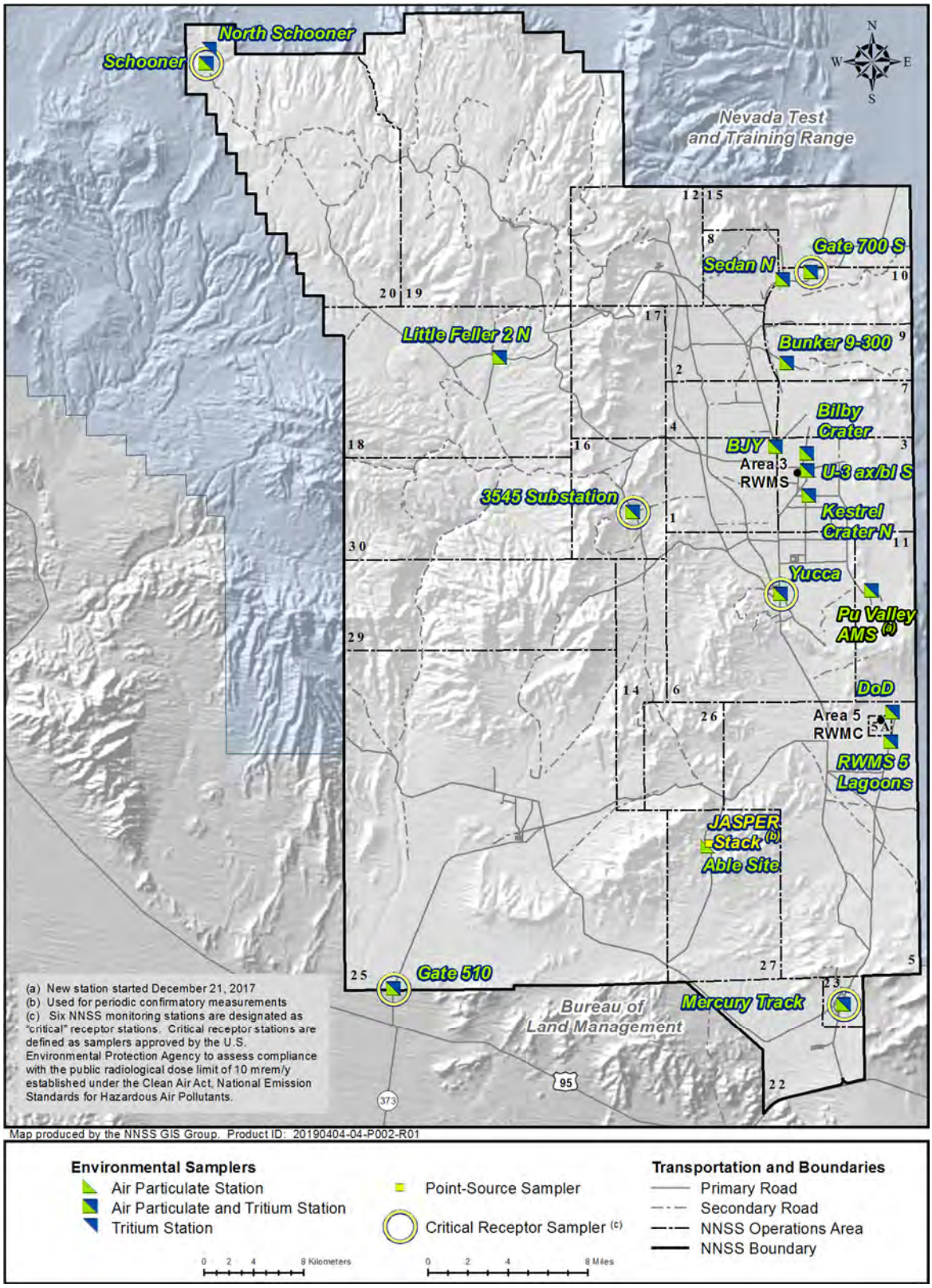

Figure 5. Air Sampling Network on the NNSS

Table 6. Distance and Direction from Critical Receptor Stations to Offsite Points of Interest

Critical Receptor Station	Distance[a] and Direction[b] to Nearest Offsite Locations		
	Offsite Residence	Offsite Business/ Office	Offsite School
Area 6, Yucca	47 km SW (Amargosa Valley)	38 km SSE (American Silica)	54 km SE (Indian Springs)
Area 10, Gate 700 S	49 km ENE (Medlin's Ranch)	56 km NNE (Rachel)	75 km SSE (Indian Springs)
Area 16, 3545 Substation	46 km SSW (Amargosa Valley)	46 km SSW (Amargosa Valley)	58 km SSW (Amargosa Valley)
Area 20, Schooner	36 km WSW (Sarcobatus Flat)	20 km WSW (Tolicha Peak)	56 km SSW (Beatty)
Area 23, Mercury Track	24 km SW (Crystal)	6.0 km SE (American Silica)	31 km SSW (Indian Springs)
Area 25, Gate 510	4 km S (Amargosa Valley)	3.5 km S (Amargosa Valley)	15 km SW (Amargosa Valley)

(a) Distance is shown in km. For miles, multiply by 0.62.
(b) N=north, S=south, E=east, W=west in all direction combinations shown.

Table 7. Distance[a] and Direction[b] from Emission Sources to Critical Receptor Stations

Emission Source		Area 6, Yucca	Area 10, Gate 700 S	Area 16, 3545 Substation	Area 20, Schooner	Area 23, Mercury Track	Area 25, Gate 510
Legacy Contamination Sites, Grouped Area Sources	Area 1	11.7 SSE	17.0 NNE	8.2 WSW	52.5 NW	44.8 SSE	50.0 SSW
	Area 2	21.1 SSE	10.4 NE	14.7 SSW	46.1 WNW	54.4 SSE	57.7 SSW
	Area 3	9.6 SSW	16.6 N	14.2 WSW	58.8 NW	42.6 S	53.0 SW
	Area 4	16.2 SSE	12.8 NE	11.3 SW	49.7 WNW	49.6 SSE	54.1 SSW
	Area 5	20.5 NNW	44.1 N	33.1 NW	> 80 km	16.9 SSW	44.7 WSW
	Area 6	2.4 NE	28.1 N	13.3 NW	63.2 NW	32.0 SSE	42.1 SW
	Area 7	15.1 S	11.0 N	16.4 WSW	56.0 WNW	48.2 S	57.5 SW
	Area 8	26.5 S	5.7 E	21.5 SSW	46.1 WNW	60.0 S	64.5 SSW
	Area 9	19.3 S	7.0 NNE	17.7 SW	52.5 WNW	52.5 S	60.2 SSW
	Area 10[c]	24.5 S	2.6 NE	21.6 SW	50.2 WNW	57.7 S	64.5 SSW
	Area 11	8.6 WSW	24.5 NNW	20.7 WNW	68.1 NW	35.4 S	52.1 SW
	Area 12[c]	30.6 SSE	13.0 ESE	22.3 S	38.8 WNW	63.8 SSE	64.2 SSW
	Area 15	28.0 S	2.7 SE	24.8 SSW	49.3 WNW	61.3 S	67.8 SSW
	Area 16	15.2 ESE	24.0 NE	1.6 SE	48.4 NW	44.7 SSE	43.5 SSW
	Area 17	22.2 SE	17.5 ENE	11.3 S	41.6 NW	54.1 SSE	52.9 SSW
	Area 18	31.5 SE	29.1 ENE	18.1 SE	32.1 NW	59.9 SSE	50.5 S
	Area 19	42.4 SSE	27.4 ESE	31.0 SSE	24.3 WNW	74.2 SSE	67.8 S
	Area 20[c]	62.8 SE	51.3 ESE	49.7 SE	0.3 WNW	> 80 km	76.0 SSE
	Area 25	24.6 NE	45.9 NNE	22.2 NNE	62.5 NNW	31.7 SE	21.0 SSW
	Area 30	29.2 E	37.2 ENE	16.8 E	41.3 NNW	51.3 SE	37.4 S
Stockpile Stewardship, Science, and Experimentation	DPFF	7.4 W	27.3 N	20.7 WNW	69.3 NW	32.2 S	49.4 SW
	NCERC	6.4 N	32.5 N	17.8 NW	67.8 NW	27.1 S	40.4 SW
Nonproliferation, Counterterrorism, and Incident Response	UNESE	32.6 SSE	13.7 ESE	24.4 S	37.9 WNW	65.9 SSE	66.2 SSW
Environmental Restoration and Waste Operations	ER-4-1	16.8 S	9.6 NNE	15.5 SW	53.0 WNW	50.2 S	57.7 SSW
	ER-7-1	13.9 SSW	13.0 N	17.7 WSW	59.0 WNW	46.2 S	57.5 SW
	PM-3	55.2 SE	48.3 E	41.7 SE	11.7 N	> 80 km	64.6 SSE
	RNM-2s & UE-5n	16.7 NNW	41.1 N	29.1 NW	79.0 NW	18.5 S	42.5 WSW
	WW C-1	5.4 NW	30.0 N	18.8 NW	68.5 NW	29.1 S	44.6 SW
	WW-3	4.5 S	21.8 N	11.3 W	59.6 NW	38.0 S	47.4 SW
	RWMS 3	10.1 SSW	16.1 N	14.4 WSW	58.6 NW	43.1 S	53.4 SW
	RWMC 5	13.3 NW	36.7 N	26.5 NW	76.3 NW	23.2 S	45.2 WSW
Mission Support	Building 23-652	33.6 N	59.2 N	43.3 NNW	> 80 km	0.2 WNW	36.5 W

(a) Distance is shown in km. For miles, multiply by 0.62.
(b) N=north, S=south, E=east, W=west in all direction combinations shown.
(c) Includes emissions from Sedan, E-Tunnel Ponds, and Schooner from Areas 10, 12, and 20, respectively.

Table 8. Average Radionuclide Concentrations at NNSS Critical Receptor Stations and Fraction of Concentration Level (CL) for CY 2018

Location	Radionuclide	Average Concentration in Air (pCi/m^3)[a]	CL[b] (pCi/m^3)	Average Concentration as Fraction of CL
Yucca	^{3}H	0.59×10^{0}	1500	0.0004
Gate 700 S		0.07×10^{0}		0.0000
3545 Substation		0.15×10^{0}		0.0001
Schooner		68.56×10^{0}		0.0457
Mercury Track		0.17×10^{0}		0.0001
Gate 510		0.13×10^{0}		0.0001
Yucca	^{137}Cs	3.98×10^{-6}	0.019	0.0002
Gate 700 S		74.32×10^{-6}		0.0039
3545 Substation		-30.17×10^{-6}		0.0000
Schooner		25.46×10^{-6}		0.0013
Mercury Track		24.83×10^{-6}		0.0013
Gate 510		-42.33×10^{-6}		0.0000
Yucca	^{241}Am	1.81×10^{-6}	0.0019	0.0010
Gate 700 S		3.34×10^{-6}		0.0018
3545 Substation		2.01×10^{-6}		0.0011
Schooner		2.91×10^{-6}		0.0015
Mercury Track		1.91×10^{-6}		0.0010
Gate 510		2.07×10^{-6}		0.0011
Yucca	^{238}Pu	1.67×10^{-6}	0.0021	0.0008
Gate 700 S		1.74×10^{-6}		0.0008
3545 Substation		3.60×10^{-6}		0.0017
Schooner		5.95×10^{-6}		0.0028
Mercury Track		0.34×10^{-6}		0.0002
Gate 510		-2.79×10^{-6}		0.0000
Yucca	$^{239+240}Pu$	6.82×10^{-6}	0.0020	0.0034
Gate 700 S		15.59×10^{-6}		0.0078
3545 Substation		3.60×10^{-6}		0.0018
Schooner		0.98×10^{-6}		0.0005
Mercury Track		0.99×10^{-6}		0.0005
Gate 510		0.50×10^{-6}		0.0002
Yucca	Sum of Fractions by Locations	Sums for analytes listed above with negative values set to zero.		0.0058
Gate 700 S				0.0143
3545 Substation				0.0047
Schooner				0.0519
Mercury Track				0.0031
Gate 510				0.0014

(a) picocuries per cubic meter (pCi/m^3)
(b) Source: Table 2 in Title 40 CFR 61, Appendix E (Compliance Procedures Methods for Determining Compliance with Subpart I) (CFR 2010a)

Table 9. Average Radionuclide Concentration Fraction of Concentration Level (CL) at all NNSS Air Stations, CY 2018

		Annual Average Concentration / Compliance Level					
Area	Sampling Station	^{3}H	^{137}Cs	^{238}Pu	$^{239+240}Pu$	^{241}Am	Sums of Fractions of CLs[a]
1	BJY	0.0001	0.0033	0.0003	0.0210	0.0040	0.0287
3	Bilby Crater	0.0002	-0.0041	0.0012	0.0294	0.0051	0.0359
3	Kestrel Crater N	0.0003	-0.0002	0.0010	0.0177	0.0047	0.0236
3	U-3ax/bl S	0.0002	-0.0008	0.0006	0.0320	0.0057	0.0384
5	DoD	0.0002	-0.0021	0.0012	0.0035	0.0023	0.0073
5	RWMS 5 Lagoons	0.0003	-0.0017	-0.0003	0.0047	0.0013	0.0063
6	Yucca[b]	0.0004	0.0002	0.0008	0.0034	0.0010	0.0058
9	Bunker 9-300	0.0002	0.0014	0.0053	0.5196	0.0873	0.6138
10	Gate 700 S[b]	0.0000	0.0039	0.0008	0.0078	0.0018	0.0143
10	Sedan N	0.0008	0.0041	0.0017	0.0167	0.0030	0.0262
11	Pu Valley AMS	0.0329	-0.0143	0.0016	0.0470	0.0117	0.0933
16	3545 Substation[b]	0.0001	-0.0016	0.0017	0.0018	0.0011	0.0047
18	Little Feller 2 N	0.0001	-0.0008	-0.0002	-0.0001	0.0014	0.0015
20	North Schooner	0.0011	NM[c]	NM[c]	NM[c]	NM[c]	0.0011
20	Schooner[b]	0.0457	0.0013	0.0028	0.0005	0.0015	0.0519
23	Mercury Track[b]	0.0001	0.0013	0.0002	0.0005	0.0010	0.0031
25	Gate 510[b]	0.0001	-0.0022	-0.0013	0.0002	0.0011	0.0014
27	Able Site	NM[c]	0.0006	-0.0013	0.0002	0.0014	0.0022

(a) Negative values set to zero before summing.
(b) Critical Receptor sample location.
(c) NM = not measured. Only air particulates or atmospheric moisture are sampled at certain locations.

CAP88-PC DOSE ASSESSMENT

The radioactive air emissions from each NNSS source listed in Table 5 were modeled using the Clean Air Package, 1988, model (CAP88-PC, Version 4.0; EPA 2014). Emission locations for Legacy Contamination Sites, Grouped Area Sources, were either the center of the most contaminated location within each of the NNSS operational areas, or the center-point of the operational area if the surface contamination was relatively uniform. Emission locations from projects or facilities were the known release points. Tritium emissions from the E-Tunnel Ponds were included in the Area 12 emission. Wind files containing frequency distributions of wind speed, direction, and stability class from CY 2018 meteorological stations on the NNSS were provided by the National Oceanic and Atmospheric Administration, Air Resources Laboratory, Special Operations and Research Division (ARL/SORD) (Appendix F). Table 10 lists CAP88-PC-predicted annual doses (mrem/y) from each emission source to each receptor location.

COMPLIANCE ASSESSMENT

As can be seen in Table 8, the annual average concentrations of detected radionuclides and their fraction of the NESHAP compliance level for each of the six NNSS critical receptor stations are all below 5% of the CLs with the ^{3}H average at the Schooner sampler station being the maximum at about 4.6% of the CL. The average concentration of ^{3}H is high at Schooner because the air sampler is so close to the Area 20 emission source (Table 7). The highest sum of the fractions at critical receptors stations, measured at the Schooner sampler, was 0.052. This is well below 1.0 and therefore in compliance with the NESHAP standard. The last column of Table 10 lists the total CAP88-PC calculated dose to offsite receptors. The highest predicted dose is at the Cinder Cone Pit Mine but nobody is known to reside there full-time. The maximally exposed individual (MEI) is predicted to be a person residing at the north end of Amargosa Valley 0.07 mrem/y. For comparison, the fractions of the 10 mrem/y air pathway dose limit from CAP-88 modeled MEI dose estimates from CY 1992 to CY 2004 and CY 2017-CY 2018 are displayed in Figure 6 along with the highest critical receptor station monitoring results (Schooner) from CY 2005 to CY 2018.

Based on the CAP88-PC modeling, the only radionuclides contributing more than 10% to the MEI dose were plutonium (^{238}Pu and $^{239+240}Pu$) at 61% and ^{241}Am at 11%. Tritium accounted for 9% and various gamma-emitting radionuclides combine for 18% of the dose.

Table 10. CAP88-PC Dose (mrem/y) from NNSS Sources (" - " indicates receptor is > 80 km [50 mi] from emission)

Location	Grouped Area Sources (a)	DPFF	NCERC	UNESE	UGTA Wells	RWMS 3	RWMC 5	Building 23-652	Total From All NNSS Sources (mrem/y)
Cinder Cone Pit	8.8E-02	4.8E-03	8.1E-03	2.6E-07	3.7E-07	2.8E-05	9.6E-06	3.7E-11	1.0E-01
Amargosa Valley (N. end)	5.2E-02	4.9E-03	1.4E-02	2.5E-07	3.7E-07	2.8E-05	9.7E-06	3.8E-11	7.1E-02
NTTR	5.5E-02	5.0E-03	8.3E-03	1.8E-06	3.6E-07	3.0E-05	9.5E-06	3.6E-11	6.9E-02
Amargosa Valley (center)	5.3E-02	4.8E-03	9.1E-03	-	3.7E-07	2.8E-05	9.6E-06	3.9E-11	6.7E-02
Crystal	4.1E-02	5.0E-03	1.8E-02	-	4.0E-07	2.9E-05	1.0E-05	4.8E-11	6.4E-02
Cactus Springs	3.3E-02	5.4E-03	2.4E-02	-	3.9E-07	3.0E-05	1.0E-05	3.6E-11	6.3E-02
U.S. Ecology	5.0E-02	4.8E-03	5.4E-03	2.0E-07	3.6E-07	2.8E-05	9.4E-06	3.6E-11	6.0E-02
Indian Springs	2.4E-02	5.3E-03	2.1E-02	-	3.8E-07	3.0E-05	9.9E-06	3.6E-11	5.0E-02
Johnnie	2.4E-02	5.1E-03	2.0E-02	-	3.9E-07	2.9E-05	1.0E-05	4.2E-11	4.9E-02
Beatty	3.2E-02	4.8E-03	2.6E-03	2.1E-07	3.6E-07	2.8E-05	9.4E-06	1.1E-09	4.0E-02
Springdale	3.0E-02	4.8E-03	2.2E-03	1.5E-07	5.3E-07	2.8E-05	1.5E-05	1.1E-09	3.7E-02
Cedar Pipeline Ranch	3.6E-02	-	-	2.4E-07	2.3E-10	2.7E-05	-	-	3.6E-02
Penoyer Farm	2.8E-02	4.7E-03	-	2.8E-07	2.3E-10	2.8E-05	-	-	3.2E-02
Cold Creek	8.6E-03	5.2E-03	1.7E-02	-	3.9E-07	2.9E-05	1.0E-05	3.6E-11	3.1E-02
Southern Desert Correctional Center	1.0E-02	5.2E-03	1.5E-02	-	3.7E-07	3.0E-05	9.7E-06	3.6E-11	3.1E-02
Medlin's Ranch	2.1E-02	4.9E-03	4.5E-03	8.6E-07	5.2E-07	2.8E-05	9.3E-06	-	3.0E-02
Rachel	2.5E-02	-	-	4.1E-07	2.1E-11	2.8E-05	-	-	2.5E-02
Tolicha Peak	2.0E-02	-	2.9E-03	9.8E-08	2.3E-10	2.7E-05	-	-	2.3E-02
Lee Canyon Residences (center point)	2.0E-03	5.1E-03	1.3E-02	-	3.8E-07	-	9.9E-06	3.6E-11	2.0E-02
Ash Meadows	2.3E-03	4.9E-03	1.0E-02	-	3.8E-07	2.8E-05	9.9E-06	4.2E-11	1.7E-02
Stateline Area	1.4E-03	4.9E-03	9.3E-03	-	3.7E-07	-	9.5E-06	4.1E-11	1.6E-02
Tempiute	1.4E-02	-	-	3.6E-07	2.0E-11	2.8E-05	-	-	1.4E-02
Mt. Charleston	1.0E-04	-	1.3E-02	-	3.8E-07	-	9.8E-06	3.6E-11	1.3E-02
Sarcobatus Flat	1.1E-02	-	-	7.8E-08	2.3E-10	-	-	-	1.1E-02
Pahrump	1.7E-04	-	1.0E-02	-	3.8E-07	-	9.8E-06	3.7E-11	1.0E-02
Death Valley Junction	7.8E-04	-	8.0E-03	-	3.7E-07	-	1.5E-05	4.0E-11	8.8E-03
Corn Creek Station	8.0E-05	5.1E-03	-	-	3.7E-07	-	9.5E-06	3.6E-11	5.2E-03
Scotty's Junction	3.4E-03	-	-	-	2.0E-10	-	-	-	3.4E-03
Tonopah Test Range	1.8E-03	-	-	-	2.0E-10	-	-	-	1.8E-03
Alamo	1.7E-03	-	-	-	1.5E-12	-	-	-	1.7E-03
Furnace Creek	7.9E-04	-	-	-	-	-	-	1.1E-09	7.9E-04
Reeds Ranch	6.6E-04	-	-	-	2.0E-10	-	-	-	6.6E-04
Ash Spring	5.4E-04	-	-	-	-	-	-	-	5.4E-04
Gold Point	4.8E-04	-	-	-	2.0E-10	-	-	-	4.8E-04
Goldfield and Lida Junction	4.6E-04	-	-	-	2.0E-10	-	-	-	4.6E-04
Gemfield	4.4E-04	-	-	-	-	-	-	-	4.4E-04
Kyle Canyon Rd Residences (mid-point)	7.6E-05	-	-	-	5.3E-07	-	1.5E-05	1.1E-09	9.2E-05
Las Vegas	7.0E-05	-	-	-	-	-	-	1.1E-09	7.0E-05

(a) Tritium from Sedan, E-Tunnel Ponds, and Schooner are included in the Grouped Area Sources for Areas 10, 12, and 20, respectively.

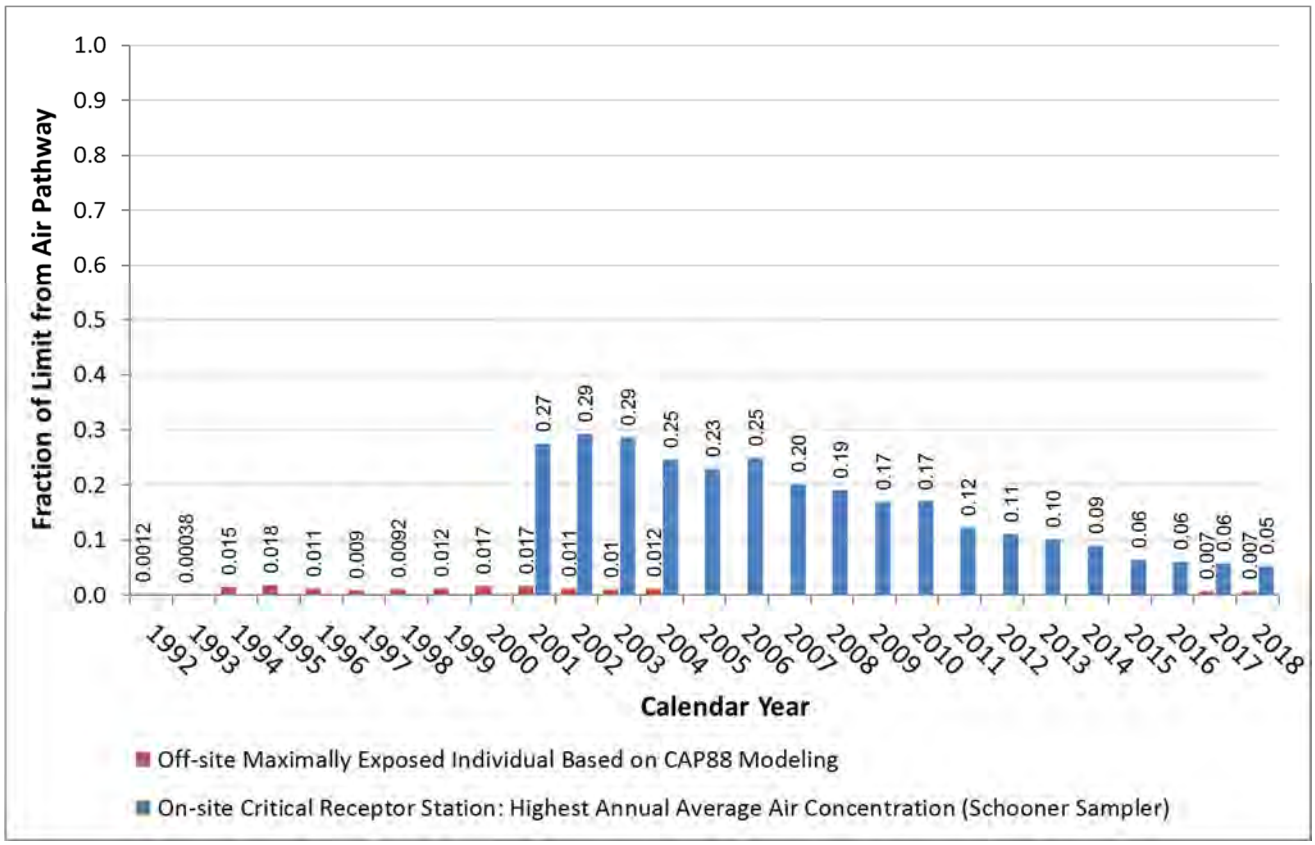

Figure 6. Fraction of the 10 mrem/y Air Pathway Dose Limit for CAP88-PC Modeled MEI Dose and Highest Critical Receptor Station Monitoring Results

SECTION IV
ADDITIONAL INFORMATION

DOSE EVALUATIONS CONDUCTED DURING CY 2018

This section summarizes radionuclide NESHAP evaluations conducted during CY 2018 for potential radionuclide releases and radiation dose estimates from new projects, construction, modifications, or periodic confirmatory measurements of existing activities. These evaluations were performed in accordance with 40 CFR 61, Subpart H, and are separated into the following general categories: Environmental Restoration Projects, Waste Management Projects, Construction Projects, Research Projects, and Periodic Confirmatory Assessments (Table 11). Minor sources are classified as having a potential dose to the offsite MEI of less than 0.1 mrem/y and do not require monitoring; they only require periodic confirmatory evaluations to confirm low emissions. All of the radiation dose assessments performed during CY 2018 were performed with CAP88-PC modeling software, in accordance with 40 CFR 61.93.

ENVIRONMENTAL RESTORATION PROJECTS

Under the *Federal Facility Agreement and Consent Order* (1996) between DOE, the U.S. Department of Defense, and the State of Nevada, radioactive soil contamination generated by historical NNSS activities is addressed. NNSS Environmental Restoration projects that involve the removal and transport of materials and soil containing low concentrations of radioactivity are evaluated for potential radionuclide emissions to air and potential dose offsite. No environmental restoration activities (soil remediation or facility deactivation and decommissioning) with potential for radionuclide air emissions were conducted on the NNSS during CY 2018; therefore, no radiation dose assessments were performed in this category. There were soil remediation activities at the Clean Slate site on the Tonopah Test Range during CY 2018. As mentioned in the Environmental Restoration portion of Section II of this report, environmental monitoring / reporting is conducted by Sandia National Laboratories for this location (http://www.sandia.gov/news/publications/environmental_reports/).

WASTE MANAGEMENT PROJECTS

The Area 5 RWMC actively received and buried waste throughout the year. Waste cells are excavated when needed. The Area 3 RWMS received waste from Clean Slate soil remediation activities during 2018. Continuous air monitoring occurs at two predominant downwind directions from each of the Area 3 RWMS and the Area 5 RWMC and near the center of the Area 3 RWMS. Radionuclide emissions from waste management sites are discussed in Appendix B.

CONSTRUCTION PROJECTS

No construction projects with potential for radionuclide emissions were initiated during CY 2018.

Table 11. NESHAP Dose Evaluations Conducted during CY 2018

Project Description	NNSS Operational Area	Emission Year	Radionuclide Emissions	MEI Dose (mrem/y) and Location
The NNSS supports a variety of nuclear security missions, including nuclear criticality safety research and training, nuclear emergency response, nuclear nonproliferation, and support for other government agencies. A potential project will receive, stage, make receipt measurements, re-palletize, and stage nuclear material. No operations will be performed on the material. If material remains sealed in packaging, there will be no airborne emissions. Although unexpected, for conservatism, this assessment was conducted to determine the potential emissions from handling the radioactive material if it is removed from its packaging.	Area 6	Not Expected	Pu-239	0.02 Cactus Springs, 45.4 km SE
An assessment completed in 2016 was revised to add one radionuclide. This was for the Underground Nuclear Explosion Signature Experiment, Tunnel Test Bed Project. It is being conducted to determine if trace quantities of radioactive noble gases injected approximately 900 feet underground can be detected as they seep to the surface in order to improve the United States' capability to detect and characterize potential underground nuclear testing by foreign states.	Area 12	2018	^{37}Ar, ^{127}Xe, and ^{133}Xe	0.006 13.7 km ESE

PERIODIC CONFIRMATORY MEASUREMENTS

NESHAP regulations require periodic confirmatory measurements for minor release sources to verify low emissions [40 CFR 61.93 (e)]. Furthermore, a Memorandum of Understanding between the EPA and DOE states that "engineering calculations and/or representative measurements may be used to comply with periodic confirmatory measurement requirements" (EPA and DOE 1995). This section lists the periodic confirmatory measurements that were conducted during CY 2018.

Joint Actinide Shock Physics Experimental Research (JASPER)

A sample of stack effluents was taken, April 24 - 25, 2018, during a test using special nuclear material. It was analyzed for ^{238}Pu, $^{239+240}$Pu, and ^{241}Am. No radionuclides were detected in the sample. There is no evidence of radionuclide emissions from JASPER operations, which confirms the assessment of this being a minor emission source (National Security Technologies, LLC, 2013a).

North Las Vegas Facility (NLVF), Building A-01

Biannual measurements of ^{3}H concentrations in air in Building A-01 are made as a best management practice. The potential dose from Building A-01 emissions is calculated each year based on this monitoring information. The emissions during CY 2018 were analogous to the past few years and the resultant dose (0.000008 mrem/y) was well below the 0.1 mrem/y level specified in 40 CFR 61.96. A summary of this is presented in Appendix D.

UNPLANNED RELEASES

There were no known unplanned radionuclide releases during CY 2018.

This page intentionally left blank

REFERENCES

CFR, see Code of Federal Regulations.

Clark County Department of Comprehensive Planning (2018 July 30). Clark County, Nevada 2018 Population Estimates. Documents "Population by Place.pdf" and "Population by ZIP Code.pdf" retrieved from http://www.clarkcountynv.gov/comprehensive-planning/advanced-planning/Pages/Demographics.aspx on 2019, April 1.

Code of Federal Regulations, Title 40, Part 61, "National Emission Standards for Hazardous Air Pollutants: Radionuclides," 2010a. U.S. Environmental Protection Agency, Washington, D.C.

Code of Federal Regulations, Title 10, Part 835, "Occupational Radiation Protection," 2010b. U.S. Department of Energy, Washington, D.C..

DOE, see U.S. Department of Energy.

EPA, see U.S. Environmental Protection Agency.

Federal Facility Agreement and Consent Order, 1996 (as amended). Agreed to by the State of Nevada; the U.S. Department of Energy, Environmental Management; the U.S. Department of Defense; and the U.S. Department of Energy, Legacy Management.

Hendricks, T. J., and S. R. Riedhauser, 1999. *An Aerial Radiological Survey of the Nevada Test Site*, DOE/NV/11718--324. U.S. Department of Energy, Nevada Operations Office, Las Vegas, NV.

National Security Technologies, LLC, 2013a. *National Emission Standards for Hazardous Air Pollutants – Radionuclide Emissions Calendar Year 2012*. DOE/NV/25946--1796. U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office, Las Vegas, NV.

National Security Technologies, LLC, 2013b. *Special Analysis for the Disposal of the Consolidated Edison Uranium Solidification Project Waste Stream at the Area 5 Radioactive Waste Management Site, Nevada National Security Site, Nye County, Nevada*. DOE/NV/25946--1678. U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, Las Vegas, NV.

Nye County Planning Department (2015, October 27). "Nye County Population Estimates Through the Third Quarter, 2015." Retrieved from http://www.nyecounty.net/DocumentCenter/View/24296 on 2018, April 18.

U.S. Department of Energy, 1991. *Radionuclides in Surface Soil at the Nevada Test Site*. DOE/NV/10845--02. Water Resources Center, Desert Research Institute, University of Nevada System, Las Vegas, NV.

U.S. Department of Energy, 1992. *Summary of the Nevada Applied Ecology Group and Correlative Programs*. DOE/NV--357. Raytheon Services Nevada, Las Vegas, NV.

U.S. Department of Energy, 1996. *National Emission Standards for Hazardous Air Pollutants Submittal - 1995*. DOE/NV/11718--032. U.S. Department of Energy, Nevada Operations Office, Las Vegas, NV.

U.S. Department of Energy, 1999a. *Radioactive Waste Management*. DOE O 435.1, Chg. 1, Office of Environmental Management, Washington, D.C.

U.S. Department of Energy, 1999b. *Radioactive Waste Management Manual*. DOE M 435.1-1, Chg. 2, Office of Environmental Management, Washington, D.C.

U.S. Department of Energy, 2003. *Routine Radiological Environmental Monitoring Plan*, DOE/NV/11718--804. U.S. Department of Energy, Nevada Site Office, Las Vegas, NV.

U.S. Department of Energy, 2011. *Quality Assurance*. DOE O 414.1D, April 25, 2011, Washington, D.C.

U.S. Department of Energy, 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. U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, Las Vegas, NV.

U.S. Environmental Protection Agency, 2001a. Letter from Jack P. Broadbent, EPA Region IX Director, Air Division, to Kenneth A. Hoar, DOE Nevada Field [Operations] Office, Environmental, Safety & Health Division, July 23, 2001.

U.S. Environmental Protection Agency, 2001b, Title 40 Code of Regulations, Part 61, "Test Methods for Measuring Radionuclide Emissions from Stationary Sources," Appendix B, Method 114, July 1, 2001 Edition.

U.S. Environmental Protection Agency, 2014. CAP88-PC Version 4.0 User Guide, Office of Radiation and Indoor Air, Washington, D.C.

U.S. Environmental Protection Agency and U.S. Department of Energy, 1995. Memorandum of Understanding Between the U.S. Environmental Protection Agency and the U.S. Department of Energy Concerning the Clean Air Act Emission Standards for Radionuclides 40 CFR Part 61, Including Subparts H, I, Q & T. Signed by Mary D. Nichols, EPA Assistant Administrator for Air and Radiation, September 29, 1994. Signed by Tara O'Toole, DOE Assistant Secretary for Environment, Safety, and Health, April 5, 1995.

U.S. Nuclear Regulatory Commission, 1983. *Radiological Assessment*, NUREG/CR-3332, Till, J. E., and H. R. Meyer, Editors, Office of Nuclear Reactor Regulation, Washington, D.C.

APPENDICES

This page intentionally left blank

Appendix A

Radionuclide Air Emission Sources

Table A.1. Facilities or Areas from Which Radionuclides Were Released to Air in Calendar Year (CY) 2018

Emission Source	Emission Type	Radionuclide(s) Emitted	Handling/ Processing	Nature of Emissions	Effluent Controls	Source Type[a]	Distance[b] and Direction[c] to Nearest Air Sampler(s)
Legacy Contamination Sites							
Sedan Crater (Plowshare), Area 10	Diffuse	Tritium (^{3}H) as tritiated water (HTO), americium (Am), plutonium (Pu), activation and fission products	None	^{3}H as HTO through evaporation from soil or transpiration from plants and suspension of contaminated soil by wind	None	Minor	• Sedan N: 0.8 kilometers (km) N • Critical receptor sampler (Gate 700 S): 2.6 km NE
Schooner Crater (Plowshare), Area 20	Diffuse	^{3}H as HTO, Am, Pu, activation and fission products	None	^{3}H as HTO through evaporation from soil or transpiration from plants and suspension of contaminated soil by wind	None	Minor	• Critical receptor sampler (Schooner): 0.3 km WNW
Grouped Area Sources – All Nevada National Security Site (NNSS) Areas	Diffuse	Am, Pu, activation and fission products (^{3}H as HTO as well, but the vast majority are emitted from Sedan and Schooner—see above)	None	Wind causing suspension of soil containing small amounts of historical fallout/legacy radioactive materials	None	Minor	• See Figure 4 and Table 7
NLVF, Building A-01	Point	Parts of the basement were contaminated with ^{3}H in 1995 including a vacant radiation source well	Air flow through building ventilation system	^{3}H as HTO through emanation from building materials into the air and exhausted from the building through the ventilation system	None	Minor	• Biannual sampling inside room that was contaminated

(a) Minor source has a potential release resulting in a dose of < 0.1 mrem/y to the maximally exposed individual.
(b) Distance is shown in km. For miles, multiply by 0.62.
(c) N=north, S=south, E=east, W=west in all direction combinations shown.

Table A.1. Facilities or Areas from Which Radionuclides Were Released to Air in Calendar Year (CY) 2018 (continued)

Facility or Area	Emission Type	Radionuclide(s) Emitted	Handling/ Processing	Nature of Emissions	Effluent Controls	Source Type[a]	Distance[b] and Direction[c] to Nearest Air Sampler(s)
Stockpile Stewardship, Science, and Experimentation							
Dense Plasma Focus, Area 11	Point	^{3}H, short-lived activation products in air	Production of neutrons using a deuterium-^{3}H reaction	^{3}H gas released through a stack exhaust	None	Minor	• Critical receptor sampler (Yucca): 7.4 km W
National Criticality Experiments Research Center, Area 6	Point	Various activation and fission products (see Table 5)	Critical mass assembly machines at very low power (< 1 watt)	Activation and fission products in gas form	Exhaust goes through HEPA filtration	Minor	• Critical receptor sampler (Yucca): 6.4 km N
Nonproliferation, Counterterrorism, and Incident Response							
Underground Nuclear Explosion Signatures Experiment, Area 12	Diffuse	^{37}Ar, ^{127}Xe, and ^{133}Xe	Underground injection	Gas seepage from underground	Soil cover	Minor	• Sedan N: 12.0 km ESE • Critical receptor sampler (Gate 700 S): 13.7 km ESE

(a) Minor source has a potential release resulting in a dose of < 0.1 mrem/y to the maximally exposed individual.
(b) Distance is shown in km. For miles, multiply by 0.62.
(c) N=north, S=south, E=east, W=west in all direction combinations shown.

Table A.1. Facilities or Areas from Which Radionuclides Were Released to Air in Calendar Year (CY) 2018 (continued)

Facility or Area	Emission Type	Radionuclide(s) Emitted	Handling/ Processing	Nature of Emissions	Effluent Controls	Source Type[(a)]	Distance[(b)] and Direction[(c)] to Nearest Air Sampler(s)
Environmental Restoration and Waste Operations							
E-Tunnel Ponds, Area 12	Diffuse	^{3}H in groundwater flowing from fissures in historical nuclear tests tunnel system	Controlled drainage and containment of groundwater from the tunnel in a series of earthen ponds	^{3}H as HTO through evaporation or transpiration from plants	None	Minor	• Little Feller 2N: 11.9 km WSW • Critical receptor sampler (Gate 700 S): 15 km E
Underground Test Area Activity wells	Diffuse	^{3}H as HTO	Groundwater pumped to the surface	Evaporation of ^{3}H as HTO	None	Minor	• Critical receptor sampler (Yucca): 4.5 km S
Area 3 Radioactive Waste Management Site (RWMS)	Diffuse	^{3}H as HTO (only radionuclide attributable to the low-level waste [LLW])	Subsurface burial of waste	^{3}H as HTO through evaporation from soil or transpiration from plants	Soil cover	Minor	• U-3ax/bl S: < 0.3 km in multiple directions; near the center of the Area 3 RWMS • Critical receptor sampler (Yucca): 10 km SSW
Area 5 Radioactive Waste Management Complex (RWMC)	Diffuse	^{3}H as HTO (only radionuclide attributable to LLW, mixed LLW)	Subsurface burial of waste	^{3}H as HTO through evaporation from soil or transpiration from plants	Soil cover	Minor	• DoD: 0.4 km from NE edge of the Area 5 RWMC • Critical receptor sampler (Yucca): 14 km to the NNW
Mission Support							
Environmental Monitoring Building 23-652, Area 23	Point	^{3}H as HTO	Distillation or drying	^{3}H emission during distillation of samples and preparation of standards	None	Minor	• Critical receptor sampler (Mercury Track): 0.2 km to the east-southeast

(a) Minor source has a potential release resulting in a dose of < 0.1 mrem/y to the maximally exposed individual.
(b) Distance is shown in km. For miles, multiply by 0.62.
(c) N=north, S=south, E=east, W=west in all direction combinations shown.

This page intentionally left blank

Appendix B

NNSS Tritium Emissions Estimated from Air Sampling Data

BACKGROUND INFORMATION

Diffuse emissions of tritiated water (HTO) from the Nevada National Security Site (NNSS) include evaporation from containment ponds, evapotranspiration of soil moisture diffusing through waste covers at the Area 3 Radioactive Waste Management Site (RWMS), the Area 5 Radioactive Waste Management Complex (RWMC), and evapotranspiration of HTO from soil contaminated by atmospheric or near-surface past nuclear weapon testing. Locations that make up the majority of diffuse tritium (^{3}H) emissions on the NNSS are the Schooner and Sedan nuclear test areas, the Area 3 RWMS, the Area 5 RWMC, and the containment ponds at E-Tunnel. Emissions from the E-Tunnel ponds were not estimated from air sampling data because the total volume of water and ^{3}H concentration of the water was known, allowing for an estimate described in Appendix E. For the remaining sites listed, emissions were estimated by scaling concentrations of ^{3}H in air predicted by a modeled 1 curie (Ci) release to concentrations measured at nearby sampling stations. Figure 5 of this report shows the current NNSS air sampling station locations, and Table B.1 lists the samplers near the major diffuse ^{3}H emission locations.

SOURCE TERM ESTIMATES

For each ^{3}H emission location, the Clean Air Package 1988 (CAP88-PC) model was used to estimate the ^{3}H concentration that would be expected at nearby air samplers if 1 Ci of ^{3}H were released from the center of the source location. The total annual emission from each source was then calculated by dividing the annual average concentration of ^{3}H measured at each sampling location adjacent to the source by the CAP88-PC-predicted annual average concentration for a 1 Ci release at each of the same sampling locations. Table B.1 lists the estimated emissions for each source location.

Table B.1. Tritium Emissions from Airborne Tritium Sampling Results during CY 2018

Emission Source	Air Sampler	Annual Average Tritium Concentration (pCi/m^3)[(a)]	CAP88-PC Concentration for 1 Ci Emission (pCi/m^3)	Predicted Tritium Emission (Ci)	Emission Source Average (Ci)[(a)]
Area 3 RWMS	Bilby Crater	0.27	0.0343	7.87	5.9
	Kestrel Crater N	0.38	0.0962	3.95	
Area 5 RWMC	DOD	0.36	0.255	1.41	1.1
	RWMS 5 Lagoons	0.48	0.595	0.81	
Area 10, Sedan	Gate 700 S [(b)]	0.07	0.0166	4.22	6.1
	Sedan N	1.14	0.144	7.92	
Area 20, Schooner	North Schooner	1.59	0.153	10.39	10.4

(a) Average of emissions predicted by samplers for an emission source
(b) Critical Receptor Station

Appendix C

Emissions of Radionuclides from Diffuse Legacy Sites Based on Historical Soil Survey Data and Soil Re-suspension Model

BACKGROUND INFORMATION

Operations Areas 1 through 12 and 15 through 30 on the Nevada National Security Site (NNSS) contain diffuse sources of radionuclides. Historical soil surveys have identified the location of these sources on the NNSS and provided estimates of the amounts of radionuclides that remain in the surface soils (U.S. Department of Energy [DOE] 1991; see Table 1 of this report). The soil, and associated radionuclides, may become airborne due to wind. Results from air samples from these areas indicate that only americium-241 (^{241}Am) and plutonium-239+240 ($^{239+240}$Pu) are routinely detected, and those are in concentrations only slightly above the minimum detectable concentrations. The total emissions (in curies [Ci]) produced each year from all known manmade radionuclides in soil at legacy sites on the NNSS are estimated with a mathematical re-suspension model. This appendix describes all the calculations involved in producing the emission estimates.

RE-SUSPENSION CALCULATIONS

These calculations are needed to estimate how much of the radionuclides in surface soils could actually become airborne (re-suspended) and therefore become an emission. A conservative estimate of emissions from diffuse sources is obtained by the use of a re-suspension equation with parameters derived from actual studies at the NNSS. In NUREG/CR-3332 (U.S. Nuclear Regulatory Commission 1983), pages 5-30, an equation for calculating a suspension rate (fraction re-suspended per second [s]) is given as follows:

$$S = K \times V_g$$

where: S = fractional re-suspension rate (per s), or the fraction of the inventory re-suspended per s
K = re-suspension factor (per meter [m])
V_g = deposition velocity (meters per second [m/s])

The values of K and V_g used in this re-suspension equation are taken from DOE (1992), with values of K provided on page 75. An average of the values is 2×10^{-10}/m. Ranges in V_g of 0.01 to 0.05 m/s, presented in DOE (1992), are used as conservative estimates. When these values are used in the above equation, S is between 2×10^{-12} and 1×10^{-11} per s. To be conservative, the higher fractional re-suspension rate of 1×10^{-11}/s is used. For example, the emission rate in picocuries (pCi)/s for $^{239+240}$Pu from Area 3 is calculated from the product of the $^{239+240}$Pu inventory (37 Ci from Table 1) and S as shown below. The estimated total annual emission is expressed in millicuries per year (mCi/y).

$$37\ Ci \times \frac{10^{-11}}{s} \times \frac{3600\ s}{hour} \times \frac{24\ hours}{day} \times \frac{365\ days}{yr} = \frac{1.17 \times 10^{-2} Ci}{yr}\ or\ \frac{11.7\ mCi}{yr}$$

This method was used for calculating the emissions of man-made radionuclides from all other areas. The results are shown in Table C.1.

Table C.1. Emission Estimates from Inventories[(a)] of Man-made Radionuclides in NNSS Surface Soil

	Annual Emission (mCi) Using Emission Factor of 1 x 10^{-11} s^{-1}								
Area	**^{60}Co**	**^{90}Sr**	**^{137}Cs**	**^{152}Eu**	**^{154}Eu**	**^{155}Eu**	**^{238}Pu**	**$^{239+240}$Pu**	**^{241}Am**
1	0.0082	2.4	1.4	1.1	0.0032	0.0025	1.6	7.6	1.9
2	0.0089	7.3	3.9	1	0.00	0.002	2.2	6.9	1.5
3	0.0074	5.2	2	1.3	0.0032	0.0025	0.78	12	2.4
4	0.012	2.1	2	0.67	0.00	0.00099	3.3	13	3.1
5	0.0044	0.14	0.066	0.73	0.0063	0.00	0.025	1.5	0.31
6	0.0015	0.56	0.46	0.00	0.00	0.00	0.83	2.6	0.74
7	0.0074	1.5	0.85	1.6	0.0063	0.0015	0.15	5	1.1
8	0.042	4	6.9	0.32	0.00	0.003	2	35	8.1
9	0.0052	2.1	1.4	1.7	0.0063	0.0015	0.55	28	3.6
10	0.072	8.7	14	0.16	0.0095	0.025	4.8	35	8.7
11	0.00	0.048	0.082	0.00	0.00	0.00	0.13	9.1	1.8
12	0.0089	2.7	3.3	0.00	0.00	0.00	2.1	12	2.8
15	0.0022	3.5	3.1	0.00	0.00	0.00	2	20	4.1
16	0.00074	0.59	0.47	0.00	0.00	0.00	0.38	1.2	0.31
17	0.0074	3	2.5	0.00	0.00	0.00	1.1	5.7	1.3
18	0.0052	2.7	1.6	0.081	0.0032	0.004	1.4	32	8.4
19	0.0082	4.9	5.9	0.00	0.00	0.00	8.1	44	10
20	0.059	0.68	0.9	0.95	0.051	0.024	7.6	13	8
25	0.00	0.016	0.033	0.029	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.0059	0.21	0.25	0.051	0.0032	0.00099	1.1	4.4	1.3
Total (mCi/y)	0.27	52	51	9.7	0.092	0.067	40	290	69

(a) Radioactive inventories from Table 5 in DOE/NV/10845--02 (DOE 1991) and decay corrected to the middle of CY 2018 (July 2, 2018), with inclusion of ingrowth of ^{241}Am from ^{241}Pu.

As shown in Table C.1, the estimated total emissions from soil inventory data and from the re-suspension model are reported to two significant figures (mCi/y). These are shown in Tables 3 and 5 of this report (as Ci/y), which summarizes all measured or computed emissions from the NNSS in calendar year 2018. The spatial relation between these diffuse emission locations and the critical receptor stations can be seen in Figure 4.

Appendix D

Potential Radionuclide Emissions and Dose from the North Las Vegas Facility

As discussed in the 1995 National Emission Standard for Hazardous Air Pollutants (NESHAP) report (U.S. Department of Energy 1996), 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. Environmental surveillance began on the day notification of the tritium leak occurred. Environmental tritiated water (HTO) samplers were installed at three locations outside the facility. Later, an HTO sampler was installed in the basement and operated continuously so that progress on cleanup of the spill could be monitored. After cleanup, the environmental samplers were removed, but the basement air sampler continued operation through January 5, 1998, at which time samples were collected one to four times annually. From 1995 to the present, results and the effective dose equivalent (EDE) to the maximally exposed individual (MEI) offsite at the perimeter fence have been reported in the annual NESHAP reports.

During the years 1999 through 2018, air sampling for HTO in the basement was conducted intermittently. For CY 2018, the results of two atmospheric moisture samples were 124 picocuries per cubic meter (pCi/m^3) for the sample collected April 9–16, 2018, and 194 pCi/m^3 for the sample collected September 11–18, 2018. The average of these sample results (159 pCi/m^3) was multiplied by the room ventilation rate (673 cubic feet per minute [ft^3/min]) to determine the total annual emission rate as shown below. The estimated total annual emission is expressed in millicuries per year (mCi/y).

$$\frac{159\ pCi}{m^3} \times \frac{673\ ft^3}{min} \times \frac{0.02832\ m^3}{ft^3} \times \frac{525{,}600\ min}{y} \times \frac{1\ \times 10^{-9}\ mCi}{pCi} = \frac{1.59\ mCi}{y}$$

A dose coefficient of 5.0×10^{-6} millirem per year per millicurie (mrem/y/mCi) released is used to determine dose to the MEI from NLVF tritium emissions. This is based on earlier results from the Clean Air Package 1988 model using conservative assumptions to maximize dose and observed tritium emissions. This coefficient multiplied by the tritium emission for CY 2018 gave the estimated EDE to the nearest member of the public outside the perimeter fence shown below in both mrem/y and microrem per year (µrem/y).

$$\frac{1.59\ mCi}{y} \times \frac{5.0\ \times 10^{-6} mrem}{mCi} = \frac{0.000008\ mrem}{y}\ or\ \frac{0.008\ \mu rem}{y}$$

A comparison of the emission rates and radiation dose to the MEI since 2005 is presented in Table D.1.

Table D.1. Comparison of Tritium Emission Rates from Building A-01, NLVF from 2005 to 2018

Year	Tritium Emission Rate (mCi/y)	EDE to MEI (µrem/y)
2005	20	0.10
2006	13.2	0.07
2007	12.3	0.06
2008	11.1	0.06
2009	8.7	0.044
2010	6.45	0.032
2011	4.83	0.024
2012	4.74	0.024
2013	2.27	0.011
2014	1.72	0.0086
2015	2.39	0.012
2016	2.14	0.011
2017	1.95	0.0098
2018	1.59	0.008

Appendix E

Calculation of Tritium Emissions from Contaminated Groundwater Discharges

The calendar year (CY) 2018 air emissions (in curies [Ci]) of tritium, as tritiated water from contaminated groundwater sources, were conservatively estimated. Emissions were computed as the product of the volume of water (in liters [L]) either pumped or naturally emerging to the surface and the tritium concentration (as picocuries per liter [pCi/L]) measured in that water using the following formula. It was assumed that all of the tritiated water evaporated.

$$Water\ Concentration\ \left(\frac{pCi}{L}\right)\ x\ Water\ Volume\ (L)\ x\ \frac{1\ x\ 10^{-12}\ Ci}{pCi}$$

Water flow-rate from the E-Tunnel is measured monthly and the tritium concentration in the water is measured annually in support of Water Pollution Control Permit NEV 96021. The total volume of water is determined by multiplying the flow-rate by the number of days in the month when the measurement was taken, then summed for all 12 months. Because the tritium concentration is decreasing over time, the value used to determine the emission was the average of the CY 2017 and CY 2018 samples (one sample collected in October of each year).

The volume of contaminated water pumped from wells is measured throughout the purging and sampling process. Samples are collected for analysis of tritium throughout the time during which water is pumped from the wells. The tritium concentration used to determine the emission is an average representative of all water pumped to the surface.

The tritium concentration and volume of groundwater discharges during 2018 are listed in Table E.1. The volume of water multiplied by the tritium concentration yields the estimated tritium emission to air during 2018 under the assumption that all of the water evaporated during 2018.

Table E.1. Tritium Concentrations, Water Volumes, and Estimated 2018 Tritium Emissions from Contaminated Groundwater Brought to the Surface

Location	Tritium Concentration (pCi/L)	Water Volume (L) [a]	Tritium Emission (Ci)
E-Tunnel Ponds	295,000 [b]	14,803,632	4.37
Well ER-4-1	341	15,751	0.0000054
Well ER-7-1	4[c]	148,195	0.00000054
Well PM-3	229 569	35,560 34,648	0.000028
Well RNM-2s	81,333	271,395	0.022
Well UE-5n	126,500	144,765	0.018
Well WW C-1	13	119,558	0.0000015
Well WW-3	9	32,581	0.00000029

(a) All water was assumed to evaporate during CY 2018.

(b) Average of results from October 2017 and October 2018 samples.

(c) Value is considered not-detected by the US DOE contractor reporting the value (Navarro) due to it being less-than the minimum detectable concentration (2.81 pCi/L) plus the error (2.05 pCi/L). It is included here because it is greater than the minimum detectable concentration.

Appendix F

Identification and Justification for the Development of Meteorological Data Used as Input to Clean Air Package 1988 (CAP88-PC)

Meteorological support, observations, and climatological services for the Nevada National Security Site (NNSS) are provided to the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) by the Air Resources Laboratory, Special Operations and Research Division (ARL/SORD). The ARL/SORD is a National Oceanic and Atmospheric Administration (NOAA) office and supports NNSA/NFO programs under the authority of an Interagency Agreement between NOAA and NNSA/NFO.

METEOROLOGICAL OBSERVATIONS

The ARL/SORD manages, operates, and maintains a meteorological monitoring program that is designed and used to support the NNSA/NFO-authorized activities on the NNSS. This vital program consists of many meteorological monitoring systems that have been brought together under the Meteorological Integrated Data Network (MIDNET). The MIDNET includes a Meteorological Data Acquisition (MEDA) network of 21 meteorological towers located on the NNSS (Figure F.1) and one on Yucca Mountain. The MIDNET consists of communications systems, local area networks, and surface-based instrumentation used to measure wind direction and speed, temperature, relative humidity, atmospheric pressure, and precipitation. The MIDNET has been operated on the NNSS for more than 40 years, has undergone several modernizations and upgrades, and serves as a solid basis for deriving climatological information.

Upper-air observations (radiosondes) were taken twice daily from Desert Rock Meteorological Observatory (DRA; elevation 1007 meters [m], located 4.8 kilometers southwest of Mercury, Nevada [Station 30 in Figure F.1]) but were discontinued in October 2010. Upper-air data are currently collected at the National Weather Service office in Las Vegas. DRA had been in operation since May 1978 and was built to replace a similar observatory that was located at the Yucca Flat Meteorological Observatory (UCC; elevation 1,196 m) from January 1962 through mid-May 1978. Consequently, surface and upper-air observations are also available from UCC for 1962–1978.

A key component of the MIDNET system is the MEDA station. A MEDA station consists of a 10-m tower, a data-logger, meteorological sensors, and a radio transmitter. The 22 MEDA stations located on or near the NNSS (Figure F.1) provide surface weather data for climatology, weather forecasts, and warnings for NNSS operations and emergency response activities. MEDA station locations were selected based on criteria to support NNSS consequence assessment activities, compliance reporting requirements, and general weather and forecasting needs.

Wind and temperature data have been collected on the NNSS for more than 40 years. These and other meteorological data have been compiled into a comprehensive climatological database for the NNSS. The MEDA data are especially useful in assessing boundary layer flow regimes on the NNSS.

The wind speed and direction sensor is located 10 m above the ground. Wind direction is measured to ±5 degrees of azimuth, and wind speed is accurate to 0.5 knots. Wind data are collected as 15-minute averages and are transmitted via radio and sent over the NNSS intranet to a central processor every 15 minutes. These data are reviewed by ARL/SORD and are stored and archived for climatological purposes.

Ambient temperature and relative humidity sensors are located approximately 1.5 m above ground level. MEDA temperature data are accurate to ±0.2 degrees Celsius (°C) (absolute range for the NNSS is −29°C to 46°C). Temperature and relative humidity measurements are 15-minute averages and are also transmitted via radio to a computer server for processing, review, display, and archiving.

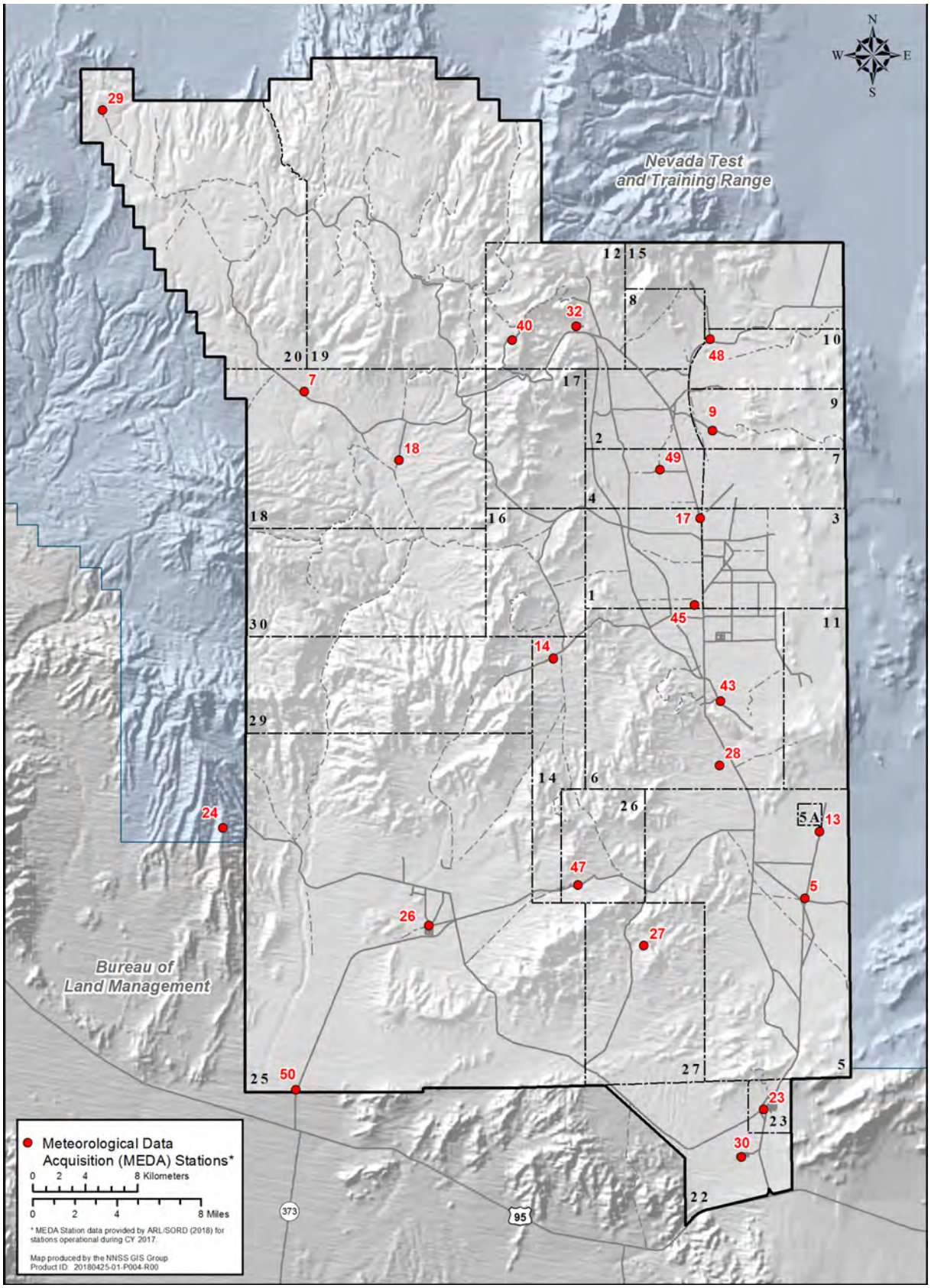

Figure F.1. Locations of MEDA Stations on the NNSS at End of CY 2018

Cloud cover observations are needed to create the Stability Array (STAR) files with the STAR program. In order to use the most representative meteorological data available for NNSS, cloud observations from DRA are melded with MEDA winds. Cloud data are available for DRA (1978–present) and for UCC (1962–1978). Based on the available data, the cloud cover climatology from DRA and UCC are quite compatible. For example, UCC experienced 192 clear days annually, while DRA has 191 days. In addition, the average annual sky cover from sunrise to sunset for both stations was/is 0.39 daily. The total number of cloudy days for UCC is 81 days and 82 days for DRA, annually. Therefore, the cloud cover observations from DRA and UCC may be considered as representative for most areas of the NNSS.

APPLICATION TO CAP88-PC INPUT

Based on the above considerations and on the limitations of the Clean Air Package 1988 (CAP88-PC) computer program, the cloud cover data from DRA are considered to be representative of the NNSS. Therefore, atmospheric soundings and cloud cover observations from DRA were melded with MEDA surface wind data for input to the STAR program to provide the best data for calculating transport and dispersion processes. The STAR file is a matrix that includes seven Pasquill stability categories (A through G), six wind speed categories, and 16 wind sectors from wind roses calculated for each specified MEDA station on the NNSS. The STAR files are used by a CAP88-PC utility program to create WIND files that are used by CAP88-PC to estimate offsite dose from NNSS emissions (Section III) and to emissions from diffuse tritium sources on the NNSS (Appendix B).

This page intentionally left blank

Appendix G

Supplemental Information

COLLECTIVE EFFECTIVE DOSE EQUIVALENT

The collective effective dose equivalent (EDE) is the sum of the dose predicted by the CAP88-PC at each offsite receptor location multiplied by the population at that location. The collective EDE for CY 2018 was 0.74 person-rem [roentgen equivalent man] per year (y) for the 503,300 people who lived within 80 km (50 mi) of NNSS emission sources.

COMPLIANCE WITH 40 CFR 61, SUBPARTS Q AND T

The NNSS is regulated by Title 40 Code of Federal Regulations (CFR) Part 61, Subpart H ("National Emission Standards for Emissions of Radionuclides Other than Radon from DOE Facilities") but not Q ("National Emission Standards for Radon Emissions from DOE Facilities") or T ("National Emission Standards for Radon Emissions from the Disposal of Uranium Mill Tailings") (CFR 2010a). However, U.S. Department of Energy Order DOE O 435.1, "Radioactive Waste Management" (DOE 1999a) does include limits on radon flux from waste disposal facilities. Therefore, radon flux measurements are routinely made at the Area 3 Radioactive Waste Management Site and at the Area 5 Radioactive Waste Management Complex (RWMC). This is done to confirm that radon fluxes are below the standard of 20 picocuries per square meter per second required by U.S. Department of Energy Manual DOE M 435.1-1, "Radioactive Waste Management Manual" (DOE 1999b). The maximum radon flux measurement taken during 2018, at the Area 5 RWMC was 2.3 $pCi/m^2/s$. An assessment of the potential risks posed by the Area 5 RWMC to the public projected that the in-growth of radon-222 from the decay of thorium-230 in thorium wastes would not exceed the standard for approximately 4,200 years (National Security Technologies, LLC, 2013b).

NON-DISPOSAL/NON-STORAGE SOURCES OF RADON EMISSIONS

None of these sources exist on the NNSS.

QUALITY ASSURANCE PROGRAM FOR NESHAP COMPLIANCE

The quality assurance program for samples collected and analyzed for NESHAP compliance is documented in an environmental monitoring plan (DOE 2003). The applicable requirements of 40 CFR 61, Appendix B, Method 114, "Test Methods for Measuring Radionuclide Emissions from Stationary Sources" (U.S. Environmental Protection Agency 2001b) and of DOE O 414.1D, "Quality Assurance" (DOE 2011) have been implemented in this plan.