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Title: 2021 Radionuclide Air Emissions Report for Los Alamos National Laboratory, Revised October 2022

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Environmental Regulatory Document

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LA-UR: 22-24785
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Mr. David Garcia, Director
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U. S. Environmental Protection Agency, Region 6
1201 Elm Street, Suite 500
Mail Code: AR
Dallas, TX 75270

Subject: 2021 Radionuclide Air Emissions Report for Los Alamos National Laboratory, Revised October 2022

Dear Mr. Garcia:

Enclosed is a revision to the Calendar Year 2021 Radionuclide Air Emissions Report for the Los Alamos National Laboratory (LANL). This report is a regulatory compliance deliverable for LANL under the Radionuclide NESHAP, 40 CFR 61 Subpart H.

The revised report is needed to correct an error identified regarding generation of wind data files. These wind data files are used for plume modeling as part of calculating off-sites doses from monitored radionuclide air emissions sources. The error resulted from a software update by LANL's meteorology team after new towers were added to the tower network. As a result of this error, incorrect wind frequencies were assigned to the different stability classes. This slightly affected the plume model calculations and subsequent off-site dose determinations for analyses using these wind files.

The error was discovered by the meteorology team in July 2022. EPA Region 6 was notified at that time. Corrected wind files were generated and doses re-calculated for all of the major source emissions. The differences were very small; some doses increased and some decreased. The net result was only a negligible change to the overall sum of doses calculated by CAP88, a total dose from these sources of 0.00364 millirem, relative to the originally calculated dose of 0.00423 millirem from these monitored stacks. No changes were needed to the portion of the 2021 dose resulting from Airnet ambient air measurements (0.246 millirem) or to the portion from minor source potential emissions (0.252 millirem). When these different components are combined, there is no change to the overall reported dose for 2021. **The annual dose from radionuclide air emissions in 2021 from LANL operations remains 0.50 millirem.** This maximally exposed individual location is a business at 132 DP Road, Los Alamos, NM. The annual dose is well below the EPA standard of 10 millirem per year as established in Subpart H.

Data in this report reflect dose calculations made with the corrected wind files. Change bars on the left margin and highlighted text indicate where changes were made. Note that when an entire table is updated (e.g., Tables 11 and 12), only the table header is highlighted. The majority of the report is unchanged; updated calculations appear first on page 25 of the attached report.

Additional details on the issue and a comparison of the original doses and corrected doses appears in a summary memo, LA-UR-22-30328. That document is available upon request.

If you have any questions, please contact David Fuehne of LANL's Environmental Protection & Compliance Division, Compliance Programs Group, at (505) 699-5619.

Sincerely,

WILLIAM MAIRSON
(Affiliate)

Digitally signed by WILLIAM
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William R. Mairson
Associate Laboratory Director, Acting
Environment, Safety, Health and Quality
Los Alamos National Laboratory
Triad National Security, LLC

Sincerely,



Theodore A. Wyka
Manager, Los Alamos Field Office
National Nuclear Security Administration
U.S. Department of Energy
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Attachment(s): 2021 LANL Radionuclide Air Emissions Report, Revised October 2022; LA-UR-22-24785

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Attachment 1
2021 LANL Radionuclide Air Emissions
Report, Revised October 2022

ESHQSS: 22-066

LA-UR-22-24785, October 2022 Revision

Date: 12/5/22

2021 LANL Radionuclide Air Emissions Report

(Revised October 2022)

Documenting compliance with 40 CFR 61, Subpart H, the Radionuclide NESHAP

Site Name: Los Alamos National Laboratory

Location: County of Los Alamos, New Mexico

DOE Offices Information:

<p>Office: Los Alamos Field Office (NA-LA)</p> <p>Address: U. S. Department of Energy National Nuclear Security Administration Los Alamos Field Office 3747 West Jemez Road Los Alamos, NM 87544</p> <p>Contact: Adrienne Nash (505) 665-5026</p>	<p>Office: Los Alamos Field Office (EM-LA)</p> <p>Address: U. S. Department of Energy Environmental Management Los Alamos Field Office 1200 Trinity Drive Los Alamos, NM 87544</p> <p>Contact: Hai Shen (505) 709-7600</p>
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Site Information:

<p>Primary Operator (NNSA): Triad National Security, LLC (Triad)</p> <p>Address: Los Alamos National Laboratory P. O. Box 1663 Los Alamos, NM 87545</p> <p>Radionuclide NESHAP Compliance Contact: David Fuehne (Triad) (505) 699-5619 / davef@lanl.gov</p>	<p>Secondary Operator (EM): Newport News Nuclear BWXT - Los Alamos (N3B)</p> <p>Address: N3B Los Alamos 1200 Trinity Drive Suite 150 Los Alamos, NM 87544</p>
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Compliance Assessment:

2021 Off-Site Effective Dose Equivalent: 0.50 mrem

2021 LANL Radionuclide Air Emissions Report

Executive Summary

This report describes the emissions of airborne radionuclides from operations at Los Alamos National Laboratory (LANL) for calendar year 2021 and the resulting off-site dose from these emissions. This document fulfills the requirements established by the National Emissions Standards for Hazardous Air Pollutants in 40 CFR 61, Subpart H – Emissions of Radionuclides other than Radon from Department of Energy Facilities, commonly referred to as the Radionuclide NESHAP or Rad-NESHAP.¹

Compliance with this regulation and preparation of this document is the responsibility of LANL’s Rad-NESHAP compliance program, which is part of the Environmental Protection and Compliance (EPC) Division. The information in this report is required under the Clean Air Act and is being submitted to the U.S. Environmental Protection Agency (EPA) Headquarters and EPA Region 6.

The highest effective dose equivalent (EDE) to an off-site member of the public was calculated using procedures specified by the EPA and described in this report. LANL’s EDE was 0.50 for 2021. The annual limit is 10 millirem per year, established by the EPA in 40 CFR 61 Subpart H. All measured air emissions are modeled to a single location, known as the Maximally Exposed Individual (MEI).

During calendar year 2021, LANL continuously monitored radionuclide emissions at 27 “major” release points, or stacks. The Laboratory estimates emissions from an additional 60 “minor” release points using radionuclide usage source terms in lieu of stack monitoring. Also, LANL uses an EPA-approved network of air samplers around the Laboratory perimeter to monitor ambient airborne levels of radionuclides. To provide data for dispersion modeling and dose assessment, LANL maintains and operates meteorological monitoring systems. From these measurement systems, a comprehensive evaluation is conducted to calculate the MEI dose for the Laboratory.

The MEI can be any member of the public at any off-site location where there is a residence, school, business, or office. In 2021, this MEI location was a business at 132 DP Road, located at the western end of DP Road. The primary contributor to the off-site dose at this location was the resuspension of legacy contaminants along DP Road during 2021; other contributors include radioactive gas emissions from sources at the LANSCE accelerator complex and potential emissions from minor sources throughout the Laboratory. Overall, the MEI dose in 2021 is similar to levels in recent years and is well below the EPA’s 10 millirem per year limit. Doses reported to the EPA for the past 10 years are shown in Table E1.

¹ *Code of Federal Regulations*, Title 40, Part 61.90, Subpart H, 1989. “National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities,” promulgated by the U. S. Environmental Protection Agency.

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Table E1. Ten-Year Summary of Rad-NESHAP Dose Assessment for LANL

Year	EDE (mrem)	Highest EDE Location
2012	0.58	2201 Trinity Drive, Airnet Station 257
2013	0.21	2101 Trinity Drive, Airnet Station 324
2014	0.24	95 Entrada Drive
2015	0.13	2470 East Road (“East Gate”)
2016	0.12	2470 East Road (“East Gate”)
2017	0.47	2101 Trinity Drive, Airnet Station 324
2018	0.35	2470 East Road (“East Gate”)
2019	0.43	278 DP Road, Airnet Station 317
2020	0.29	132 DP Road, Airnet Station 326
2021	0.50	132 DP Road, Airnet Station 326

Human Health Impact

The EPA has established a dose limit of 10 millirem per year for public exposure to airborne releases of radioactive material from DOE facilities. This value was established to be protective of even the most vulnerable population groups and keep lifetime public radiological doses well below levels that have any measurable health consequences. For comparison, the average member of the public receives hundreds of millirem per year in naturally occurring radiation. For details on radiation exposure, risks, and regulatory limits, please see <https://www.epa.gov/radiation>.

As shown in Table E1 above, LANL’s air emissions typically result in less than 5% of the EPA limit. Emissions can increase during environmental remediation actions (e.g., MDA-B in 2011 as discussed in the annual report for 2011 operations). All sources that are likely to have air emissions that would approach 1 millirem per year have an established emissions management plan to ensure that EPA regulations are met and the public health is protected.

2021 Noteworthy Events

Several events that took place in 2021 are worth discussion in this Executive Summary. They are divided into administrative events, dealing with execution of the compliance program at LANL; facility operational events, pertaining to changes at LANL’s air emissions sources; and new facility/permitting actions in 2021.

Administrative & Programmatic Events

LANL Prime Contract Separation.

The DOE contract to manage operations at Los Alamos National Lab was split in 2018. The bulk of LANL operations is managed by the National Nuclear Security Agency (NNSA) Field Office in Los Alamos, referred to as NA-LA. Triad National Security, LLC is the operations contractor for NA-LA. The DOE's Environmental Management Los Alamos Field Office (referred to as EM-LA) manages legacy waste operations and cleanup activities on the site. Newport News Nuclear BWXT Los Alamos, LLC (N3B) performs this scope for EM-LA. N3B manages legacy waste operations, primarily at the Technical Area (TA-) 54 waste disposal facility and the TA-21 legacy cleanup site, along with other environmental cleanup sites around LANL and the nearby community. All other LANL operations are operated by Triad for NA-LA.

The current operational protocol has all LANL operations collected under a single Rad-NESHAP compliance program, managed by the NNSA contractor (Triad). This makes operational sense due to the small program on the EM side in comparison with the larger NNSA program and also meets the desire of EPA Region 6 to keep a single point of contact for the radionuclide operations at LANL. Triad performs all stack emissions measurements, ambient air monitoring, compliance evaluations, and regulatory reporting for all LANL sites in a single program. These services are provided by Triad for N3B operations under a Service Agreement between the two entities.

Impacts from COVID-19 Pandemic.

The worldwide pandemic of COVID-19 resulted in a change in the Laboratory operations posture starting in March 2020. The Laboratory quickly moved to a Mission Critical Operations Only posture, then later in 2020 transitioned into a mode of Limited Operations, then to Normal Operations with Maximized Telework. These changes were aimed at protecting the LANL workforce while still meeting Laboratory mission requirements. The effects of these operational modes were discussed more thoroughly in the 2020 Annual Report.

Operations at LANL began to slowly ramp up over the summer of 2020. LANL moved to and remained in a mode of Normal Operations with Maximized Telework throughout the remainder of 2020 and through 2021 due to surges of COVID-19 cases. As in 2020, continuous monitoring was maintained at all sample locations, Airnet sampling continued on its standard

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biweekly change-out schedule, and support activities continued as facility schedules allowed. LANL returned to Normal Operations as of May 2, 2022.

Off-site Analytical Laboratory Sample Analysis Delays.

Beginning in May 2021, the Radionuclide NESHAP compliance program noticed a delay in obtaining results from the off-site analytical laboratory. After speaking with the analytical laboratory multiple times via email about the issue, the Rad-NESHAP team was able to meet via a teleconference with the analytical laboratory to fully discuss the problem in early 2022. Due to staffing shortages, management changes, and supply chain issues due to COVID-19, the analytical laboratory was unable to maintain the expected turn-around for sample results. After discussing LANL's needs with the analytical laboratory, weekly results began to come in closer to the expected return times. Despite the delays in analysis results, LANL was able to process the results and complete the annual report for 2021 on time.

New Meteorological Towers.

In 2021, three new meteorological towers began taking data at LANL. These new towers will supplement the existing network of meteorological towers, measuring wind speed and direction, temperature, and other data. The towers were sited to directly support nuclear facility operations at TA-16, TA-54, and TA-55. Data from these towers will also be used in future years for plume modeling and Radionuclide NESHAP compliance; however, since they only operated for part of the year in 2021, these new towers were not used for 2021 compliance calculations.

Facility Operational Events

Radioactive Material Remediation on DP Road.

As discussed in the 2020 annual report, radiological material was discovered on DP Road in 2020 in areas that has previously been transferred from LANL to Los Alamos County. This discovery resulted in DOE & LANL providing assistance from radiological control technicians, air and soil sampling staff, and dose assessment personnel. As part of the LANL response, Airnet station #326 immediately downwind of the excavation work area was reactivated on February 26, 2020. As excavation work on DP Road and EM cleanup activities at TA-21 continue, the need for increased coverage of the Airnet network resulted in the reactivation of Airnet stations #327

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and #328 on DP Road on May 17, 2021. These three stations continue operation currently in 2022, and are managed as part of the Airnet compliance program.

The air sample results for 2021 show that station 326 measured airborne radioactive material concentrations corresponding to a dose of 0.25 millirem. This dose, about half from legacy plutonium air concentration and half from resuspension of natural uranium in the soil, is consistent with other DP Road data. Elevated concentrations of natural uranium in the air are expected at any location where there is significant excavation and construction activities in the area due to wind-borne resuspension of soil. While this measured dose is well below the EPA limit of 10 millirem per year, Station 326 was the site-wide MEI for LANL air emissions for 2021. More details are provided later in this document.

Self-Identified Error in LANSCE Gas Emissions Calculation Process.

When reviewing the annual emissions for 2020 and updating associated procedures, an error was discovered in the calculation of gaseous mixed activation product (GMAP) emissions from the Los Alamos Neutron Science Center (LANSCE) main stack, designated 53000702. The error pertained to the method used for determining the relative concentrations of different short-lived radionuclides emitted from the stack. The net effect was very small, corresponding to a less than 0.001 millirem per year change in dose, but needed to be addressed as it affected several years' worth of data, 2015-2019. More details on the issue and impact were included in the 2020 annual report.

This issue was entered into the LANL issues management tracking system, and a full assessment was initiated in 2021 and finalized in early 2022. This assessment report has been sent to EPA Region 6. Again, the result of the dose assessment based on the recalculated radionuclide emissions from LANSCE does not change the reported MEI dose for any of the affected years.

New Sampling Systems at TA-55 PF-4.

As described in prior reports, new samplers have been installed in the basement of the TA-55 plutonium facility, PF-4. These new systems use single-point shrouded probes and are state-of-the-art upgrades over the multi-point samplers installed on the PF-4 roof. Both sets of samplers were in operation beginning in 2019. Until the new systems are fully integrated into the Rad-NESHAP operations program, including flow measurements and inspections, these new

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systems will continue to be considered “R&D” systems and not used for formal EPA compliance. LANL is reporting emissions based on the existing rooftop samplers for 2021. A full statistical analysis comparing the data sets from the two sets of samplers is forthcoming.

TA-59-0001 Operations.

Operations from the aged Chemical & Metallurgical Research (CMR) facility at LANL TA-3 are moving to new locations. Some of these operations are moving into existing radiological laboratories within TA-59 Building 1. This building is an existing minor source of radionuclide emissions, so no notifications or monitoring is required under the Radionuclide NESHAP. Operations began transition in 2020, and have been included in the annual analysis of minor source potential emissions throughout LANL, called the Radioactive Material Usage Survey.

As operations in TA-59-1 increase, this source may need to transition from a minor source up to major source status. At this point, LANL will submit an Application for Pre-Construction Approval to EPA Region 6 prior to operations reaching major status.

TA-53-0984 Operational Issues.

The Isotope Production Facility (IPF) at TA-53-0984 is currently a minor source of radionuclide air emissions. IPF was intended to operate for the duration of the 2021 run cycle, which extended to the end of December. However, beam tuning activities in October 2021 resulted in a failure of the vacuum window at the exit of the IPF beam pipe. This failure resulted in an early cessation of beam operations in 2021. The exhaust stack is monitored for radioactive gas releases and the monitoring system was fully operational at this time; no unusual emissions were detected at the time of failure. The beam pipe window has been repaired and a full operational schedule is anticipated for 2022, starting in June.

Minor Unplanned Releases.

A small number of minor unplanned releases took place in 2021. These are mentioned below and appear again in the “Unplanned Releases” section of this report.

At the TA-50-0001 Radioactive Liquid Waste Treatment Facility (RLWTF), a piping failure resulted in the spill of approximately 3,500 gallons of treated effluent in March 2021. This effluent was being sent to the Mechanical Evaporation System (MES) at TA-50-0257. The

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spilled water did not leave the site, reach a storm drain, or adversely affect any Solid Waste Management Unit. This spill was reported to the New Mexico Environment Department on April 2, 2021, per procedure. Potential airborne emissions from this event are included in the tracking for the MES, which is a minor source of radionuclide air emissions.

EPC staff were notified in November 2021 about a spill of contaminated water within the beam tunnel of the TA-53-0984 IPF. This spill is unrelated to the beam pipe window failure mentioned above; rather, it resulted from the cooling water system in the beam tunnel. The beam tunnel is normally held stagnant, but it is exhausted through a stack during times when personnel need to work in the tunnel. Facility radiation protection staff provided characterization data for the area, and EPC staff performed a bounding dose calculation. The worst-case off-site dose from this is less than $3E-08$ millirem (0.00000003 millirem) per year. This will be tracked in future years as a potential minor airborne emissions source.

In July 2021, there was a spill of approximately 200 gallons of contaminated water within the LANL Plutonium Facility at TA-55-0004 (PF-4). This incident was reported in local media. The contaminated liquid flowed into an air vent and into an inactive glove box used for handling radioactive materials, but it did not leave the confines of the PF-4 building. Any potential airborne emissions would be measured by the stack monitoring system; no unusual emissions were noted.

Engineers at the TA-55-0400 Radiological Laboratory/Utility/Office Building (RLUOB) notified EPC staff in July that one of the facility high-efficiency particulate air (HEPA) filter banks failed its annual aerosol penetration test. HEPA filters are normally rated for >99.95% removal of airborne particulates, and this filter test indicated only about 80% removal. The filter was last successfully tested in May 2020. RLUOB is considered a major source of emissions, and the stack is continuously monitored for airborne particulate releases. No unusual emissions were noted on the RLUOB stack monitor.

New Facilities & Permitting Actions

Flanged Tritium Waste Container (FTWC) Project.

The planned project to remediate (vent) four flanged tritium waste containers (FTWCs) at TA-54 was a primary focus of the Rad-NESHAP compliance team in 2021. This project was

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described in the Application for Pre-Construction Approval² submitted to EPA Region 6 in May 2019, and EPA approval was received later that month. The project is intended to vent the headspace gas within the FTWCs to allow them to be safely transported to the LANL tritium facility at TA-16 for further processing and waste segregation, followed by disposal off-site. The venting process is required to remove any pressure that may have built up in the headspace of the FTWCs in order to allow safe handling of the units. Tritium may have built up in the headspace gas, so the vented headspace gas will be directed through an emissions control system prior to being released through a monitored exhaust stack.

The venting was originally scheduled for June 2019, but the project has experienced several operational delays. In 2021, the majority of the year was spent addressing findings from the Federal Readiness Assessment completed in November 2020. In addition to updating documents to address the findings, operations staff worked on maintaining operational readiness by continuing operational rehearsals, maintaining calibration of equipment to be used, and updating processes with minor changes as needed.

In October 2021 EPA requested additional information regarding the FTWC project, requesting an update of the status of the project and additional details on emissions controls and monitoring. LANL's response to EPA was submitted in January 2022. At the time of this writing, LANL is still awaiting a response from Region 6 regarding this supplemental information package.

NNSA and Triad are continuing the readiness review process for the proposed headspace gas venting of the FTWCs. NNSA is also awaiting final approvals from the Department of Energy's Office of Environmental Management and the New Mexico Environment Department. Venting will not take place until all formal readiness processes are complete. An updated Notice of Intent to operate will be sent to EPA Region 6 prior to operations commencing.

Planned Change in Source Status for TA-53-0984, the Isotope Production Facility.

The Isotope Production Facility at TA-53 generates radionuclides for medical diagnostic and therapeutic use. This source has been a minor (unmonitored) source since its operations started in 2004. To meet increased demand for their products, the facility expressed a desire to

² LA-UR-18-26283r2, Application for Pre-Construction Approval under 40 CFR 61 Subparts A and H for Venting of Flanged Tritium Waste Containers (FTWCs) at TA-54. Submitted to EPA Region 6 as part of letter EPC-DO-19-137, May 17, 2019. EPA approval received May 22, 2019.

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increase the number and type of targets irradiated each year, which would increase the level of potential emissions from the facility. To allow for this increased operational flexibility, the facility will transition from a minor source to a major source and will be managed as a fully monitored emissions source. In late 2020 and into 2021, the stack sample location was successfully tested to verify that it met sampling criteria put forth in ANSI N13.1. The transition to major source status will be facilitated by an Application for Pre-Construction Approval; submittal of this Application will be held until after other pending Applications are addressed, per request of the Region 6 EPA.

We do not anticipate the actual level of emissions from the facility to significantly increase, even with expanded operations. Most emissions are gaseous radionuclides coming from general beam operations and are not dependent on the type or number of irradiated targets. Gas emissions have been monitored for years, even as a minor source. The expanded monitoring suite will include particulate and vapor sampling as well.

Low-Level Liquid Waste Facility Construction.

Major construction was completed in 2018 on the Low-Level Liquid Waste (LLW) facility at TA-50 Building 230, designed as the first phase of replacing the aged Radioactive Liquid Waste Treatment Facility (TA-50 Building 1). Since that time, the LLW facility has been going through a series of operational readiness activities. We anticipate radiological operations to commence in 2023. This summer, the Rad-NESHAP team will conduct commissioning tests on the stack sampling system at LLW in preparation for these operations.

Transuranic Liquid Waste Facility.

As described in the reports for prior years, the Transuranic Liquid Waste (TLW) facility is undergoing design. The design was completed in 2021, and the project moved into preparation for construction. The Application for Pre-Construction Approval was submitted to EPA Region 6 on November 11, 2021. EPA approved this Application on April 19, 2022, including certain conditions of approval. In response to condition number 5 in the approval, LANL provided EPA Region 6 with written notification that construction on TLW is planned to commence on or shortly after May 31, 2022. Similar notifications were made to nearby Pueblo communities as well, and briefings were offered to Los Alamos County personnel.

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Abstract

The emissions of radionuclides from Department of Energy Facilities such as Los Alamos National Laboratory (LANL) are regulated by the 1990 Amendments to the Clean Air Act, National Emissions Standards for Hazardous Air Pollutants (40 CFR 61 Subpart H). These regulations established an annual dose limit of 10 mrem to the maximally exposed member of the public attributable to emissions of radionuclides from LANL. This document describes the emissions of radionuclides from LANL and the dose calculations resulting from these emissions for calendar year 2021, meeting reporting requirements established in the regulations. For 2021, the effective dose equivalent received by the maximally exposed individual member of the public was 0.50 millirem.

Section I. Facility Information

61.94(b)(1) Name and Location of Facility

Los Alamos National Laboratory (LANL or the Laboratory) and the adjacent residential areas of Los Alamos and White Rock are located in Los Alamos County in north-central New Mexico, approximately 100 km (60 mi) north-northeast of Albuquerque and 40 km (25 mi) northwest of Santa Fe. Figure 1 illustrates the Laboratory's location with respect to the nation, state, and county.

61.94(b)(2) List of Radioactive Materials Used at LANL

Since the Laboratory's inception in 1943, its primary mission has been nuclear weapons research and development. Programs include weapons development, stockpile stewardship, nonproliferation, magnetic and inertial fusion, nuclear fission, nuclear safeguards and security, isotope production, and supercomputing applications. There is also research in the areas of physics, chemistry, and biology.

The primary facilities involved in the emissions of radioactivity are outlined in this section. The facility locations are designated by technical area (shown in Figure 2) and building. For example, the facility designation TA-3-29 is Building 29 at Technical Area (TA-) 3. Potential radionuclide release points are listed in Table 1, with supporting information in later tables and in Section II of this report. Some of the sources described below are characterized as non-point (diffuse or fugitive) emissions. Off-site doses resulting from non-point emissions of radioactive particles and tritium oxide (tritiated water vapor or HTO) are measured and calculated using LANL's ambient air sampling network (Airnet).

Radioactive materials used at LANL include weapons-grade plutonium, heat-source plutonium, enriched uranium, depleted uranium, and tritium. Also, a variety of materials are generated through the

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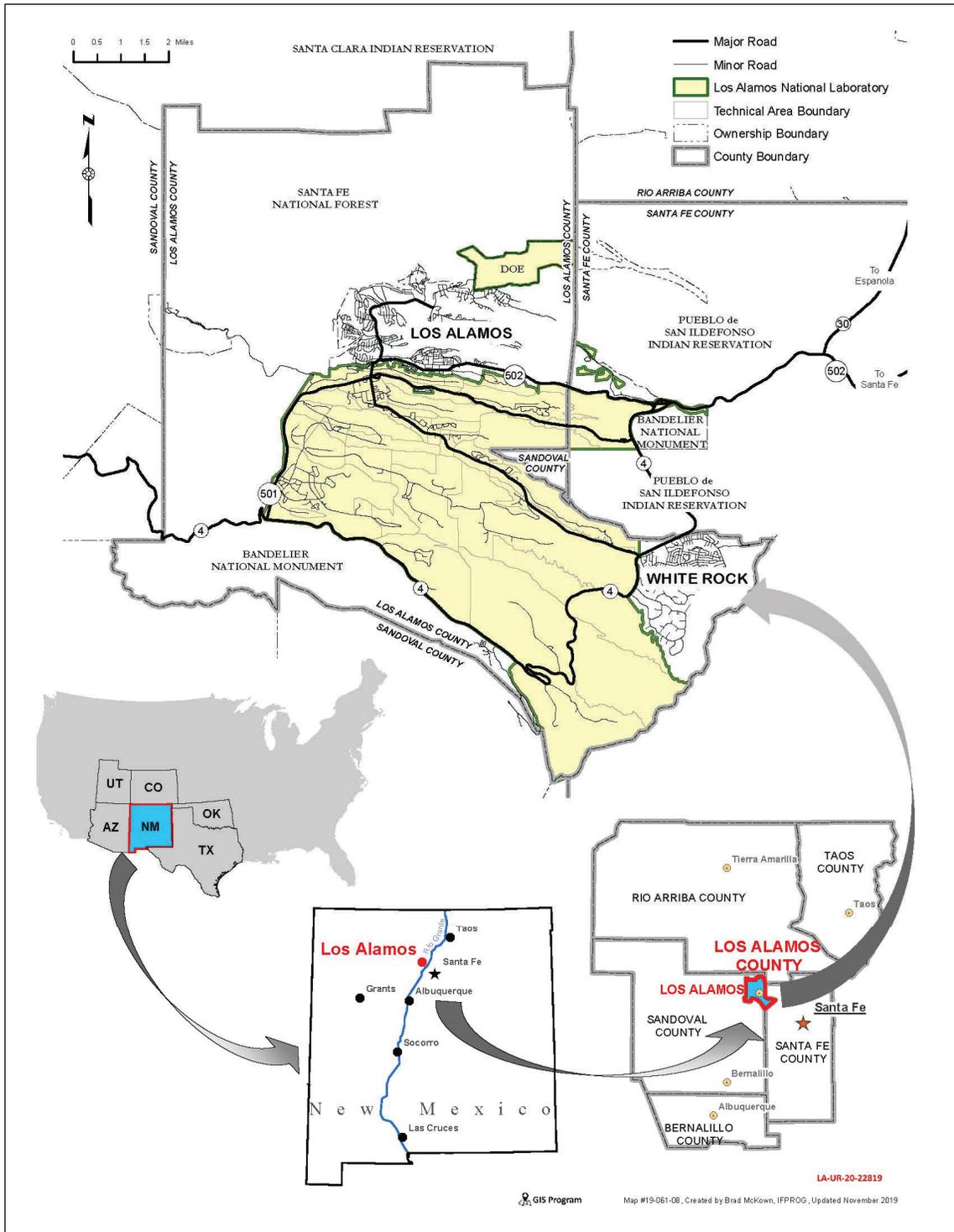


Figure 1. Location of Los Alamos National Laboratory.

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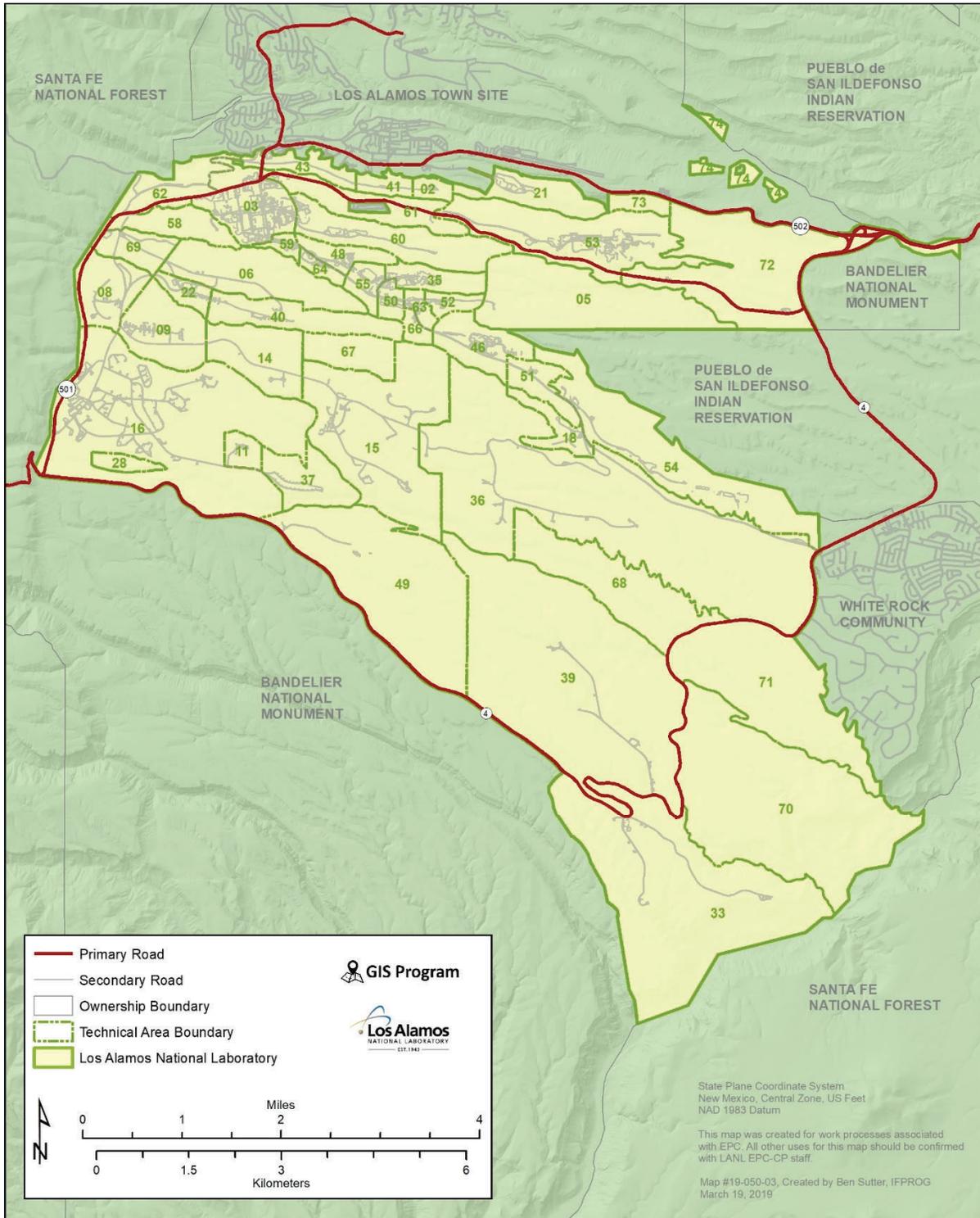


Figure 2. Los Alamos National Laboratory technical areas by number.

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process of activation; consequent emissions occur as gaseous mixed activation products (GMAP) and other particulate or vapor activation products (P/VAP).

The radionuclides emitted from monitored point sources at LANL in calendar year 2021 are listed in Table 2. Tritium is released as either tritiated water vapor (called HTO) or elemental tritium gas (HT). Plutonium-239 can also contain Pu-240; the two isotopes are virtually indistinguishable by alpha spectroscopy but have similar off-site dose conversions. Reported emissions of Pu-239/240 are simply referred to as Pu-239 for brevity. GMAP emissions include ^{41}Ar , ^{11}C , ^{13}N , ^{14}O , and ^{15}O . Various radionuclides such as $^{197\text{m}}\text{Hg}$, ^{68}Ge , and ^{82}Br make up the majority of the P/VAP emissions.

61.94(b)(3) Handling and Processing of Radioactive Materials at LANL Technical Areas

LANL technical areas and operations summaries are listed below. Additional descriptions of LANL technical areas can be found in the Annual Site Environmental Report for LANL.³ More thorough descriptions of LANL operations can be found in the Annual Site-Wide Environmental Impact Statement Yearbooks, the most recent addressing LANL operations in 2020.⁴ A complete list of non-monitored sources and activities is found in the Radioactive Materials Usage Survey (RMUS), described in the next section.

The primary facilities responsible for radiological airborne emissions are as follows:

TA-3-29: The Chemistry and Metallurgy Research (CMR) facility conducts chemical and metallurgical research. The principal radionuclides used are isotopes of plutonium and other actinides. There are a variety of activities involving plutonium and uranium, which support many LANL and other U.S. Department of Energy (DOE) programs. As mentioned in prior years' reports, work has been consolidated from six wings down to just three wings; these three wings will remain active for a few more years, when operations are planned for phase-out in this facility. In late 2012, one stack fan was shut down (ES-37) and the associated sampling system turned off. Stack sampling in the remaining wings is ongoing, due to the potential for radionuclide emissions from duct holdup. Sampling systems and fans may be shut down in coming years as operations dictate. In 2018, one stack (ES-24) had not operated for several months and the facility indicated it would not be repaired; we therefore ceased sampling at the end of March. The fan was subsequently restarted in May 2018, so we resumed sampling.

³ Los Alamos National Laboratory, "ASER Annual Site Environmental Report 2020," LA-UR-21-28555, March 2022.

⁴ Los Alamos National Laboratory, "SWEIS Yearbook 2020," LA-UR-22-20010, April 2022.

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TA-3-66: The TA-3-66 Sigma facility is used for a variety of nuclear materials work. Primary materials are metallic and ceramic radionuclides, including depleted uranium. The uranium foundry is located in this building. In recent years, research and development work with low-enriched uranium (LEU) fuels used in research reactors has been performed in this facility. The stacks at Sigma are considered “minor” sources under 40 CFR 61, Subpart H and are not monitored.

TA-3-102: This machine shop is used for the metalworking of radioactive materials, primarily depleted uranium. The monitored stack at this facility (ES-22) was shut down in 2011; only minor operations are performed in this facility, and these operations do not meet requirements for a monitored stack.

TA-3-1698: This facility is the Materials Science Laboratory. The building was designed to accommodate a wide variety of chemicals used in small amounts that are typical of many university and industrial labs conducting research in materials science. Small amounts of radioactive materials are used in experiments on materials properties (e.g., stress/strain measurements).

TA-15 and TA-36: These facilities conduct open-air explosive tests involving depleted uranium and weapons development testing. One building, TA-36-99, houses a “gas gun” focused explosive experiment that is ventilated through a non-monitored stack.

TA-15-312: This is the Dual-Axis Radiographic HydroTest (DARHT) Facility. DARHT conducts high-explosive-driven experiments to investigate weapons functions and behavior during nonnuclear tests using advanced radiography. Starting in 2007, explosive operations at DARHT are conducted in containment vessels. Use of these vessels virtually eliminates air emissions from these operations. Following explosive operations, containment vessels undergo cleanout in building 15-534 and, if needed, repair in building 15-285. Both of these latter two buildings are non-monitored point sources tracked in the RMUS.

TA-16-205 and -450: This is the Weapons Engineering Tritium Facility (WETF). Buildings 205 and 450 were specifically designed and built to process tritium safely. The operations at WETF are divided into two categories: tritium processing and activities that support tritium processing. Examples of tritium-processing operations include repackaging of tritium into different quantities and the packaging of tritium and other gases to user-specified pressures. Other operations include reacting tritium with other materials to form compounds and analyzing the effects of tritium. WETF operations have historically been housed in building 205, while building 450 was built for other tritium activities. Expansion of WETF into building 450 began in 2007. As part of this expansion, exhaust ducts were reconfigured so that emissions from TA-16-205 were routed into the TA-16-450 ES-05 stack. Therefore, the TA-16-205

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stack ES-04 is discontinued as a point source and TA-16-450 ES-05 is the emissions point source for both buildings. The older emissions sampling system for building 205 is located in the exhaust duct coming out of building 16-205, and this system remains operational and able to measure emissions from that building. The new stack sampling system in stack ES-05 was certified to measure emissions from building 450, whenever that portion of the complex becomes active. This system will also measure emissions from building 205 operations, but it was not certified for these operations under ANSI/HPS N13.1-1999 criteria. As discussed in the 2009 emissions report, the ES-05 stack monitor experienced technical problems, and its operations were discontinued in June 2009. Since significant tritium operations have not commenced in 16-450, this stack system is not needed for compliance purposes. Reported emissions in this document are measured with the 16-205 duct monitor but exhausted through and modeled from the 16-450 ES-05 stack.

TA-21: The great majority of buildings at this decommissioned radiochemistry site have been decontaminated and demolished. The tritium operations in TA-21 were relocated in 2006 to other LANL sites, primarily WETF. In 2009, demolition of office and support buildings began. Radiological process buildings were demolished in 2010, and only isolated structures remain at TA-21. Final remediation of these structures, building foundations, subsurface equipment, and legacy disposal areas will take place in coming years. The plans for these operations were discussed with EPA Region 6 during the August 2014 site visit. The MDA-B legacy waste disposal site is also considered part of TA-21. Excavation of MDA-B was completed in 2011; removal of excavation structures was achieved in late 2012. In 2021, sampling and support operations continued as part of preparing the remaining structures at TA-21 for final remediation.

TA-41-4: This building was formerly used as a tritium-handling facility. The tritium sources were removed in 2002. Most of the process buildings have been demolished. Diffuse tritium emissions could result from residual tritium contamination and cleanup operations.

TA-48: The principal activities carried out in this facility are radiochemical separations and hot cell operations supporting the medical radioisotope production program, the Yucca Mountain program, nuclear chemistry experiments, and geochemical and environmental research. These separations involve nanocurie to curie amounts of radioactive materials and use a wide range of analytical chemical separation techniques, such as ion exchange, solvent extraction, mass spectroscopy, plasma emission spectroscopy, and ion chromatography. Besides the hot cell operations, the building also houses the Actinide Research Facility (ARF) and includes the other radiochemical operations described above. Building 1 at TA-48 contains the majority of operations, exhausted through three monitored stacks and

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several non-monitored stacks. Smaller (non-monitored) operations take place in other buildings around TA-48-1. Building 1 of TA-48 was the first to adopt SD 1027G radionuclide inventory thresholds as described in the prior annual reports. While a larger number of isotope processing operations may theoretically result in increased air emissions, this trend has not been significant in recent years. The facility did perform a “one-off” plutonium experiment in 2017 that vented through ES-45 at TA-48-1, a minor (unmonitored) source; potential emissions from this activity approached the 0.1 millirem/year limit, but did not exceed it. Future operations of this type will be evaluated to determine if they can continue in areas vented through the minor source ES-45 or if they should move to an area vented through a monitored stack.

TA-50-1: This waste management site consists of an industrial low-level radioactive liquid waste treatment facility, RLWTF. Transuranic liquid waste is also treated in this building. The building has one monitored stack (ES-2) and other smaller non-monitored point sources. Two small cooling towers described in the 2010 executive summary had been used for non-radiological purposes in the past. These cooling towers operated briefly to evaporate treated radiological effluent from RLW in 2010 but have not operated since 2010, and that practice has been discontinued. A new fuel-fired evaporator (described in the 2011 report) started radiological operations in 2011 and is being tracked as a non-monitored source. Use of solar evaporative tanks for evaporation of treated effluent have been built but their operations have not commenced. Over time, operations in TA-50-1 will be transitioned to the new Low-level Liquid Waste (LLW) facility at TA-50-230 and to a Transuranic Liquid Waste (TLW) facility at TA-50-269, planning to break ground in late spring.

TA-50-37: Currently there are no operations involving radioactive material in this building; plans for future radiological operations have not come to fruition. Stack sampling took place due to legacy contamination issues. In September 2013, potentially contaminated ventilation duct components were removed to eliminate sources of emissions from this building. Emissions measurements continued through June 2014. With no detectable emissions in the first half of 2014 and no radiological operations or source term present, the monitoring system was shut down in late September 2014. The building is now used exclusively for non-radiological operations.

TA-50-69: This waste management site consists of a waste characterization, volume reduction, and repackaging facility. Waste drums are repackaged for on-site or off-site disposal. There is one monitored stack, ventilating the primary drum processing glove box, and three non-monitored sources at this building.

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TA-53: This technical area houses the Los Alamos Neutron Science Center (LANSCE), a linear particle accelerator complex. There are two monitored stacks (on buildings TA-53-3 and TA-53-7) and several sources tracked in the non-monitored stacks program. The accelerator is used to conduct research in stockpile stewardship, radiobiology, materials science, and isotope production, among other areas. LANSCE consists of the Manuel Lujan Neutron Scattering Center, the Proton Storage Ring, the Weapons Neutron Research (WNR) facilities, the Proton Radiography facility, and the high-intensity beam line (Line A). The facility accelerates protons and H⁻ ions to energies of 800 MeV into target materials such as graphite and tungsten to produce neutrons and other subatomic particles. The design current of the accelerator is approximately 1000 microamperes, but most operations take place at beam currents of 120 microamperes or less. Airborne radioactive emissions result from proton beams and secondary particles passing through and activating air in target cells, beam stop, and surrounding areas, or activating water used in target cooling systems. The majority of the emissions are short-lived activation products such as ¹¹C, ¹³N, and ¹⁵O. Most of the activated air is vented through the main stacks; however, a fraction of the activated air becomes a fugitive emission from the target areas.

As a by-product of accelerator operations, cooling water can contain trace amounts of radionuclides. Two solar evaporative tanks were constructed and began operation in 1999 to evaporate this wastewater from the accelerator. Evaporation of water from these open-air tanks can result in a diffuse source of airborne tritium and other particulates. To support other Laboratory operations, these tanks can be used for evaporation of water from other LANL facilities.

In 2004, the Isotope Production Facility (IPF) began operations as part of the LANSCE facility. IPF uses a portion of the LANSCE beam to irradiate a variety of targets for different medical research and treatment uses. After irradiation, targets are processed at LANL hot cells at TA-48 or CMR. IPF has two stacks which are managed as part of the minor (non-monitored) source program. The main stack at IPF, ES-1, is being prepared to have monitoring systems installed in order to move the stack to “major” source status. This will allow for expanded operations at IPF and more flexibility in irradiation target options.

In 2014, two new sources were identified at the LANSCE facility. The first is a diffuse source at the IPF building. An improvement to the air emissions detection system resulted in measurements of trace radioactive gases in the high bay area around the IPF target and in the equipment aisle above the IPF beam tunnel. This air is the result of migration of beam tunnel air through drains and cable penetrations up into worker occupied spaces, which is then vented to the environment as a diffuse/non-point source. For 2021, radionuclide air concentrations are continuously measured at the most conservative location

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within the equipment aisle, and these measurements are used to calculate emissions from this diffuse source.

The second new source was from the WNR facility, Target 4. Air from around the WNR Target 4 is normally exhausted by vacuum pump into the WNR Target 2 area, which in turn is exhausted by the Building 7 stack fan. However, the vacuum pump discharge line was discovered to be cracked in late 2014, so all air from Target 4 was released directly to the atmosphere. These emissions calculations were discussed in the 2014 annual report. The pump discharge pipe was fixed in late 2014, returning air into the building for eventual exhaust through the monitored stacks. No radionuclide emissions evaluation from this discharge point was required for 2021.

As described in the executive summary and in more detail in the 2018 report, a new radioactive air emissions source was found in 2018 when a fan malfunction resulted in pressurizing the beam tunnel in one of the LANSCE experimental areas. Radioactive air in the tunnel, normally held stagnant or exhausted out a monitored stack, was instead pushed out from TA-53 Sector N as a fugitive release. The issue was detected and addressed late in the 2018 run cycle and addressed prior to 2019 beam operations to prevent a repeat of this event.

TA-54: This waste management site consists of active and inactive shallow land burial sites for solid waste and is the primary storage area for mixed and transuranic radioactive waste. Waste characterization and processing operations also take place at TA-54 to prepare waste for shipment to the Waste Isolation Pilot Plant (WIPP). Shipments of transuranic waste for disposal at WIPP began in 1999. Characterization work includes analysis of headspace gases and radiography of waste drum contents; processing includes sorting, segregating, size-reduction, and repackaging of waste.

Materials Disposal Area G (MDA-G or Area G) at TA-54 is also a known source of diffuse emissions of tritium vapor and direct radiation from above-ground storage of radioactive waste. Resuspension of soil contaminated with low levels of plutonium/americium has also created a diffuse source. Point sources at Area G include operations involving characterization, processing, or repackaging of waste containers. Two new monitored point sources came on-line in 2010, at Building 412 and Dome 231. These two sources are waste processing facilities, where drums are repackaged, inspected, and otherwise prepared for off-site disposal. The Dome 231 processing facility was expanded in 2012 to increase throughput capacity of the dome. In March 2014, a new building (Dome 375) began radiological operations to process larger waste containers. Non-monitored (minor) sources of emissions at TA-54 include drum characterization work at Building 33 and Dome 224 as well as air sample management work outside of Area G in Building 1001.

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Note that after the WIPP radiological release in February 2014 was tracked back to a waste drum originating at LANL, air monitoring around TA-54 was increased. Drums which contained waste similar to that in the drum involved in the WIPP release were isolated in Dome 375. Other waste drums of concern were stored at Dome 231. Most waste handling activities at TA-54 were reduced while the facility dealt with storing and treating these Remediated Nitrate Salt (RNS) drums in recent years; now that the RNS processing was completed in 2017, routine waste drum handling operations began ramping up again. Also, the additional air monitoring (real-time environmental continuous air monitors) ceased operations after the RNS drums were moved out of Dome 375.

TA-54 Building 1028 houses four legacy tritium waste containers, referred to as Flanged Tritium Waste Containers (FTWCs). These units are high-pressure tritium containers and were originally packed with small amounts of lead waste, making these FTWCs mixed-waste items. To address these issues, LANL will be venting any tritium in the headspace and then moving the FTWCs to the TA-16 tritium facility for further waste processing. This venting operation will be a new major source of emissions, and an application for pre-construction approval⁵ was submitted and approved in 2018. Programmatic delays have pushed this operation to 2022. The venting is expected to take less than a month once operations begin.

TA-55-4: Building 4 of the Plutonium Facility (PF-4) provides a pit manufacturing capability and continues the role of providing the capability for research and development applications in chemical and metallurgical processes for recovering, purifying, and converting plutonium and other actinides. A wide range of activities (e.g., heating, dissolution, forming, and welding of special nuclear materials) are also conducted. Additional activities include investigating the means to safely ship, receive, handle, and store nuclear materials and to manage wastes and residues from TA-55. Limited-scope tritium operations also take place in certain areas of TA-55. There are two monitored stacks at TA-55 Building 4. In 2017, new samplers were installed in the “Zone 1” ventilation system for each operational area of PF-4; these new systems use shrouded probe technology to provide state-of-the-art sampling for the nuclear facility. These new systems went operational for the 2018 calendar year but are still being treated as R&D systems until we can establish a full maintenance and inspection program for the new sample systems and until a full comparison can be made to evaluate these new systems with the current stack monitoring systems.

⁵ LA-UR-18-26283, rev.1. Application for Pre-Construction Approval under 40 CFR 61 Subparts A and H for Venting of Flanged Tritium Waste Containers (FTWCs) at TA-54. Submitted to EPA Region 6 by memo EPC-DO-18-281, August 8, 2018. Approved by EPA Region 6 on September 25, 2018. Due to project delays, this Application was re-submitted in May 2019.

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Building 2 of TA-55 houses associated support facilities for operations in PF-4, including the radiological sample analysis laboratory. Operations from this laboratory are tracked as part of LANL's non-monitored source program.

TA-55-400: Building 400 at TA-55 is the Radiological Laboratory / Utility / Office Building (RLUOB), the first phase of the project to replace capabilities in TA-3 Building 29. A Congressionally approved line-item project may eventually include a nuclear facility to replace remaining capabilities from TA-3 Building 29. Design of a CMR Replacement (CMRR) nuclear facility was underway but the Administration announced its intent to delay construction for at least five years. RLUOB is designed to perform materials characterization work and actinide chemistry research. While the RLUOB stack became active in November 2012, radiological operations did not commence until late 2014. Although this facility was originally constructed as a radiological facility, DOE has commissioned a review to evaluate increasing the operations level to that of a limited-scope Category 3 nuclear facility. This move was approved⁶ in July 2018, allowing RLUOB to maintain inventory of up to 400 grams of Pu-239 or equivalent. As described in the Executive Summary in the 2019 report, in late 2019 LANL submitted a request and received EPA approval to increase the RLUOB operational scope to reflect these new limits. RLUOB officially became a Category 3 nuclear facility in November 2020; however, this update did not make it into the 2020 report. In addition, since RLUOB was already a major source and monitored, a notice of intent to start and the notice of actual start were not submitted.

TA-59-1: This building houses low-level radiochemistry operations. Some laboratories are being retrofitted to move some operations from the existing CMR facility into this building. Initial work scope planned for these operations will be at the minor (unmonitored) source level, but the systems are being designed to support sampling systems in the event that these new operations expand to that of a major source.

TA-63: This is the site of the Transuranic Waste Facility (TWF), a cluster of small buildings where waste characterization work is performed. Activities include analysis of headspace gases within waste drums and non-destructive assay and radiography on these drums prior to their shipment off-site for disposal. Operations started in 2019, beginning with headspace gas analysis on some drums. These and future operations at this facility will be tracked in the RMUS, as the TWF is anticipated to be a minor

⁶ United States Department of Energy, "Finding of No Significant Impact for the Environmental Assessment of Proposed Changes for Analytical Chemistry and Materials Characterization at the Radiological Laboratory/Utility/Office Building, Los Alamos National Laboratory, Los Alamos, New Mexico," July 25, 2018.

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source. In 2019, operations in all buildings at TWF were reported as a single source for RMUS reporting. As operations increase, we may divide analyses up to reflect the building in which operations take place.

Section II. Air Emissions Data

61.94(b)(4) Point Sources

Monitored and non-monitored release points at LANL are listed in Table 1. The point sources are identified using an eight-digit identification number for each exhaust stack (StackID); the first two digits represent the LANL technical area, the next four the building, and the last two digits the stack number. Also listed in Table 1 are type, number, and efficiency of the emissions control systems used on the release points. More information on these emissions control systems appear below. Note that Table 1 and all subsequent tables appear together at the end of the text of this report.

LANL has 48 buildings in which radiological operations can take place and be vented through a point source, as listed in Table 1. In these buildings, there are 27 sources that are monitored (“major”) point sources and 60 non-monitored (“minor”) release points. Under 40 CFR 61.93(b)(4)(i), sampling of these minor release points is not required because each release point has a potential effective dose equivalent (PEDE) of less than 0.1 mrem/year at the critical receptor. However, in order to verify that emissions from non-monitored point sources remain low, LANL conducts periodic confirmatory measurements in the form of the annual *Radioactive Materials Usage Survey for Unmonitored Point Sources*.⁷ The purpose of this survey is to collect and analyze radioactive materials usage and process information for the non-monitored point sources at LANL. In alternate years, the survey is expanded to review monitored sources and ensure proper emissions monitoring is taking place at these facilities. For 2020, the most significant minor sources were analyzed, the evaluated sources were those designated "Tier III" whose potential emissions exceed 0.001 millirem but fall below the 0.1 millirem per year threshold at which continuous monitoring is required. For 2021, all minor sources will be evaluated; Tier III sources as above and Tier IV sources which have potential emissions below 0.001 millirem per year. A full description of which sources are analyzed in each year is included in the RMUS report.

The distance between each of the release points and the critical receptor for each facility is provided in Table 1. The critical receptor can be a residence, school, business, or office. In this report, the critical receptor is defined as the member of the public (at a fixed structure location) most

⁷ R. Sturgeon, “2021 Radioactive Materials Usage Survey for Unmonitored Point Sources.” EPC-CP internal memo, pending final publication at time of report development.

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significantly impacted by a given release point. Air dispersion modeling is taken into account to determine the most critical receptor location; the nearest public receptor is not always the critical receptor if the nearest location is upwind from a source.

In compliance with Appendix D to 40 CFR 61, we have used data collected from the facilities in conjunction with engineering calculations and other methods to develop conservative emissions estimates from non-monitored point sources. Estimated PEDEs are calculated by modeling these emissions estimates using EPA-approved CAP88 dose modeling software. Version 4 of CAP88-PC has been used to determine offsite dose consequence from LANL emissions sources from 2014 to 2020. Beginning in 2021, version 4.1 of CAP88-PC is now used. The Laboratory has established administrative requirements to evaluate all potentially new sources. These requirements are established for the review of new Laboratory activities and projects, ensuring that air quality regulatory requirements will be met before the activity or project begins.⁸

Non-point Sources

There are a variety of non-point sources within the 111 km² of land (43 square miles) occupied by LANL. Non-point sources can occur as diffuse or large-area sources or as leaks or fugitive emissions from facilities. Examples of non-point sources of airborne radionuclides include surface impoundments, evaporative tanks and basins, shallow land burial sites, open burn sites, live firing sites, outfalls, container storage areas, unvented buildings, waste treatment areas, solid waste management units, and tanks. Additionally, LANL considers a building to be a non-point source if there is no active process exhaust (e.g., no fume hood, glove box, etc.); no forced air exhaust to the environment; or is equipped with only standard heating/ventilating/air conditioning systems (e.g., occupational comfort cooling or heating).

LANL determines the potential impacts of non-point sources by measuring air concentrations of significant radionuclides at ambient air-sampling sites at locations of public receptors surrounding the Laboratory and at selected locations on Laboratory property. This network of ambient air sampling stations is called Airnet. The LANL Airnet system was originally approved for use in monitoring LANL's non-point radioactive air emission sources in 1996 and reaffirmed as part of the Airnet system re-evaluation in 2015.⁹ New activities are reviewed to ensure adequate Airnet coverage exists for new

⁸ LANL Environmental Protection and Compliance Division – Compliance Programs Group, Functional Series Document, “Air Quality Reviews,” EPC-CP-FSD-002, May 2021.

⁹ U.S. Environmental Protection Agency emailed approval, George Brozowski to Tony Grieggs, February 18, 2015. Approval and concurrence of proposals in “Update to the Ambient Air Sampling Network (Airnet) at LANL,” document ID LA-UR-15-21001, transmitted to EPA via memo ENV-DO-15-0046, February 17, 2015.

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sources, or if additional stations are required. As described in the 2015 annual report, modifications to LANL's ambient air monitoring program were proposed in 2014 and approved by EPA Region 6 in early 2015. This updates the siting of Airnet stations to reflect current LANL operations and the locations of public receptors and also updates other operational parameters of the Airnet program. The overall intent and general operational scope of the program remains unchanged, to measure air concentrations of significant LANL radionuclides at public locations. As described in the Executive Summary, two additional Airnet stations have been added to the northern perimeter of LANL to fully monitor emissions from pending environmental remediation activities at TA-21.

Radionuclide Emissions

Table 2 lists the radionuclides released from monitored point sources, along with the annual emissions in curies for each radionuclide. For a source with no detectable emissions, the term "none" appears in the radionuclide column. Extensive notes appear at the end of the source term table. A map showing the general locations of the facilities continuously monitored for radionuclide emissions is shown in Figure 3.

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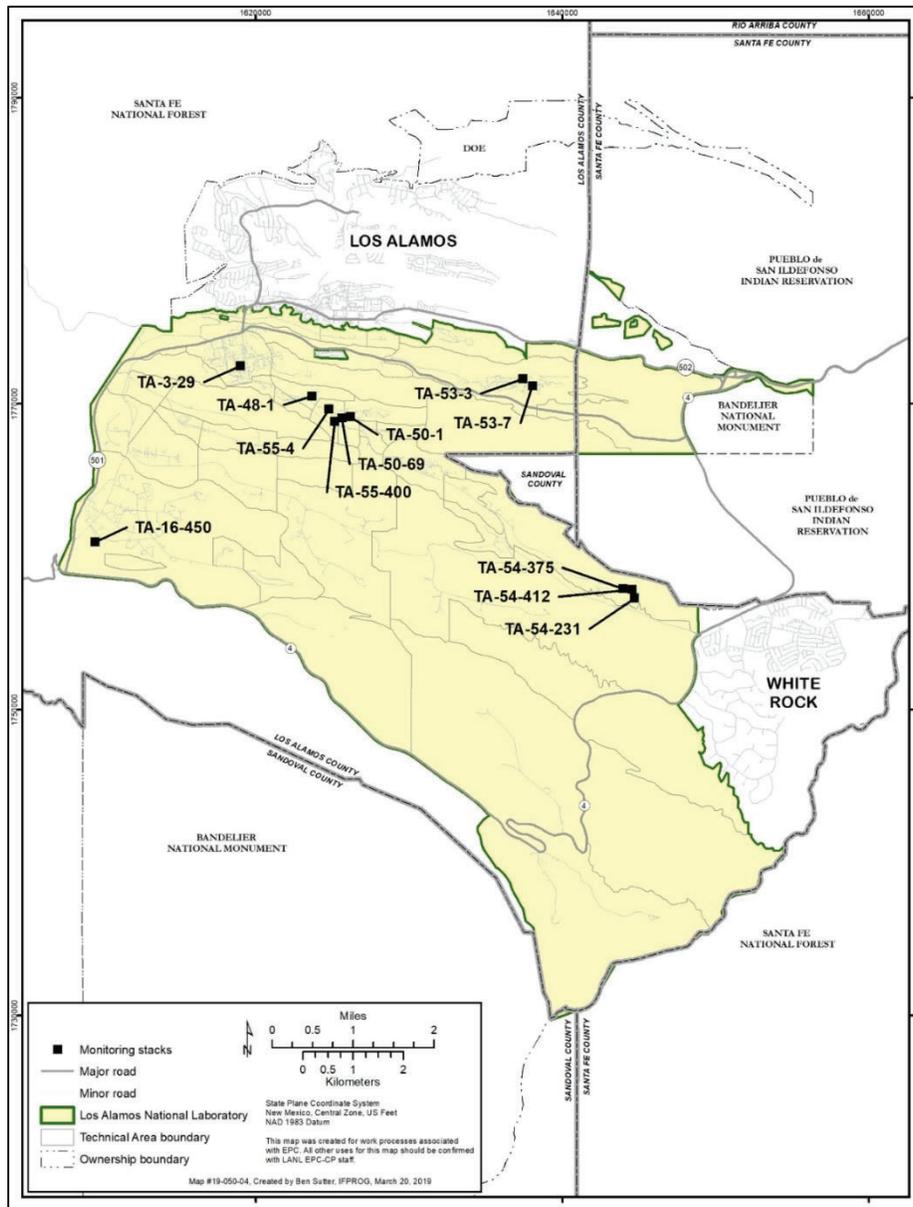


Figure 3. Location of facilities with continuously operated stack-sampling systems for airborne radionuclide emissions.

Emission Controls

The most common type of filtration for emission control purposes at LANL is the high-efficiency particulate air (HEPA) filter, as noted in Table 1. HEPA filters are constructed of sub-micrometer glass fibers that are pressed and glued into a compact, paper-like, pleated media.

At LANL, each HEPA filter system that is credited for performance on active operational sources is tested at least once every 12 months. The nominal performance criteria for HEPA filter systems are a maximum penetration of 5×10^{-4} for one stage (99.95% removal) and maximum penetration of 2.5×10^{-7} for two stages in series (99.999925% removal). In these quoted values, filter penetration and percent removal are defined below.

$$\text{Penetration} = (\text{downstream concentration}) / (\text{upstream concentration})$$

$$\text{Removal} = [1 - (\text{penetration})] * 100\%$$

Note that in recent years, changes to HEPA filter testing methods and equipment at LANL have resulted in limitations in the ability to certify very high levels of aerosol removal. Therefore, LANL is now only certifying filters at the “single stage” penetration & removal criteria, regardless of the number of filter bank stages installed at the facility. Table 1 lists the number of filter banks installed at the facility and the nominal removal efficiency, not the certified tested removal efficiency.

Other types of filters used in ventilation systems are Aerosol 95; RIGA-Flow 220, 221, and 222; and FARR 30/30. These units are typically used as pre-filters in HEPA filtration systems. These filters are significantly less efficient than HEPA filters and are typically used for removing gross particulate matter larger than 5 μm .

The above-mentioned filters are only effective for particles. When the contaminant of concern is in the form of a gas or vapors, activated charcoal beds can be used. Charcoal beds collect the gas contaminant through an adsorption process in which the gas comes in contact with the charcoal and adheres directly to the surface of the charcoal. The charcoal can be coated with different types of materials to make the adsorption process more efficient for specific types of contaminants. Typically, charcoal beds achieve an efficiency of 98% capture. Efficiency of a charcoal filter can vary with different chemical pollutants in the exhaust air stream. Activated charcoal filters are currently in use at one stack, the hot cell stack (ES-7) at TA-48-1.

Tritium effluent controls are generally composed of a catalytic reactor and a molecular sieve bed. Tritium-contaminated effluent is passed through a catalyst that converts gas-phase or elemental tritium (HT) into tritiated water vapor (HTO). This HTO is then collected as water on a molecular sieve bed.

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This process can be repeated until the tritium level is at, or below, the desired level. The effluent is then vented through the stack.

A delay system is used to reduce some of the short-lived radionuclides generated by activation at LANSCE. Emissions from a concentrated source of activated gas (the off-gas system for the 1L target cooling system) are directed into a long transport line. The transit time through this system allows short-lived gaseous radionuclides to decay before being emitted from the stack. This delay system is used to provide a reduction in radionuclide emissions from the 1L target area exhausted through stack 53000702.

Compliance with Maintenance and Inspection Requirements under the Revised Rad-NESHAP

The 2003 revisions to 40 CFR 61 Subpart H established several inspection and maintenance requirements for monitored stacks. These requirements are based on American National Standards Institute/Health Physics Society N13.1-1999, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*. Annual visual inspection of particulate monitoring systems is a component of the Laboratory's program to comply with these requirements.¹⁰ In 2021, we performed stack inspections and/or cleaning operations on 26 monitored stacks. Note that LANL's policy on inspections and cleanings is that when only trace deposition is noted that in the inspector's judgement will not affect sampler performance, the cleaning is put off until the following year's inspection cycle. If significant issues are noted, the system will be cleaned that same year.

Cleaning activities were performed on 7 of these systems in 2021 to remove trace particulate within the sample systems noted in the previous year. Of the inspections performed in 2021, sample systems on 9 stacks showed evidence of particulate deposition in the sampler or transport line. These systems will be addressed as part of the 2022 sampler inspection cycle, along with systems which are cleaned each year. In 2021, no radiological material was measured on inspection or cleaning equipment. Therefore, no additions to the source term are required from this pathway for this year.

For the tritium sampling systems at TA-16 and TA-55, a visual inspection of the system piping was conducted in 2021. Internal sampler inspections with a borescope is not possible on tritium systems. Particulate deposition on these gas/vapor systems are not critical to sampler performance as long as flow is maintained through the sampler.

¹⁰ Procedure EPC-CP-TP-0142, "Inspecting and Cleaning Stack Sampling Systems." Results documented in internal memo, Richard Sturgeon to David Fuehne, Dec 3, 2021.

Section III. Dose Assessment

61.94(b)(7) Description of Dose Calculations

Effective dose equivalent (EDE or dose) calculations for point sources, unmonitored point sources, and non-point gaseous activation products from LANSCE were performed with the CAP88 code. LANL had used the original mainframe version of CAP88 (version 0) through the 2005 report; CAP88 version 3 was used for 2006-2012 reports; and CAP88 version 4 was adopted for use in the 2013-2019 annual reports. CAP88 version 4.1 was adopted for use in the 2020 report as well as this report. Verification of the CAP88 code is performed by running the EPA test case before performing the dose calculations.

Development of Source Term

The 2021 source term for radionuclide air emissions is fully documented in a LANL internal memorandum¹¹ and full explanations of methods are provided in that document. A summary appears below.

Tritium Emissions

Tritium emissions from the Laboratory's tritium facilities are measured using a collection device known as a bubbler. This device enables the Laboratory to determine not only the total amount of tritium released but also if it is in the chemical form of elemental tritium (HT) or tritiated water vapor (HTO). The bubbler operates by pulling a continuous sample of air from the stack, which is then "bubbled" through three sequential vials containing ethylene glycol. The ethylene glycol collects the water vapor from the sample of air, including any tritium that is part of a water molecule (tritium oxide, or HTO). After bubbling through these three vials, essentially all water vapor (including HTO) is removed from the air, leaving elemental tritium, or HT. The sample air stream is then passed through a palladium catalyst that converts the HT to HTO. The sample is pulled through three additional vials containing ethylene glycol, which collects the newly formed HTO. The amount of HTO and HT is determined by analyzing the ethylene glycol for the presence of tritium using liquid scintillation counting. Since different chemical forms are collected in different vials, the system will discriminate HTO vapor from HT gas, allowing separate dose assessment with CAP88-PC versions 3, 4, and 4.1. Bubblers are in use to measure tritium emissions from TA-16 (WETF) and TA-55 PF-4's south stack, 55000416.

¹¹ Memo EPC-DO-22-133, "2021 Annual Source Term for Radionuclide Air Emissions," David P. Fuehne to Rad-NESHAP Project Files. May 12, 2022.

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Tritium emissions from LANSCE do not require monitoring under 40 CFR 61.93(b)(4)(i). The primary source for airborne tritium emissions at LANSCE is activation of water vapor in air and activation and subsequent evaporation of water in the cooling system of beam targets. Because of the low contribution of tritium to the off-site dose at LANSCE, formal monitoring for tritium was discontinued after July 2001. Tritium emissions at LANSCE continue to be calculated based on the rate of generation measured in 2001, using representative parameters.

In past years, very low-level tritium operations also took place from TA-55 Building 4, in the northern portion of the building exhausted through ES-15. While the southern stack ES-16 is monitored for tritium emissions, at ES-15, tritium is not a pollutant of concern and falls well below the ten percent of the PEDE criteria at which monitoring is required. Similarly, the WCRR waste repackaging facility at TA-50-69 occasionally processes waste drums containing trace amounts of tritium. No tritium operations took place in the northern portion of TA-55 Building 4 or at WCRR in 2021.

Radioactive Particulate Emissions

Emissions of radioactive particulate matter, generated by operations at facilities such as the CMR facility (TA-3-29) and the Plutonium Facility (TA-55), are sampled using a glass-fiber filter. A continuous sample of stack air is pulled through the filter, where small particles of radioactive material are captured. These samples are analyzed weekly using gross alpha/beta counting and gamma spectroscopy to identify any increase in emissions and to identify short-lived radioactive materials. Every six months, LANL composites these stack samples for subsequent analysis at an off-site laboratory. These composite samples are analyzed to determine the total activity of materials such as ^{234}U , ^{235}U , ^{238}U , ^{238}Pu , ^{239}Pu , and ^{241}Am . These semiannual composite data are then combined with estimates of sampling losses and stack and sample flows to calculate emissions. Short-lived progeny are assumed to be emitted in secular equilibrium with their long-lived parent nuclides. For example, we measure for the presence of ^{90}Sr and assume that an equal amount of the progeny ^{90}Y is emitted as well.

Vapor Form Emissions

Vapor emissions, generated by LANSCE operations and by hot-cell activities at TA-3-29 and TA-48, are sampled using an activated charcoal filter cartridge. A continuous sample of stack air is pulled through a charcoal filter upon which vaporous emissions of radionuclides are adsorbed. The amount and identity of the radionuclide(s) present on the filter are determined through the use of gamma spectroscopy. These analytical results are used in conjunction with facility information to calculate emissions. Examples of radionuclides of this type include ^{68}Ge and ^{76}Br .

Gaseous Mixed Activation Products (GMAP)

GMAP emissions resulting from activities at LANSCE are measured using real-time monitoring data. A continuously-operating air flow-through ionization chamber is operated in series with a high-purity germanium (HPGe) detector and data acquisition system. A sample of stack air is pulled through the ionization chamber to measure the total amount of radioactivity in the sample, while the specific radioisotope composition is identified through the use of gamma spectroscopy and decay curve analysis with the HPGe system. This information is then used to calculate emissions. Radionuclides of this type include ^{11}C , ^{13}N , and ^{15}O .

Summary of Input Parameters

The effective dose equivalent to potential receptors was calculated for all radioactive air emissions from sampled LANL point sources. The radionuclide emissions (source term) for the monitored point sources are provided in Table 2. Input parameters for these point sources are provided in Table 3. The geographic locations of the release points, given in decimal degrees, are provided in Table 4. Table 5 shows the distance and direction from each of the LANL monitored stacks to the LANL-wide highest receptor location for this report year. Other site-specific parameters used in CAP88 and the sources of these data are provided in Table 6.

LANL operates an on-site network of meteorological monitoring towers. Data gathered by the towers are summarized and formatted for input into the CAP88 program. For 2021, data from three different towers were used for the air-dispersion modeling; the tower data that are most representative of the release point are applied. Copies of the meteorological data files used for the annual 2021 dose assessments are provided in Appendix A at the end of this report. There are three files included in Appendix A, detailing wind speed and direction information from the TA-6, TA-53, and TA-54 meteorology towers.

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The Laboratory also enters population array data into the CAP88 program. The data file represents a 16-sector polar-type array, with 20 radial distances for each sector. Population arrays are developed for each release point using U.S. Census data, and the population files used at LANL were updated in late 2012 using 2010 census data¹². Different population files are used depending on where the dominant LANL source is located in a given year. A full description of the population dose assessment calculation appears later in this document. Note this population dose does not include potential emissions from non-monitored sources but is solely based on measured emissions in Table 2. For agricultural array input, LANL is currently using the default values in CAP88 for the state of New Mexico. For conservatism, the “local” option is used for the “food source” determination.

Public Receptors

Compliance with the annual dose standard is determined by calculating the highest EDE to any member of the public at any off-site point where there is a residence, school, business, or office. The Laboratory routinely evaluates public areas to assure that any new residence, school, business, or office is identified for the EDE calculation. As per EPA guidance,¹³ personnel that work in leased space within the boundaries of the Laboratory are not considered members of the public for the EDE determination. Personnel of this type are considered to be subcontractors to DOE, similar to security guards and maintenance workers.

Point Source Emissions Modeling

The CAP88 version 4.1 program was used to calculate doses from both the monitored and unmonitored point sources at LANL. The CAP88 program uses on-site meteorological data to calculate atmospheric dispersion and transport of the radioactive effluents. CAP88 version 4.1 includes all

¹² LA-UR-12-22801, “Population Files for use with CAP88 at Los Alamos. M. McNaughton and B. Brock. January 2012.

¹³ Frank Marcinowski, Acting Director, Radiation Protection Division, “Criteria to Determine Whether a Leased Facility at Department of Energy (DOE) is Subject to Subpart H,” Office of Radiation and Indoor Air, U. S. Environmental Protection Agency, March 26, 2001.

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radionuclides for which there are dose conversion factors in the EPA's Federal Guidance Reports.^{14,15,16} In 2021, all monitored radionuclides were included in CAP88 for the monitored stacks source term. Some minor sources (non-monitored stacks) used exotic radionuclides (usually very short-lived) not in the CAP88 version 4.1 library; these were addressed per LANL procedure.¹⁷ Updates of “non-CAP88 nuclides” for monitored and non-monitored point sources were described in previous memos to EPA Region 6, most recently in a 2011 memo.¹⁸

LANSCE Diffuse / Fugitive Emission Modeling

Some of the GMAP created at the accelerator target cells or at other accelerator beam line locations migrate into room air and into the environment. These diffuse or fugitive sources are continuously monitored throughout the beam-operating period. In 2021, approximately 20.8 Ci of ¹¹C and 1.72 Ci of ⁴¹Ar were released from LANSCE as fugitive emissions. These sources were modeled as area sources using CAP88 version 4.1, and the specific input parameters are provided in Table 8. The dominant fugitive emissions source was the 53DIF1LS source.

Environmental Data Used for Non-point Source Emission Estimation

The Airnet system of ambient air sampling stations is shown in Figure 4 (Los Alamos County only) and Figure 5 (Los Alamos and Northern New Mexico). These stations represent compliance stations and some LANL facility surveillance stations.

Airnet samples are planned and tracked using the Environmental Information Management (EIM) database, a cloud-based server which handles all of LANL's environmental data. EIM is also used to calculate radionuclide concentrations and resulting radiological doses. These calculations are checked annually and the evaluation included in the annual source term memo.

¹⁴ K. F. Eckerman, A. B. Wolbarst, and A. C. B. Richardson, Federal Guidance Report No. 11, “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,” Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C., 1988.

¹⁵ K. F. Eckerman and J. C. Ryman, Federal Guidance Report No. 12, “External Exposures to Radionuclides in Air, Water, and Soil Exposure-to-Dose Coefficients for General Application,” U.S. Environmental Protection Agency, Washington, D.C., 1993

¹⁶ K. F. Eckerman, R. W. Leggett, C. B. Nelson, J. S. Puskin, and A. C. B. Richardson, Federal Guidance Report No. 13, “Cancer Risk Coefficients for Environmental Exposure to Radionuclides,” U.S. Environmental Protection Agency, Washington, D.C., 1999

¹⁷ LANL procedure EPC-ES-TP-512, R5, “Dose Factors for Non-CAP88 Radionuclides,” November 2021.

¹⁸ WES-EDA-11-0023, “Documentation of Dose Calculation Methods for Radionuclides Not Included in CAP88 Version 3.” M. McNaughton memo to G. Brozowski, December 21, 2011.

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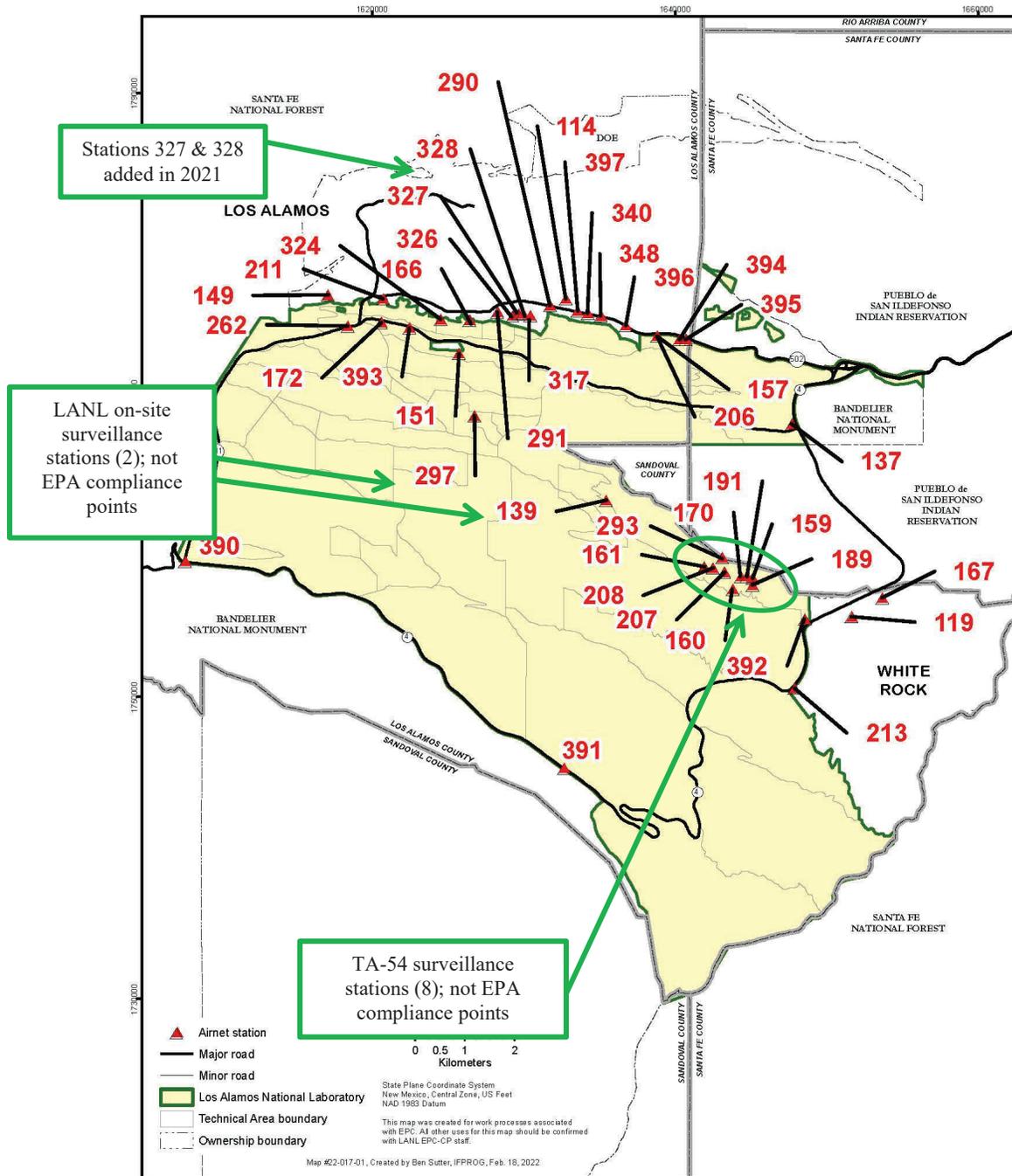


Figure 4. Locations of air sampling stations around Los Alamos County. Stations that are not EPA Compliance points are indicated.

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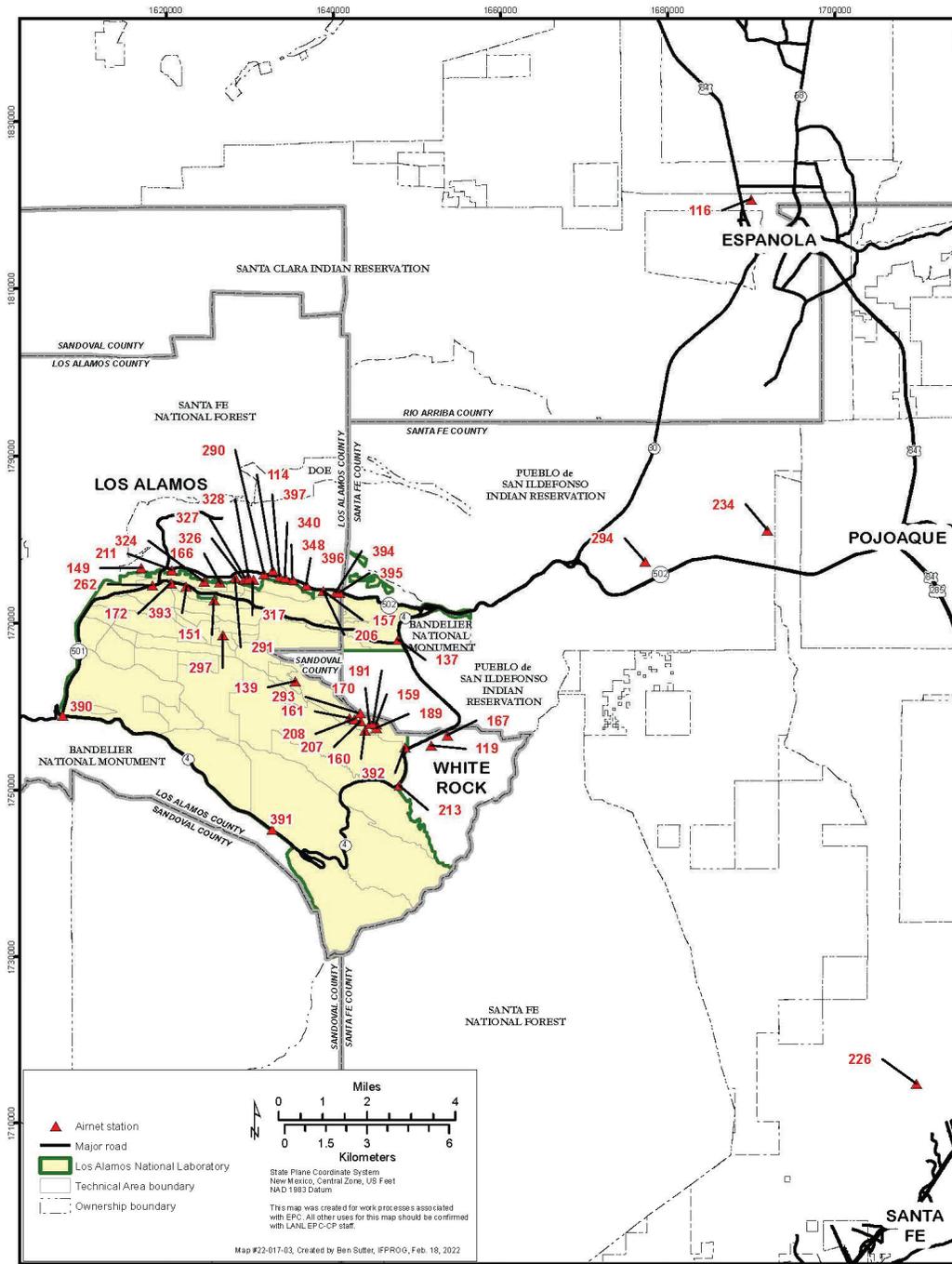


Figure 5. Locations of air sampling stations around Los Alamos County and also regional Northern New Mexico stations. Not all are EPA Compliance points; some are for facility environmental surveillance. See Figure 4 for more details.

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The net annual average ambient concentration of airborne radionuclides measured at air sampling stations is calculated by subtracting an appropriate background concentration value.¹⁹ The net concentration at each air sampler is converted to the annual effective dose equivalent (EDE) using Table 2 of Appendix E of 40 CFR 61 and applying the valid assumption that each Table 2 value is equivalent to 10 mrem/year from all appropriate exposure pathways (100% occupancy assumed at the respective location). Dose assessment results from each air sampler are given in Table 9 of this document. The operational performance and analytical completeness of each air sampler is provided in Table 10.

Note that per guidance put forth by the Department of Energy²⁰, negative numbers may be reported for both concentrations and resulting radionuclide doses for environmental data. This is to best approximate the true value of these data at the sampling locations. For more discussion on air concentration, uncertainties, and off-site dose consequence, please refer to the Annual Site Environmental Report published each year.

LANSCE Monthly Assessments

The Laboratory evaluates and reports the dose from short-lived radioactive gases released from LANSCE exhaust stack 53000702 on a monthly basis. This is performed to track and trend the emissions throughout the year and identify any operational issues that may need addressing. The doses from these monthly emissions are calculated with CAP88 using actual meteorology for the month and are shown in Table 11. For 2021, the Laboratory also evaluated this stack's total gaseous emissions for the year in a single CAP88 run and compared the results to the sum of monthly values. When evaluated to the LANSCE facility critical receptor at East Gate, the sum of monthly doses is a dose of 0.0488 millirem, and the annual total single analysis result is 0.0538 millirem, a difference of 9.8% (see Table 11 for details). These differences are due to meteorological parameters modeled by monthly runs (e.g., wind speed and direction, atmospheric mixing height) for the specific months of interest as opposed to those factors representing the entire calendar year. For conservatism, LANL uses the maximum value of either the annual evaluation or the sum of the monthly doses for EPA reported doses.

Because the Entrada Drive receptor is a critical receptor for a LANSCE source and the DP Road Fire Station was determined to be the MEI in 2021 (see the next section), this same comparison was repeated for stack GMAP emissions from 53000702 to those locations. When emissions are modeled to the DP Road Fire Station receptor, the sum of monthly analyses is 0.000973 millirem and a single annual

¹⁹ LANL procedure EPC-CP-QP-0502, "Air Pathway Dose Assessment," June 2020.

²⁰ DOE-HDBK-1216-2015, "DOE Handbook: Environmental Radiological Effluent Monitoring and Environmental Surveillance, 2015.

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analysis is equal to 0.000946 millirem. This difference is 2.8%. When emissions are modeled to the Entrada Drive receptor, the sum of monthly analyses is equal to 0.0140 millirem and a single annual analysis is equal to 0.0140 millirem. This difference is 0.4% when comparing non-rounded values.

Aside from these monthly assessments of GMAP emissions from 53000702, all other CAP88 assessments are performed using annual source term and annual meteorological inputs. The summary of off-site dose analyses from the LANSCE facility to the facility critical receptors at East Gate and Entrada Drive are included in Table 11.

Highest EDE Determination

Historically, the maximally exposed individual (MEI) location has been at 2470 East Road, usually referred to as "East Gate." The dose was primarily a result of LANSCE stack emissions. Emissions reduction efforts in place at LANSCE since 2005 have resulted in very low off-site doses from these stacks. Emissions were further reduced by improvements made in the new beam Target/Moderator/Reflector System (TMRS) that was installed in early 2010. Because the LANSCE emissions are so low in recent years, the location of the MEI is not as readily apparent as in the past and requires more detailed evaluation, as follows.

The dose from LANSCE stack and diffuse emissions can be significant contributors at receptor locations at East Gate and at Entrada Drive, but much less so at other possible MEI locations. To evaluate different MEI locations, LANL first calculates doses from LANSCE stacks and diffuse emissions sources to the East Gate and Entrada Drive receptor locations. These CAP88 sums are then combined with the ambient air doses measured at Airnet stations at these locations to establish dose comparison points. The doses measured at other Airnet locations are examined to see if there are any sites which could be candidates to match or exceed these dose comparison points at East Gate and Entrada Drive. CAP88 is used to model the LANSCE facility emissions and other significant stack sources to these locations, and the results are shown in Table 11. The Airnet measured dose is added to the stack modeled doses to determine the total LANL dose consequence at each location, keeping in mind that the MEI location must be a school, business, residence, or office.

In 2021, the dominant Airnet measured dose location was Station 326, located at the west end of DP Road next to the fire station. This site's Airnet dose and dose from LANSCE stacks modeled to Station 326 were then compared to the dose comparison points from two receptors near LANSCE. Results are shown below, with doses in millirem.

- East Gate: LANSCE = 0.0827 mrem; Airnet #157 = 0.0756 mrem; Total = 0.158 mrem

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- Entrada Drive: LANSCE = 0.0238 mrem; Airnet #396 = 0.104 mrem; Total = 0.128 mrem
- DP Fire Station: LANSCE = 0.00198 mrem; Airnet #326 = 0.246 mrem; Total = 0.248 mrem

For the East Gate location, the maximum Airnet dose of two stations at that site is used. For 2021, the primary East Gate station (#157) is the conservative value at 0.0756 mrem as opposed to the East Gate Duplicate station (#206) which measured 0.0237 mrem in 2021.

Based on the list above, the MEI for 2021 is the DP Road Fire Station. Emissions from the remaining monitored stacks were modeled from their sources to this location. The total MEI dose at this location is shown in Table 12. The overall dose is the sum of the following sources:

- emissions from all LANL stacks (major sources), modeled by CAP88 to this location;
- emissions from LANSCE diffuse sources, modeled by CAP88 to this location;
- the dose measured at the nearby Airnet station; and
- the sum of all minor sources potential emissions, modeled by CAP88 to each source's own critical receptor.

61.92 Compliance Assessment

The highest EDE to any member of the public at any off-site point where there is a residence, school, or business was 0.50 mrem for radionuclides released by LANL in 2021. This dose was calculated by adding up (1) the dose contributions for each of the monitored point sources at LANL, modeled to the MEI location; (2) the diffuse/fugitive gaseous activation products from LANSCE modeled to this MEI location; (3) the dose measured by the ambient air sampler in the vicinity of the public receptor location; and (4) the potential dose contribution of 0.252 mrem from non-monitored stacks (minor sources). Because the emissions estimates from non-monitored stacks do not account for pollution control systems, the actual dose from these minor sources is significantly less than the reported potential dose value. Table 12 of this report provides the compliance assessment summary, broken down by stack. The location of the Maximally Exposed Individual (MEI) from LANL operations is a fire station (business) at 132 DP Road, locally known as the DP Fire Station, and close to Airnet Station 326. The EDE for this year is well below the EPA limit of 10 millirem per year.

Section IV. Construction and Modifications

61.94(b)(8) Constructions, Modifications, and 61.96 Activity Relocations

A brief description of construction and modifications that were completed in the past year and for which the requirement to apply for approval to construct or modify was waived under section 61.96 is typically provided in this section. Items below are identified with their Air Quality Review (AQR) number or Permit Requirements Identification (PR-ID) number for tracking when applicable. There were two activities that met this requirement in 2021.

TA-48 Building 107 Renovation Project (10P-0118)

Radiological operations occurred in this building in 2021 including operations such as radiochemistry processes performed on bioassay samples, ultra-trace analysis, and isotope analysis. Potential emissions for 2021 were less than 1E-06 millirem. This source will be tracked using the RMUS as an unmonitored source.

TA-50 Building 1 Clarifier I Project (18P-0235)

Operations at TA-50-0001, RLWTF, are decommissioning the settling tanks, or “clarifiers” from the old process lines. Clarifier 1 was started in 2021. The clarifier tank has been drained but some sludge remains. The remediation project is performed within a confinement tent; exhaust from the tent is run outside of a building window and to the air, making this a forced-air exhaust release point which in turn makes it a new point source. Emissions will be tracked using the RMUS as an unmonitored source. Staff developed a very conservative estimate of potential emissions, using worst-case analytical results and bounding quantities of radioactive material processed during the decommissioning process. The bounding estimate of alpha-emitting radionuclides, modeled as Pu-239, for 2021 is 1.231 curies. This resulted in an off-site estimated dose of 0.07 millirem to the maximally exposed individual. Operations personnel performed periodic measurements of emissions, indicating the actual emissions are well within the bounding estimate.

Section V. Additional Information

This section is provided pursuant to DOE guidance and is not required by Subpart H reporting requirements.

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Unplanned Releases

There were 4 unplanned releases for calendar year 2021. A brief description of each incident is provided here. A brief summary of these unplanned releases can also be found in the Executive Summary.

TA-50-1 RLWTF Release of Treated Effluent

At the TA-50-0001 Radioactive Liquid Waste Treatment Facility (RLWTF), a piping failure resulted in the spill of approximately 3,500 gallons of treated effluent in March 2021. This effluent was being sent to the Mechanical Evaporation System (MES) at TA-50-0257. The spilled water did not leave the site, reach a storm drain, or adversely affect any Solid Waste Management Unit. This spill was reported to the New Mexico Environment Department on April 2, 2021, per procedure. Potential airborne emissions from this event are included in the tracking for the MES, which is a minor source of radionuclide air emissions.

TA-53-984 Contaminated Water Spill

EPC staff were notified in November 2021 about a spill of contaminated water within the beam tunnel of the TA-53-0984 IPF. This spill resulted from the cooling water system in the beam tunnel. The beam tunnel is normally held stagnant, but it is exhausted through a stack during times when personnel need to work in the tunnel. Facility radiation protection staff provided characterization data for the area, and EPC staff performed a bounding dose calculation. The worst-case off-site dose from this is less than $3\text{E-}08$ millirem (0.00000003 millirem) per year. This will be tracked in future years as a potential minor airborne emissions source.

TA-55-4 Contaminated Water Spill

In July 2021, there was a spill of approximately 200 gallons of contaminated water within the LANL Plutonium Facility at TA-55-0004 (PF-4). This incident was reported in local media. The contaminated liquid flowed into an air vent and into an inactive glove box used for handling radioactive materials, but it did not leave the confines of the PF-4 building. Any potential airborne emissions would be measured by the stack monitoring system; no unusual emissions were noted.

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TA-55-400 RLUOB HEPA Filter Failure

Engineers at the TA-55-0400 Radiological Laboratory/Utility/Office Building (RLUOB) notified EPC staff in July that one of the facility high-efficiency particulate air (HEPA) filter banks failed its annual aerosol penetration test. HEPA filters are normally rated for >99.95% removal of airborne particulates, and this filter test indicated only about 80% removal. The filter was last successfully tested in May 2020. RLUOB is considered a major source of emissions, and the stack is continuously monitored for airborne particulate releases. No unusual emissions were noted on the RLUOB stack monitor.

Environmental Monitoring

In addition to the Airnet monitors identified in this report, additional environmental monitoring stations are operated at LANL and include several environmental monitoring stations located near the LANSCE boundary inhabited by the public. Measurement systems at these and other stations include thermoluminescent dosimeters, continuously operated air samplers, and in-situ high-pressure ion chambers. The combination of these measurement systems allows for monitoring of radionuclide air concentrations and the radiation exposure rate. Results for air sampling associated with NESHAP compliance are included in this document, while results for all monitoring data are published in the Annual Site Environmental Report for compliance with DOE Orders.

Other Supplemental Information

The following information is included for completeness, but not directly required under 40 CFR 61 Subpart H regulations.

- 80-km collective effective (population) dose for 2021 airborne releases: **0.10 person-rem**.
To calculate this dose, the source term (Table 2) from all Laboratory monitored stacks and LANSCE diffuse sources were modeled in two CAP88 files from each emissions source. The source term from all TA-53 sources was modeled as being emitted from the 53000702 stack using the population array for TA-53 sources; the total dose in this evaluation is **0.0339 person-rem**. The remainder of the LANL monitored stacks source term was modeled as being emitted from the 48000107 stack using the general LANL-area population file, resulting in a dose of **0.0618 person-rem**. All other CAP88 parameters were identical to the individual dose calculations for each stack. The population dose from the two CAP88 analyses are summed together to obtain the reported population dose above.
- Compliance with Subparts Q and T of 40 CFR 61—Radon-222 Emissions.

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These regulations apply to ^{222}Rn emissions from DOE storage/disposal facilities that contain by-product material. “By-product material” is the tailings or wastes produced by the extraction or concentration of uranium from ore. Although this regulation targets uranium mills, LANL has likely stored small amounts of by-product material used in experiments in the TA-54 low-level waste facility, MDA G; this practice makes the Laboratory subject to this regulation. Subject facilities cannot exceed an emissions rate of $20 \text{ pCi/m}^2 \text{ s}$ of ^{222}Rn . In 1993 and 1994, LANL conducted a study to characterize emissions from the MDA G disposal site.²¹ This study showed an average emission rate of $0.14 \text{ pCi/m}^2 \text{ s}$ for MDA G. The performance assessment for MDA G has determined that there will not be a significant increase in ^{222}Rn emissions in the future.²²

- Potential to exceed 0.1 mrem from LANL sources of ^{222}Rn or ^{220}Rn emissions: not applicable at LANL.
- Status of compliance with EPA effluent monitoring requirements as of June 3, 1996: LANL is in compliance with these requirements as put forth in the Federal Facility Compliance Agreement.

The following pages contain Tables 1 through 12 as referenced in the previous sections.

²¹ Bart Eklund, “Measurements of Emission Fluxes from Technical Area 54, Areas G and L,” Radian Corporation report, Austin, Texas, 1995

²² Los Alamos National Laboratory, “Performance Assessment and Composite Analysis for Los Alamos National Laboratory Materials Disposal Area G,” LA-UR-97-85, 1997.

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Table 1. 40-61.94(b)(4-5) Release Point Data

Stack ID	Location TA-Bldg	Effluent Controls	# of Effluent Controls*	Control Efficiency*	Monitored Stack?	Monitoring System Uptime	Nearest Receptor (m)	Receptor Direction
03002913	TA-03-29-1	unknown	0	0%			859	NE
03002914	TA-03-29-2	HEPA	2*	99.95% each*	X	98.93%	733	NE
03002915	TA-03-29-2	HEPA	2*	99.95% each*	X	98.93%	734	NE
03002919	TA-03-29-3	Aerosol 95	1	80%	X	100.00%	838	NNE
03002920	TA-03-29-3	Aerosol 95	1	80%	X	100.00%	837	NNE
03002923	TA-03-29-4	FARR 30/30	1	20%	X	100.00%	618	NNW
03002924	TA-03-29-4	FARR 30/30	1	20%	X	100.00%	618	NNW
03002928	TA-03-29-5	HEPA	2*	99.95% each*	X	100.00%	938	NE
03002929	TA-03-29-5	HEPA	2*	99.95% each*	X	100.00%	939	NE
03002932	TA-03-29-7	HEPA	2*	99.95% each*	X	100.00%	858	NNE
03002933	TA-03-29-7	HEPA	2*	99.95% each*	X	100.00%	857	NNE
03002944	TA-03-29-9	RIGA-Flow	1	80%	X	100.00%	939	NNE
03002945	TA-03-29-9	RIGA-Flow	1	80%	X	100.00%	941	NNE
03002946	TA-03-29-9	RIGA-Flow	1	80%	X	100.00%	940	NNE
03003299	TA-03-32	unknown	0	0%			641	NNE
03003400	TA-03-34	none	0	0%			668	NNE
03006601	TA-03-66	none	0	0%			695	N
03006602	TA-03-66	none	0	0%			709	N
03006603	TA-03-66	none	0	0%			708	N
03006604	TA-03-66	none	0	0%			708	N
03006605	TA-03-66	none	0	0%			714	N
03006626	TA-03-66	HEPA	1	99.95%			618	N
03006654	TA-03-66	HEPA	1	99.95%			665	N
03006699	TA-03-66	none	0	0%			669	N
03010225	TA-03-102	HEPA	1	99.95%			772	N
03014101	TA-03-141	none	0	0%			637	NNE
03169800	TA-03-1698	none	0	0%			717	NNE
09002103	TA-09-21	none	0	0%			3044	NE
09003499	TA-09-34	none	0	0%			2879	NE
15028599	TA-15-285	HEPA	1	99.95%			3719	NNE
15053401	TA-15-534	HEPA	1	99.95%			3282	N

Table 1 (Continued) Release Point Data

Stack ID	Location TA-Bldg	Effluent Controls	# of Effluent Controls	Control Efficiency*	Monitored Stack?	Monitoring System Uptime	Nearest Receptor (m)	Receptor Direction
16020299	TA-16-202	none	0	0%			1185	S
16020599	TA-16-205	none	0	0%			752	SSW
16045005	TA-16-450	none	0	0%	X	99.97%	772	SSW
35000200	TA-35-2	none	0	0%			1294	NNW
35021305	TA-35-213	none	0	0%			1010	N
35045599	TA-35-455	unknown	0	0%			1055	N
36000104	TA-36-1	unknown	0	0%			5379	SE
39006999	TA-39-69	unknown	0	0%			3071	ENE
43000100	TA-43-1	none	0	0%			122	NE
46002499	TA-46-24	none	0	0%			2887	N
46003100	TA-46-31	none	0	0%			2792	N
46015405	TA-46-154	none	0	0%			2769	N
46015899	TA-46-158	none	0	0%			3053	N
46020099	TA-46-200	none	0	0%			2743	N
48000107	TA-48-1	HEPA/Charcoal	2*	99.95% each*	X	100.00%	754	NNE
48000111	TA-48-1	none	0	0%			874	NNE
48000115	TA-48-1	none	0	0%			764	NNE
48000135	TA-48-1	none	0	0%			797	NNE
48000145	TA-48-1	none	0	0%			893	N
48000154	TA-48-1	HEPA	2*	99.95% each*	X	100.00%	756	NNE
48000160	TA-48-1	HEPA	1	99.95%	X	100.00%	769	NNE
48000166	TA-48-1	HEPA	2*	99.95% each*			867	NNE
48000167	TA-48-1	HEPA	2*	99.95% each*			897	NNE
48000168	TA-48-1	none	0	0%			874	NNE
48000171	TA-48-1	none	0	0%			883	N
48004500	TA-48-45	none	0	0%			742	N
48010700	TA-48-107	none	0	0%			919	NE
50000102	TA-50-1	HEPA	1	99.95% each*	X	99.97%	1185	N
500001C1	TA-50-1	none	0	0%			1150	N
50000299	TA-50-2	none	0	0%			1215	N

Table 1 (Continued) Release Point Data

Stack ID	Location TA-Bldg	Effluent Controls	# of Effluent Controls	Control Efficiency*	Monitored Stack?	Monitoring System Uptime	Nearest Receptor (m)	Receptor Direction
50006901	TA-50-69	HEPA	1	99.95%			1199	N
50006902	TA-50-69	HEPA	1	99.95%			1188	N
50006903	TA-50-69	HEPA	2*	99.95% each*	X	100.00%	1187	N
50006999	TA-50-69	unknown	0	0%			1190	N
50025799	TA-50-257	none	0	0%			1201	N
53000116	TA-53-1	unknown	0	0%			1061	NE
53000303	TA-53-3	HEPA	1	99.95%	X	98.74%	806	NNE
53000702	TA-53-7	HEPA	1	99.95%	X	98.74%	957	NNE
53000799	TA-53-7	none	0	0%			926	NNE
53001599	TA-53-15	none	0	0%			1096	NNE
53098401	TA-53-984	none	0	0%			965	NNE
53098402	TA-53-984	none	0	0%			976	NNE
53109099	TA-53-1090	none	0	0%			1009	NNE
53130299	TA-53-1302	none	0	0%			1024	NNE
54003399	TA-54-33	none	0	0%			2058	ESE
54022499	TA-54-224	none	0	0%			2246	ESE
54023199	TA-54-231	HEPA	1	99.95%	X	100.00%	1480	SE
54037599	TA-54-375	HEPA	1	99.95%	X	99.98%	1783	SE
54041299	TA-54-412	HEPA	1	99.95%	X	99.98%	1660	SE
54100199	TA-54-1001	none	0	0%			4999	ESE
55000201	TA-55-2	none	0	0%			1111	NNE
55000415	TA-55-4	HEPA	4*	99.95% each*	X	99.53%	1018	NNE
55000416	TA-55-4	HEPA	4*	99.95% each*	X	100% particulate 99.95% tritium	1091	NNE
55040099	TA-55-400	HEPA	1	99.95%	X	100.00%	1318	NNE
59000100	TA-59-1	none	1	0%			1104	N
63000000	TA-63-All	none	0	0%			1526	NNW

Notes: * As described in the main text, LANL only tests HEPA filter banks down to 0.0005 penetration & 99.95% removal. This table reports the actual number of installed HEPA bank stages and nominal/design removal efficiencies, not tested efficiencies.

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Table 2. 40-61.94(b)(7) User Supplied Data—Radionuclide Emissions

StackID	Nuclide	Annual Emission (Ci)	StackID	Nuclide	Annual Emission (Ci)
03002914	Pu-238	4.78E-09	03002928	Pu-239	1.78E-07
03002914	Pu-239	1.39E-09	03002928	Th-230	9.17E-09
03002914	Th-228	8.15E-09	03002929	Am-241	9.91E-09
03002914	Th-230	4.61E-09	03002929	Pu-238	1.04E-07
03002914	Th-232	2.75E-09	03002929	Pu-239	1.00E-08
03002915	Pu-238	2.48E-09	03002929	Th-230	8.01E-09
03002915	Th-230	8.59E-09	03002932	Am-241	8.60E-06
03002915	Th-232	4.16E-09	03002932	Pu-238	8.34E-06
03002919	Am-241	2.05E-07	03002932	Pu-239	5.59E-06
03002919	Pu-238	1.06E-07	03002932	Th-228	2.92E-07
03002919	Pu-239	1.74E-06	03002932	Th-230	1.20E-08
03002919	Th-228	1.55E-08	03002933	Pu-238	2.49E-08
03002919	Th-230	1.82E-08	03002933	Pu-239	1.21E-08
03002920	Am-241	3.54E-09	03002933	Th-230	2.90E-09
03002920	Pu-238	4.43E-09	03002944	U-238	8.18E-09
03002920	Pu-239	7.25E-09	03002944	Pa-234m (p)	8.18E-09
03002920	Th-228	6.43E-09	03002944	Th-234 (p)	8.18E-09
03002923	Am-241	6.78E-09	03002945	Th-232	4.51E-09
03002923	Pu-238	1.98E-08	03002946	Pu-239	5.92E-09
03002923	Pu-239	7.16E-09	03002946	Th-228	3.10E-08
03002923	Th-228	1.06E-08	03002946	Th-230	7.29E-09
03002923	Th-230	6.05E-09	03002946	Th-232	1.41E-08
03002923	Th-232	2.90E-09	16045005	H-3(Gas)	1.88E+01
03002923	U-234	4.28E-07	16045005	H-3(HTO)	2.58E+01
03002923	U-238	3.83E-08	48000107	As-74	9.81E-08
03002923	Pa-234m (p)	3.83E-08	48000107	Br-77	5.45E-06
03002923	Th-234 (p)	3.83E-08	48000107	Ge-68	4.25E-07
03002924	Am-241	1.58E-08	48000107	Ga-68 (p)	4.25E-07
03002924	Pu-238	2.67E-07	48000107	Se-75	1.05E-05
03002924	Pu-239	5.93E-08	48000107	Th-228	5.67E-10
03002924	Th-228	1.09E-07	48000107	Th-230	1.67E-10
03002924	Th-230	1.81E-09	48000154	Th-228	1.47E-09
03002924	U-234	3.77E-06	48000154	Th-230	9.01E-10
03002924	U-235	2.07E-08	48000154	Th-232	4.71E-10
03002924	U-238	4.04E-08	48000160	As-74	2.96E-08
03002924	Pa-234m (p)	4.04E-08	48000160	Se-75	1.53E-06
03002924	Th-234 (p)	4.04E-08	48000160	Th-228	4.86E-10
03002928	Am-241	3.09E-08	48000160	Th-230	5.67E-10
03002928	Pu-238	1.57E-06			

Table continued next page

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Table 2 Notes (continued):

Starting in 2018, particulate emissions from TA-55 stacks 55000415 and 55000416 are also measured from basement samplers in addition to the rooftop sample systems. There are four zones that are being sampled from and are identified as 55410015, 55420015, 55430016, and 55440016. The RADAIR database then sums the emissions from the sample systems for each stack and gives the resulting emissions the stack ID 5500415Z and 5500416Z, where “Z” indicates the calculated value from the sampled zones. We are currently treating the “Z” sample systems as R&D systems, pending formal comparison between the basement samplers and rooftop samplers. Until these new sample systems can be proven to report representative emissions similar to the rooftop samplers, the results of 5500415X and 5500416X will be reported.

Radionuclides with the designator “(p)” are short-lived progeny in secular equilibrium with their parent radionuclide; e.g., “(p) Ga-68” (progeny) is in equilibrium with “Ge-68” (parent).

The term “None” in the Nuclide column indicates that there were no detectable emissions from this source for this calendar year.

Stack 16045005 (ES-5) exhausts buildings TA-16-450 and TA-16-205. The ES-5 stack sampler was not operational, so reported emissions are measured by the sampler in the exhaust duct from 16-205, designated 16020504. That sampler captures all emissions from the facility, as 16-450 operations have not commenced.

Non-point emissions sources 53DIF3SY, 53DIF1LS, and 53DIF984 are separated from the main source term table because they are addressed in different sections of the annual emissions report.

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**Table 3. 40-61.94(b)(7) User-Supplied Data
Monitored Stack Parameters**

StackID	Height (m)	Diameter (m)	Exit Velocity (m/s)	Nearest Meteorological Tower
03002914	15.9	1.07	9.4	TA-6
03002915	15.9	1.05	22.7	TA-6
03002919	15.9	1.07	15.3	TA-6
03002920	15.9	1.07	0*	TA-6
03002923	15.9	1.07	8.2	TA-6
03002924	15.9	1.06	1.9	TA-6
03002928	15.9	1.05	16.8	TA-6
03002929	15.9	1.07	17.6	TA-6
03002932	15.9	1.07	15.3	TA-6
03002933	15.9	1.06	15.0	TA-6
03002944	16.5	1.52	0*	TA-6
03002945	16.5	1.52	1.6	TA-6
03002946	16.5	1.88	10.8	TA-6
16045005	18.3	1.18	13.7	TA-6 (TA-16B**)
48000107	13.4	0.30	17.8	TA-6
48000154	13.1	0.91	4.7	TA-6
48000160	12.4	0.38	9.0	TA-6
50000102	15.5	1.82	10.9	TA-6 (TA-63**)
50006903	10.5	0.31	5.6	TA-6 (TA-63**)
53000303	33.5	0.91	10.0	TA-53
53000702	13.1	0.91	7.7	TA-53
54023199	0.61	0.61	0.0 vertical 8.7 horizontal	TA-54
54037599	0.76	0.90	0.0 vertical 6.8 horizontal	TA-54
54041299	0.61	0.61	0.0 vertical 2.7 horizontal	TA-54
55000415	9.5	0.93	8.7	TA-6 (TA-63**)
55000416	9.5	0.94	9.3	TA-6 (TA-63**)
55040099	26.0	1.88	16.0	TA-6 (TA-63**)

* Exhaust fans operated only intermittently for stack 03002920 and 03002944. Emissions were calculated using 3-year historical maximum flow rates, and doses modeled using 0.0 m/s stack velocity. These two assumptions result in conservative off-site doses.

**Three additional met towers came online in 2021: TA-16B, TA-54B, and TA-63. Because these new towers do not have data for all of 2021, met data was obtained from the original 4 met towers and used accordingly.

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**Table 4. 61.94(b)(7) User-Supplied Data
Monitored Stack Locations**

StackID	Latitude	Longitude
03002914	35.872344°	-106.321697°
03002915	35.872342°	-106.321714°
03002919	35.871092°	-106.321439°
03002920	35.871096°	-106.321422°
03002923	35.872106°	-106.323334°
03002924	35.872103°	-106.323349°
03002928	35.870858°	-106.323053°
03002929	35.870858°	-106.323075°
03002932	35.870864°	-106.321383°
03002933	35.870869°	-106.321372°
03002944	35.870464°	-106.322333°
03002945	35.870461°	-106.322367°
03002946	35.870465°	-106.322350°
16045005	35.839638°	-106.354564°
48000107	35.866547°	-106.306789°
48000154	35.866431°	-106.306272°
48000160	35.866397°	-106.306717°
50000102	35.862137°	-106.298125°
50006903	35.862078°	-106.300078°
53000303	35.868906°	-106.257708°
53000702	35.867553°	-106.257964°
54023199	35.829631°	-106.235356°
54037599	35.831244°	-106.237844°
54041299	35.831542°	-106.235983°
55000415	35.863936°	-106.302472°
55000416	35.863408°	-106.303128°
55040099	35.861225°	-106.301950°

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Table 5. 40-61.94(b)(7) User-Supplied Data—Highest Off-Site Dose Location for Monitored Release Points

StackID	Associated Meteorological Tower	Distance to LANL Highest Dose Location (m)	Direction to LANL Highest Dose Location
03002914	TA-06	3164	ENE
03002915	TA-06	3166	ENE
03002919	TA-06	3177	ENE
03002920	TA-06	3176	ENE
03002923	TA-06	3314	ENE
03002924	TA-06	3315	ENE
03002928	TA-06	3325	ENE
03002929	TA-06	3327	ENE
03002932	TA-06	3180	ENE
03002933	TA-06	3178	ENE
03002944	TA-06	3275	ENE
03002945	TA-06	3278	ENE
03002946	TA-06	3276	ENE
16045005	TA-06	7462	NE
48000107	TA-06	2219	NE
48000154	TA-06	2191	NE
48000160	TA-06	2224	NE
50000102	TA-06	2106	NNE
50006903	TA-06	2196	NNE
53000303	TA-53	2931	WNW
53000702	TA-53	2971	WNW
54023199	TA-54	7239	NW
54037599	TA-54	6957	NW
54041299	TA-54	7042	NW
55000415	TA-06	2149	NE
55000416	TA-06	2232	NE
55040099	TA-06	2363	NNE

Table 6. 40-61.94(b)(7) User-Supplied Data—Other Input Parameters

Description	Value	Units	CAP88 Variable Name (source code/V0 identifiers)
Annual rainfall rate	44	cm/y	RR
Lid height*	1600	m	LIPO
Annual ambient temperature	9.6	deg C	TA
Absolute humidity	4.3	g/m ³	
E-vertical temperature gradient	0.02	K/m	TG
F-vertical temperature gradient	0.035	K/m	TG
G-vertical temperature gradient	0.035	K/m	TG
Food supply fraction - local vegetables	1		F1V
Food supply fraction - vegetable regional	0		F2V
Food supply fraction - vegetable imported	0		F3V
Food supply fraction - meat local	1		F1B
Food supply fraction - meat regional	0		F2B
Food supply fraction - meat imported	0		F3B
Food supply fraction - milk local	1		F1M
Food supply fraction - milk regional	0		F2M
Food supply fraction - milk imported	0		F3M
Ground surface roughness factor	0.5		GSCFAC

* Note for the monthly LANSCE runs, the atmospheric lid height used in each monthly run uses the average value for each specific month. The annual average of 1600 meters is used for full-year runs. Procedure 501 has full details²³.

²³ LANL Procedure EPC-CP-QP-0501, “Dose Assessment Using CAP88.” November 2021.

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Table 7. 40-61.94(b)(7) User-Supplied Data—Population Arrays
 Estimated 2010 Population within 80 km of Los Alamos National Laboratory (revised 2012)

Direction (sector)	Distances from Los Alamos – “LANL Area Source”												
	250	750	1500	2500	3500	4500	7500	15000	25000	35000	45000	55000	70000
N	4	13	89	231	274	514	1350	16	103	1077	0	945	641
NNW	4	17	102	173	375	282	1299	7	22	291	0	0	528
NW	8	4	58	146	218	266	1030	2	27	56	821	0	1153
WNW	4	19	34	65	115	142	281	0	35	41	0	0	3305
W	0	0	22	26	25	30	18	14	119	575	0	135	257
WSW	0	0	0	0	0	0	2	14	1	696	0	4673	0
SW	0	0	0	0	0	0	5	5	0	0	0	3965	0
SSW	0	0	0	0	0	0	36	6	1766	2392	5674	4591	100236
S	0	0	0	0	0	0	20	9	31	274	0	0	6060
SSE	0	0	0	0	0	0	765	51	406	6811	3328	0	0
SE	0	0	0	0	0	0	5764	1	1318	88346	9870	218	6
ESE	0	0	0	0	0	0	36	14	868	10461	0	803	2430
E	0	0	22	26	25	30	18	1915	5002	511	588	1	598
ENE	4	19	34	65	115	142	281	2600	5419	4317	194	1128	1752
NE	8	4	58	146	218	266	1030	1314	17067	2878	1604	1597	3527
NNE	4	17	102	173	375	282	1299	15	2739	479	3483	0	58

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**Table 7.2
Distances from Los Alamos – “TA-53 Source”**

Direction (sector)	250	750	1500	2500	3500	4500	7500	15000	25000	35000	45000	55000	70000
N	0	50	0	157	184	183	0	16	103	1077	0	945	641
NNW	0	0	0	566	276	397	50	7	22	291	0	0	528
NW	0	0	0	312	647	786	1336	2	27	56	821	0	1153
WNW	0	0	0	38	959	1047	5063	0	35	41	0	0	3305
W	0	0	0	0	161	169	15	14	119	575	0	135	257
WSW	0	0	0	0	0	0	2	14	1	696	0	4673	0
SW	0	0	0	0	0	0	5	5	0	0	0	3965	0
SSW	0	0	0	0	0	0	36	6	1766	2392	5674	4591	100236
S	0	0	0	0	0	0	20	9	31	274	0	0	6060
SSE	0	0	0	0	0	0	765	51	406	6811	3328	0	0
SE	0	0	0	0	0	0	5764	1	1318	88346	9870	218	6
ESE	0	0	0	0	0	0	36	14	868	10461	0	803	2430
E	0	0	0	0	0	0	3	1915	5002	511	588	1	598
ENE	0	0	0	0	0	0	0	2600	5419	4317	194	1128	1752
NE	0	0	0	0	0	0	0	1314	17067	2878	1604	1597	3527
NNE	0	0	0	0	0	0	0	15	2739	479	3483	0	58

**Table 8. 40-61.94(b)(7) User-Supplied Data
Modeling Parameters
for LANL Non-Point Sources**

Non-Point Source	Area of Source (m²)	Height of Source (m)	Radionuclide	Emission (Ci)
TA-53-1L Service Area Stack ID = 53DIF1LS	1.0	0	⁴¹ Ar ¹¹ C	5.94E-01 1.43E+01
TA-53 Beam Switchyard StackID = 53DIF3SY	484	0	⁴¹ Ar ¹¹ C	2.66E-01 6.37E+00
TA-53 Building 984 Stack ID = 53DIF984	200	3.0	⁴¹ Ar ¹¹ C	8.59E-01 1.52E+01

Non-Point Source	Distance to Nearest Receptor Location [Critical receptor] (meters)	Direction to Nearest Receptor Location [Critical Receptor]
TA-53-1L Service Area Stack ID = 53DIF1LS	943	NNE
TA-53 Beam Switchyard StackID = 53DIF3SY	774	NNE
TA-53 Building 984 Stack ID = 53DIF984	973	NNE

Non-Point Source	Distance to LANL Maximum Dose Location (m)	Direction to LANL Maximum Dose Location
TA-53-1L Service Area Stack ID = 53DIF1LS	2972	WNW
TA-53 Beam Switchyard StackID = 53DIF3SY	2888	WNW
TA-53 Building 984 Stack ID = 53DIF984	2227	WNW

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Table 9. Environmental Data—Compliance Stations
2021 Effective Dose Equivalent measured at air sampling locations around LANL (net millirem)

Site	Site Name	H-3	Am-241	Pu-238	Pu-239	U-234	U-235	U-238	Total (mrem)
114	Los Alamos Airport	0.002	-0.004	-0.001	0.004	0.008	0.001	0.002	0.012
119	Rocket Park	0.005	-0.003	0.003	0.010	0.008	0.002	0.006	0.031
137	Well PM-1	0.006	-0.002	0.000	0.000	0.008	0.001	0.007	0.020
149	48th Street	0.001	-0.002	0.001	0.000	0.000	0.001	0.000	0.001
151	Royal Crest	0.002	0.000	0.001	0.001	0.002	0.001	0.002	0.009
157	East Gate	-0.001	0.030	0.018	0.002	0.012	0.002	0.012	0.075
166	McDonalds	0.001	-0.002	0.001	-0.001	0.009	0.001	0.003	0.012
167	WR Fire Station	0.002	-0.002	0.002	-0.003	0.004	0.000	0.004	0.007
172	LA County Landfill	0.036	0.001	0.001	0.000	0.031	0.002	0.024	0.095
206	East Gate - Backup	0.002	-0.003	0.000	0.003	0.013	0.001	0.008	0.024
211	LA Hospital	0.000	-0.001	0.002	0.004	0.008	0.001	0.005	0.019
213	Monte Rey South	0.000	-0.003	0.004	0.003	0.003	0.001	0.002	0.010
262	TA-3 Research Park	0.002	0.001	-0.001	-0.002	0.005	0.001	0.003	0.009
290	Airport Road	0.000	0.003	0.000	0.000	0.007	0.002	0.008	0.020
291	Knights of Columbus	0.001	-0.001	0.002	0.018	0.060	0.004	0.059	0.143
317	DP Road	0.001	0.002	0.005	0.062	0.026	0.003	0.021	0.120
324	Hillside 138	0.001	0.000	0.001	0.027	0.006	0.000	0.006	0.041
326	DP Rd - Fire Station	0.003	0.001	0.003	0.141	0.048	0.004	0.046	0.246
327	DP Rd - Ace	0.002	-0.002	0.003	0.011	0.016	0.001	0.015	0.046
328	DP Rd - Monitor	0.000	0.000	0.001	0.021	0.018	0.001	0.017	0.058
340	502 East Runway	0.004	0.003	0.006	0.005	0.009	0.002	0.008	0.037
348	NM 502/Mid-Runway	0.002	0.002	0.001	0.007	0.010	0.002	0.007	0.031
390	West Gate	0.004	0.002	0.004	0.000	0.006	0.000	0.003	0.019
391	Bandelier Gate	0.001	0.000	0.000	0.002	0.000	0.001	0.002	0.006
392	WR Pajarito Road	0.006	-0.001	0.000	-0.001	0.009	0.002	0.005	0.020
393	Transit Mix	0.000	0.000	0.001	0.000	0.013	0.000	0.012	0.026
394	East Gate Shed	0.003	-0.002	0.002	-0.002	0.004	0.001	0.003	0.009
395	East Gate Tank	0.002	-0.001	0.000	0.000	0.004	0.001	0.005	0.011
396	Co-Op Market	0.002	0.001	0.003	0.021	0.039	0.003	0.035	0.104
397	502 West Runway	0.001	0.005	0.011	0.020	0.011	0.001	0.011	0.060

Highlights indicate sites that were evaluated for the maximally exposed individual (MEI) location.

Results have been rounded to three decimal places in this table for clarity.

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**Table 10. Environmental Data—Compliance Stations
2021 Sampler Operational Completeness and Analytical Completeness**

Site #	Site Name	% Run Time	H-3	Am-241	Pu-238	Pu-239	U-234	U-235	U-238
114	Los Alamos Airport	99.6	100	100	100	100	100	100	100
119	Rocket Park	99.8	100	100	100	100	100	100	100
137	Well PM-1	99.8	100	100	100	100	100	100	100
149	48th Street	99.2	100	100	100	100	100	100	100
151	Royal Crest	99.7	100	100	100	100	100	100	100
157	East Gate	99.6	100	100	100	100	100	100	100
166	McDonalds	99.3	100	100	100	100	100	100	100
167	WR Fire Station	99.7	96	100	100	100	100	100	100
172	LA County Landfill	98.5	100	100	100	100	100	100	100
206	East Gate - Backup	99.7	100	100	100	100	100	100	100
211	LA Hospital	99.8	100	100	100	100	100	100	100
213	Monte Rey South	99.8	100	100	100	100	100	100	100
262	TA-3 Research Park	99.8	100	100	100	100	100	100	100
290	Airport Road	99.6	100	100	100	100	100	100	100
291	Knights of Columbus	99.4	100	100	100	100	100	100	100
317	DP Road	99.5	100	100	100	100	100	100	100
324	Hillside 138	99.7	100	100	100	100	100	100	100
326	DP - Fire Station	99.8	100	100	100	100	100	100	100
327	DP - Ace	92.3	100	100	100	100	100	100	100
328	DP - Monitor	92.3	100	100	100	100	100	100	100
340	502 East Runway	93.0	100	100	100	100	100	100	100
348	NM 502/Mid-Runway	98.6	100	100	100	100	100	100	100
390	West Gate	99.8	100	100	100	100	100	100	100
391	Bandelier Gate	99.8	100	100	100	100	100	100	100
392	WR Pajarito Road	99.8	100	100	100	100	100	100	100
393	Transit Mix	99.7	100	100	100	100	100	100	100
394	East Gate Shed	99.6	100	100	100	100	100	100	100
395	East Gate Tank	99.8	96.2	100	100	100	100	100	100
396	Co-Op Market	99.8	100	100	100	100	100	100	100
397	502 West Runway	97.7	100	100	100	100	100	100	100

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Table 11. LANSCE Monthly Assessments, Comparison with Annual Analyses, and Facility Dose Summary

Description	StackID	Dose at @ East Gate (mrem)	Dose at @ Entrada Drive (mrem)	Dose at @ DP Fire Station(mrem)
LANSCE stack January GMAP	53000702	None	None	None
LANSCE stack February GMAP	53000702	None	None	None
LANSCE stack March GMAP	53000702	None	None	None
LANSCE stack April GMAP	53000702	None	None	None
LANSCE stack May GMAP	53000702	None	None	None
LANSCE stack June GMAP	53000702	3.19E-03	1.21E-03	1.11E-04
LANSCE stack July GMAP	53000702	1.06E-02	2.54E-03	1.37E-04
LANSCE stack August GMAP	53000702	7.47E-03	1.32E-03	8.42E-05
LANSCE stack September GMAP	53000702	4.48E-03	1.45E-03	6.10E-05
LANSCE stack October GMAP	53000702	6.30E-03	2.13E-03	1.87E-04
LANSCE stack November GMAP	53000702	7.33E-03	2.94E-03	2.47E-04
LANSCE stack December GMAP	53000702	9.41E-03	2.36E-03	1.46E-04
Sum of monthly GMAP runs for this stack	53000702	4.88E-02	1.40E-02	9.73E-04
GMAP single annual analysis for this stack	53000702	5.38E-02	1.40E-02	9.46E-04
<i>Difference, sum of monthly vs. annual analyses:</i>		<i>9.8%</i>	<i>0.4%</i>	<i>2.8%</i>

To be conservative, the **maximum value** of the either the single annual analysis or the sum of monthly analyses will be used for all further reporting of GMAP emissions from the main LANSCE stack 53000702.

Reporting values are highlighted above for each receptor location.

SUMMARY OF LANSCE FACILITY DOSE		Dose at @ East Gate (mrem)	Dose at @ Entrada Drive (mrem)	Dose at @ DP Fire Station(mrem)
LANSCE stack	53000303	7.09E-03	2.86E-03	3.34E-04
LANSCE stack GMAP (see above)	53000702	5.38E-02	1.40E-02	9.73E-04
LANSCE stack PVAP	53000702	7.05E-03	2.30E-03	4.21E-04
LANSCE Diffuse/Fugitive Emissions – 1L Service Area	53DIF1LS	8.58E-03	2.34E-03	1.33E-04
LANSCE Diffuse/Fugitive Emissions – Beam Switchyard	53DIF3SY	5.72E-03	1.54E-03	6.44E-05
LANSCE Diffuse/Fugitive Emissions – Building 984	53DIF984	4.74E-04	7.80E-04	5.30E-05
2021 LANSCE facility summary:		8.27E-02	2.38E-02	1.98E-03

GMAP = Gaseous Mixed Activation products; short-lived radioactive gases (e.g., C-11, O-15, Ar-41).

PVAP = Particulate & Vapor Activation Products (e.g., Na-24, Br-76).

Note: All CAP88 analyses above are annual assessments, with the exception of the monthly GMAP analyses for stack 53000702, as described.

Note: For completeness, the “Summary” portion of this table is reproduced in Table 12, next page, for both the individual facility critical receptors for each source and for the LANL Maximally Exposed Individual (MEI) receptor.

Note: 53DIF984 is about 750 meters west of the other sources at TA-53. As such, the critical receptor for Building 984 is not the East Gate complex, but rather a business on Entrada Drive. Doses in the above table are shown to each location.

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Table 12. 40-61.92 Highest Effective Dose Equivalent Summary

All LANL Sources

Description	StackID	Dose for Facility Critical Receptor (mrem)	Dose at LANL MEI receptor – DP Road (mrem)
CMR Stack – Wing 2	03002914	1.62E-06	3.27E-07
CMR Stack – Wing 2	03002915	4.96E-06	1.08E-06
CMR Stack – Wing 3	03002919	4.93E-05	1.02E-05
CMR Stack – Wing 3	03002920	9.42E-05	2.20E-05
CMR Stack – Wing 4	03002923	6.47E-06	1.52E-06
CMR Stack – Wing 4	03002924	1.22E-03	2.97E-04
CMR Stack – Wing 5	03002928	2.15E-06	5.20E-07
CMR Stack – Wing 5	03002929	4.26E-08	9.87E-09
CMR Stack – Wing 7	03002932	2.50E-07	6.00E-08
CMR Stack – Wing 7	03002933	2.02E-06	5.32E-07
CMR Stack – Wing 9	03002944	8.80E-03	1.24E-03
CMR Stack – Wing 9	03002945	4.81E-06	1.42E-06
CMR Stack – Wing 9	03002946	1.64E-07	4.69E-08
WETF Stack – new	16045005	7.20E-07	2.06E-07
Radiochemistry Stack	48000107	4.39E-07	2.23E-07
Radiochemistry Stack	48000154	6.21E-09	2.85E-09
Radiochemistry Stack	48000160	7.09E-03	3.34E-04
Waste Management Stack	50000102	5.38E-02	9.73E-04
Waste Management Stack	50006903	7.05E-03	4.21E-04
LANSCE-Stack	53000303	8.58E-03	1.33E-04
LANSCE-Stack – GMAP (See Note 1)	53000702	5.72E-03	6.44E-05
LANSCE- Annual – Partic/Vapor	53000702	7.80E-04	5.30E-05
LANSCE Fugitive – 1L Service Area	53DIF1LS	8.10E-08	5.59E-10
LANSCE Fugitive – Beam Switch Yard	53DIF3SY	4.50E-08	3.27E-07
LANSCE Fugitive – Building 984	53DIF984	1.62E-06	1.08E-06
Waste Processing Stack	54023199	4.96E-06	1.02E-05
Waste Processing Stack	54037599	4.93E-05	4.97E-10
Waste Processing Stack	54041299	0.00E+00	0.00E+00
Plutonium Facility Stack	55000415	4.24E-07	1.87E-07
Plutonium Facility Stack	55000416	1.15E-04	5.46E-05
Radiological Lab/Utility/Office Bldg	55040099	4.45E-07	2.34E-07
Minor Sources (Unmonitored) (See Note 2)	99000000	2.52E-01	2.52E-01
Air Sampler Net Dose @ MEI location	99000010	N/A	2.46E-01
Total dose to off-site maximally exposed individual (mrem)			= 0.502 mrem Reporting value: 0.50 mrem
<p>Note 1: As described in Table 11, the reporting value for GMAP emissions from 53000702 is the maximum value of either the annual GMAP dose assessment or the sum of monthly GMAP dose assessments. Data for TA-53 sources here is reproduced from Table 11.</p> <p>Note 2: The doses above for Minor Sources (Unmonitored) reflect calculated potential emissions, with no credit for emission controls. The summed dose from all minor sources to each source's MEI is shown in this table.</p>			

2021 LANL Radionuclide Air Emissions Report

61.94(b)(9) Certification

Operator – Triad National Security, LLC

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. 100%1.

Signature: WILLIAM MAIRSON (Affiliate) Digitally signed by WILLIAM MAIRSON (Affiliate)
Date: 2022.11.01 09:20:52 -06'00' Date: 11/1/22

Operator: William R. Mairson
Associate Laboratory Director, Acting
Environment, Safety, Health, and Quality
Triad National Security, LLC
Los Alamos National Laboratory

2021 LANL Radionuclide Air Emissions Report

61.94(b)(9) Certification

Owner – Department of Energy Office – National Nuclear Security Administration

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. 100%1.

Signature:



Owner:

Theodore A. Wyka
Manager
National Nuclear Security Administration
Los Alamos Field Office
U. S. Department of Energy

Date:

11/30/2022

2021 LANL Radionuclide Air Emissions Report

61.94(b)(9) Certification

Operator – Newport News Nuclear BWXT-Los Alamos, LLC (N3B)

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. 100%1.

Signature: Robert M. H. Macfarlane Digitally signed by Robert M. H. Macfarlane
Date: 2022.11.03 06:34:24 -06'00'

Operator: Robert Macfarlane Date: 11/3/22
Program Manager
Environment, Safety, Health and Quality
Newport News Nuclear BWXT-Los Alamos, LLC
Los Alamos National Laboratory

2021 LANL Radionuclide Air Emissions Report

61.94(b)(9) Certification

Owner – Department of Energy Office – Environmental Management

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. 100%1.

Signature: Michael A. Mikolanis Digitally signed by Michael A. Mikolanis
Date: 2022.11.08 18:45:42 -07'00'

Owner: Michael A. Mikolanis
Site Manager
Environmental Management
Los Alamos Field Office
U. S. Department of Energy

Date: 11/8/22

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Appendix A – Meteorology Data

Required by 40-61.94(b)(7) User-Supplied Data—Wind Frequency Arrays

Table A1: TA-6 meteorological tower data, 2021 (fixed Sep 2022)

Table A2: TA-53 meteorological tower data, 2021 (fixed Sep 2022)

Table A3: TA-54 meteorological tower data, 2021 (fixed Sep 2022)

Table A1
CAP88 Input Data for 2021 TA-6 Meteorological Tower
(99% Data Completeness)

N	A	0.000800	.000460	.000000	.000000	.000000	.000000
NNE	A	0.001400	.000830	.000000	.000000	.000000	.000000
NE	A	0.003760	.001150	.000000	.000000	.000000	.000000
ENE	A	0.005160	.002470	.000000	.000000	.000000	.000000
E	A	0.005590	.003410	.000000	.000000	.000000	.000000
ESE	A	0.003470	.002920	.000000	.000000	.000000	.000000
SE	A	0.003180	.002980	.000000	.000000	.000000	.000000
SSE	A	0.002320	.002580	.000000	.000000	.000000	.000000
S	A	0.001380	.001610	.000000	.000000	.000000	.000000
SSW	A	0.000720	.000660	.000000	.000000	.000000	.000000
SW	A	0.000570	.000340	.000000	.000000	.000000	.000000
WSW	A	0.000340	.000170	.000000	.000000	.000000	.000000
W	A	0.000340	.000340	.000000	.000000	.000000	.000000
WNW	A	0.000490	.000290	.000000	.000000	.000000	.000000
NW	A	0.000540	.000290	.000000	.000000	.000000	.000000
NNW	A	0.000920	.000370	.000000	.000000	.000000	.000000
N	B	0.000230	.000340	.000030	.000000	.000000	.000000
NNE	B	0.000460	.000750	.000030	.000000	.000000	.000000
NE	B	0.001000	.001750	.000060	.000000	.000000	.000000
ENE	B	0.001260	.002690	.000030	.000000	.000000	.000000
E	B	0.001690	.003810	.000000	.000000	.000000	.000000
ESE	B	0.001030	.003330	.000000	.000000	.000000	.000000
SE	B	0.000950	.003870	.000000	.000000	.000000	.000000
SSE	B	0.000490	.002670	.000060	.000000	.000000	.000000
S	B	0.000260	.001520	.000030	.000000	.000000	.000000
SSW	B	0.000230	.001090	.000000	.000000	.000000	.000000
SW	B	0.000110	.000460	.000060	.000000	.000000	.000000
WSW	B	0.000170	.000520	.000030	.000000	.000000	.000000
W	B	0.000060	.000320	.000060	.000000	.000000	.000000
WNW	B	0.000110	.000290	.000110	.000000	.000000	.000000
NW	B	0.000060	.000260	.000030	.000000	.000000	.000000
NNW	B	0.000200	.000260	.000060	.000000	.000000	.000000
N	C	0.000370	.000750	.000140	.000000	.000000	.000000
NNE	C	0.001000	.002240	.000260	.000000	.000000	.000000
NE	C	0.001180	.003700	.000430	.000000	.000000	.000000
ENE	C	0.001890	.006190	.000260	.000000	.000000	.000000
E	C	0.001920	.006770	.000170	.000000	.000000	.000000
ESE	C	0.001030	.007170	.000140	.000000	.000000	.000000
SE	C	0.001090	.008940	.000400	.000000	.000000	.000000
SSE	C	0.001200	.011070	.001180	.000000	.000000	.000000
S	C	0.000750	.005910	.002290	.000030	.000000	.000000
SSW	C	0.000430	.002260	.001400	.000060	.000000	.000000

(Table continued next page)

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Table A1 (continued)

SW	C	0.000290	.001230	.000800	.000000	.000000	.000000
WSW	C	0.000370	.000800	.000950	.000000	.000000	.000000
W	C	0.000060	.001000	.001290	.000060	.000000	.000000
WNW	C	0.000140	.000970	.001720	.000140	.000000	.000000
NW	C	0.000090	.001060	.000860	.000090	.000000	.000000
NNW	C	0.000140	.000830	.000520	.000030	.000000	.000000
N	D	0.005300	.006880	.002870	.001030	.000060	.000000
NNE	D	0.005250	.010350	.005960	.002240	.000030	.000000
NE	D	0.003760	.007080	.002840	.000520	.000000	.000000
ENE	D	0.003580	.004840	.000890	.000060	.000000	.000000
E	D	0.004040	.004590	.000540	.000000	.000000	.000000
ESE	D	0.002720	.005070	.000950	.000230	.000000	.000000
SE	D	0.003410	.010460	.004560	.000230	.000030	.000000
SSE	D	0.004390	.015680	.015050	.001660	.000260	.000000
S	D	0.004760	.020780	.033600	.009200	.000340	.000000
SSW	D	0.003760	.021500	.031620	.007050	.000540	.000000
SW	D	0.004870	.013330	.025800	.011180	.001120	.00003
WSW	D	0.004190	.010720	.014300	.010460	.001580	.00014
W	D	0.004410	.009430	.013730	.008690	.001490	.00029
WNW	D	0.003640	.008920	.016110	.009260	.001950	.00011
NW	D	0.004040	.009550	.013100	.005590	.000630	.00009
NNW	D	0.005070	.006970	.003500	.001060	.000060	.00000
N	E	0.003120	.005050	.001890	.000000	.000000	.00000
NNE	E	0.002060	.003780	.000750	.000000	.000000	.00000
NE	E	0.001920	.001400	.000030	.000000	.000000	.00000
ENE	E	0.001150	.000490	.000030	.000000	.000000	.00000
E	E	0.001180	.000230	.000000	.000000	.000000	.00000
ESE	E	0.000720	.000460	.000030	.000000	.000000	.00000
SE	E	0.001180	.000720	.000060	.000000	.000000	.00000
SSE	E	0.001430	.001980	.000200	.000000	.000000	.00000
S	E	0.002550	.007340	.000770	.000000	.000000	.00000
SSW	E	0.002780	.016880	.002320	.000000	.000000	.00000
SW	E	0.003240	.018600	.010660	.000000	.000000	.00000
WSW	E	0.002810	.013790	.005880	.000000	.000000	.00000
W	E	0.002950	.008630	.001720	.000000	.000000	.00000
WNW	E	0.002690	.010260	.003150	.000000	.000000	.00000
NW	E	0.003760	.010860	.003070	.000000	.000000	.00000
NNW	E	0.003240	.007080	.001060	.000000	.000000	.00000
N	F	0.004900	.005160	.000000	.000000	.000000	.00000
NNE	F	0.003100	.001000	.000000	.000000	.000000	.00000
NE	F	0.001520	.000090	.000000	.000000	.000000	.00000
ENE	F	0.000920	.000170	.000000	.000000	.000000	.00000
E	F	0.000370	.000030	.000000	.000000	.000000	.00000
ESE	F	0.000690	.000030	.000000	.000000	.000000	.00000
SE	F	0.000720	.000090	.000000	.000000	.000000	.00000
SSE	F	0.000970	.000090	.000000	.000000	.000000	.00000
S	F	0.001380	.000540	.000000	.000000	.000000	.00000
SSW	F	0.002870	.002440	.000000	.000000	.000000	.00000
SW	F	0.005050	.012240	.000000	.000000	.000000	.00000
WSW	F	0.006940	.022730	.000000	.000000	.000000	.00000
W	F	0.005990	.022130	.000000	.000000	.000000	.00000
WNW	F	0.005820	.013270	.000000	.000000	.000000	.00000
NW	F	0.006360	.016800	.000000	.000000	.000000	.00000
NNW	F	0.005480	.007510	.000000	.000000	.000000	.00000

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Table A2
CAP88 Input Data for 2021 TA-53 Meteorological Tower
(99% Data Completeness)

N	A	0.001030	.000230	.000000	.000000	.000000	.000000
NNE	A	0.002370	.000600	.000000	.000000	.000000	.000000
NE	A	0.004400	.001510	.000000	.000000	.000000	.000000
ENE	A	0.006230	.002890	.000000	.000000	.000000	.000000
E	A	0.005830	.003510	.000000	.000000	.000000	.000000
ESE	A	0.004200	.003660	.000000	.000000	.000000	.000000
SE	A	0.003690	.002890	.000000	.000000	.000000	.000000
SSE	A	0.003230	.002510	.000000	.000000	.000000	.000000
S	A	0.002340	.002400	.000000	.000000	.000000	.000000
SSW	A	0.001060	.000910	.000000	.000000	.000000	.000000
SW	A	0.000800	.000310	.000000	.000000	.000000	.000000
WSW	A	0.000430	.000370	.000000	.000000	.000000	.000000
W	A	0.000340	.000230	.000000	.000000	.000000	.000000
WNW	A	0.000400	.000110	.000000	.000000	.000000	.000000
NW	A	0.000570	.000260	.000000	.000000	.000000	.000000
NNW	A	0.000460	.000290	.000000	.000000	.000000	.000000
N	B	0.000110	.000290	.000030	.000000	.000000	.000000
NNE	B	0.000600	.000540	.000000	.000000	.000000	.000000
NE	B	0.000970	.001340	.000000	.000000	.000000	.000000
ENE	B	0.001570	.002800	.000000	.000000	.000000	.000000
E	B	0.001170	.003200	.000000	.000000	.000000	.000000
ESE	B	0.000690	.002770	.000000	.000000	.000000	.000000
SE	B	0.000690	.002460	.000000	.000000	.000000	.000000
SSE	B	0.000510	.002800	.000030	.000000	.000000	.000000
S	B	0.000430	.002230	.000000	.000000	.000000	.000000
SSW	B	0.000230	.000740	.000030	.000000	.000000	.000000
SW	B	0.000090	.000430	.000000	.000000	.000000	.000000
WSW	B	0.000030	.000290	.000000	.000000	.000000	.000000
W	B	0.000030	.000200	.000060	.000000	.000000	.000000
WNW	B	0.000140	.000170	.000000	.000000	.000000	.000000
NW	B	0.000090	.000200	.000030	.000000	.000000	.000000
NNW	B	0.000110	.000230	.000000	.000000	.000000	.000000
N	C	0.000400	.000690	.000310	.000030	.000000	.000000
NNE	C	0.000800	.001710	.000710	.000030	.000000	.000000
NE	C	0.001540	.004030	.000660	.000000	.000000	.000000
ENE	C	0.001740	.006970	.000290	.000000	.000000	.000000
E	C	0.001770	.008060	.000310	.000000	.000000	.000000
ESE	C	0.001090	.006230	.000110	.000000	.000000	.000000
SE	C	0.000770	.004860	.000170	.000000	.000000	.000000
SSE	C	0.000710	.007400	.000490	.000000	.000000	.000000
S	C	0.000740	.005660	.000770	.000000	.000000	.000000
SSW	C	0.000110	.002430	.000740	.000000	.000000	.000000
SW	C	0.000290	.000910	.000460	.000000	.000000	.000000
WSW	C	0.000140	.000770	.000490	.000000	.000000	.000000
W	C	0.000170	.000710	.000570	.000000	.000000	.000000
WNW	C	0.000140	.000310	.000400	.000000	.000000	.000000
NW	C	0.000310	.000400	.000430	.000000	.000000	.000000
NNW	C	0.000290	.000490	.000170	.000030	.000000	.000000

(Table continued next page)

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Table A2 (continued)

N	D	0.006540	.009860	.007430	.002860	.000260	.00003
NNE	D	0.006200	.011860	.009060	.002910	.000230	.00000
NE	D	0.005970	.010320	.005230	.000600	.000030	.00000
ENE	D	0.003510	.009170	.003170	.000230	.000000	.00000
E	D	0.004120	.007170	.001940	.000090	.000030	.00000
ESE	D	0.002830	.004740	.001140	.000200	.000000	.00000
SE	D	0.002510	.005060	.002230	.000260	.000030	.00000
SSE	D	0.002430	.008690	.009400	.002890	.000570	.00040
S	D	0.003090	.017000	.032260	.017920	.000860	.00000
SSW	D	0.002400	.013720	.039780	.031430	.002600	.00020
SW	D	0.002460	.014000	.031550	.017490	.001510	.00009
WSW	D	0.002230	.006830	.015890	.010400	.002310	.00043
W	D	0.002260	.006230	.013000	.007400	.001030	.00011
WNW	D	0.002630	.005170	.008970	.006340	.001060	.00003
NW	D	0.004340	.003970	.004940	.003170	.000490	.00009
NNW	D	0.004720	.004460	.003720	.002110	.000510	.00009
N	E	0.006340	.008660	.001030	.000000	.000000	.00000
NNE	E	0.005200	.007260	.001630	.000000	.000000	.00000
NE	E	0.003460	.004430	.000830	.000000	.000000	.00000
ENE	E	0.002860	.002200	.000140	.000000	.000000	.00000
E	E	0.002430	.001660	.000030	.000000	.000000	.00000
ESE	E	0.002060	.001230	.000030	.000000	.000000	.00000
SE	E	0.001170	.001370	.000260	.000000	.000000	.00000
SSE	E	0.001140	.001940	.000890	.000000	.000000	.00000
S	E	0.000970	.005340	.005740	.000000	.000000	.00000
SSW	E	0.001940	.015570	.030150	.000000	.000000	.00000
SW	E	0.002460	.023460	.016350	.000000	.000000	.00000
WSW	E	0.001940	.011750	.015460	.000000	.000000	.00000
W	E	0.002030	.011690	.012630	.000000	.000000	.00000
WNW	E	0.002740	.007490	.004340	.000000	.000000	.00000
NW	E	0.003830	.005830	.003110	.000000	.000000	.00000
NNW	E	0.004600	.006540	.002140	.000000	.000000	.00000
N	F	0.003200	.001340	.000000	.000000	.000000	.00000
NNE	F	0.003460	.001170	.000000	.000000	.000000	.00000
NE	F	0.003940	.000970	.000000	.000000	.000000	.00000
ENE	F	0.003060	.000510	.000000	.000000	.000000	.00000
E	F	0.002230	.000230	.000000	.000000	.000000	.00000
ESE	F	0.002140	.000110	.000000	.000000	.000000	.00000
SE	F	0.002140	.000660	.000000	.000000	.000000	.00000
SSE	F	0.002310	.000910	.000000	.000000	.000000	.00000
S	F	0.002710	.002340	.000000	.000000	.000000	.00000
SSW	F	0.003510	.004630	.000000	.000000	.000000	.00000
SW	F	0.003490	.002570	.000000	.000000	.000000	.00000
WSW	F	0.002400	.006030	.000000	.000000	.000000	.00000
W	F	0.002400	.006770	.000000	.000000	.000000	.00000
WNW	F	0.002710	.003940	.000000	.000000	.000000	.00000
NW	F	0.002940	.001310	.000000	.000000	.000000	.00000
NNW	F	0.002510	.001200	.000000	.000000	.000000	.00000

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Table A3
CAP88 Input Data for 2021 TA-54 Meteorological Tower
(99% Data Completeness)

N	A	0.000630.000370.000000.000000.000000.000000
NNE	A	0.000690.000690.000000.000000.000000.000000
NE	A	0.001950.001520.000000.000000.000000.000000
ENE	A	0.003980.003150.000000.000000.000000.000000
E	A	0.008380.003550.000000.000000.000000.000000
ESE	A	0.006350.002260.000000.000000.000000.000000
SE	A	0.003950.002090.000000.000000.000000.000000
SSE	A	0.002230.001400.000000.000000.000000.000000
S	A	0.001320.001800.000000.000000.000000.000000
SSW	A	0.001140.001030.000000.000000.000000.000000
SW	A	0.000940.000690.000000.000000.000000.000000
WSW	A	0.000570.000490.000000.000000.000000.000000
W	A	0.000490.000200.000000.000000.000000.000000
WNW	A	0.000310.000110.000000.000000.000000.000000
NW	A	0.000370.000230.000000.000000.000000.000000
NNW	A	0.000520.000200.000000.000000.000000.000000
N	B	0.000140.000290.000000.000000.000000.000000
NNE	B	0.000170.000340.000030.000000.000000.000000
NE	B	0.000370.001690.000000.000000.000000.000000
ENE	B	0.000940.002000.000000.000000.000000.000000
E	B	0.002200.003750.000000.000000.000000.000000
ESE	B	0.000860.001550.000000.000000.000000.000000
SE	B	0.000370.001140.000000.000000.000000.000000
SSE	B	0.000460.001490.000000.000000.000000.000000
S	B	0.000260.001340.000000.000000.000000.000000
SSW	B	0.000110.001120.000030.000000.000000.000000
SW	B	0.000060.000600.000030.000000.000000.000000
WSW	B	0.000110.000260.000000.000000.000000.000000
W	B	0.000140.000200.000000.000000.000000.000000
WNW	B	0.000060.000200.000000.000000.000000.000000
NW	B	0.000140.000140.000000.000000.000000.000000
NNW	B	0.000060.000230.000000.000000.000000.000000
N	C	0.000310.000940.000030.000000.000000.000000
NNE	C	0.000200.001800.000170.000000.000000.000000
NE	C	0.000540.004780.000260.000000.000000.000000
ENE	C	0.001570.006040.000310.000000.000000.000000
E	C	0.001950.007900.000110.000000.000000.000000
ESE	C	0.000890.002490.000090.000000.000000.000000
SE	C	0.000540.002600.000060.000000.000000.000000
SSE	C	0.000660.003120.000230.000000.000000.000000
S	C	0.000430.004980.000800.000000.000000.000000
SSW	C	0.000290.003230.000940.000000.000000.000000
SW	C	0.000060.001570.000340.000000.000000.000000
WSW	C	0.000230.000740.000430.000000.000000.000000
W	C	0.000090.000660.001000.000060.000000.000000
WNW	C	0.000110.000490.000490.000030.000000.000000
NW	C	0.000060.000340.000310.000000.000000.000000
NNW	C	0.000140.000370.000230.000000.000000.000000

(Table continued next page)

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Table A3 (continued)

N	D	0.004660	.005780	.003750	.001690	.000400	.00006
NNE	D	0.004660	.011450	.010160	.002980	.000340	.00006
NE	D	0.004780	.016510	.008150	.001120	.000090	.00000
ENE	D	0.003860	.009610	.002780	.000200	.000000	.00000
E	D	0.003320	.007320	.001260	.000060	.000000	.00000
ESE	D	0.002030	.002690	.000830	.000110	.000000	.00000
SE	D	0.001340	.002430	.000660	.000230	.000090	.00000
SSE	D	0.001260	.003890	.004230	.004950	.000830	.00086
S	D	0.001460	.009610	.021230	.022490	.003780	.00009
SSW	D	0.002120	.011960	.040660	.044640	.005810	.00043
SW	D	0.002780	.011450	.025950	.022600	.002150	.00011
WSW	D	0.002490	.007810	.009040	.006700	.001140	.00009
W	D	0.003120	.006750	.009100	.003520	.000460	.00014
WNW	D	0.003460	.004320	.007730	.002320	.000030	.00000
NW	D	0.003690	.006410	.004210	.002320	.000110	.00000
NNW	D	0.004320	.005060	.002320	.000970	.000140	.00006
N	E	0.004750	.006670	.003400	.000000	.000000	.00000
NNE	E	0.002830	.004860	.002660	.000000	.000000	.00000
NE	E	0.001750	.002260	.000570	.000000	.000000	.00000
ENE	E	0.001230	.001140	.000090	.000000	.000000	.00000
E	E	0.001340	.000800	.000030	.000000	.000000	.00000
ESE	E	0.000770	.000540	.000060	.000000	.000000	.00000
SE	E	0.000940	.000600	.000090	.000000	.000000	.00000
SSE	E	0.000600	.000690	.000400	.000000	.000000	.00000
S	E	0.001060	.002780	.004550	.000000	.000000	.00000
SSW	E	0.001340	.008210	.015220	.000000	.000000	.00000
SW	E	0.001430	.019110	.029300	.000000	.000000	.00000
WSW	E	0.002460	.014650	.011300	.000000	.000000	.00000
W	E	0.003890	.017140	.007530	.000000	.000000	.00000
WNW	E	0.004010	.012700	.003520	.000000	.000000	.00000
NW	E	0.006580	.014960	.002800	.000000	.000000	.00000
NNW	E	0.006500	.010500	.003060	.000000	.000000	.00000
N	F	0.004520	.009330	.000000	.000000	.000000	.00000
NNE	F	0.002860	.005550	.000000	.000000	.000000	.00000
NE	F	0.002090	.001860	.000000	.000000	.000000	.00000
ENE	F	0.000860	.000400	.000000	.000000	.000000	.00000
E	F	0.000400	.000030	.000000	.000000	.000000	.00000
ESE	F	0.000400	.000000	.000000	.000000	.000000	.00000
SE	F	0.000490	.000090	.000000	.000000	.000000	.00000
SSE	F	0.000400	.000000	.000000	.000000	.000000	.00000
S	F	0.000370	.000630	.000000	.000000	.000000	.00000
SSW	F	0.000920	.002950	.000000	.000000	.000000	.00000
SW	F	0.001750	.011160	.000000	.000000	.000000	.00000
WSW	F	0.002230	.016970	.000000	.000000	.000000	.00000
W	F	0.004230	.019540	.000000	.000000	.000000	.00000
WNW	F	0.005750	.012900	.000000	.000000	.000000	.00000
NW	F	0.007320	.028810	.000000	.000000	.000000	.00000
NNW	F	0.005690	.014680	.000000	.000000	.000000	.00000