DOE/ID-11485
Revision 2

U.S. Department of Energy
Idaho Operations Office

Technical Basis for Environmental Monitoring and Surveillance at the Idaho National Laboratory Site

July 2023

Idaho National Laboratory

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July 2023

Prepared for the
U.S. Department of Energy
DOE Idaho Operations Office

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ABSTRACT

This document explains the technical basis for the design and implementation of INL's environmental monitoring program, consisting of effluent monitoring and environmental surveillance, which effectively evaluate planned and unplanned releases at the INL to protect workers, the public, and the environment. The document also identifies the critical pathways for radionuclides for the INL Site and discusses the monitoring design criteria and rationale for monitoring locations, sampling methods, and target analysis.

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ACRONYMS

AEC	U.S. Atomic Energy Commission
ALARA	as low as reasonably achievable
AMWTP	Advanced Mixed Waste Treatment Project
ANL-W	Argonne National Laboratory-West
ARA	Auxiliary Reactor Area
ARP	Accelerated Retrieval Project
ASER	Annual Site Environmental Report
ATR	Advanced Test Reactor
BEA	Battelle Energy Alliance, LLC
BLM	Bureau of Land Management
BLR	Big Lost River
CAES	Center for Advanced Energy Studies
CEM	continuous emission monitoring
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
CITRC	Critical Infrastructure Test Range Complex
COC	contaminants of concern
CWP	Cold Waste Ponds
CY	calendar year
D&D	decontamination and decommissioning
DCG	derived concentration guide
DCS	derived concentration standard
DEQ	Idaho Department of Environmental Quality
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy–Idaho Operations Office
DQO	data quality objective
EBR-I	Experimental Breeder Reactor I
EDE	effective dose equivalent
EFS	Experimental Field Station
EML	Environmental Measurements Laboratory
EPA	U.S. Environmental Protection Agency
ERM	effluent radiation monitor

ESER	Environmental Surveillance, Education, and Research (Program)
ESL	evaporative sewage lagoon
ESRF	Environmental Science & Research Foundation
ESRP	Eastern Snake River Plain
ESRPA	Eastern Snake River Plain Aquifer
ETR	Engineering Test Reactor
FAA	Federal Aviation Administration
FCF	Fuel Conditioning Facility
FD	frequency of detection
FDA	U.S. Food and Drug Administration
FY	fiscal year
gpd	gallons per day
gpm	gallons per minute
GPRS	global positioning radiometric scanner GPS global positioning system
GSS	Gonzales-Stoller Surveillance, LLC
HDPE	high-density polyethylene
HEPA	high-efficiency particulate air
HFEF	Hot Fuel Examination Facility
HPGe	high purity germanium
HSS	Office of Health, Safety and Security HVAC heating, ventilation, and air conditioning
ICDF	Idaho CERCLA Disposal Facility
ICP	Idaho Cleanup Project
IDEQ	Idaho Department of Environmental Quality
IEC	Idaho Environmental Coalition, LLC
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IOP	Idaho National Laboratory Oversight Program
IRC	Idaho National Laboratory Research Center
ISU	Idaho State University
IWCS	Industrial Wastewater Collection System
IWP	Industrial Waste Pond
IWTU	Integrated Waste Treatment Unit
LLMW	low-level mixed waste
LOFT	Loss of Fluid Test Facility
MAPEP	Mixed Analyte Performance Evaluation Program

MCL	maximum contaminant level
MDA	minimum detectable activity
MDC	minimum detectable concentration
MEI	maximally exposed individual
MFC	Materials and Fuels Complex
MTR	Materials Test Reactor
NCRP	National Council on Radiation Protection and Measurements
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NRAD	Neutron Radiography Reactor
NRC	U.S. Nuclear Regulatory Commission
NRF	Naval Reactors Facility
OSLD	optically stimulated luminescence dosimeter
PBF	Power Burst Facility
PCS	Primary Constituent Standard
PINS	Portable Isotopic Neutron Spectroscopy System
PL	Primary Line
POTW	publicly owned treatment works
QA	quality assurance
QAO	quality assurance objective
QAPjP	QA Project Plan
QC	quality control
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RESL	Radiological and Environmental Sciences Laboratory
RLWTF	Radioactive Liquid Waste Treatment Facility
ROD	Record of Decision
RP	Reuse Permit
RWMC	Radioactive Waste Management Complex
SBL	Southwestern Boundary Line
SCCM	standard cubic centimeters per minute
SCML	secondary maximum contaminant levels
SD	standard deviation
SDA	Subsurface Disposal Area
SMC	Specific Manufacturing Capability

SNF	spent nuclear fuel
SRPA	Snake River Plain Aquifer
STF	Sewage Treatment Facility
TAN	Test Area North
TDS	total dissolved solids
TED	total effective dose
TIC	time-integrated concentration
TKN	Total Kjeldahl nitrogen
TLD	thermoluminescent dosimeter
TREAT	Transient Reactor Test Facility
TSS	total suspended solids
U.S.	United States
USGS	U.S. Geological Survey
UTL	upper tolerance limit
UV	ultraviolet
VOCs	volatile organic compounds
WCUC	West Campus Utility Corridor
WMF	Waste Management Facility

TERMS AND DEFINITIONS

acute—A high **dose** of **ionizing** radiation received in a short time.

administrative controls—Limits on or changes in work schedules or operations that reduce **exposure** to a hazard.

ambient air—The surrounding **atmosphere**, usually the outside air.

analyte—A substance measured in the laboratory.

aquifer—An underground geological unit of permeable material that is saturated and capable of yielding significant quantities of water to wells and springs.

area source—A collection of individually small emission sources within a single geographic area that produces similar air pollutants. Area sources are classified together by air quality control (QC) agencies to facilitate estimating emissions from their activities because they are usually too small or too numerous to be inventoried individually.

atmosphere—The layer of air surrounding the earth.

atomic nucleus—The very dense region consisting of **protons** and **neutrons** at the center of an atom.

background level—An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

biota—The plants and animals of a region.

biotic intrusion—The penetration into buried radioactive waste by plants via roots or by burrowing mammals.

carcinogen—A substance that causes cancer or is believed to cause cancer.

CERCLA—The Comprehensive Environmental Response, Compensation, and Liability Act, otherwise known as CERCLA or 'Superfund,' provides a Federal Superfund to clean up uncontrolled or abandoned hazardous-waste sites, as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment.

chronic—A low **dose** of ionizing radiation received either continuously or intermittently over a prolonged period of time.

contaminants of concern—specific hazardous substances that are identified for evaluation in the risk assessment process.

cold waste ponds—P**ermitted** infiltration ponds located near the southeast corner of the ATR Complex.

composite sample—A sample of an environmental medium containing a certain number of sample portions collected over a period of time, possibly from different locations. The constituent samples may or may not be collected at equal time intervals over a predefined period of time, such as 24 hours.

concentration—The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

conceptual model—A diagram that defines entities, objects, or conditions of a system and the relationships between them.

contamination—Unwanted radioactive and/or hazardous material that is dispersed on or in equipment, structures, objects, air, soil, or water.

continuous emissions monitoring—A system that constantly collects and records data from permitted sources, such as stacks, that are used as a means to comply with air emission standards, such as state-permitted emission standards.

Demographics—The current statistical characteristics of a population.

Deposition—The process of particles collecting or depositing themselves on solid surfaces, decreasing the concentration of the particles in the air.

Detection limit—The lowest concentration of a substance that can reliably be distinguished from a zero concentration.

Dispersion—The environmental transport of contaminants through air or water. In air, contaminants in an airborne release are transported downwind and are affected by turbulent eddies in the atmosphere, which diffuse the effluent material as the entire plume is being transported downwind. With respect to groundwater, it is the phenomenon by which dissolved material tends to spread out from the path it would follow simply due to the motion of the groundwater in which it is dissolved. It causes dilution of the dissolved material. It occurs because of physical mixing during fluid movement between the solid grains in the rock (fluid in the center of the pore moves faster than fluid at the boundary of the pore) and the crossing of flow paths as the fluid flows around the solid grains in the rock and because of molecular diffusion.

DOE (U.S. Department of Energy)—The federal agency that promotes scientific and technical innovation to support the national, economic, and energy security of the United States.

dose—Short for **radiation dose,** the amount of energy from ionizing radiation that is actually absorbed by the body.

dosimeter—A portable detection device for measuring exposure to ionizing radiation.

DQO (data quality objective)—A process developed by U.S. Environmental Protection Agency (EPA) for facilities to use when describing their environmental monitoring matrices, sampling methods, locations, frequencies, and measured parameters, as well as methods and procedures for data collection, analysis, maintenance, reporting, and archiving. The DQO process also addresses data that monitor quality assurance and quality control.

ecosystem—A system formed by the interaction of a community of organisms with their environment.

effective dose equivalent—A value used to express the health risk from radiation exposure to tissue in terms of an equivalent whole-body exposure. It is a 'normalized' value that allows the risk from radiation exposure received by a specific organ or part of the body to be compared with the risk due to whole-body exposure. The effective dose equivalent (EDE) equals the sum of the doses to different organs of the body multiplied by their respective weighting factors. It includes the sum of the EDE due to radiation from sources external to the body and the committed EDE due to the internal deposition of radionuclides. EDE is typically expressed in rems and is calculated for air emissions at INL to demonstrate compliance with the 10 mrem standard set by 40 CRF 61, Subpart H, "National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities."

effluent—Any treated or untreated air emission or liquid discharge, including storm-water runoff.

effluent monitoring—This report uses the following definitions from the National Council on Radiation Protection and Measurements (NCRP 2010):

- Effluent monitoring is the collection and analysis of particulate, gaseous, and liquid samples at or before their entry into the environment
- Environmental surveillance is the collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media and the measurement of external radiation in the environment.

electron—(Symbol: e-) A subatomic particle with a negative elementary electric charge.

emissions—Any gaseous or particulate matter discharged to the **atmosphere**.

engineering controls—Designing equipment, tools, and workplaces to reduce workers' exposures to factors that cause harm.

entrainment—To carry (suspended particles, for example) along in a current.

environmental surveillance—The collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media from DOE sites and their environs and the measurement of external radiation for purposes of demonstrating compliance with applicable standards, assessing radiation exposure to members of the public, and assessing effects, if any, on the environment.

evaporation—The process by which a liquid (generally water) converts to a gas.

evaporation pond—An artificial pond designed to evaporate water by sunlight and exposure to ambient temperatures.

exposure—Generally, contact of an organism with a harmful agent. In this document, humans exposed to ionizing radiation, either by direct radiation or contamination.

exposure pathway—The route a substance takes from its source (where it began) to its end point (where it ends) and how people may come into contact with (or be exposed to) it.

exposure routes—Means by which people may be exposed to hazardous environmental agents. Some basic routes are inhalation, ingestion, injection, dermal contact, and direct exposure.

fallout—Radioactive material made airborne as a result of aboveground nuclear weapons testing that has been deposited on the Earth's surface.

gross alpha/beta—Analytic radiation screening method. No radionuclide-specific information is obtained.

groundwater—Any water that occurs underground in a saturated geological formation of rock or soil.

HPGe—High purity germanium, a type of semiconductor that is used to detect, identify, and quantify gamma-emitting radionuclides.

IDAPA—Numbering designation for all administrative rules in Idaho promulgated according to the Idaho Administrative Procedure Act.

Idaho National Laboratory (INL)—The definition of INL depends on the context of its use within the document. In this document, INL will be used as follows:

INL—INL is the U.S. DOE Office of Nuclear Energy lead nuclear laboratory operated by Battelle Energy Alliance, LLC (BEA).

INL Site—INL Site consists of an 890-square-mile area in southeastern Idaho located between the town of Arco to the west and the cities of Idaho Falls and Blackfoot to the east.

ingestion—The act of swallowing something through eating, drinking, or mouthing objects.

inhalation—The act of breathing in air or other substances, including agents of exposure.

immersion—A potential **exposure pathway**; possible in scenarios with contaminated water.

injection—The insertion of a material, usually a liquid, into another material.

injection well—A vertical pipe in the ground into which water, other liquids, or gases are pumped or allowed to flow.

in situ—For this document: In place, direct measurements of environmental gamma-emitting radionuclides using tripod-mounted high purity germanium (HPGe) detectors.

ionizing radiation—Radiation with sufficient energy to remove **electrons** from atoms or molecules; units, generally reported in **rems** or **sieverts.**

irrigation—The process of applying controlled amounts of water to land to assist the production of crops and landscape vegetation.

leaching—The loss of water-soluble contaminants from solid buried waste through contact with water.

MEI (maximally exposed individual)—A hypothetical individual whose location and habits tend to maximize his/her radiation dose, resulting in a dose higher than that received by other individuals in the general population. The MEI is used to demonstrate that air emissions at INL are in compliance with the 10 mrem standard set by 40 CRF 61, Subpart H, "National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities."

media—Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

molecular sieve—Material containing tiny pores of a precise and uniform size that is used as an adsorbent for gases and liquids.

monitoring—The collection and analysis of samples or measurements of effluents and emissions for the purpose of characterizing and quantifying potential contaminants and demonstrating compliance with applicable standards or **permits**.

neutron—(Symbol n or n0) A subatomic particle found in the **atomic nucleus** with no net electric charge and a mass slightly larger than that of a proton.

nonradiological contaminants—A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

pathway analysis—An evaluation of the potential ways a release could impact human health and the environment. A pathway analysis generally includes a look at potential soil contamination impacts, air pollution impacts, ecological impacts, including endangered species assessment, and water pollution impacts.

percolation—The process of a liquid slowly passing through a material such as sediment.

percolation pond—A pond (usually man-made) designed to allow water to percolate slowly into the ground.

permit—An authorization issued by a federal, state, or local regulatory agency. Permits grant permission to operate, discharge, or construct, and may include emission/effluent limits and other requirements, such as the use of pollution control devices, monitoring, record keeping, and reporting.

planchet—A small shallow metal container in which a radioactive substance is deposited for measurement of its activity.

plume—A body of contaminated **groundwater** or polluted air flowing from a specific source.

point source—Any confined and discrete conveyance (e.g., pipe, ditch, well, stack) of a discharge.

proton—(Symbol p or p+) A subatomic particle found in the **atomic nucleus** with a positive electric charge of one elementary charge. One or more protons are present in the nucleus of each atom. The number of protons in each atom is its atomic number.

quality assurance (QA)—In environmental monitoring, any action to ensure the reliability of monitoring and measurement data. Aspects of QA include procedures, inter-laboratory comparison studies, evaluations, and documentation.

quality control (QC)—In environmental monitoring, the routine application of procedures to obtain the required standards of performance in monitoring and measurement processes. QC procedures include the calibration of instruments, control charts, and an analysis of replicate and duplicate samples.

radiation—Excess energy released in the form of charged particles or electromagnetic waves. Some atoms possess excess energy causing them to be physically unstable until radiation is released, thus moving the atom toward a more stable state.

radiation dose—The amount of energy from radiation that is actually absorbed by the body.

radioactivity—The spontaneous transition of an unstable **atomic nucleus** from a higher energy to a lower energy state. This transition is accompanied by the release of a charged particle or electromagnetic waves from the atom. Also known as 'activity.'

radionuclide—A radioactive element characterized by the number of **protons** and **neutrons** in the nucleus. There are several hundred known radionuclides, both artificially produced and naturally occurring.

radiological contaminants—The presence of radioactive substances where their presence is unintended.

receptors—Humans, animals, or plants that receive a dose or exposure.

release—Spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a hazardous substance, pollutant, or contaminant into the environment. The National Contingency Plan also defines the term to include a threat of release.

Research and Education Complex—The portion of INL located outside of the 890-square-mile (2,305-square-kilometer) complex located between Arco, Blackfoot, and Idaho Falls. It occupies 30 facilities, including laboratories.

re-suspension—The process by which radioactive particles become airborne after being deposited on the ground, potentially becoming a secondary source of contamination long after a release has stopped.

roentgen—(Symbol R) A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions carrying one electrostatic unit of electrical charge in 1 cm^3 of dry air under standard conditions. It is named after the German scientist Wilhelm Roentgen, who discovered x-rays.

roentgen equivalent man—(Symbol rem) A unit by which human radiation dose is assessed (*see also* **Sv**). The rem is a risk-based value used to estimate the potential health effects to an exposed individual or population. 100 rem = 1 sievert.

source—The point at which something derives or is released.

source term—The types, quantities, and chemical forms of the radionuclides that encompass the source of potential exposure to radioactivity.

submersion—A type of exposure in which an entity is dunked in water or other fluid.

surveillance—Sampling for contaminants in air, water, sediment, soil, food stuffs, plants, and animals, either by directly measuring or by collecting and analyzing samples.

sievert—(Symbol Sv) A unit for assessing the risk of human radiation dose, used internationally and, with increasing frequency, in the U.S. 1 Sv = 100 rem.

target analytes—The set of substances coming from INL that are monitored because they could present a risk to human health and the environment.

transport pathway—A means by which contaminants move from a **source** to receptors such as air or water.

uptake—The taking in or absorption of a substance by a living organism or bodily organ.

warm waste pond—A remediated three-celled percolation pond that received liquid waste other than sewage from ATR between about 1952 and 1992.

watershed—The region or area drained by a river, stream, etc.; drainage area.

wind rose—A diagram that shows the frequency of wind from different directions at a specific location.

Technical Basis for Environmental Monitoring and Surveillance at the Idaho National Laboratory Site

1. INTRODUCTION

1.1 Purpose and Scope

The Idaho National Laboratory (INL) Site, with an area of 2,305 square kilometers (890 square miles), is located west of Idaho Falls, Idaho (Figure 1). During World War II, the United States (U.S.) Navy and U.S. Army used a large portion of the area that is now the INL Site as a gunnery and bombing range. In 1949, the U.S. Atomic Energy Commission (AEC) established the National Reactor Testing Station on the Site. Its purpose was to conduct nuclear energy research and related activities. The National Reactor Testing Station was renamed three times: as Idaho National Engineering Laboratory (INEL) in 1974, as the Idaho National Engineering and Environmental Laboratory (INEEL) in 1997, and as INL since 2005.

INL's current mission is to discover, demonstrate, and secure innovative nuclear energy solutions, clean energy options, and critical infrastructure. The vision for INL is to change the world's energy future and secure our critical infrastructure.

The U.S. Department of Energy–Idaho Operations Office (DOE-ID) and its predecessors, the AEC and Energy Research and Development Administration, as well as other federal agencies, various contractors, and state agencies, have performed environmental monitoring at the INL Site since its inception in 1949. The organization of environmental monitoring programs has remained consistent throughout much of the Site's history. The AEC's Health Services Laboratory, later named DOE-ID Radiological and Environmental Sciences Laboratory (RESL), was responsible for conducting most on-Site and off-Site environmental surveillance tasks from the early 1950s to 1993. Beginning in 1993, contractors operating the various Site facilities became responsible for monitoring activities performed in and around the facility boundaries, including effluent monitoring.

At the request of DOE-ID for the purposes of continuous improvement, the DOE Office of Independent Oversight, within the DOE Office of Health, Safety, and Security (DOE-HSS), performed an assessment of environmental monitoring and surveillance at the INL Site during March and April 2010 (DOE-HSS 2010). The independent assessment focused on determining the adequacy of the INL Site Environmental Monitoring Program components for evaluating significant potential impacts from laboratory and cleanup operations on the surrounding environment and the public; evaluating potential pathways of contaminant emission; and identifying strengths, lessons learned, and opportunities for improvement.

Consistent with the DOE-ID-requested scope, the 2010 DOE HSS assessment did not assess compliance with environmental laws and regulations, permit requirements, or certain federal compliance-driven environmental monitoring activities, such as air-effluent (stack) monitoring, dose calculation (National Emission Standards for Hazardous Air Pollutants [NESHAP]), and drinking water and groundwater monitoring.

The 2010 DOE-HSS assessment stated, "The environmental monitoring and surveillance activities on the INL Site are comprehensive and effectively support the overall statements in the Annual Site Environmental Report, and the independent assessment did not identify any program vulnerabilities that would affect the ability of the INL Site to detect significant site impacts" (DOE-HSS 2010).

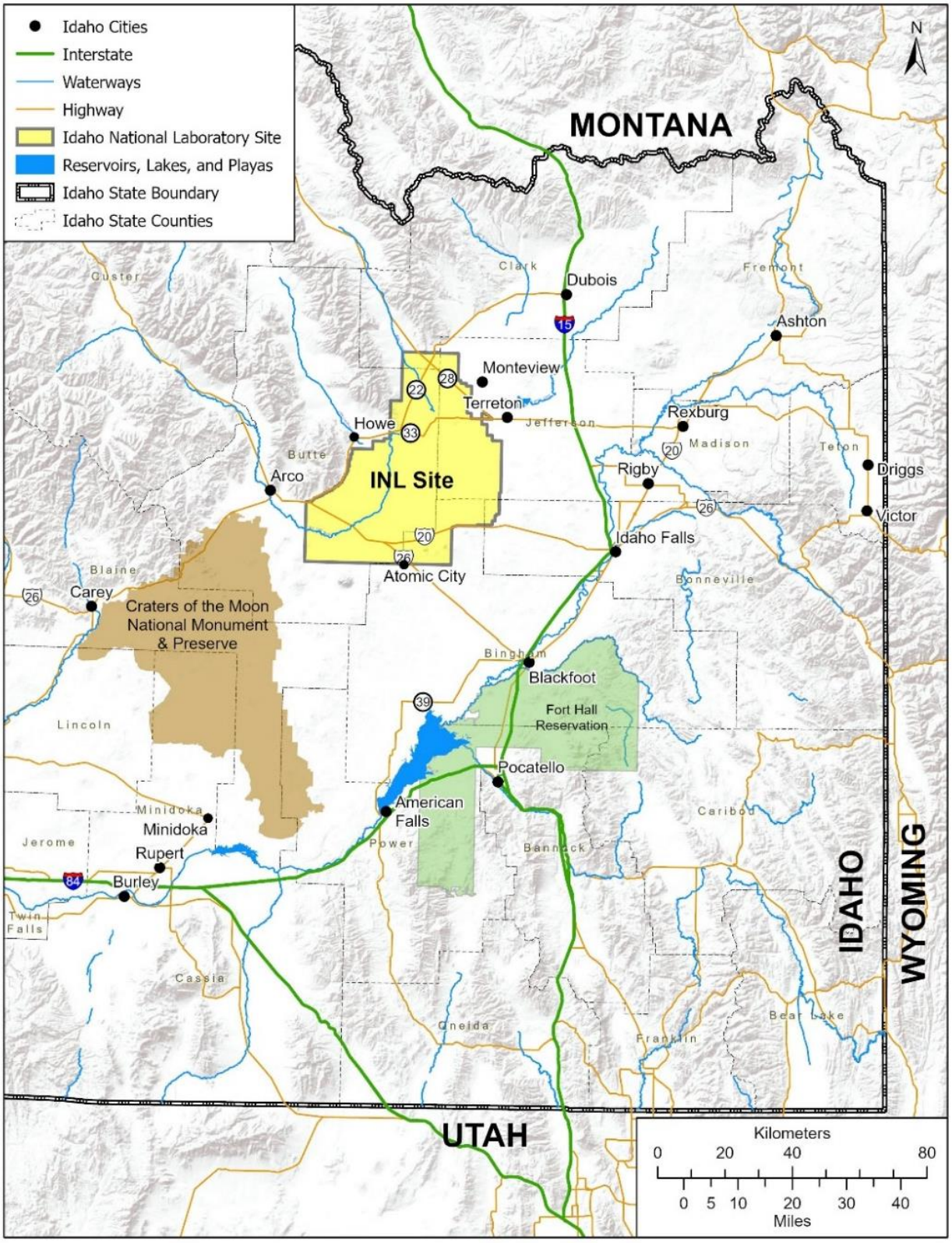

Figure 1. Location of the INL Site.

However, the 2010 DOE-HSS assessment identified four main areas for enhancement (DOE-HSS 2010):

1. The current programmatic design does not provide a complete definition of the technical basis for all environmental monitoring and surveillance activities being conducted at the INL Site.
2. Some aspects of the program were not sufficiently coordinated and communicated among contractors. Some information in published environmental reports was not fully accurate and clear.
3. Implementation of certain quality assurance (QA) protocols and media-specific monitoring and surveillance actions were not fully effective.

This report was prepared to address the areas for enhancement identified by the 2010 DOE-HSS assessment (DOE-HSS 2010), emphasizing the scientific basis for the radiological environmental surveillance activities.

To adequately ensure that the DOE-HSS assessment concerns regarding programmatic design and QA protocols (Items 1 and 4 above) for environmental surveillance are properly addressed, U.S. Environmental Protection Agency (EPA) guidance (EPA 2006) was followed. The data quality objective (DQO) process is a series of logical steps that guides monitoring personnel to a plan for the resource-effective acquisition of environmental data. This process was used to develop DQOs for each media type that clarify environmental monitoring objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data for each media type being monitored. DQO documents for the individual media types are referenced in the associated sections below. These documents contain detailed information regarding the methodology used to determine the number of sampling locations, assignment of individual locations, and determine thresholds to be used during data analysis.

Figure 2, Figure 3, and Figure 4, illustrate the general approach to effluent radiological monitoring and radiological environmental surveillance at the INL Site (NCRP 2010). As new facilities or projects are proposed, potential releases are identified (Figure 2). Estimates of the magnitude of releases and affected environmental pathways are developed and assessed, typically with mathematical models of varying complexity depending on the projected dose and compared to regulatory criteria to determine monitoring requirements (Figure 3). Even if effluent monitoring is not required by regulatory criteria, environmental surveillance may be desirable based on other considerations, such as DOE orders or public perception (Figure 3 and Figure 4).

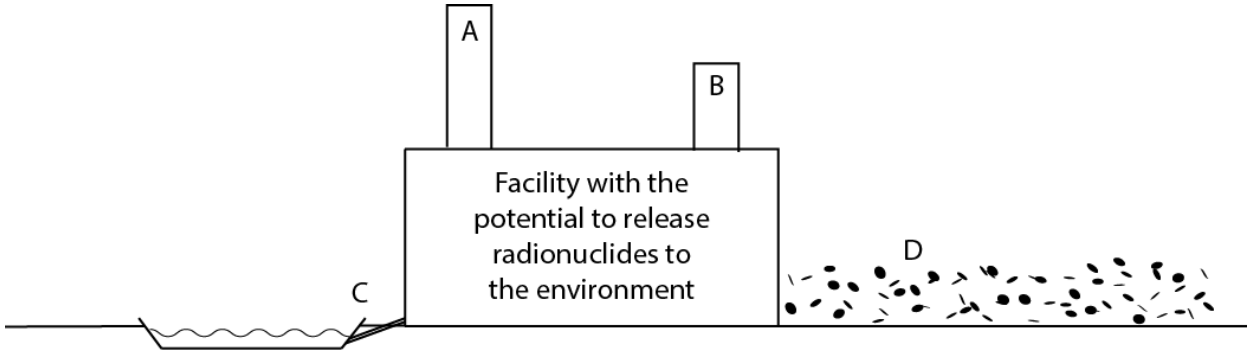

Figure 2. Schematic of radioactive releases from a nuclear facility (NCRP 2010).

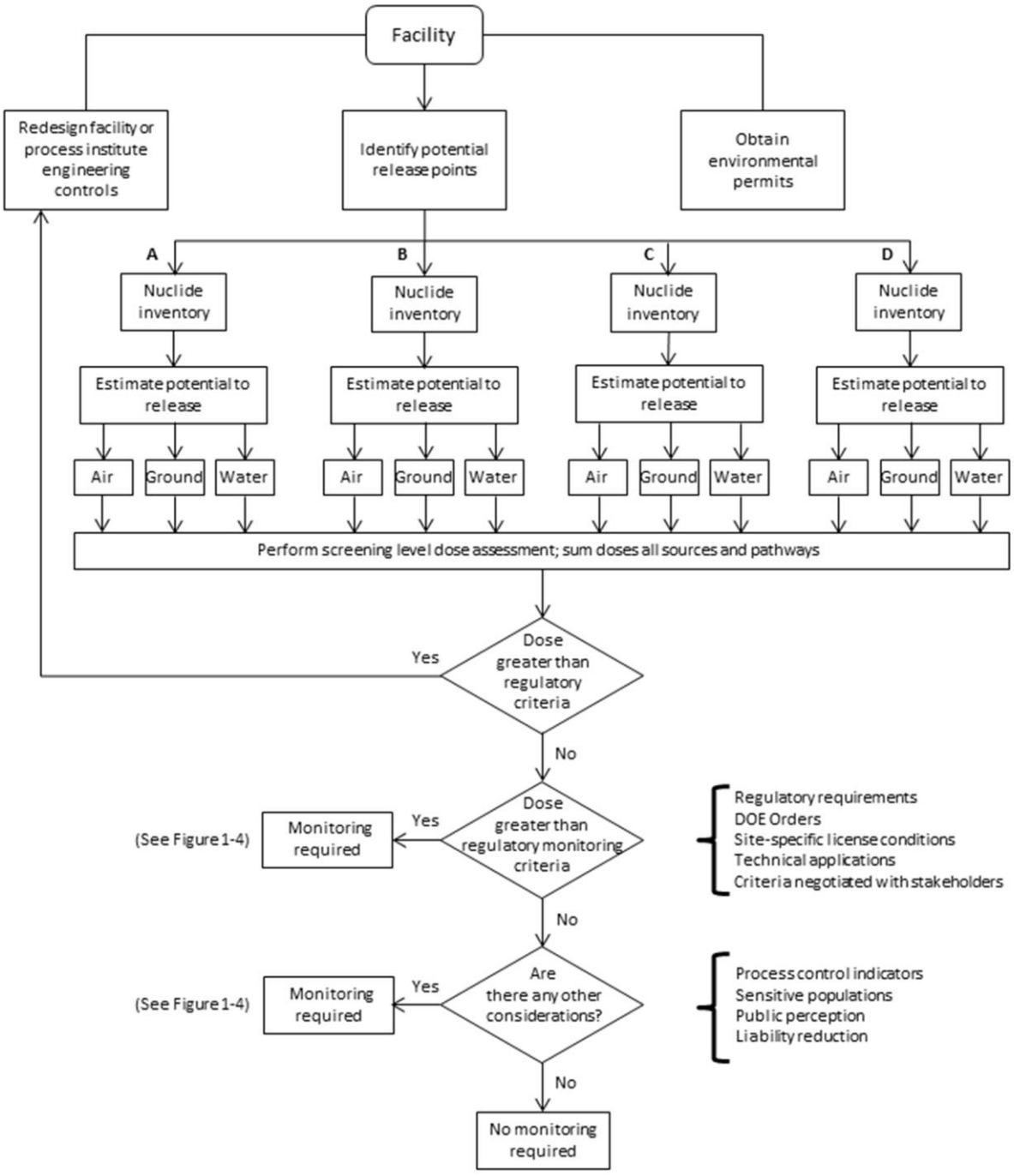

Figure 3. Radiological effluent monitoring decision tree (NCRP 2010).

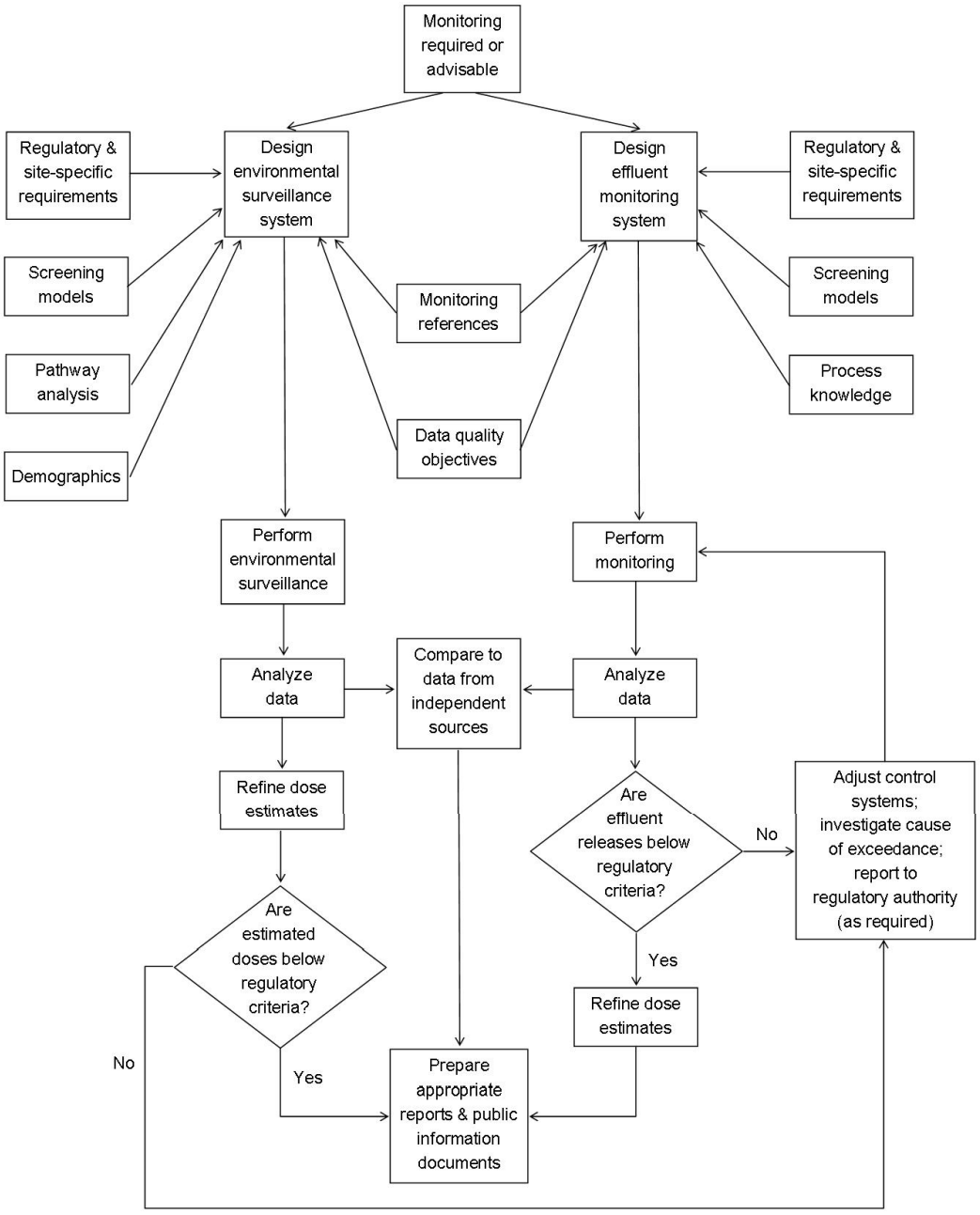

Figure 4. Radiological effluent monitoring and environmental surveillance design and implementation (NCRP 2010).

On a broad level, all new projects or modifications to projects are evaluated in accordance with the National Environmental Policy Act (42 USC Chapter 55) with final approval required through the DOE-ID NEPA Compliance Officer. In addition, all new or modified sources are evaluated in compliance with Subpart H of the National Emission Standards for Emissions of Radionuclides Other Than Radon from DOE facilities to determine whether stack monitoring or approval to construct is required. Air emissions are evaluated using the air permitting applicability determination process. Liquid radiological discharges to the ground are prohibited at the INL. INL also evaluates the impact to the public and environment in accordance with DOE Order 458.1, "Radiation Protection of the Public and the Environment."

On a level specific to ambient air surveillance, as mentioned, the current network has been shown to be adequate to achieve DQOs and performance objectives for the detection of minimal radionuclide concentrations capable of causing a dose to the public from all current potential emission sources. So, changes to emissions (i.e., potentially higher concentrations) are by default already captured by the network. The geographic locations of new facilities and projects will need to be evaluated using the model to determine if they are outside the bounds of the current network and if and where additional monitoring stations are required.

Figure 5 provides a simple illustration of the importance of source characterization and periodic evaluation of the effluent radiological monitoring and environmental surveillance programs. During the late 1950s, iodine-131 was one of the principal radionuclides released to the atmosphere at the INL Site; however, the activity of iodine-131 released to the atmosphere decreased dramatically in 1960. Releases of strontium-90 exceeded iodine-131 in the 1960s. Figure 6 provides a hierarchy for effluent monitoring and environmental surveillance programs.

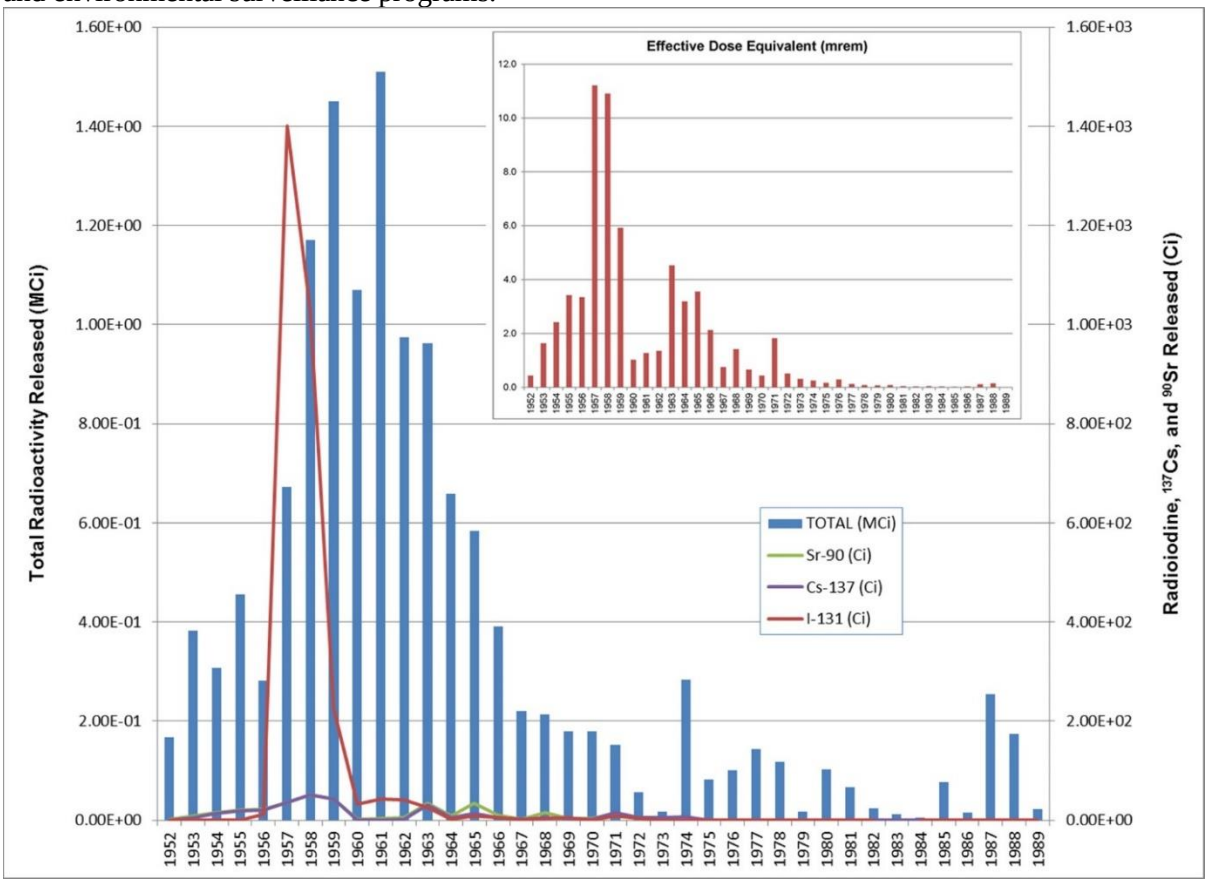

Figure 5. Summary of atmospheric releases at the INL Site (1952–1989) (DOE-ID 1991).

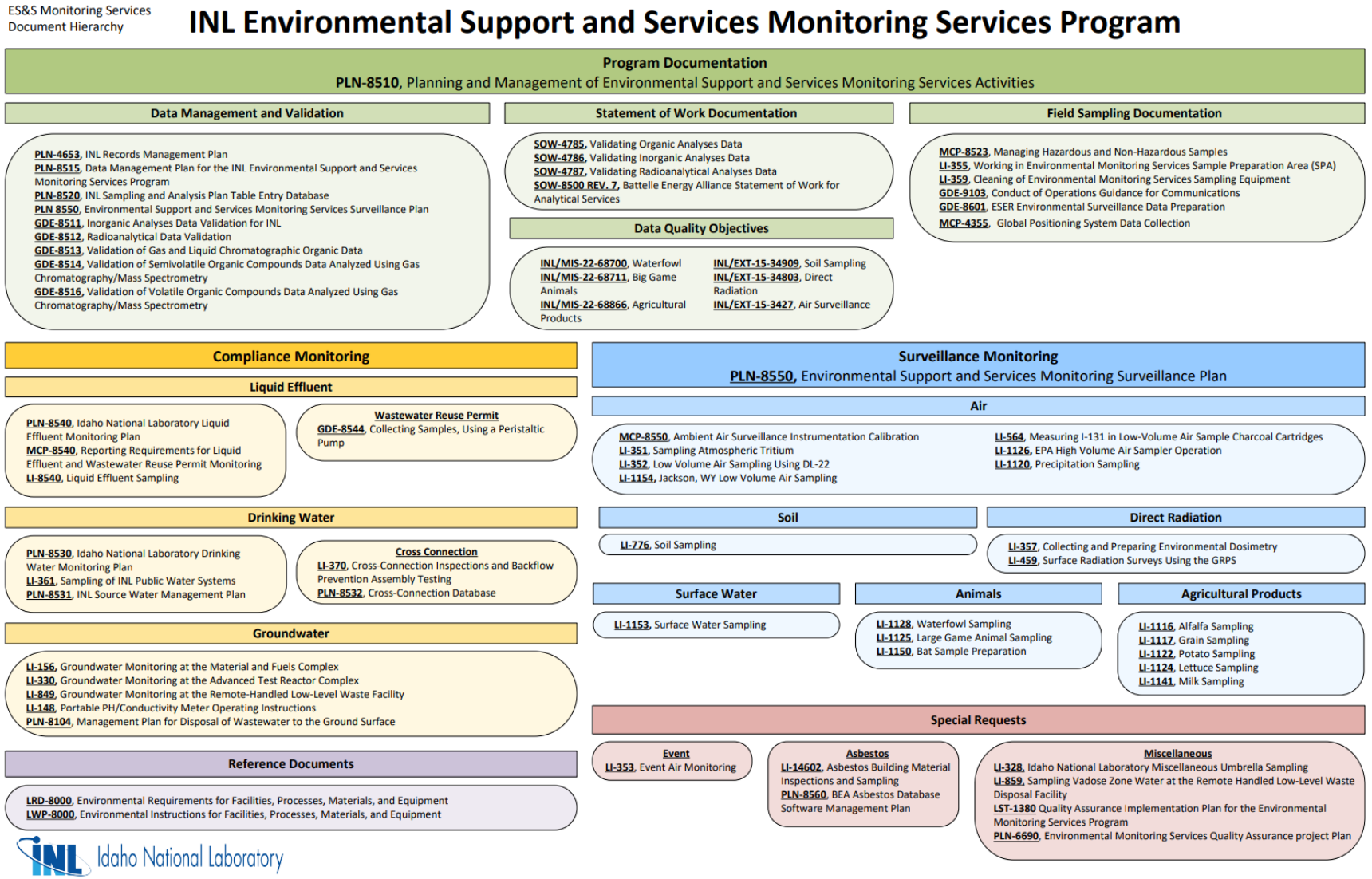

Figure 6. Effluent monitoring and environmental surveillance programs document hierarchy.

1.2 Organization of this Report

The goal of this report is to document the technical basis for the design and implementation of an environmental monitoring program, consisting of effluent monitoring and environmental surveillance, which will effectively evaluate planned and unplanned releases at the INL Site to protect workers, the public, and the environment. The need for a sound technical basis for environmental monitoring and surveillance activities at DOE facilities was clearly demonstrated during the radiological release event at the Waste Isolation Pilot Plant on February 14, 2014. The accident investigation report concluded, "There is an inadequate technical basis for the existing ventilation and airborne monitoring systems. It is unclear that they adequately provide protection to the underground workers, the co-located worker, the public, and the environment from the transuranic mixed waste or hazardous constituents…" (DOE 2019).

The organization of this report is addressed in Table 1.

Table 1. Report organization.

Section/Appendix	Description
Section 1	Introduces report.
Section 2	Identifies critical pathways and radionuclides for the INL Site. Discusses relevant exposure routes and provides a summary of releases at the Site.
Sections 3–12	Provide technical basis for effluent monitoring and environmental surveillance programs. Discuss monitoring design criteria and rationale for monitoring locations, sampling methods, and target analytes. Discuss media-specific recommendations from 2010 DOE-HSS assessment (DOE-HSS 2010).
Appendix A	Discusses environmental surveillance being performed at INL facilities located in Idaho Falls.
Appendix B	Discusses estimates of recent air emissions at the INL Site, primarily to benchmark current monitoring and surveillance activities and provide a tool for quick evaluation of potential impacts from proposed/planned projects.

INL Site background information, such as environmental characteristics and history, is available in other reports (DOE-ID 2022; DOE-ID 2021). The Environmental Surveillance, Education, and Research (ESER) website (https://idahoeser.inl.gov/) provides detailed information on the ecology of the Site and provides links to other organizations that study the environment at the Site, including the National Oceanic and Atmospheric Administration (NOAA) (http://www.noaa.inel.gov/) and the U.S. Geological Survey (USGS) (http://id.water.usgs.gov/).

2. CRITICAL ENVIRONMENTAL PATHWAYS AND RADIONUCLIDES

Prior to the implementation of an environmental surveillance program, a critical pathway analysis (radionuclide/media) should be performed (DOE 2015). This is to ensure the acquisition of appropriate data to meet the overall program purposes and identify the critical radionuclides, pathways, and exposed individuals (NCRP 2010).

A critical pathway analysis is used to identify environmental pathways by which radioactivity or radiation from a facility or site can reach human or biotic receptors. The analysis is also used to identify important radionuclides that can contribute significantly to the estimated radiation dose along a critical path to a reasonably maximally exposed individual (MEI) off the Idaho National Laboratory (INL) Site. This individual is a hypothetical person residing in a local community (NCRP 2010). The primary purpose of a pathway analysis is to indicate those critical pathways and significant radionuclides that require monitoring as part of the environmental surveillance program.

2.1 Air

2.1.1 Exposure Routes

Air is the most important transport media from the INL Site to Distant receptors (Apostoaei 2005; Maheras and Thorne 1993; DOE-ID 1991). This is because radionuclides from Site operations are released to air and air is the most direct and continuous route to humans. As shown in Figure 7, people living outside the INL Site Boundary could be exposed to radiation from a number of pathways:

- External exposures because of direct radiation from radionuclides in the air or deposited on the ground
- Internal exposures because of inhalation of radionuclides in the air or the ingestion of foods or soil that have been contaminated by radioactive materials that have moved beyond the INL Site Boundary.

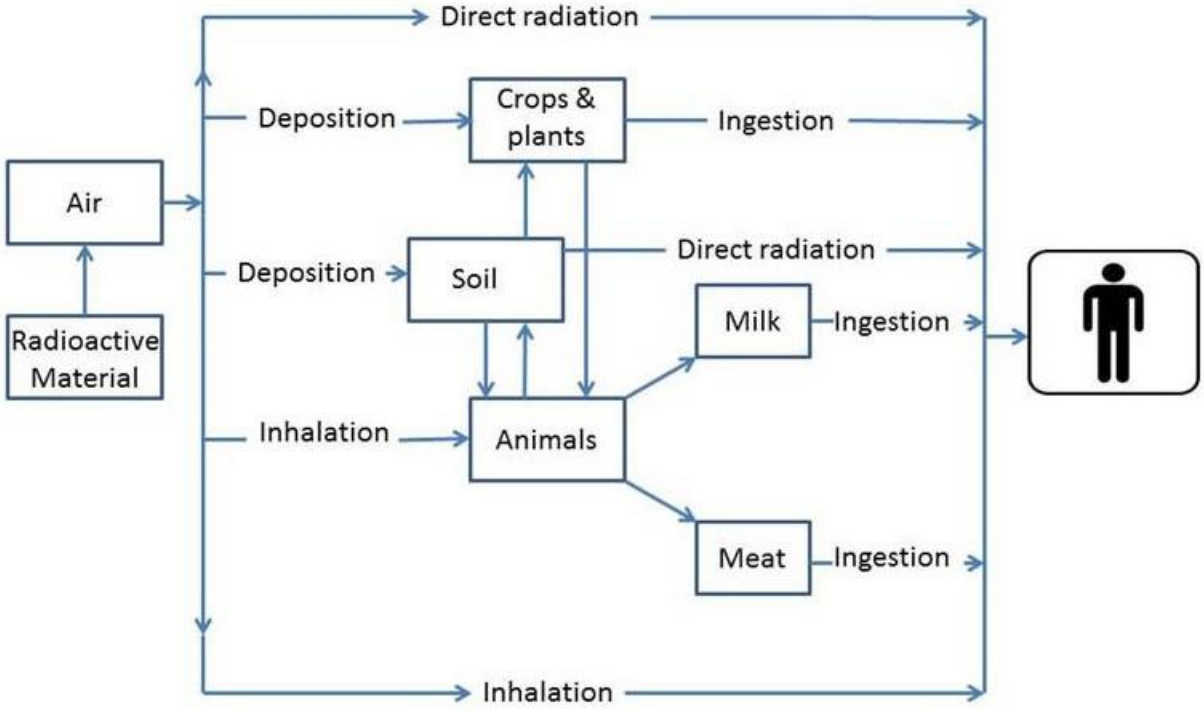

Figure 7. Potential pathways from air to humans living outside INL Site Boundary.

To monitor the pathways shown in Figure 7, the INL Site and Distant environmental surveillance locations focus on:

- Air, using air samplers (Section 4) and precipitation and air moisture samplers (Section 5)
- Direct radiation (Section 6)
- Surface water and drinking water (Section 7)
- Soil (Section 8)

- Agricultural products (Section 9)
- Game animals (Section 10 and 11).

The magnitude of human exposure to atmospheric releases of radionuclides depends on atmospheric transport, diffusion, and deposition processes. If possible, dose assessments should be based on results of measurements of air concentrations, ground concentrations, agricultural product concentrations, and radiation fields resulting from these releases. While each of these media is monitored, the low concentrations are often indistinguishable from background, and mathematical models must be used to estimate the impact of radionuclide releases to air to humans through the exposure of impacted media.

Compliance with U.S. Environmental Protection Agency (EPA)-established dose limits is calculated each year using the reported Site airborne emissions and EPA air-dispersion code CAP88-PC (EPA 2020).

CAP88-PC uses site-specific meteorology to model airborne radionuclide transport from stacks or areas through various environmental media (e.g., air, soil, agricultural products) to Distant receptors.

2.1.2 Significant Radionuclides

Each year, the estimated air emissions of about 300 radionuclides from the INL Site are modeled with EPA air-dispersion code CAP88-PC for the annual National Emission Standards for Hazardous Air Pollutants (NESHAP) report (EPA 2020; DOE-ID 2014, Appendix B). **Error! Reference source not found.**Figure 8 illustrates the total releases and dose to the MEI reported in the annual NESHAP reports for 2014 to 2021. The emissions have generally decreased over time. The majority of radioactive airborne activity is in the form of noble gases (e.g., argon, krypton, xenon), as observed in Figure 9. Most of the remaining activity is from tritium, with lesser contributions from iodine, strontium-90, cesium-137, plutonium, uranium, and americium.

The percent of the total emissions, as shown in Figure 10, are from the Advanced Test Reactor (ATR) Complex, Idaho Nuclear Technology and Engineering Complex (INTEC), the Materials and Fuels Complex (MFC), the Radioactive Waste Management Complex (RWMC), and Test Area North (TAN) from 2014 to 2021. Sources of these airborne emissions include point sources (e.g., stacks, vents) and non-point sources, such as radioactive waste ponds, contaminated soils, and decontamination and demolition of inactive facilities (see Appendix B). As can be seen in Figure 8, Figure 9, and Figure 10, the amount and composition, as well as the facility contributions, have changed as a function of the changing Site mission. For example, the relative contribution of ATR has increased, as it is now the only continuously functioning reactor at the INL Site. INTEC's contribution has decreased from greater than 40% in 2016 to less than 5% in 2017 and later. The largest facility contributors to the airborne emissions are currently the ATR Complex, MFC, and RWMC, with relatively minor contributions from TAN and INTEC (Figure 7; Appendix B).

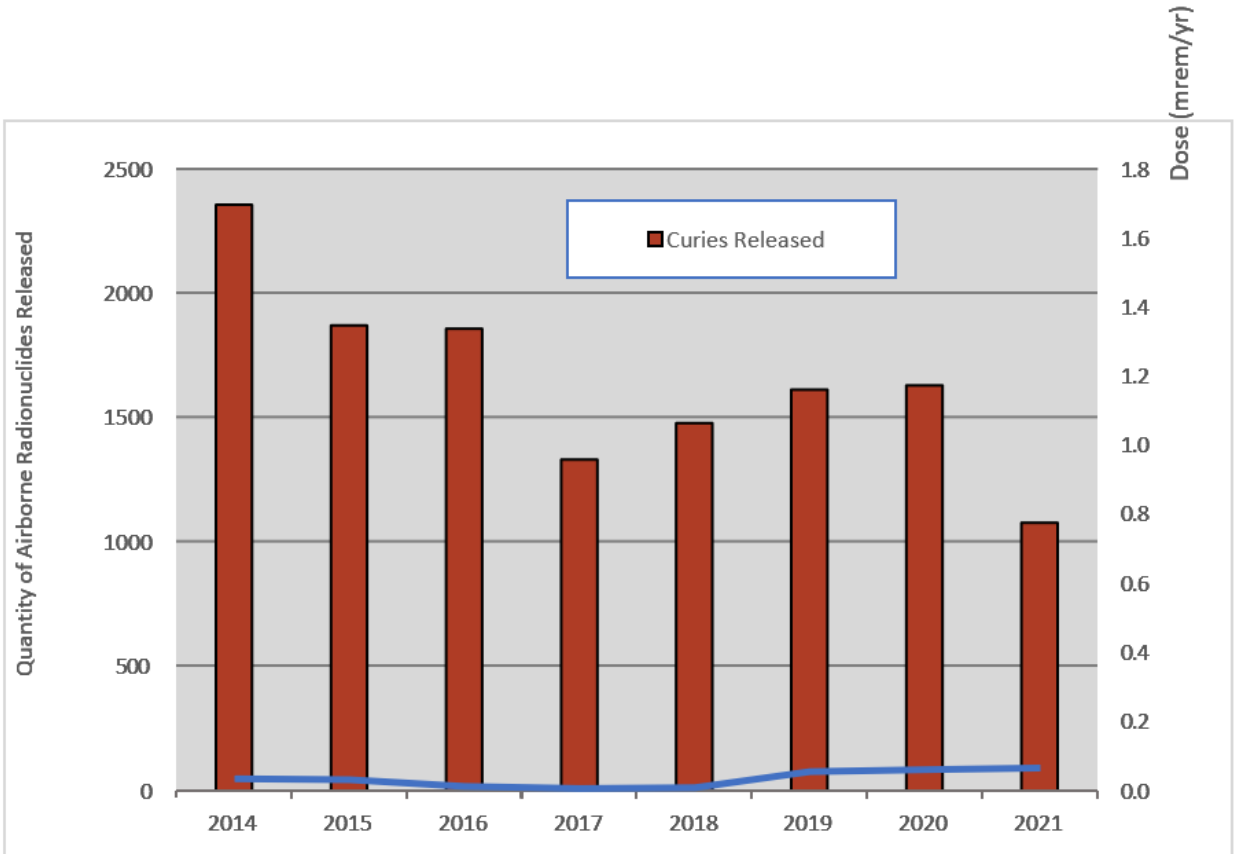

Figure 8. Total curies released in air and dose to MEIs as calculated by EPA's air-dispersion code CAP88-PC (2014–2021).

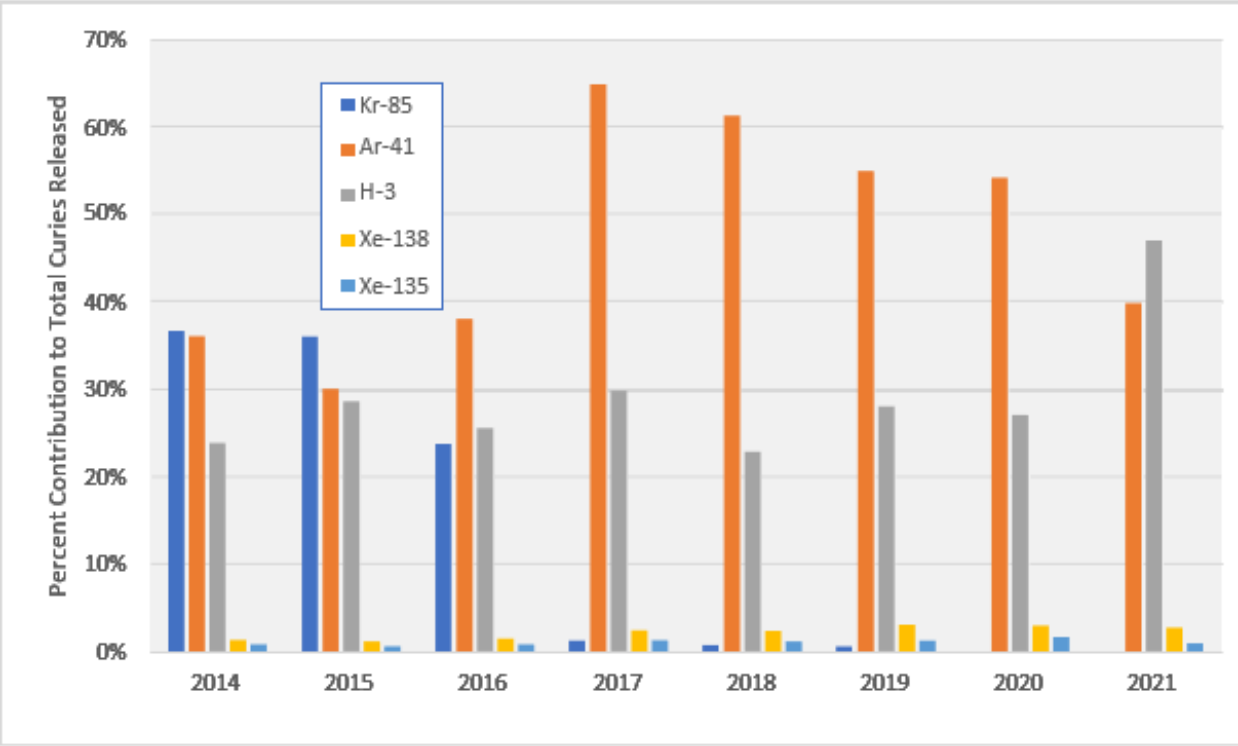

Figure 9. Principal radionuclides in estimated air emissions at the INL Site (2014–2021).

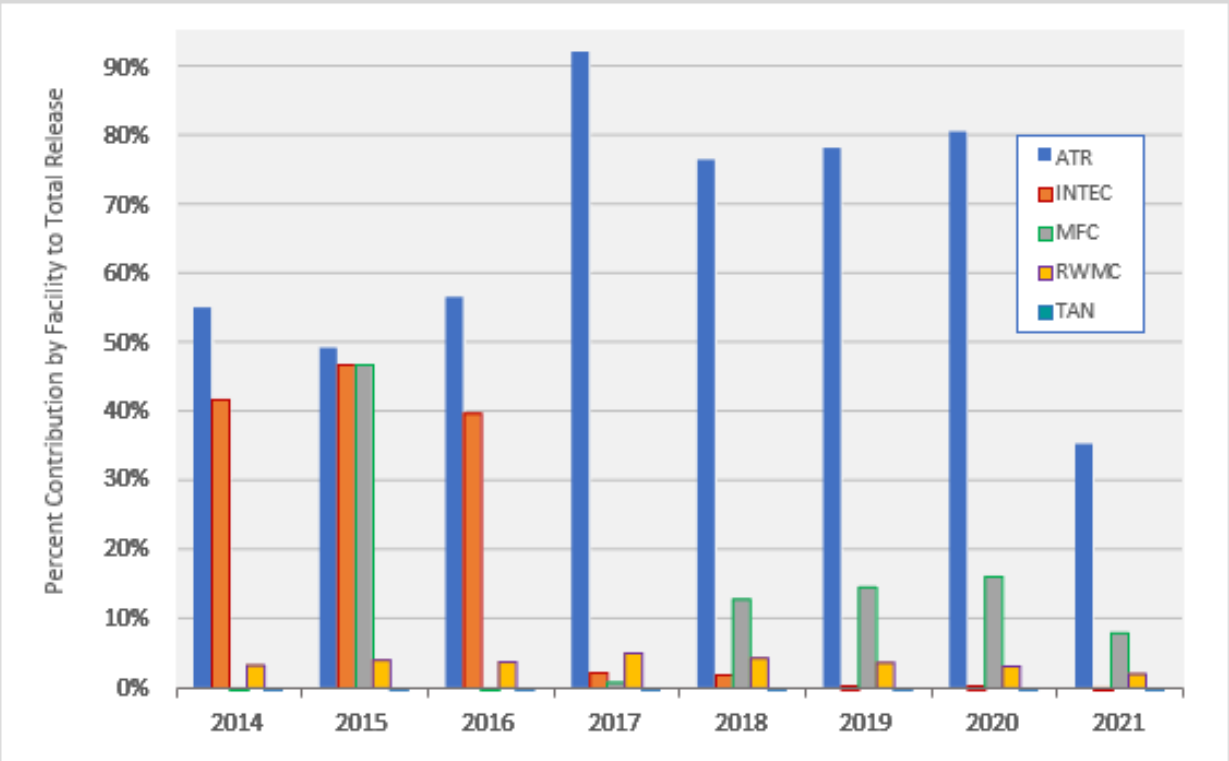

Figure 10. Percent contribution, by facility, of INL Site airborne radionuclide releases (2014–2021). All facilities listed contributed to overall dose in each of the years listed, however some are comparatively small and are not visible at the scale shown.

Cesium-137, uranium-234, uranium-238, chlorine-36, zinc-75, iodine-131, and uranium-235 are currently the top dose contributors, each representing greater than 3% of the annual dose estimated for the MEI from 2019 to 2021. Prior to 2019, the MEI was located at Receptor 1, otherwise known as Frenchmen's Cabin. Due to the majority of emissions that contribute the most to overall dose now coming from MFC, the MEI has shifted east to Receptor 54. Before the MEI change, the principal radionuclides contributing to the total dose were tritium, americium-241, strontium-90, plutonium-239, iodine-129, argon-41, cesium-137, cobalt-60, and carbon-14, as can be seen in Figure 7. Figure 11(a) and (b) summarize the average contribution of the radionuclides that contributed most of the estimated dose from 2014 to 2018, as shown in Figure 11(a), and from 2019 to 2021, as observed in Figure 11(b). While the relative contributions of each radionuclide change from year to year, these radionuclides account for greater than 94% of the estimated annual dose each year.

Table 2 depicts the shift in the collection of radionuclides that are considered major dose contributors. The only radionuclide that continues to contribute to greater than 3% of total dose to MEI both before and after the MEI-shift is cesium-137.

Table 2. Percent contribution by radionuclides contributing greater than 3% to dose to the MEI calculated in NESHAP reports (2014–2021).

Percent Contribution to Total Dose by Radionuclide and Year									
	2014	2015	2016	2017	2018		2019	2020	2021
Hydrogen-3	**29%**	**34%**	**23%**	**30%**	**22%**		2%	2%	1%
Americium-241	**23%**	**28%**	**7%**	**5%**	<1%		<1%	<1%	<1%
Strontium-90	**14%**	**7%**	**13%**	**14%**	**15%**		1%	1%	1%
Plutonium-239	**9%**	**6%**	**4%**	**3%**	**1%**		<1%	<1%	<1%
Iodine-129	**8%**	**11%**	**19%**	**9%**	**10%**		<1%	<1%	<1%
Argon-41	**8%**	**8%**	**12%**	**21%**	**16%**		1%	1%	1%
Cobalt-60	**1%**	**<1%**	**4%**	**7%**	**5%**		<1%	<1%	<1%
Carbon-14	**1%**	**1%**	**2%**	**2%**	**6%**		<1%	<1%	<1%
Cesium-137	**4%**	**3%**	**12%**	**6%**	**23%**		**56%**	**55%**	**55%**
Uranium-238	<1%	<1%	<1%	<1%	<1%		**20%**	**16%**	**16%**
Uranium-234	<1%	<1%	<1%	<1%	<1%		**8%**	**8%**	**8%**
Chlorine-36	<1%	<1%	<1%	<1%	<1%		**6%**	**6%**	**6%**
Zinc-65	<1%	<1%	<1%	<1%	<1%		**3%**	**6%**	**7%**
Iodine-131	<1%	<1%	<1%	<1%	<1%		<1%	**3%**	<1%
Uranium-235	<1%	<1%	<1%	<1%	<1%		<1%	<1%	**4%**
ALL	96%	97%	97%	98%	98%		98%	99%	99%
2014-2018	**96%**	**97%**	**97%**	**98%**	**98%**		4%	4%	3%
2019-2021	<1%	<1%	<1%	<1%	<1%		**94%**	**95%**	**96%**

MEI changed from Receptor 1 to Receptor 54

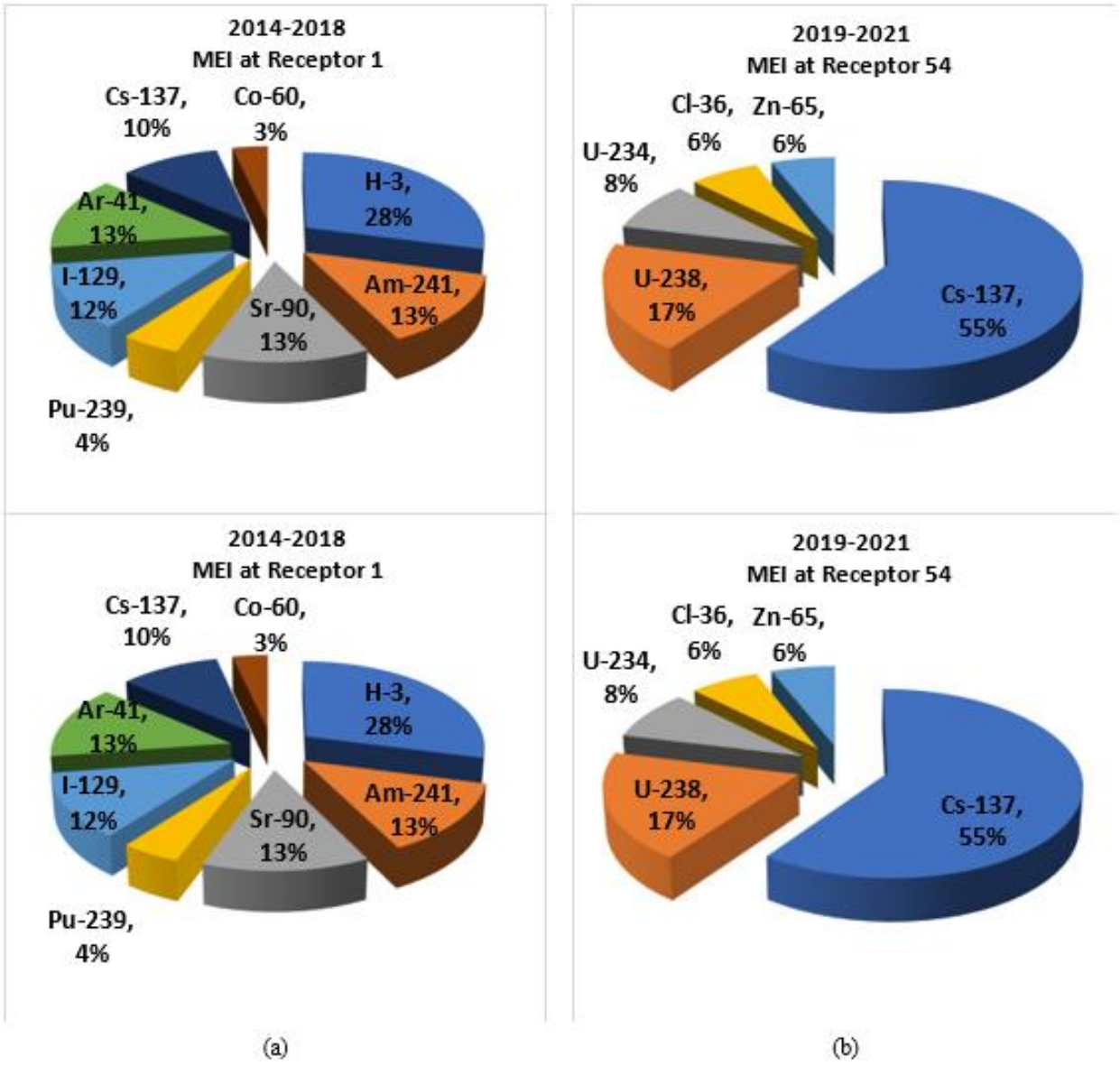

Figure 11. Average percentage contribution to total dose to hypothetical MEI from INL Site releases (2014–2018 and 2019–2021).

The majority of the radioactive airborne effluent released at the INL Site over the last several years was in the form of noble gases (e.g., argon, krypton, xenon). The noble gases are chemically inert, and therefore, do not participate in biological processes and are not transported through the food chain (ANL 2007). Consequently, the noble gases contribute to dose primarily through immersion in air (external exposure). Table 3 summarizes the noble gases released at the Site, primarily from reactor operations at ATR and spent fuel storage at INTEC. Table 3 illustrates that most of the noble gases are short-lived.

Table 3. Principal noble gases released at INL Site.

Isotope	Half-Life	Decay Mode	Comments
Argon-41	1.827 hr	Beta, gamma	Neutron activation product
Krypton-85	10.72 yr	Beta	Fission product
Krypton-85m	4.48 hr	Beta	Fission product
Krypton-87	76.3 min	Beta	Fission product
Krypton-88	2.84 hr	Beta	Fission product
Krypton-89	3.15 min	Beta	Fission Product
Xenon-133	5.245 days	Beta	Fission product
Xenon-135	9.09 hr	Beta	Fission product
Xenon-135m	15.29 min	Gamma	Fission product
Xenon-138	14.17 min	Beta	Fission product

Transuranics are those radionuclides with an atomic number greater than that of uranium (92). Only americium and plutonium are important for the air pathway at the INL Site. Most transuranics at United States (U.S.) Department of Energy (DOE) sites were produced in nuclear reactors by neutron capture. The radioactive properties of selected transuranics are summarized in Table 4. Transuranics pose a risk because of their relatively long half-lives, combined with their emission of alpha particles, which pose a hazard if they are taken into the body where they tend to accumulate in the bones and liver. The most common form of americium and plutonium in the environment is the oxide form. Americium and plutonium are typically very insoluble, with the oxide being less soluble in water than ordinary sand (e.g., quartz). They adhere tightly to soil particles and tend to remain in the top few centimeters of soil as the oxide. In aquatic systems, americium and plutonium tend to settle out and adhere strongly to sediments, again remaining in the upper layers. This results in inhalation being the dominant pathway (ANL 2007).

Table 4. Principal transuranics released at the INL Site.

Isotope	Half-Life	Decay Mode
Americium-241	432.2 yr	Alpha
Plutonium-238	87.74 yr	Alpha
Plutonium-239	24,065 yr	Alpha
Plutonium-240	6,537 yr	Alpha

Other radionuclides important to the air pathway at the INL Site include cesium-137, iodine-129, strontium-90, and tritium, as observed in Figure 11(a) and Figure 11(b). Cesium-137 is a fission product with a relatively high yield of about 6% (meaning about six atoms of cesium-137 are produced per 100 fissions). Consequently, cesium-137 is a major radionuclide in spent nuclear fuel (SNF), high-level radioactive wastes resulting from the processing of SNF, and radioactive wastes associated with the operation of nuclear reactors and fuel reprocessing plants. Cesium-137 has a half-life of 30 years and decays by beta emission to barium-137m, which emits an energetic gamma ray that is the primary dose contributor. When taken into the body, cesium-137 behaves in a manner similar to potassium and distributes uniformly throughout the body. Cesium has been shown to biomagnify in aquatic food chains. Radioactive cesium is present in soil around the world largely as a result of fallout from past atmospheric nuclear weapons tests. The concentration of cesium-137 in surface soil from fallout ranges from about 0.1 to 1 picocurie per gram (pCi/g), averaging <0.4 pCi/g.

Cesium is also present as a contaminant at certain locations, such as nuclear reactors and facilities that process SNF. Cesium is generally one of the less mobile radioactive metals in the environment. It preferentially adheres quite well to soil, and the concentration associated with sandy soil particles is estimated to be 280 times higher than in interstitial water (e.g., the water in the pore space between soil particles); concentration ratios are much higher (about 2,000 to more than 4,000) in clay and loam soils. Thus, cesium is generally not a major contaminant in groundwater at DOE sites or other locations (ANL 2007).

Iodine-129 is a fission product of uranium-235. The fission yield of iodine-129 is about 1%. Iodine-129 is persistent in the environment because of its long half-life (15.7 million years) and tends to accumulate in the thyroid. The ratio of stable iodine-127 to radioactive iodine-129 in the environment is more than 10 million to 1. The human body contains 10 to 20 mg of iodine; more than 90% is contained in the thyroid gland. Iodine-129 is present in soil around the world as a result of fallout from past atmospheric nuclear weapons tests. Iodine may also be found as a contaminant at facilities where SNF was processed. Iodine-129 is one of the more mobile radionuclides in soil and can move downward with percolating water to groundwater. Iodine concentrations in sandy soil are about the same as in interstitial water (in the pore spaces between soil particles). It binds more preferentially to loam, where the concentration in soil is estimated to be five times higher than in interstitial water (ANL 2007).

Strontium-90 is a beta-emitter with a half-life of about 29 years. It is only a health hazard if taken into the body, where it behaves similar to calcium and concentrates in the bone. Beyond the four stable isotopes naturally present in soil, strontium-90 is also present in surface soil around the world as a result of fallout from past atmospheric nuclear weapons tests. Current strontium-90 levels in surface soil typically range from 0.01 to 1 pCi/g, reflecting various rainfall and wind patterns, elevation, and terrain; most levels fall between 0.05 and 0.5 pCi/g, with 0.1 pCi/g as a general average.

Strontium-90 is relatively mobile and can move down through soil with percolating water to groundwater. Environmental transport of strontium is strongly influenced by its chemical form. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (in the pore spaces between soil particles); concentration ratios are typically higher (110) in clay soil. As a note, many years ago, the EPA established a maximum contaminant level for strontium-90 in public drinking water supplies. That value, based on extant dosimetry models, is 8 pCi per liter (pCi/L). The value using current, improved dosimetry models would be 36 pCi/L (ANL 2007).

Tritium is a radioactive isotope of hydrogen that is formed by natural processes and by the nuclear activities of man. Tritium is primarily a fission product, although a small amount of tritium is produced naturally from the interaction of cosmic radiation with gases in the upper atmosphere. It follows the hydrologic cycle because most of it combines with oxygen to form HTO, or tritiated water, so it behaves the same as water in the environment and in the body. It has a half-life of about 12 years and decays via beta emission. The transport of tritium in the biosphere can be predicted based on knowledge of the hydrologic cycle.

2.2 Groundwater and Surface Water

The Eastern Snake River Plain (ESRP) Aquifer (ESRPA) is one of the most productive aquifers in the U.S. (Knobel, Bartholomay, and Rousseau 2005). The aquifer is the water source for nearly all municipal and domestic needs in the area, as well as for irrigation, aquaculture, and industrial needs (Cosgrove and others 1999). Recharge to the ESRPA is affected by local surface drainage. The aquifer primarily is recharged from infiltration of irrigation water, infiltration of stream flow, groundwater inflow from adjoining mountain drainage basins, and infiltration of precipitation. The Big Lost River (BLR), which flows through the INL Site, drains more than 1,400 square miles of mountainous area that includes parts of the Lost River Range and Pioneer Range west of the Site (Knobel, Bartholomay, and Rousseau 2005). Flow in the BLR infiltrates to the ESRPA along its channel and at sinks and playas at the river's terminus at the BLR sinks on the INL Site. Most of the flow in the BLR is diverted for irrigation and groundwater recharge prior to reaching the INL site, so flow only reaches the INL site during wet years or when heavy rainfall or rapid snowmelt warrant brief periods of high discharge out of Mackay Reservoir. When flow in the BLR exceeds about 300 cubic feet per second in the river channel, excess streamflow is diverted to spreading areas where it rapidly infiltrates. The excess streamflow has been diverted since 1965 to spreading areas in the southwestern part of the INL to prevent potential flooding at INL facilities (Bartholomay et al. 2020).

Water in the ESRPA primarily moves through fractures and interflow zones in basalt, generally flows southwestward, and eventually discharges at springs along the Snake River near Twin Falls, ID, about 100 miles southwest of the INL Site. Estimated discharge from the springs was about 3.55 million acre-feet per year for water year 2018 (Bartholomay et al. 2020).

2.2.1 Exposure Routes

Radiochemical and chemical effluent discharged since 1952 to infiltration ponds and disposal wells at the INL Site has affected water quality in the ESRPA and perched groundwater zones in some areas beneath the INL Site. The U.S. Geological Survey (USGS), in cooperation with DOE, maintains aquifer and perched groundwater monitoring networks at the INL Site to determine hydrologic trends and delineate the movement of radiochemical and chemical wastes in the ESRPA and perched groundwater zones (Bartholomay et al. 2020).

Groundwater is not considered a significant contributor to the dose of a member of the public off the INL Site. INL and Idaho Cleanup Project (ICP) contractors currently monitor drinking water at public water systems on the INL Site to ensure the safety of workers and comply with State of Idaho and EPA public water system requirements. Tritium concentrations continue to decrease with time and are well below drinking water maximum contaminant levels established by the EPA (DOE-ID 2021b). Detectable concentrations of radiochemical constituents in water samples from aquifer wells or multilevel monitoring system-equipped wells in the ESRPA at the INL Site generally decreased or remained constant during 2016 to 2018 (Bartholomay et al. 2020). Decreases in concentrations were attributed to radioactive decay, changes in waste-disposal methods, and dilution from recharge and underflow. The tritium plume extends south-southwestward in the general direction of groundwater flow.

Surface water is sampled on the INL Site. Springs and public water systems are sampled at locations outside of the INL Site Boundary because of the importance of the ESRPA. Figure 12 shows the potential pathways to people living outside the INL Site Boundary.

The primary pathway of concern is internal exposure because of ingestion of drinking water that could have been contaminated by radioactive materials.

To monitor the pathways shown in Figure 12, environmental surveillance performed on the INL Site and at Distant locations focus on the BLR, springs down-gradient of the INL Site, and drinking water off the INL Site (Section 7).

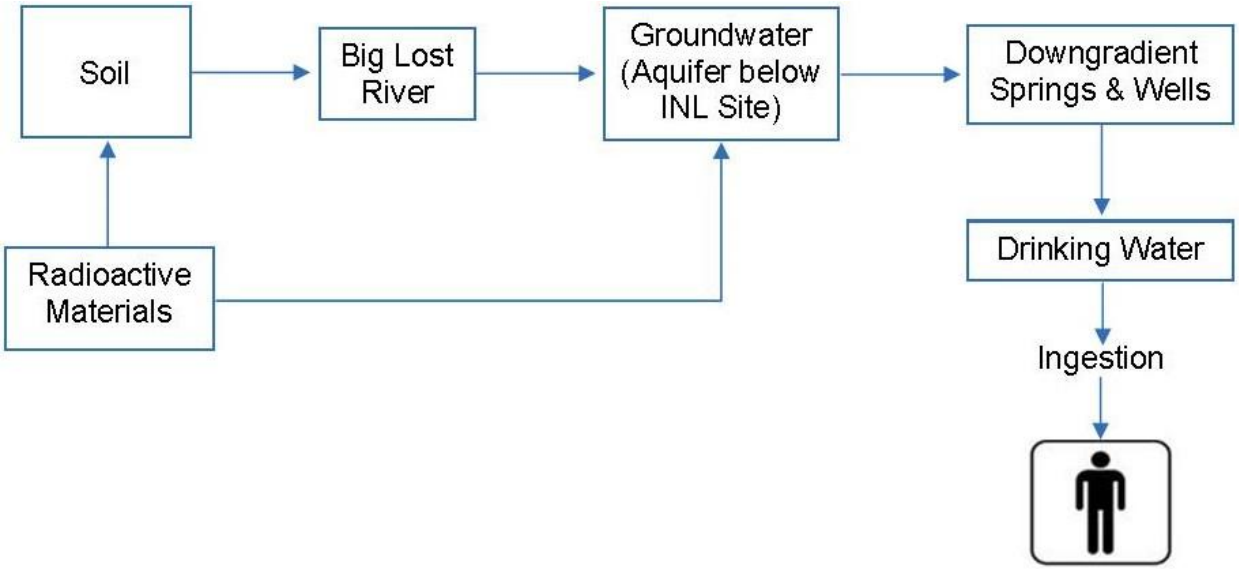

Figure 12. Primary potential pathways from surface water and groundwater to humans living outside the INL Site Boundary.

2.2.2 Significant Radionuclides

Historic waste disposal practices have produced localized areas of radiochemical contamination beneath the INL Site in perched water and the ESRPA. These areas are regularly monitored by the USGS, and reports are published showing the extent of contamination plumes (Davis 2010; Davis, Bartholomay, and Rattray 2013; Bartholomay et al. 2020). The selection of radiochemical and chemical constituents for analyses by the USGS are based on waste-disposal history. The radionuclides monitored by the USGS in the ESRPA at the INL Site are primarily tritium, strontium-90, gamma-emitting radionuclides, and plutonium and americium isotopes (Bartholomay et al. 2020; DOE-ID 2021b). The USGS also uses gross alpha and beta measurements to screen for radioactivity in the ESRPA as a possible indicator of groundwater contamination. Tritium is considered the most important because of the relatively large concentrations disposed of, and because it is the most mobile radionuclide and therefore a leading indicator of how far the contamination has moved.

Contaminated soil particles could become entrained and run off surface soil into the BLR. Past studies (Martin, Halford, and Marty 2004) of the BLR sink sediments do not indicate that this has occurred.

2.3 Soil

2.3.1 Exposure Routes

As shown in Figure 13, humans can be exposed to contaminated soil through direct radiation, the ingestion of soil, and the inhalation of resuspended particles (i.e., soil particles that are suspended in air through the action of wind).

To monitor the potential pathways shown in on the INL Site and at Distant environmental surveillance locations, focus on measurement of radionuclides in air, using air samplers (Section 4), direct radiation (Section 6), and soil (Section 8).

Although none of the exposure routes for soil are a critical pathway in terms of dose to humans off the INL Site, soil samples are collected because contaminants of Site origin have been measured in soils around specific facilities, as shown in Table 5. It also is known that Site air emissions are dispersed and deposited off the INL Site.

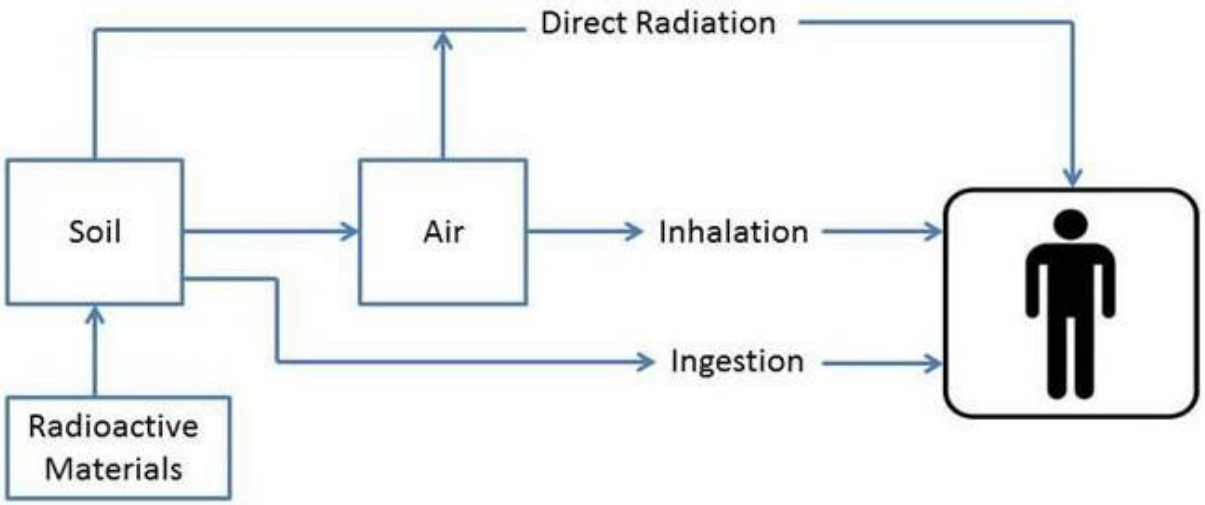

Figure 13. Potential pathways from soil to humans living outside of the INL Site.

Table 5. Radionuclides detected in on-Site soil samples (DOE-ID 2018).

Location	Radionuclide	Detected Concentration (pCi/g)[b] Minimum	Maximum
ATR Complex	Cesium-137	2.0×10^{-1}	6.1×10^{-1}
	Strontium-90	—[c]	5.8×10^{-2}
	Plutonium-238	5.9×10^{-3}	4.3×10^{-2}
	Plutonium-239/240	1.7×10^{-2}	2.2×10^{-2}
ARA/CITRC	Cesium-134	4.0×10^{-2}	6.0×10^{-2}
	Cesium-137	1.3×10^{-1}	3.0
	Strontium-90	2.1×10^{-1}	3.7×10^{-1}
	Plutonium-238	—	3.9×10^{-3}
	Plutonium-239/240	1.3×10^{-2}	1.8×10^{-2}
	Americium-241	5.5×10^{-3}	8.5×10^{-3}
EFS	Cesium-137	1.5×10^{-1}	6.8×10^{-1}
MFC	Cesium-134	4.0×10^{-2}	6.0×10^{-2}
	Cesium-137	1.3×10^{-1}	4.9×10^{-1}
	Cobalt-60		

Location	Radionuclide	Detected Concentration (pCi/g)[b] Minimum	Maximum
	Plutonium-239/240	—	5.0×10^{-2}
	Americium-241	1.5×10^{-2}	2.9×10^{-2}
		4.3×10^{-3}	1.2×10^{-2}
INTEC	Cesium-134	—	8.0×10^{-2}
	Cesium-137 Strontium-90	3.0×10^{-2}	3.5
	Plutonium-238 Plutonium-239/240	4.9×10^{-1}	7.1×10^{-1}
		2.5×10^{-2}	4.3×10^{-2}
	Americium-241	1.1×10^{-2}	2.9×10^{-2}
		6.1×10^{-3}	8.1×10^{-3}
Rest Area	Cesium-137 Plutonium 239/240	1.4×10^{-2}	4.5×10^{-2}
		—	2.4×10^{-2}
NRF	Cesium-134	—	6.0×10^{-2}
	Cesium-137 Plutonium-239/240 Americium-241	—	3.3×10^{-1}
		5.7×10^{-3}	1.6×10^{-2}
		4.3×10^{-3}	9.7×10^{-3}
RWMC	Cesium-134	3.0×10^{-2}	9.0×10^{-2}
	Cesium-137 Srontium-90	6.5×10^{-2}	6.0×10^{-1}
	Plutonium-238 Plutonium-239/240	1.0×10^{-1}	3.5×10^{-1}
	Americium-241[d]	2.2×10^{-3}	1.5×10^{-2}
		1.9×10^{-2}	9.5×10^{-1}
		4.7×10^{-2}	6.2×10^{-1}
TAN/SMC	Cesium-134 Cesium-137	4.0×10^{-2}	6.0×10^{-2}
	Plutonium-239/240	1.1×10^{-1}	3.1
	Americium-241	1.3×10^{-2}	1.7×10^{-2}
		3.2×10^{-3}	5.7×10^{-3}
ALL	Cesium-134	3.0×10^{-2}	9.0×10^{-2}
	Cesium-137	1.4×10^{-2}	3.5
	Cobalt-60	—	5.0×10^{-2}
	Strontium-90	1.0×10^{-2}	7.1×10^{-1}
	Plutonium-238	2.2×10^{-3}	4.3×10^{-2}
	Plutonium-239/240	5.7×10^{-3}	9.5×10^{-1}
	Americium-241[d]	3.2×10^{-3}	6.2×10^{-1}

a. ARA = Auxiliary Reactor Area; ATR = Advanced Test Reactor; CITRC = Critical Infrastructure Test Range Complex; MFC = Materials and Fuels Complex; INTEC = Idaho Nuclear Technology and Engineering Center; NRF = Naval Reactors Facility; RWMC = Radioactive Waste Management Complex; TAN/SMC = Test Area North/Specific Manufacturing Capability. See Figure 35.

b. Legend

a. Results measured in 2013-2014 using in situ gamma spectroscopy.
b. Results measured by laboratory analyses of soil samples collected in 2005.
c. Results measured by laboratory analyses of soil samples collected in 2006.
d. Results measured by laboratory analyses of soil samples collected in 2012.
e. Results measured by laboratory analyses of soil samples collected in 2015.
f. Results measured by laboratory analyses of soil samples collected in 2017.

c. ‘ ’ indicates that only one measurement was taken and is reported as the maximum result.

d. The data were the results of laboratory analysis for Americium-241 in soil samples.

2.3.2 Significant Radionuclides

DOE-ID (1991) classified historic atmospheric releases at the INL Site as operational or episodic because of differing requirements for atmospheric dispersion calculations. Operational releases are continuous, somewhat uniform releases that occur over a year or portion of a year and span a variety of meteorological conditions. Episodic releases refer to short-term operations, experiments, tests, and other events that take place over a short period of time (typically a few hours). During 1952 to 1989, approximately 13.5 mCi of radionuclides, primarily fission products released from the Site in airborne effluents, were characterized as operational releases (DOE-ID 1991). By comparison, an estimated 800,000 Ci were released as episodic releases during the same period. Mohler et al. (2004) ranked the routine releases from 1952 to 1992 using screening models developed by the National Council on Radiation Protection and Measurements (NCRP) for atmospheric releases (NCRP 1996). The ranking values for specific radionuclides indicate that the majority of doses to individuals from all pathways (e.g., inhalation, ingestion, external exposure) were related to iodine-131, strontium-90, and cesium-137, as observed in Figure 14. Figure 15 shows the amounts of total radionuclides, iodine-131, strontium-90, and cesium-137 released to the atmosphere from 1952 to 1989, as well as the doses estimated in the historical dose evaluation conducted in 1991 (DOE-ID 1991). The highest doses occurred from 1957 to 1959 and were primarily due to iodine-131 releases from fuel reprocessing at the Idaho Chemical Processing Plant (located at the current INTEC facility and decommissioned in 2002). Radioiodine is no longer in the environment due to its short half-life (8 days). Some strontium-90 and cesium-137 from past Site operations may still remain in the soil because of the longer half-lives of 28 and 30 years, respectively. With the decrease in historical radioiodine emissions, other radionuclides such as transuranics have increased in importance (see Figure 7).

Figure 10 shows the concentrations of radionuclides of concern in contaminated soils around specific INL Site facilities. Particulates containing these radionuclides could become resuspended and airborne as a result of wind. While it is highly unlikely that resuspended particulates contribute significantly to dose, these radionuclides are also present in air emissions (Figure 7) that could be deposited in soils, and should therefore be monitored in soils located outside the INL Site Boundary.

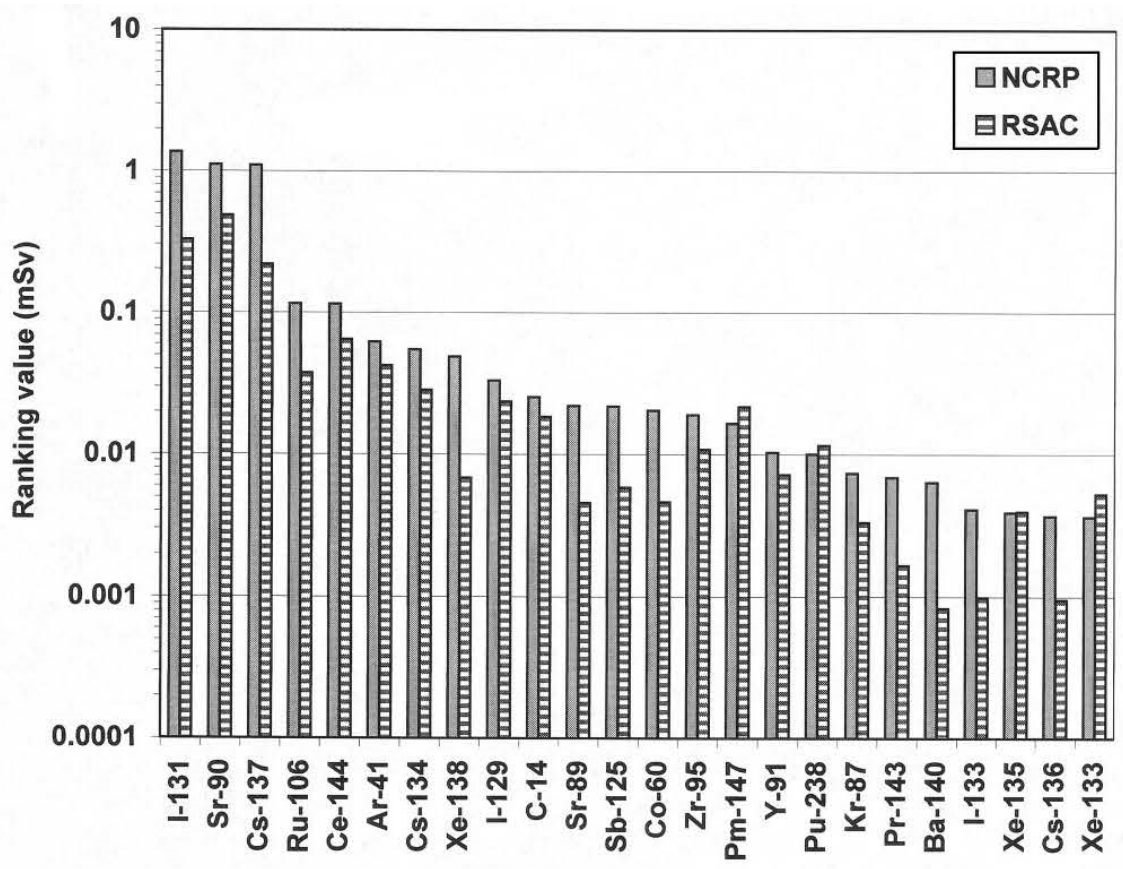

Figure 14. Ranking results for individual radionuclides released during routine operations at the INL Site from 1952 to 1992 considering all pathways of exposure using the National Council on Radiation Protection and Measurements screening method and the Radiological Safety Analysis Code (Mohler et al. 2004).

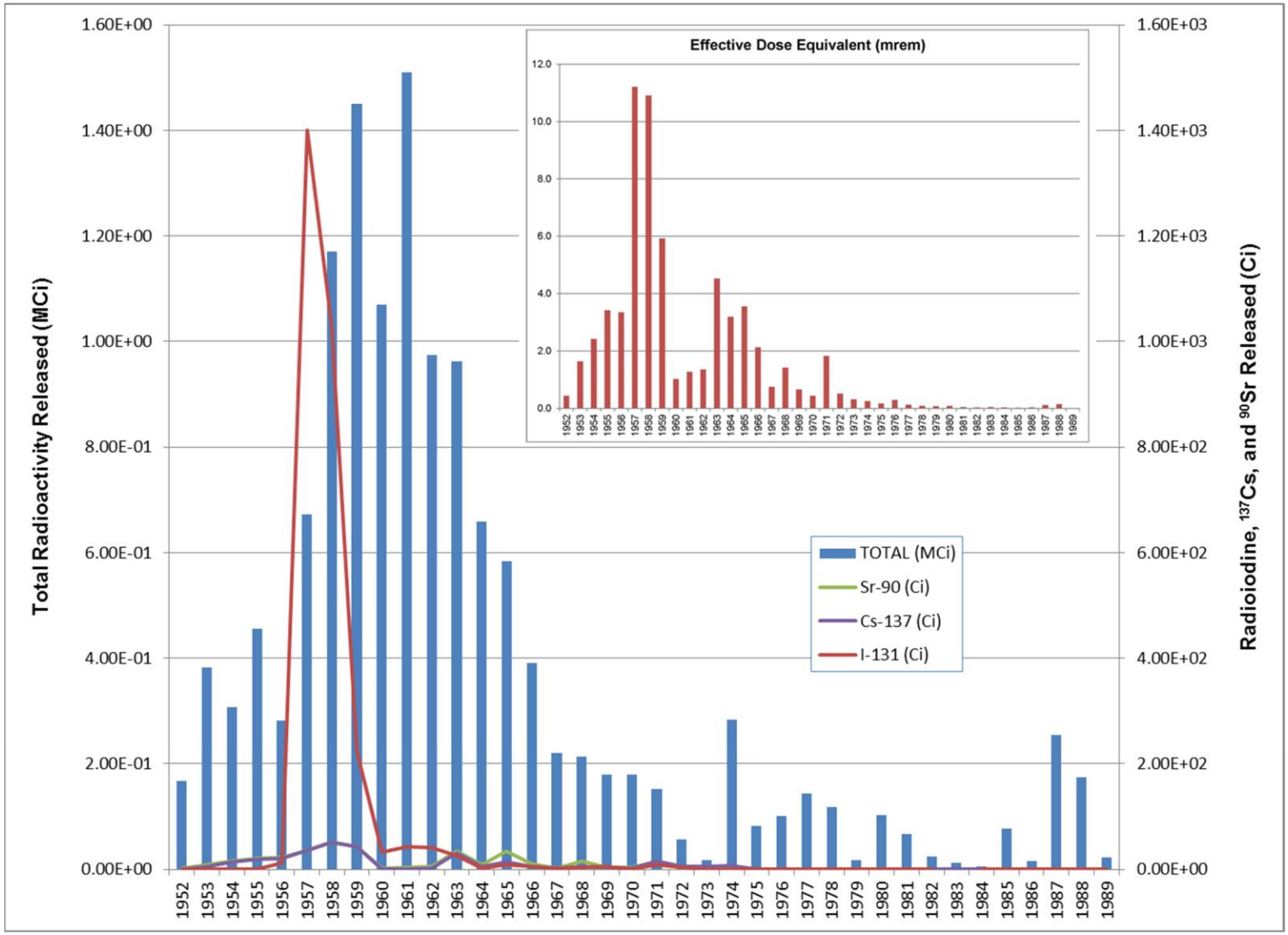

Figure 15. Total radionuclide, radioiodine, cesium-137, and strontium-90 atmospheric releases from the INL Site and estimated effective dose equivalent (EDE) to MEI from 1951 to 1989 (DOE-ID 1991).

2.4 Game Animals

2.4.1 Exposure Routes

Game animals are considered a critical transport media because they can ingest soil, water, and vegetation contaminated by radionuclides released by the INL Site and then be consumed by hunters living off-Site, as observed in Figure 16. Ducks migrating through the INL Site can land on ponds that receive liquid effluents—most notably the ATR Complex evaporation pond discussed in Section 3.1.2. The ponds are lined to prevent infiltration to the aquifer; however, radionuclides can build up in pond sediments. Rooted vegetation and water can be ingested by waterfowl. The waterfowl, in turn, can fly off the Site and be hunted on a distant body of water and consumed. Historical studies have demonstrated that ducks spending time on radioactive effluent ponds at the Site can become contaminated (Warren, Majors, and Morris 2001).

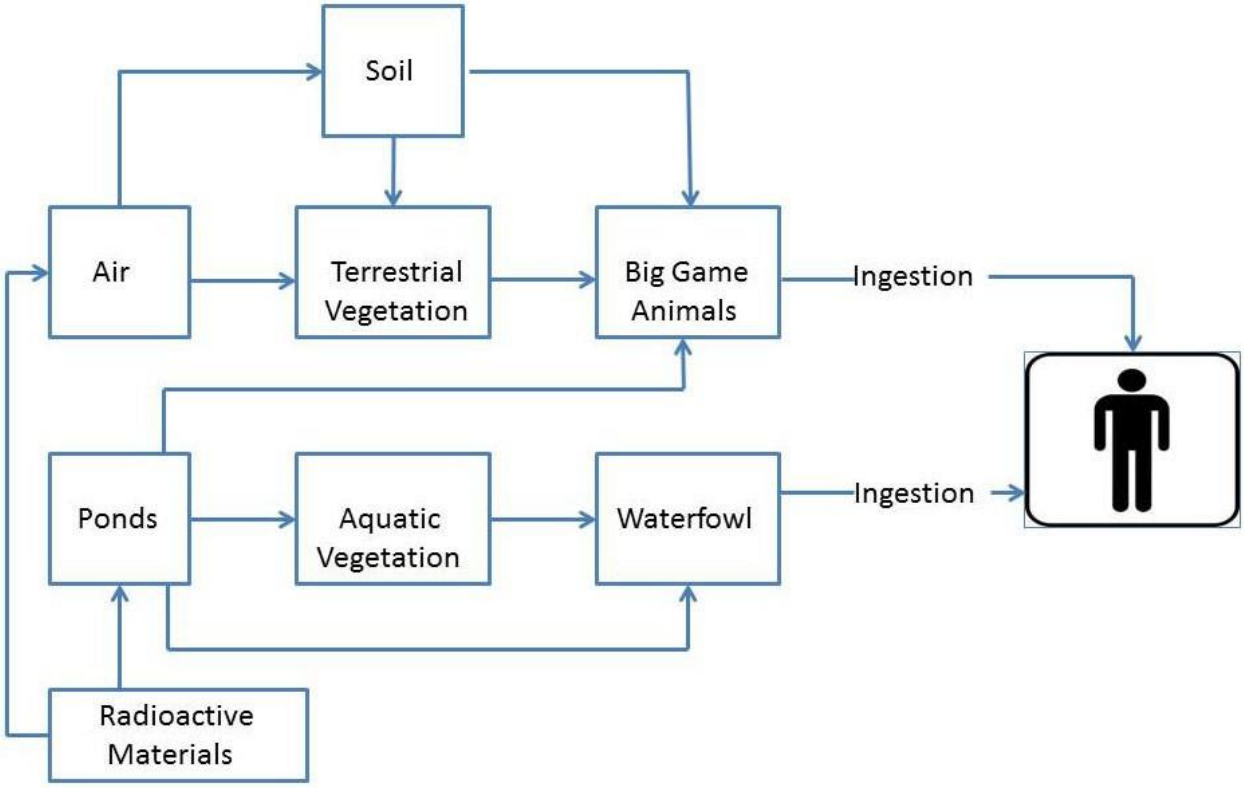

Figure 16. Potential pathways via game animals to humans living outside of INL Site.

Big game animals (e.g., elk, pronghorn, mule deer) can forage on contaminated soils and vegetation and have been observed drinking from liquid effluent ponds on the INL Site. The soils and vegetation can either be contaminated on the INL Site or at a distant location from the INL Site (via air). Animals can be hunted and eaten.

To monitor the exposure pathways to humans shown in Figure 16, environmental surveillance on the INL Site focuses on sampling big game animals that have been killed on roads at the Site and waterfowl on ponds at the Site (see Sections 10 and 11, respectively).

2.4.2 Significant Radionuclides

Potential doses to humans from game animals have been estimated by analyzing tissues from waterfowl accessing wastewater ponds at the INL Site and tissues from big game animals killed by vehicles on or near the Site. Conservative estimates were made using radionuclide concentrations measured in edible tissues. Assumptions used in the analyses included:

- Maximum concentrations of radionuclides
- The animal would be consumed soon after leaving the INL Site (i.e., no biological or radioactive decay occurred before consumption).

The doses estimated for consumption of waterfowl collected from the ATR Complex evaporation pond and reported in the Annual Site Environmental Reports (ASERs) from 2009 to 2013 are shown in Table 6. Cesium-137, cobalt-60, strontium-90, and zinc-65 are common constituents in the wastewater discharged to the pond. Note that the effluent to the pond is not analyzed for transuranics; see Section 3, Table 10. The assumptions used in the dose calculations from the consumption of waterfowl from the INL Site are very conservative and produce doses to the public well below regulatory standards.

Monitoring this media is important due to the mobility of these media and public concern.

Table 6. Estimated doses (mrem/yr) from consuming waterfowl collected at wastewater ponds.

Year	Americium-241	Plutonium-238	Plutonium-239	Cobalt-60	Cesium-137	Strontium-90	Zinc-65	Total Dose
2009	ND	ND	ND	6.95E-05	2.45E-03	1.70E-03	1.57E-03	5.78E-03
2010	ND	8.62E-05	1.91E-03	3.01E-04	3.09E-02	2.41E-02	1.71E-03	5.90E-02
2011	ND	ND	ND	1.54E-04	1.58E−03	ND	2.29E-03	4.02E-03
2012	ND	ND	ND	1.37E-04	8.81E-03	ND	ND	8.95E-03
2013	ND	ND	ND	3.60E-03	1.82E-02	2.19E-3	3.55E-02	3.55E-02

The doses estimated for the consumption of big game animals (e.g., antelope, deer, elk) have ranged from 2.0E-04 to 1.7E-02 mrem/yr for 2009 to 2013. In each case, the only radionuclide detected in the meat was cesium-137, a fallout product. In 1998 and 1999, muscle samples from four pronghorn, five elk, and eight mule deer were collected as background samples from hunters across the western U.S., including three from central Idaho, three from Wyoming, three from Montana, four from Utah, and one each from New Mexico, Colorado, Nevada, and Oregon (DOE-ID 2002). Each background sample had small, but detectable, cesium-137 concentrations in its muscle. These concentrations likely can be attributed to the ingestion of plants containing radionuclides from fallout associated with aboveground nuclear weapons testing. Allowing for radioactive decay since the time of the study, background measurements would be expected to range from about 4 to 11 pCi/kg in 2012. All detected values have been within the expected range of background (about 4 and 11 pCi/kg) (DOE-ID 2012).

Based on the measurements made during 2009 to 2013, the radionuclides of concern for consumption of waterfowl are gamma-emitting radionuclides (e.g., cobalt-60, cesium-137, zinc-65), strontium-90, and transuranic radionuclides (e.g., americium-241, plutonium-238, plutonium-239/240). The media contributing to contaminants in waterfowl are wastewater ponds and sediment within those ponds.

The radionuclides of concern for consumption of game animals are gamma-emitting radionuclides (primarily cesium-137). This is a radionuclide associated with global fallout (see Section 2.2), but it is always conservatively assumed that any detection of this radionuclide comes from the INL Site.

2.5 Summary

The relevant pathways at the INL Site are illustrated graphically in the conceptual model presented in Figure 17. The major components of the model are: (1) sources, (2) transport media, (3) transport pathways, (4) exposure routes, (5) human receptors, and (6) dose. The major transport media through which radionuclides can be transported to humans are: (1) air, (2) groundwater, (3) waterfowl, (4) terrestrial game animals, (5) agricultural products, and (6) surface water. The routes by which humans can receive doses are via (1) inhalation, (2) ingestion, and (3) external exposure.

The INL Site has historic releases to groundwater and surface soil. The groundwater in certain areas beneath the INL Site is contaminated primarily from historic ATR Complex and INTEC liquid effluent directly injected into the aquifer and from the infiltration of effluents released into unlined ponds for approximately 50 years. Therefore, the groundwater pathway to down-gradient wells and springs begins primarily with the contaminated groundwater beneath the INL Site.

The surface soil at and around RWMC was contaminated primarily by flooding of buried Rocky Flats waste in 1962 and 1969 and subsequent wind transport in the northeast direction (Markham, Puphal, and Filer 1978). The area was subsequently engineered with a diversion dam and spreading areas to divert water during flooding events. In addition, contaminated portions of the burial site were covered with topsoil. Radionuclides (primarily transuranics) detected in the surface soils outside RWMC were determined to be below EPA guidance for health protection of the general population, except for a few locations adjacent to the RWMC perimeter that are not accessible to the public. Some low but measurable concentrations of plutonium isotopes and americium-241 still exist outside the RWMC perimeter fence (Jessmore, Lopez, and Haney 1994).

The pathways shown in Figure 17 are not equal in importance (i.e., do not necessarily result in similar doses to a human receptor) or of equal concern to members of the public. Some pathways are included because they may be a concern to stakeholders even though they do not necessarily result in significant doses to human receptors. For example, the BLR is distinctive because it flows through the INL Site, enters the ground at the BLR sinks, and re-emerges via groundwater in down-gradient springs along the Snake River. While it is unlikely to contribute to dose, it is nonetheless included in the conceptual model because it is a special pathway of concern to members of the public and stakeholders.

The biotic receptors (e.g., plants and animals in their natural environments that may uptake or be exposed to radionuclides), as shown in Figure 17, are not only a source of dose to humans who eat them, but also receive doses through the ingestion of, inhalation of, and exposure to radionuclides in the environment. Based on historical INL Site data and the findings of the DOE's Biota Dose Assessment Committee in development of DOE Standard, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE 2002), biota (e.g., plants and animals in their natural environments) access radionuclides and could receive doses primarily through contaminated soils and contaminated wastewater ponds and associated sediments. The air release pathway is not a major source of exposure because biota inhalation and immersion in air was estimated to be minor in comparison (DOE 2002).

Historical studies have shown that biota can access buried waste; however, the level of transport to the surface was insignificant (<0.05%) (Arthur and Markham 1983). In addition, historical studies on direct exposure to small mammals residing on waste disposal could provide significant exposures (Arthur et al. 1986; Halford and Markham 1978). However, cleanup of waste facilities over the years have reduced the significance of this impact to plant and animal populations residing on these areas (DOE-ID 2012). Radiation dose assessments for terrestrial and aquatic biota are reported in the ASERs and have never exceeded the DOE Biota Concentration Guides since they were first evaluated in 2002.

Table 7 summarizes the potential environmental pathways and the significant radionuclides for the INL Site.

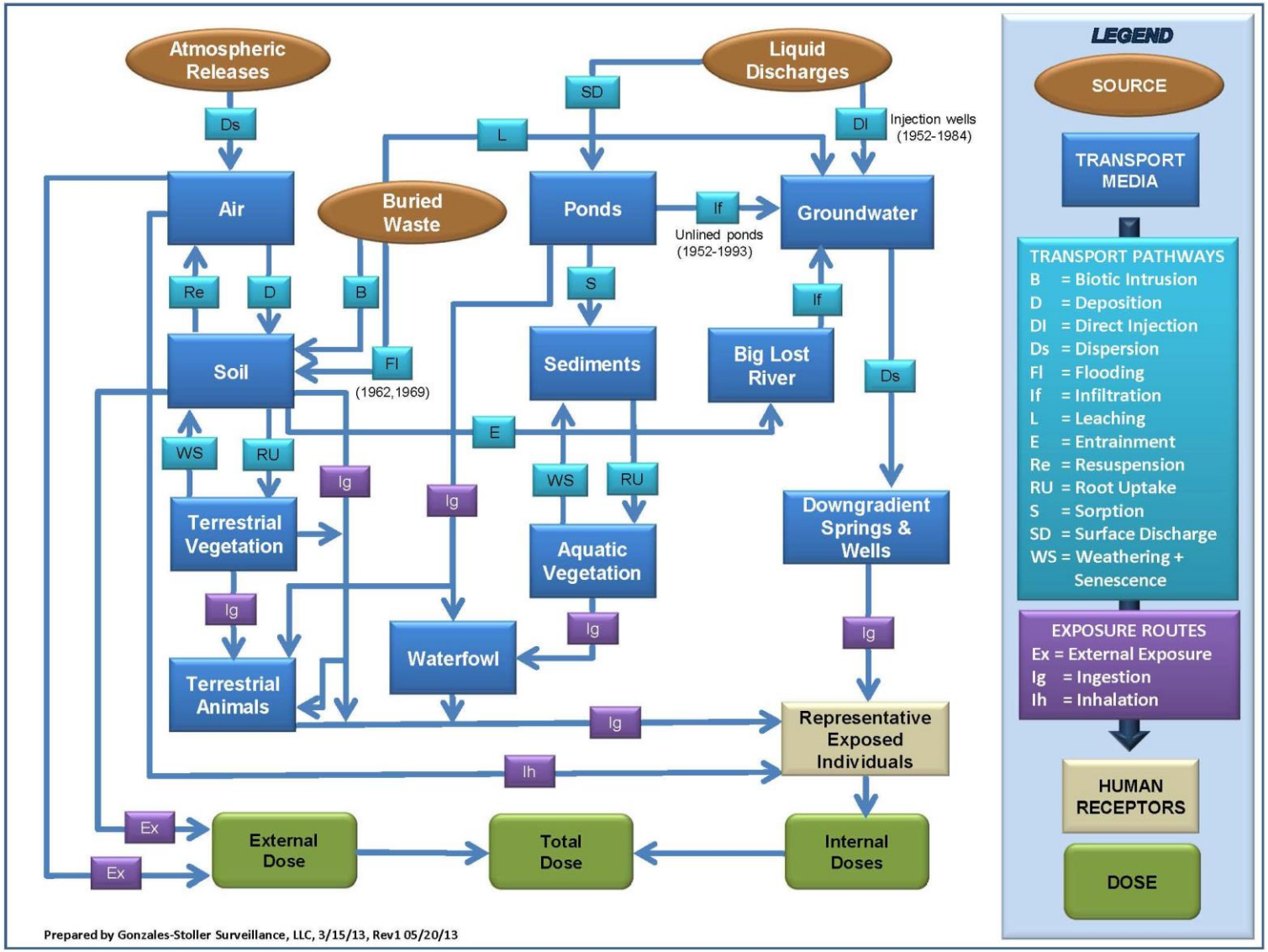

Figure 17. Environmental transport pathways and exposure routes contributing to potential doses to humans from INL Site releases.

Table 7. Environmental pathways and exposure routes for radiological emissions at the INL Site based on DOE recommendations (DOE 1991).

Exposure Route	Environmental Pathway	Potential Dose to Receptor		Significant Radionuclides	Modeling/Monitoring Programs		Comments
		Onsite	Offsite		Monitoring	Modeling	
External	Direct facility radiation	Yes	No	Gamma-emitters, Neutrons	External radiation	None	Contractor radiation control programs evaluate occupational exposures.
	Immersion in airborne plume	Yes	Yes	Noble gases	External radiation	NESHAP	—
	Contaminated land	Yes	Yes	Gamma-emitters (Cesium-137, Cobalt-60)	External radiation, soil	NESHAP	—
	Aquatic recreation (boating/swimming)	No	No	None	None	None	No INL Site facilities discharge liquid effluent directly to lakes or streams.
Inhalation	Airborne plume	Yes	Yes	Tritium, Transuranics	Atmospheric moisture, air	NESHAP	—
	Resuspended material	Yes	Yes	Transuranics	Air	NESHAP	—
Ingestion of terrestrial foods	Vegetables, fruit, cereal grains	No	Yes	Cesium-137, Iodine-129, Strontium-90, Tritium	Agricultural products	NESHAP	—
	Animal products (milk, cheese, meat, eggs)	No	Yes	Cesium-137, Iodine-131, Strontium-90, Tritium	Agricultural products	NESHAP	—
	Big game animals	No	Yes	Cesium-137, Iodine-131	Big game animals	None	—

Exposure Route	Environmental Pathway	Potential Dose to Receptor		Significant Radionuclides	Modeling/Monitoring Programs		Comments
		Onsite	Offsite		Monitoring	Modeling	
	Waterfowl	No	Yes	Cesium-137, Strontium-90, Transuranics	Waterfowl	None	—
Ingestion of aquatic foods	Fish	No	No	None	None	None	No INL Site facilities discharge liquid effluent directly to lakes or streams.
Ingestion of soil	Grazing Animals Humans (children)	Yes No	Yes Yes	Cesium-137, Strontium-90, Transuranics Cesium-137, Strontium-90, Transuranics	Soil Soil	NESHAP None	—
Ingestion of drinking water	Surface Water	No	No	None	Surface water (BLR)	None	No INL Site facilities discharge liquid effluent directly to lakes or streams. Drinking water in the area is from wells, but BLR recharges the aquifer.
	Well Water	Yes	Yes	Tritium, Cesium-137, Strontium-90, Technetium-99, Iodine-129	Drinking water see comments	NESHAP, CERCLA investigations, USGS	Monitoring programs for locations within the INL Site Boundary are described in DOE-ID (2021a) and DOE-ID (2021c).
	Rainwater	No	No	None	None	None	Drinking water in the area is from wells.

3. LIQUID EFFLUENT MONITORING

It is the policy of the United States (U.S.) Department of Energy (DOE) to conduct liquid effluent monitoring to determine whether the public and environment are adequately protected during DOE operations and whether operations comply with DOE and other applicable federal, state, and local regulations and requirements (DOE 2015). Some Idaho National Laboratory (INL) Site operations retain wastewater in lined, total containment evaporative ponds constructed to eliminate liquid effluent discharges. Other INL Site operations discharge liquid effluent to unlined infiltration basins or ponds. These systems have the potential to impact groundwater, affect air quality via evaporation or fugitive dust emissions, or contaminate waterfowl.

As summarized in Table 8, effluent monitoring is performed to demonstrate compliance with:

- Requirements in effluent reuse permits issued according to the Idaho Department of Environmental Quality (DEQ) Rules, IDAPA 58.01.17, "Recycled Water Rules" (DEQ 2022d)
- Requirements of the DEQ Rules, IDAPA 58.01.11, "Ground Water Quality Rule" (DEQ 2022b)
- Requirements of the DEQ Rules, IDAPA 58.01.16, "Wastewater Rules" (DEQ 2022c)
- Requirements in an air quality permit to construct issued according to the DEQ Rules, IDAPA 58.01.01, "Rules for the Control of Air Pollution in Idaho" (DEQ 2022a).
- Guidance in DOE-HDBK-1216-2015, "Environmental Radiological Effluent Monitoring and Environmental Surveillance" (DOE 2015):
  - Demonstrate compliance with the applicable requirements of DOE O 458.1, "Radiation Protection of the Public and the Environment" (DOE 2013).
  - Quantify radionuclides discharged from each discharge point.
  - Alert affected process supervisors of upsets in processes and emission controls.
- Requirements in DOE O 458.1:
  - Characterize planned and unplanned releases of liquids containing radionuclides.
  - Comply with the as low as reasonably achievable (ALARA) process requirements.
  - Conduct activities to ensure that liquid releases containing radionuclides from DOE activities are managed in a manner that protects groundwater resources.
  - Conduct activities to ensure that liquid discharges containing radionuclides from DOE activities do not exceed the annual average concentrations identified in the order.
  - Ensure that radionuclides from DOE activities contained in liquid effluents do not cause private or public drinking water systems to exceed the drinking water limits.
  - Prohibit the use of soil columns.

Liquid radioactive effluents have not, to this date, produced measurable exposure to an off-Site member of the public. In the past, liquid radioactive materials were disposed of directly to the Eastern Snake River Plain Aquifer (ESRPA) through injection wells. This practice was discontinued in 1984. Unlined surface water disposal ponds were used to dispose of low-level radioactive liquids until 1993. Water from these ponds percolated through the soil and basalt to the aquifer. Some of the radionuclides sorbed on the soil column before they could reach the aquifer. Others, mainly tritium, migrated with water through the soil column to the aquifer.

Most of the liquid discharge of radionuclides occurred during 1954 to 1979. The peak occurred in 1959, when approximately 4800 Ci was released (DOE-ID 1991). The total released from 1952 to 1989 was about 76,000 Ci (DOE-ID 1991). Some radionuclides—primarily tritium, strontium-90, and iodine-129—are still detected in the aquifer below the INL Site. Groundwater impacts from historical wastewater discharges are discussed in Section 7.

Table 8. Summary of liquid-effluent monitoring at INL Site.

Facility	Monitoring Requirements		
	DOE Orders/ Guidance	Idaho Air Quality Permit	Idaho Wastewater Reuse Permit
ATR Complex CWP	X	—	X
ATR Complex Evaporation Pond	X	X	—
ATR Complex Sewage Treatment Lagoons	—	No routine monitoring	
CFA Sewage Treatment Facility	—	No routine monitoring	
INTEC Percolation Ponds	X	—	X
MFC Evaporative Sewage Lagoons	—	No routine monitoring	
MFC Industrial Waste Pond	X	—	X
MFC Secondary Sanitary Sewage Lagoon	—	Closed in 2012	
RWMC Municipal Wastewater Lagoons	—	No routine monitoring	
SMC Wastewater Lagoons	—	No routine monitoring	

3.1 Advanced Test Reactor Complex

The ATR Complex consists of buildings and structures used to conduct research associated with developing, testing, and analyzing materials used in nuclear and reactor applications and both radiological and non-radiological laboratory analyses. There are three separate wastewater disposal facilities at the ATR Complex that include the Cold Waste Ponds, Evaporation Pond, and Sewage Treatment Lagoons (Figure 18).

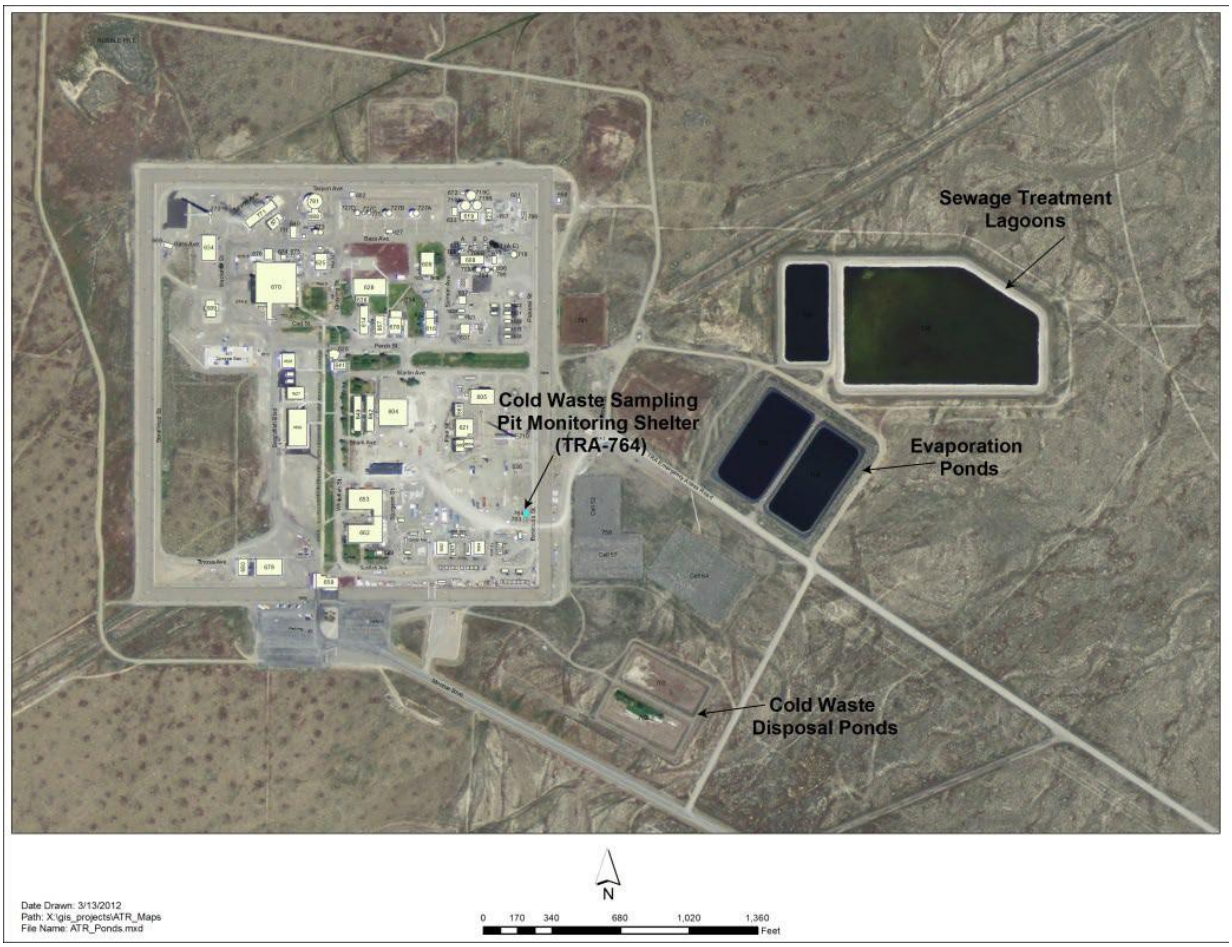

Figure 18. Wastewater ponds at the ATR Complex.

3.1.1 Advanced Test Reactor Complex Cold Waste Ponds

3.1.1.1 Drivers for Sampling Program

The wastewater effluent discharged to the ponds is sampled to demonstrate compliance with reuse permits issued by the DEQ. In February 2008, the DEQ issued permit LA-000161-01 (DEQ 2008). Permit

LA-000161-01 was replaced by permit I-161-02 in November 2014 (DEQ 2014). Permit I-161-02 was replaced by permit I-161-03 in October 2019 (DEQ 2019c).

Environmental surveillance monitoring at the ATR Complex Cold Waste Ponds (CWP) is performed to meet the following requirements:

- DOE O 458.1 (DOE 2013)
- DOE-HDBK-1216-2015 (DOE 2015).

3.1.1.2 Background

The CWP is located approximately 450 ft from the southeast corner of the ATR Complex compound and approximately 3/4 mile southwest of the Big Lost River (BLR) channel (Figure 18). The CWP was excavated in 1982 and consist of two unlined cells, each with dimensions of 180 × 430 ft across the top of the berms, and a depth of 10 ft. Total surface area for the two cells at the top of the berms is approximately 3.55 acres. The maximum capacity is approximately 10,220,000 gal (31.3 acre-ft).

The CWP function as percolation basins for the infiltration of nonhazardous industrial liquid effluent consisting primarily of noncontact cooling tower blowdown, once-through cooling water for air conditioning units, coolant water from air compressors, secondary system drains, and other nonradioactive drains throughout the ATR Complex. Chemicals used in the cooling tower and other effluent streams discharged to the CWP include commercial biocides and corrosion inhibitors (INL 2006a). Examples include chlorine dioxide biocide generated by mixing sulfuric acid and sodium chlorate/sodium chloride, and phosphate-based corrosion inhibitors. The CWP receives noncontact cooling water from the ATR, so radionuclides are not discharged to the CWP under normal operating conditions. In the event of radioactive contamination in the cold drain system from an upset condition or design basis event, the effluent can be routed to the evaporation pond (Rasch 2006).

The CWP effluent flows through collection piping to the Test Reactor Area (TRA)-764 Cold Waste Sample Pit, where the flow rate is recorded, and samples are collected. The effluent then flows to the Cold Waste Sump Pit (TRA-703), which contains submersible pumps that route the water to the appropriate CWP cell through 8 in. valves.

CWP effluent enters the pond through concrete inlet basins located near the west end of each cell. Most of the water percolates into the porous ground a short distance from the inlet basins. The entire floor of a cell is rarely submerged. If the water level rises significantly in a cell (e.g., 5 ft), the flow would be diverted to the adjacent cell, allowing the first cell to dry out. An overflow pipe connects the two cells at the 9-ft level. Approximately 220 million gallons are discharged to the CWP annually (INL 2021a).

The CWP was evaluated during the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) investigation at the INL Site as site ID TRA-08, and arsenic and cesium-137 were identified as contaminants of concern (COCs). The presence of cesium-137 is believed to be from windblown soil contamination originating from the warm waste pond, and the presence of arsenic is the result of historical disposal practices at the CWP (DOE-ID 2007). Post-Record of Decision sampling data (DOE-ID 1998a) confirmed that the pond sediments are below the 18.3-mg/kg final remediation goal for arsenic and the Resource Conservation and Recovery Act (RCRA) toxicity characteristic leaching procedure's regulatory limit. The elimination of arsenic as a COC reduced the number of COCs at the pond from two to one, which doubled the final remediation goal for cesium-137 from 11.7 to 23.3 pCi/g (DOE-ID 1997; DOE-ID 2000). Remedial actions were conducted at the CWP in 1999. Approximately 80 yd^3 of cesium-137-contaminated soil was removed from the northern pond and transported to Cell 1957 of the warm waste pond for disposal. Institutional controls were established, thereby restricting the site to industrial land use until residential risk is $<10^{-4}$ (DOE-ID 2007).

3.1.1.3 Sampling Basis and Design

Samples of the effluent to the ATR Complex CWP are analyzed for radiological and non-radiological constituents to demonstrate compliance with the reuse permit and DOE orders. Samples are collected at the weir impoundment located at the TRA-764 Cold Waste Sample Pit, which, per DOE (2015), is located downstream of the last component stream and is protected from the elements to prevent freezing of the sampling line. Locating the sampler near the flow meter in TRA-764 simplifies the collection of the composite samples required by the reuse permit. Samples are collected with an automated refrigerated sampler that collects the sample aliquots via a peristaltic pump into a carboy in a refrigerated unit to minimize biological growth. DOE (2015) recommends sampling materials that are compatible with the effluent, so inert components such as Teflon, stainless steel, polyvinyl chloride or silicone tubing, and high-density polyethylene plastic are used. To meet the recommendation for a substitute sample collection system in DOE (2015), spare parts and portable samplers are kept on hand.

The reuse permit requires collection of a composite sample every month. The composite sample is achieved by collecting a 24-hour flow proportional sample via the automated sampler. Samples are collected on a randomly selected date. Flow proportional sampling meets the requirements of DOE (2015) and is appropriate for obtaining representative samples from streams with fluctuating flow rates orradionuclide concentrations. Therefore, samples for environmental surveillance monitoring are collected in the same manner as the samples required for the reuse permit. The surveillance samples are collected at the same time as the permit samples to improve efficiency and minimize sampling costs.

"An Implementation of the Risk-based Approach to Liquid Effluent Monitoring at the INEL" (Einerson 1996) developed a risk-based approach to liquid-effluent monitoring using historical data. The approach was based on the likelihood of exceeding a release limit, paired with the response time for corrective action. Einerson (1996) remains generally applicable because discharge to the pond is still dominated by secondary cooling water from the reactor.

Einerson (1996) noted that sulfate and total dissolved solids (TDS) concentrations in the CWP effluent had historically exceeded the release limits and recommended continued monitoring for these constituents and a process review/change. Einerson (1996) recommended quarterly monitoring for the other constituents in Table 9 to demonstrate that concentrations were below release levels. However, when the first reuse permit LA-000161-01 was issued in 2008, the sampling frequency was increased to monthly to match the permit requirements.

Table 9. Summary of environmental monitoring at Advanced Test Reactor Complex CWP during the period of reuse permit LA-000161-01.

Analyte	Sampling Frequency	Driver[a]	Screening Level	May 2008–November 2014	
				Minimum	Maximum
Metals (µg/L)					
Aluminum	Monthly	GW	None	<25	105
Antimony	Monthly	Einerson (1996)	2,200[b]	<0.25	1.5
Arsenic	Monthly	DEQ, Einerson (1996)	5,000[c]	<2.5	7.5
Barium	Monthly	DEQ, Einerson (1996)	100,000[c]	42	193
Beryllium	Monthly	DEQ, Einerson (1996)	60[b]	<0.5	<0.8
Cadmium	Monthly	DEQ, Einerson (1996)	1,000[c]	<1	<1
Chromium	Monthly	DEQ, Einerson (1996)	5,000[c]	2.8	13.9
Cobalt	Monthly	DEQ	None	<2.5	<2.5
Copper	Monthly	DEQ, Einerson (1996)	None	<1	10.8
Iron	Monthly	DEQ, Einerson (1996)	None	<25	248
Lead	Monthly	Einerson (1996)	5,000[c]	<0.25	0.44
Manganese	Monthly	DEQ, Einerson (1996)	1.3E+08[b]	<2.5	13.4
Mercury	Monthly	DEQ, Einerson (1996)	200[c]	<0.2	<0.2
Nickel	Monthly	Einerson (1996)	54,000[b]	<2.5	3.06J
Selenium	Monthly	DEQ, Einerson (1996)	1,000[c]	0.82	5.9
Silver	Monthly	DEQ, Einerson (1996)	5,000[c]	<5	<10

Analyte	Sampling Frequency	Driver[a]	Screening Level	May 2008–November 2014	
				Minimum	Maximum
Sodium	Monthly	Einerson (1996)	None	7,940	38,500
Thallium	Monthly	Einerson (1996)	24[b]	<0.25	<0.25
Zinc	Monthly	Einerson (1996)	5E+06[b]	<2.5	18.6
Non-Metals (mg/L)					
Chloride	Monthly	DEQ, Einerson (1996)	None	9.87	42.6
Fluoride	Monthly	DEQ, Einerson (1996)	2.1E+05[b]	0.131	0.639
Sulfate	Monthly	DEQ, Einerson (1996)	None	20.4	724
Total dissolved solids	Monthly	DEQ, Einerson (1996)	None	226	1330
Total suspended solids	Monthly	DEQ	100[d]	<4	6.8
Nitrate+nitrite as nitrogen	Monthly	DEQ, Einerson (1996)	See total nitrogen	0.677	3.79
Total Kjeldahl nitrogen (TKN)	Monthly	DEQ	See total nitrogen	<0.1	0.859
Total nitrogen (sum of TKN and nitrate+nitrite as nitrogen)	Monthly	DEQ	20[d]	0.777	4.291
Radionuclides (pCi/L)					
Gamma spectroscopy	Monthly	DOE, Einerson (1996)	—	—	—
Silver-108m	—	—	Not calculated[e]	ND[f]	ND
Silver-110m	—	—	90[e]	ND	4.27±1.15
Americium-241	—	—	15[e]	ND	ND
Cerium-144	—	—	30[e]	ND	ND
Cobalt-58	—	—	300[e]	ND	ND
Cobalt-60	—	—	100[e]	ND	ND
Cesium-134	—	—	80[e]	ND	ND
Cesium-137	—	—	200[e]	ND	ND
Europium-152	—	—	200[e]	ND	ND
Europium-154	—	—	60[e]	ND	ND
Europium-155	—	—	600[e]	ND	ND
Potassium-40	—	—	None	ND	46.7±13.2
Manganese-54	—	—	300[e]	ND	ND
Niobium-95	—	—	300[e]	ND	ND

Analyte	Sampling Frequency	Driver[a]	Screening Level	May 2008–November 2014	
				Minimum	Maximum
Radium-226	—	—	Naturally occurring[g]	ND	ND
Ruthenium-103	—	—	200[e]	ND	ND
Ruthenium-106	—	—	30[e]	ND	ND
Antimony-125	—	—	300[e]	ND	ND
Uranium-235	—	—	66[h]	ND	ND
Zinc-65	—	—	300[e]	ND	ND
Zirconium-95	—	—	200[e]	ND	ND
Gross alpha	Monthly	DOE, Einerson (1996)	15[g,i]	ND	7.69±2.04
Gross beta[j]	Monthly	DOE, Einerson (1996)	4 mrem/yr[j]	ND	23.3±2.18
Strontium-89/90	Annually	DOE	8[i]	ND	0.835±0.163
Strontium-90	Contingency[k]	DOE	8[i]	ND	ND
Tritium	Annually	DOE	20,000[i]	ND	ND
Iodine-129	Annually	DOE	1[e]	ND	ND

a. DOE = DOE orders for radiation protection; DEQ = reuse permit LA-000161-01, GW = Analyte for groundwater samples collected for the reuse permit.
b. Screening release levels for surface pathway from Ansley et al. (1997).
c. From 40 CFR 261.24 (toxicity characteristic).
d. Maximum 30-day average concentrations from IDAPA 58.01.017.600.06 (rapid infiltration systems).
e. Maximum Contaminant Level (MCL) from EPA (2000).
f. ND = not detected.
g. The limit is 5 pCi/L if process-derived radium-226 is present in the wastewater.
h. Calculated from the MCL of 30 µg/L. The specific activity for uranium-234 was used to calculate the MCL for uranium-233/234.
i. Primary Constituent Standard (PCS) from IDAPA 58.01.11.
j. The "Ground Water Quality Rule," IDAPA 58.01.11, specifies a Primary Constituent Standard (PCS) for combined beta/photon emitters of 4 millirems/year effective dose equivalent (EDE). Speciation of the individual radionuclides present would be necessary to determine the equivalent PCS in units of pCi/L. For comparison purposes only, the EPA also specifies a MCL of 4 mrem/year for public drinking water systems and uses a screening level of 50 pCi/L. Public drinking water samples with gross beta activity greater than 50 pCi/L must be analyzed to identify the major radionuclides present.
k. If the gross beta activity in the sample exceeds 15 pCi/L, the sample is analyzed for strontium-90.

Einerson (1996) suggested quarterly sampling for volatile organic compounds (VOCs) because of a limited number of detections of methylene chloride and Freon-11 in the early 1990s. Analyses for VOCs were performed on quarterly samples until the second quarter of 1997 when VOC analyses were discontinued because most compounds were not detected, with the exception of sporadic detections of methylene chloride (a common laboratory contaminant) and Freon-11 at very low concentrations.

Samples for a broad spectrum of radionuclides were collected to monitor for upset conditions in the reactor cooling system or accidental releases and to demonstrate compliance with DOE orders, as observed in Table 9. Samples for gamma spectroscopy, gross alpha, and gross beta are collected monthly. These analyses provide a relatively inexpensive screening for gross radioactivity and a variety of fission and activation products. Samples for strontium-89/90, tritium, and iodine-129 were collected annually through 2014, as seen in Table 9. Constituent concentrations collected from March 2008 to December 2013 were well below the screening release levels (Table 9).

Based on the data collected for reuse permit LA-000161-01, INL requested that DEQ eliminate the monitoring requirements for arsenic, barium, cadmium, chromium, cobalt, copper, fluoride, iron, manganese, mercury, selenium, and silver from the next reuse permit I-161-02 because they are typically not detected or are an order of magnitude below the drinking water standard (INL 2012b).

The radionuclide analyte list was reviewed with personnel from the ATR Complex who determined that the most likely scenario for the release of radionuclides to the CWP was failure of containment of the primary coolant water (E. King, personal communication, February 21, 2013). The resultant release profile would be similar to releases to the ATR Complex evaporation pond (see Section 3.1.2.2). The following changes to the surveillance monitoring at the CWP were implemented coincident to the revised monitoring for reuse permit I-161-02 issued in November 2014:

- Discontinue the annual analysis for strontium-89/90 because of the contingency analysis for strontium-90 if the gross beta concentration in a monthly sample exceeds 15 pCi/L.
- Discontinue analyses for iodine-129 because numerous fission products that are more common and easy to detect (e.g., europium, cesium) are included in the analyte list for gamma spectroscopy.
- Increase the frequency of tritium sampling to monthly.

The environmental monitoring implemented at the ATR Complex CWP in December 2014 with the issuance of reuse permit I-161-02 is summarized in Table 10. Reuse permit I-161-02 retained the requirements for chromium, iron, and manganese monitoring (DEQ 2014).

Table 10. Summary of environmental monitoring at the ATR Complex CWP during the period of reuse permit I-161-02.

Analyte	Sampling Frequency	Driver[a]	Screening Level	December 2014–October 2019	
				Minimum	Maximum
Field Parameters					
pH	Monthly	DEQ	2-12.5[b]	6.51	8.24
Electrical conductivity	Monthly	DEQ	None	368	1727
Metals, Filtered (µg/L)					
Aluminum	Monthly	DEQ	None	<15	65
Chromium	Monthly	DEQ	5,000[c]	2.73	16.3
Iron	Monthly	DEQ	None	<25	310
Manganese	Monthly	DEQ	1.3E+08[d]	<1	8.22

Analyte	Sampling Frequency	Driver[a]	Screening Level	December 2014–October 2019	
				Minimum	Maximum
Metals, Total (µg/L)					
Aluminum	Monthly	Comparison to filtered	None	<15	43.8
Chromium	Monthly	DEQ	5,000[c]	2.81	16.4
Iron	Monthly	Comparison to filtered	None	<25	356
Manganese	Monthly	Comparison to filtered	1.3E+08[d]	<1	8.37
Non-Metals (mg/L)					
Chloride	Monthly	DEQ	None	9.20	57.7
Sulfate	Monthly	DEQ, Einerson (1996)	None	19.8	675
Total dissolved solids	Monthly	DEQ, Einerson (1996)	None	189	1330
Nitrate+nitrite as nitrogen	Monthly	DEQ	None	0.815	4.020
TKN	Monthly	DEQ	None	<0.033	1.500
Total nitrogen (sum of TKN and nitrate+nitrite as nitrogen)	Monthly	DEQ	None	<0.896	5.020
Radionuclides (pCi/L)					
Gamma spectroscopy	Monthly	DOE	—	—	—
Silver-108m	—	—	Not calculated[e]	ND	ND
Silver-110m	—	—	90[e]	ND	-3.08 ± 0.862
Americium-241	—	—	15[e]	ND	ND
Cerium-144	—	—	30[e]	ND	ND
Cobalt-58	—	—	300[e]	ND	ND
Cobalt-60	—	—	100[e]	ND	ND
Cesium-134	—	—	80[e]	ND	ND
Cesium-137	—	—	200[e]	ND	ND
Europium-152	—	—	200[e]	ND	ND
Europium-154	—	—	60[e]	ND	ND
Europium-155	—	—	600[e]	ND	ND

Analyte	Sampling Frequency	Driver[a]	Screening Level	December 2014–October 2019	
				Minimum	Maximum
Potassium-40	—	—	None	ND	55.2 ± 13.1
Manganese-54	—	—	300[e]	ND	ND
Niobium-95	—	—	300[e]	ND	ND
Radium-226	—	—	Naturally occurring[f]	ND	ND
Ruthenium-103	—	—	200[e]	ND	ND
Ruthenium-106	—	—	30[e]	ND	ND
Antimony-125	—	—	300[e]	ND	ND
Uranium-235	—	—	66[g]	ND	ND
Zinc-65	—	—	300[e]	ND	ND
Zirconium-95	—	—	200[e]	ND	ND
Gross alpha	Monthly	DOE	15[f,h]	ND	5.77 ± 1.43
Gross beta[i]	Monthly	DOE	4 mrem/yr[i]	ND	8.19 ± 1.06
Strontium-90	Contingency[j]	DOE	8[h]	N/A[j]	N/A[j]
Tritium	Monthly	DOE	20,000[h]	ND	ND

a. DOE = DOE orders for radiation protection; DEQ = reuse permit I-161-02.
b. From 40 CFR 261.22 (corrosivity limits).
c. From 40 CFR 261.24 (toxicity characteristic).
d. Screening release levels for surface pathway from Ansley et al. (1997).
e. MCL from EPA (2000).
f. The limit is 5 pCi/L if process-derived radium-226 is present in the wastewater.
g. Calculated from the MCL of 30 µg/L. The specific activity for uranium-234 was used to calculate the MCL for uranium-233/234.
h. Primary Constituent Standard (PCS) from IDAPA 58.01.11.
i. The "Ground Water Quality Rule," IDAPA 58.01.11, specifies a Primary Constituent Standard (PCS) for combined beta/photon emitters of 4 millirems/year Effective Dose Equivalent (EDE). Speciation of the individual radionuclides present would be necessary to determine the equivalent PCS in units of pCi/L. For comparison purposes only, the EPA also specifies a MCL of 4 mrem/year for public drinking water systems and uses a screening level of 50 pCi/L. Public drinking water samples with gross beta activity greater than 50 pCi/L must be analyzed to identify the major radionuclides present.
j. If the gross beta activity in the sample exceeds 15 pCi/L, the sample is analyzed for strontium-90. ^{90}Sr was not sampled during this period.

Based on the data collected for permit I-161-02, INL requested that DEQ eliminate the monitoring requirements for TKN and total nitrogen from the next reuse permit I-161-03 because they are typically not detected, or at low concentrations near background with no or decreasing trends indicating no impacts to the aquifer, and no applicable regulatory ground water or drinking water standard (INL 2019c). In addition to accommodating INL's request, DEQ also eliminated the monitoring requirements for filtered aluminum, chloride, and filtered manganese due to low concentrations well below ground water and drinking water standards, a significant number of non-detect results, and either no or decreasing trends in downgradient monitoring wells (DEQ 2019b, DEQ 2019c). The current environmental monitoring implemented at the ATR Complex CWP in November 2019 with the issuance of reuse permit I-161-03 is summarized in Table 11. Samples for radionuclides continue to be collected to monitor for upset conditions in the reactor cooling system or accidental releases to the cold waste system, and to demonstrate compliance with DOE orders. Samples for gamma spectroscopy, gross alpha, gross beta, and tritium are collected monthly. Effluent samples for strontium-90 are collected on a contingency basis.

Table 11. Summary of environmental monitoring at the ATR Complex CWP required under reuse permit I-161-03 issued in 2019.

Analyte	Sampling Frequency	Driver[a]	Screening Level
Field Parameters			
pH	Monthly	DEQ	2-12.5[b]
Electrical conductivity	Monthly	DEQ	None
Metals, Filtered (µg/L)			
Chromium	Monthly	DEQ	5,000[c]
Iron	Monthly	DEQ	None
Metals, Total (µg/L)			
Chromium	Monthly	DEQ	5,000[c]
Iron	Monthly	Comparison to filtered	None
Non-Metals (mg/L)			
Nitrate+nitrite as nitrogen	Monthly	DEQ	None
Sulfate	Monthly	DEQ, Einerson (1996)	None
Total dissolved solids	Monthly	DEQ, Einerson (1996)	None
Radionuclides (pCi/L)			
Gamma spectroscopy	Monthly	DOE	—
Silver-108m	—	—	Not calculated[d]
Silver-110m	—	—	90[d]
Americium-241	—	—	15[d]
Cerium-144	—	—	30[d]
Cobalt-58	—	—	300[d]
Cobalt-60	—	—	100[d]
Cesium-134	—	—	80[d]
Cesium-137	—	—	200[d]

Analyte	Sampling Frequency	Driver[a]	Screening Level
Europium-152	—	—	200[d]
Europium-154	—	—	60[d]
Europium-155	—	—	600[d]
Potassium-40	—	—	None
Manganese-54	—	—	300[d]
Niobium-95	—	—	300[d]
Radium-226	—	—	Naturally occurring[e]
Ruthenium-103	—	—	200[d]
Ruthenium-106	—	—	30[d]
Antimony-125	—	—	300[d]
Uranium-235	—	—	66[f]
Zinc-65	—	—	300[d]
Zirconium-95	—	—	200[d]
Gross alpha	Monthly	DOE	15[e,g]
Gross beta[h]	Monthly	DOE	4 mrem/year[h]
Strontium-90	Contingency[i]	DOE	8[h]
Tritium	Monthly	DOE	20,000[h]

a. DOE = DOE orders for radiation protection; DEQ = reuse permit I-161-02.
b. From 40 CFR 261.22 (corrosivity limits).
c. From 40 CFR 261.24 (toxicity characteristic).
d. MCL from EPA (2000).
e. The limit is 5 pCi/L if process-derived radium-226 is present in the wastewater.
f. Calculated from the MCL of 30 µg/L. The specific activity for uranium-234 was used to calculate the MCL for uranium-233/234.
g. Primary Constituent Standard from IDAPA 58.01.11.
h. The Ground Water Quality Rule, IDAPA 58.01.11, specifies a PCS for combined beta/photon emitters of 4 millirems/year Effective Dose Equivalent (EDE). Speciation of the individual radionuclides present would be necessary to determine the equivalent PCS in units of pCi/L. For comparison purposes only, the EPA also specifies a MCL of 4 mrem/year for public drinking water systems and uses a screening level of 50 pCi/L. Public drinking water samples with gross beta activity greater than 50 pCi/L must be analyzed to identify the major radionuclides present.
i. If the gross beta activity in the sample exceeds 15 pCi/L, the sample is analyzed for strontium-90.

In addition to the composite samples collected for the permit and environmental surveillance, bi-weekly grab samples are collected at the TRA-764 Monitoring Shelter by ATR operations personnel and analyzed on site for gamma spectroscopy.

3.1.1.4 Decision Limits and Actions

The screening levels for discharge to the CWP are in Table 11. If the reported concentration of a constituent exceeds a screening level, environmental management and facility personnel are notified and an assessment is performed to determine whether additional action is necessary. Additional samples are collected if warranted.

3.1.2 Advanced Test Reactor Complex Evaporation Pond

3.1.2.1 Drivers for Sampling Program

The DEQ issued the initial Air Quality Permit to Construct (PTC) for the former TRA (now ATR) Evaporation Pond in 1990. The last revision of the PTC was issued in 2002 (DEQ 2002). In May 2020, DEQ terminated the PTC. The DEQ termination letter states INL modeling verified that the dose to the maximally exposed person from operation of the TRA Evaporation Pond met the 0.1 mrem/year exemption threshold. Actual dose impacts ranged from 2.85E-3 to 6.90E-3 mrem/year between 2011 and 2018; therefore, approval to construct is not required by 40 CFR Part 61 Subpart H and the source also qualifies for an exemption from the need to obtain a PTC from DEQ in accordance with IDAPA 58.01.01.221.02 (DEQ 2022a). Emissions continue to be reported under the requirements of 40 CFR 61 Subpart H. Refer to the previous version of this document for the historical monitoring that was performed under the now-terminated PTC (DOE-ID 2014).

3.1.2.2 Background

The TRA Evaporation Pond is a fenced 5-acre pond located about 1500 ft east of the ATR Complex that has been in operation since 1993. The pond is divided into two double-lined cells each measuring 550 ft × 225 ft × 10 ft deep. The combined volume of both cells is about 18 M gal. The leak-detection system in the east cell consists of perforated pipes in the sand layer between the Hypalon® surface liner and the polyvinyl chloride subsurface liner. The pipes drain into two manholes located in the berm separating the two compartments. The west cell liner was replaced in 2016, which added two additional Hypalon liners and an additional leak detection system that consists of two sump pumps between the new liner materials with an automatic actuation based on water level. There has been no water observed between the new liner layers since installation, indicating there has been no leakage. The east liner is scheduled for replacement in 2023 utilizing the same design as was installed in the west pond cell.

The Evaporation Pond receives low-level radioactively contaminated wastewater (‘warm’ wastewater) from the warm wastewater system at the ATR Complex and includes infrequent discharges from sources outside the ATR Complex. The warm wastewater system consists of two 50 ft^3 mixed-ion exchange beds in each of two warm waste-treatment facilities. The ion exchange beds are designed to remove radioactive impurities. Approximately 98–99% of the warm wastewater discharged to the evaporation pond is from ion-exchange-treated ATR primary coolant (radioactive) (Rasch 2006).

As a best management practice, the effluent stream to the evaporation pond is monitored with a Canabera effluent radiation monitor (ERM) to monitor for gross gamma radiation. The detector triggers an alarm if the discharge-stream radionuclide loading is much higher than normal levels, and the discharge stream can be diverted to interim storage tanks. Emissions from the evaporation pond continue to be reported in accordance with the requirements of 40 CFR 261 Subpart H.

3.1.3 Advanced Test Reactor Complex Sewage Treatment Lagoons

3.1.3.1 Drivers for Sampling Program

The ATR Complex Sewage Lagoons are designed and operated as a total containment, evaporative lagoon system that does not discharge liquid effluent; therefore, effluent sampling is not performed. To comply with the seepage testing requirements of the “Wastewater Rules” (DEQ 2022c), and ensure the public and environment are adequately protected, the Sewage Lagoons undergo periodic seepage tests in lieu of routine environmental monitoring. Laboratory analyses may be required to demonstrate that nonroutine discharges into the lagoons meet the wastewater acceptance criteria for the sewage lagoons, which prohibits discharges that exceed the drinking water standards for radionuclides (INL 2007).

3.1.3.2 Background

The ATR Complex Sewage Treatment Lagoons were constructed in 1995 and receive domestic wastewater from approximately 40 buildings inside the ATR Complex. Domestic wastewater is sanitary wastewater from basic sanitation activities associated with personnel and office administrative areas such as urinals/toilets, restroom and lunchroom sinks, shower rooms (not emergency showers or eyewash stations), and janitorial sinks not in process areas. Examples of sanitary wastewater include, but are not limited to, raw sewage, mop water, cleaning solutions used to disinfect, soaps and detergents, floor wash residue, and blowdown from water softeners (INL 2007). The lagoons are designed and operated as total containment, evaporative, non-discharging lagoons, and have the following characteristics:

- Gravity flow collection system
- Wet well/lift station that pumps wastewater to the lagoons
- Lagoon 1 is 2.9 acres at an 8-ft depth
- Lagoon 2 is 13.8 acres at an 8-ft depth
- Bentonite-lined lagoons.

The lagoons were designed to treat up to 60,000 gallons per day (gpd) with current flows averaging around 28,000 gpd. Wastewater flows by gravity from Lagoon 1 to Lagoon 2 through a transfer structure located on the north end of the berm between the lagoons.

In accordance with the "Wastewater Rules" (DEQ 2022a), seepage tests are performed every 10 years to determine compliance with the allowable seepage rate of 0.25 in./day required for lagoons constructed before April 15, 2007. Seepage tests were performed at the ATR Complex Sewage Lagoons during June and July 2010. The 15-day seepage rate for Lagoon 1 was 0.1243 in./day; the seepage rate for Lagoon 2 was 0.0199 in./day. (INL 2010d). Seepage testing was required in 2020; however, due to the COVID-19 global pandemic, DEQ granted a 1-year extension of the testing deadline (DEQ 2020). Testing was completed in August 2021 and the seepage rates were 0.186 in./day for Lagoon 1 and 0.00 (zero) in./day for Lagoon 2 (INL 2021b).

3.2 Central Facilities Area Sewage Treatment Facility

3.2.1 Drivers for Sampling Program

As discussed below, the last effluent discharge to the Central Facilities Area (CFA) Sewage Treatment Facility (STF) reuse site occurred in 2011. Lagoon #3 and the reuse site were closed and decommissioned in 2016 and 2017. In response to the reuse site closure, DEQ terminated reuse permit LA-000141-03 in December 2017. Routine effluent and surveillance monitoring are no longer performed. Lagoon seepage testing is the remaining driver for the CFA STF.

Prior to 2012, wastewater effluent was applied to the land surface at the CFA STF reuse site and sampled to demonstrate compliance with the reuse permit LA- 000141-03 issued by DEQ in March 2010 (DEQ 2010a). Samples of the effluent to the irrigation pivot were collected monthly at sampling location CFA STF while land-applying wastewater, as shown in Figure 19. Refer to the previous version of this document for details on the historical monitoring that was performed at that time (DOE-ID 2014).

Prior to 2012, environmental surveillance monitoring of effluent discharged from the CFA STF to the land application site was also performed in the same manner as the reuse permit monitoring to meet the following requirements:

- DOE O 458.1
- DOE-HDBK-1216-2015 (DOE 2015):

As discussed in Section 3.2.2, lagoon seepage testing is performed every 10 years to demonstrate compliance with the "Wastewater Rules" (DEQ 2022a). Seepage testing was performed on the three CFA STF lagoons in 2014 and the results showed the seepage rate for Lagoon No. 3 exceeded the allowable limit of 0.25 in/day specified in IDAPA 58.01.16 (DEQ 2022c) for lagoons constructed prior to April 15, 2007 (INL 2014a). Due to a significant reduction in wastewater influent flows to the STP, it was determined that Lagoon No. 1 and Lagoon No. 2 had adequate capacity to function as total containment, evaporative, non-discharging lagoons. The decision was made to decommission Lagoon No. 3 and the reuse site, convert Lagoons 1 and 2 to a total containment evaporative system with no discharge, and terminate the reuse permit. Per the approved closure plan (INL 2016), Lagoon No. 3 was decommissioned by allowing it to dry then removing and placing the biosolids in Lagoon No. 2, puncturing the bentonite liner to prevent future ponding and eliminate vectors, and capping the primary and bypass inlet pipes. Electricity to the land application effluent pump and center pivot was disconnected rendering the land application site unusable. Upon review of INL's final closure report (INL 2017), DEQ approved the final closure report and terminated reuse permit LA-000141-03 in December 2017 (DEQ 2017b). While Lagoon No. 3, effluent discharge pump, center pivot, and reuse site remain visible, they are decommissioned, disconnected, and inoperable. Routine effluent and surveillance monitoring is no longer performed at the CFA STF. The last permit and surveillance monitoring events occurred in August 2011 (INL 2012c). Routine effluent and surveillance monitoring are no longer performed at the CFA STF.

3.2.2 Background

As shown in Figure 19, prior to the closure of Lagoon No. 3 and the reuse system in 2017, the sewage treatment facility consisted of a:

- 1.7-acre partial-mix, aerated lagoon (Lagoon No. 1)
- 10.3-acre facultative lagoon (Lagoon No. 2)
- 0.5-acre polishing pond (Lagoon No. 3)
- 73.5-acre wastewater land application area consisting of desert steppe and crested wheatgrass vegetative communities
- Computerized center-pivot, sprinkler irrigation system.

After closure of the reuse site and Lagoon No. 3, as well as termination of the reuse permit in 2017, the CFA STF has operated as a non-discharging, total containment evaporative system consisting of:

- 1.7-acre partial-mix, aerated lagoon (Lagoon No. 1)
- 10.3-acre facultative lagoon (Lagoon No. 2).

The treatment facility, which was constructed in the 1990s and has been operational since 1995, serves all major CFA facilities (INL 2011). The wastewater is derived from bus and vehicle maintenance areas; boiler blowdown; heating, ventilation, and air conditioning (HVAC) systems; employee showers and restrooms; laboratories; craft shops; a fire station; and a medical dispensary. Additional wastewater may be transported from other area comfort stations, septic tanks, and portable toilets. The last land application of effluent to the reuse site occurred in 2011 where approximately 1.22 million gallons of wastewater was applied to the 73.5-acre irrigation area in 2011(INL 2012c), which equates to a hydraulic application rate of 0.61 in./acre.

Due to historical releases to the CFA sewer system, access points are posted with a Special Instruction to contact INL radiation control prior to accessing the system. Small quantities of radionuclides are used for radiochemical research and development (R&D) at the CFA Laboratory Complex (CFA-625). CFA-625 does not have any 'hot' drains to the sewer system and all radioactive waste is properly disposed. Any radiological liquid wastes that may be generated are containerized for off-Site disposal.

Seepage tests were performed on the lagoons in 2006. The calculated seepage rates were 0.028 in./day for Lagoon No. 1, 0.046 in./day for Lagoon No. 2, and 0.054 in./day for Lagoon No. 3 (INL 2006c). The seepage tests were performed to demonstrate compliance with the allowable seepage rate of 0.25 in./day required for lagoons constructed prior to April 15, 2007 (DEQ 2022c).

Seepage tests were performed on the lagoons again in 2014. Lagoon No. 3 failed to meet the 0.25 in./day criteria with a seepage rate of 0.455 in./day (INL 2014). Consequently, INL proposed closing Lagoon No. 3 by draining and discontinuing use of the lagoon, closing the land application area, and converting remaining Lagoons No. 1 and No. 2 into total containment, evaporative, non-discharging lagoons (INL 2015). INL's revised closure plan (INL 2016) included removing the biosolids from Lagoon No. 3 and placing into Lagoon No. 2, puncturing the liner of Lagoon No. 3, capping the primary and bypass inlet pipes to Lagoon No. 3, and disconnecting power to the effluent pump and land application center pivot. Upon review and approval of the final closure report (INL 2017), DEQ terminated reuse permit LA-000141-03 (DEQ 2017).

The last permit and surveillance monitoring event occurred in August 2011, which was the last land application event to the reuse site (INL 2012c). Routine effluent and surveillance monitoring are no longer performed at the CFA STF. Lagoon seepage testing will continue to occur every 10 years to demonstrate compliance with the seepage testing requirements of the "Wastewater Rules" (DEQ 2022c).

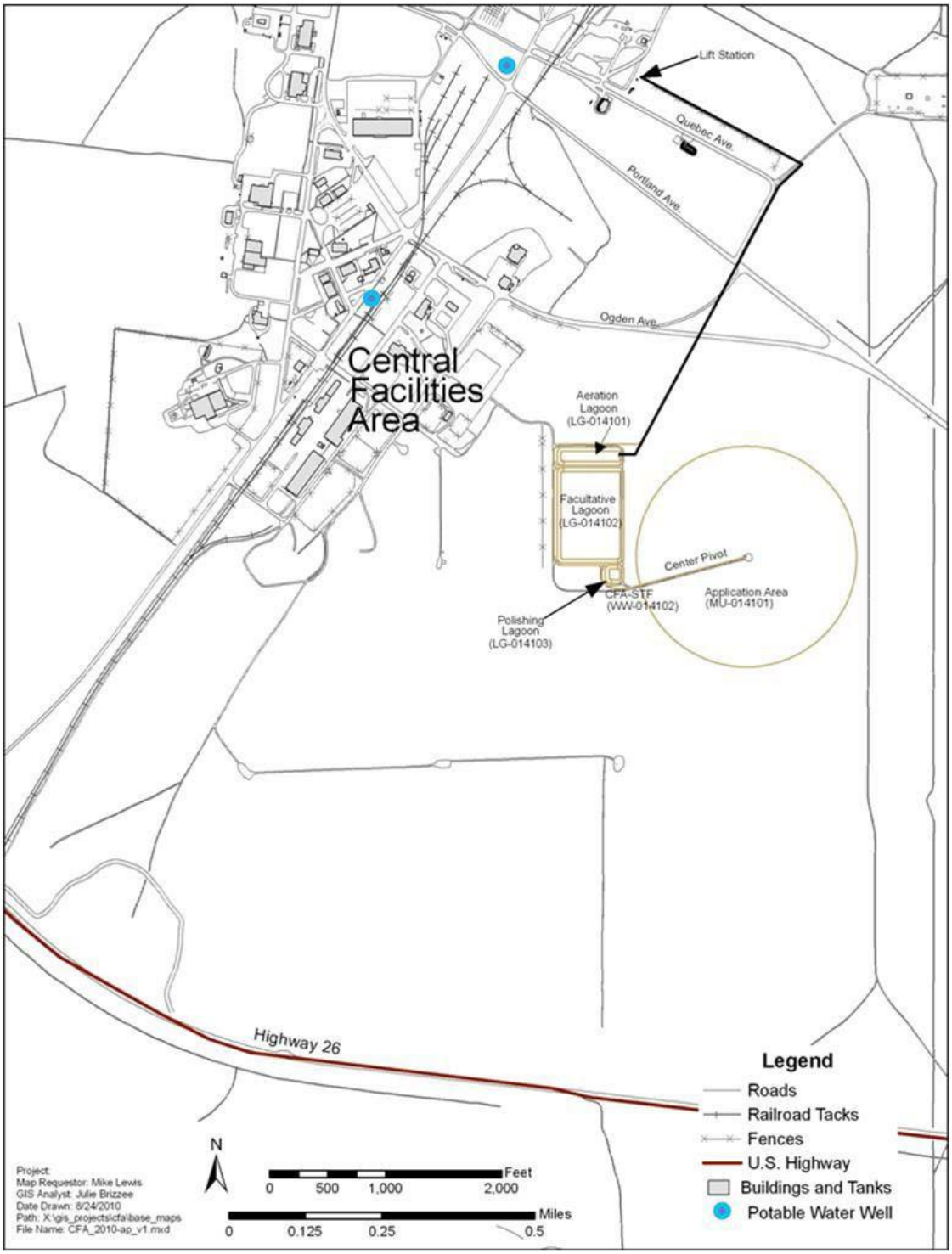

Figure 19. Samples are collected at the irrigation pump pivot, sampling point CFA STF.

3.3 Idaho Nuclear Technology and Engineering Center New Percolation Ponds

3.3.1 Drivers for Sampling Program

The wastewater discharged to the INTEC New Percolation Ponds is monitored to demonstrate compliance with Municipal and Industrial Wastewater Reuse Permits issued by the DEQ. In November 2004, DEQ issued permit LA-000130-04 (DEQ 2004). Permit was replaced by LA-000130-05 in March 2012 (DEQ 2012). Permit LA-00130 was replaced by M-130-06 in June 2017 (DEQ 2017). The permit covers the combined effluent from the sanitary and service waste systems at INTEC.

In addition to the monitoring performed for the permit, environmental surveillance samples are collected to meet the following requirements:

- DOE O 458.1 (DOE 2013)
- DOE-HDBK-1216-2015 (DOE 2015).

Radiological and hazardous liquid wastes generated at INTEC are treated at the Process Equipment Waste Evaporator system and/or containerized for proper disposal. Liquid waste generated from CERCLA environmental restoration activities at the INL Site, such as purge water from groundwater sampling activities, are discharged to the lined evaporation ponds at the Idaho CERCLA Disposal Facility (ICDF).

3.3.2 Background

The New Percolation Ponds consists of two unlined ponds excavated into the surficial alluvium and surrounded by bermed alluvial material, as shown in Figure 20. Each pond is approximately 305 ft × 305 ft at the top of the berm and is approximately 10 ft deep. Each pond is designed to accommodate a continuous wastewater discharge rate of approximately 3 million gallons per day.

During normal operation, wastewater discharges to only one pond at a time. Unless an operational need is identified or a special request is received, the ponds are normally switched quarterly to minimize algae growth and maintain good percolation rates. Wastewater depth in the ponds is recorded monthly using permanently mounted staff gauges. The ponds also are inspected monthly to check for dike erosion, excessive vegetative growth, leaks, and adequate freeboard.

The New Percolation Ponds receive discharges of only nonhazardous, nonradioactive industrial and municipal wastewater. Treated sanitary waste from the INTEC Sewage Treatment Plant is also combined with the service waste and disposed of to the New Percolation Ponds. Two sets of electric pumps transfer wastewater from CPP-797 to the New Percolation Ponds. During the 2021 reporting year (November 1, 2020, to October 31, 2021), an average of 556,891 gal of service waste was generated per day.

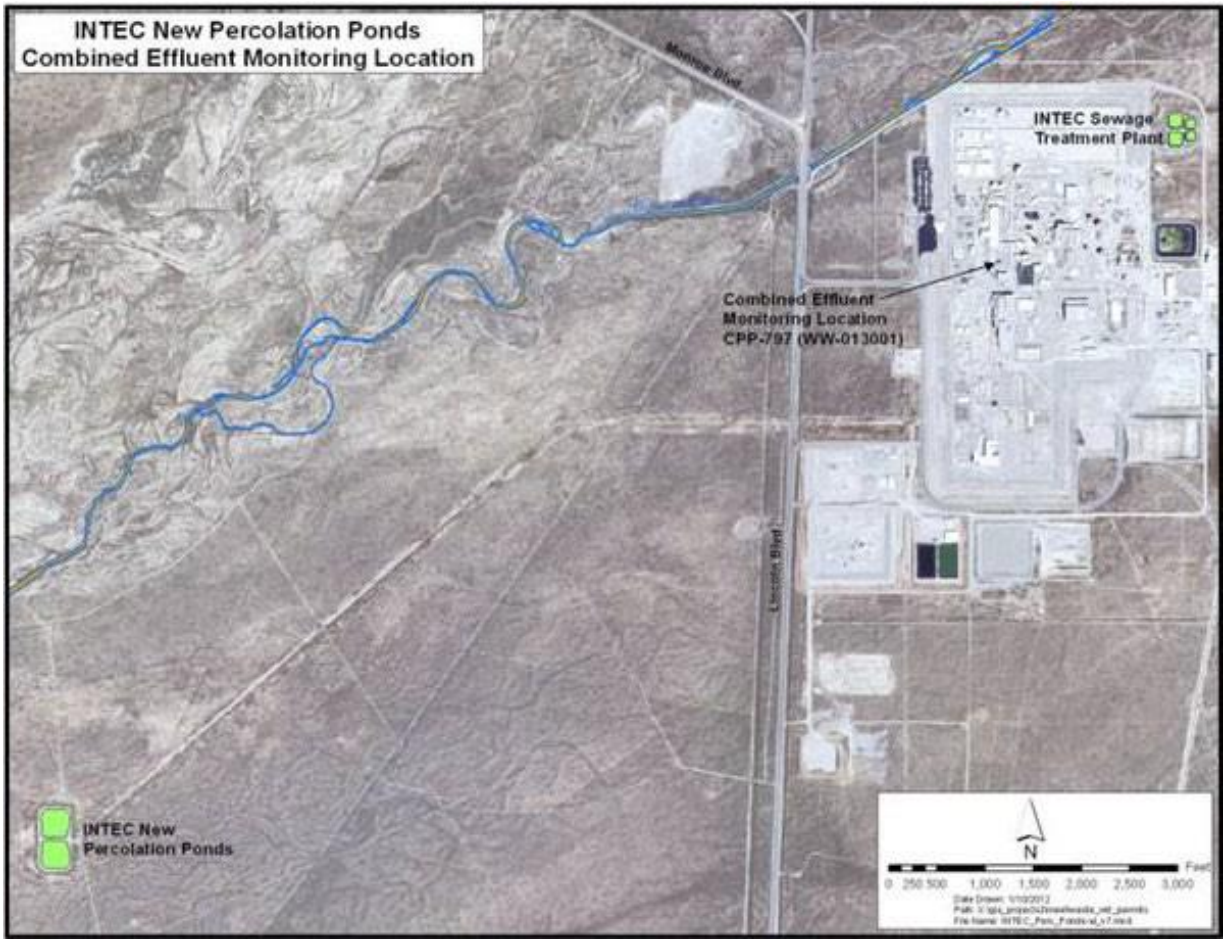

Figure 20. INTEC New Percolation Ponds and combined effluent monitoring location CPP-797 (WW-013001).

3.3.2.1 Sanitary Waste System Description and Operation

The Sewage Treatment Plant is located east of INTEC, outside the INTEC security fence, and treats sanitary and other related wastes (e.g., wastewater generated from the INTEC cafeteria, building HVAC systems, and nonhazardous industrial process) at INTEC, as observed in Figure 21. The Sewage Treatment Plant also receives routine discharges of septage from porta potties, comfort stations, shower trailers, and septic tanks generated at other Idaho Cleanup Project (ICP) locations.

The Sanitary Waste Collection System consists of six lift stations: CPP-724, CPP-728, CPP-733, CPP-768, CPP-1772, and CPP-2715. The two main lift stations, CPP-728 and CPP-733, contain sewage grinders that the wastewater passes through before being pumped to the Sewage Treatment Plant. Under M-130-06, the Sewage Treatment Plant consists of:

- Two aerated lagoons (Cell No. 1 and 2)
- Two quiescent, facultative stabilization lagoons (Cell Nos. 3 and 4)
- Five control stations or weir boxes (e.g., CPP-769, CPP-770, CPP-771, CPP-772, CPP-773)
- Lift Station, CPP-2714, used to pump the treated effluent to the Service Waste System.

Because the Sewage Treatment Plant depends on natural biological and physical processes (e.g., digestion, oxidation, photosynthesis, respiration, aeration, evaporation) to treat the wastewater, the five control stations are used to direct the wastewater flow to the proper sequence of lagoons. After treatment in the lagoons, the effluent is gravity-fed to Lift Station CPP-2714, where it is pumped to the Service Waste System at Manhole MAH-PHE-SW-106.

Seepage tests were performed on the INTEC Sewage Treatment Plant Lagoon Cells 1, 2, 3, and 4 in June of 2015. The lagoons were tested to satisfy the Idaho Department of Environmental Quality (DEQ) Rules IDAPA 58.01.16 that require all lagoons be tested at a frequency of every 10 years and the requirement of the INTEC permit. Test results for each cell was less than 0.25 in/day, the maximum seepage rate allowed for lagoons built prior to April 15, 2007 (ICP 2015). Testing of the INTEC Sewage Treatment Plant Lagoons will be performed again in 2025.

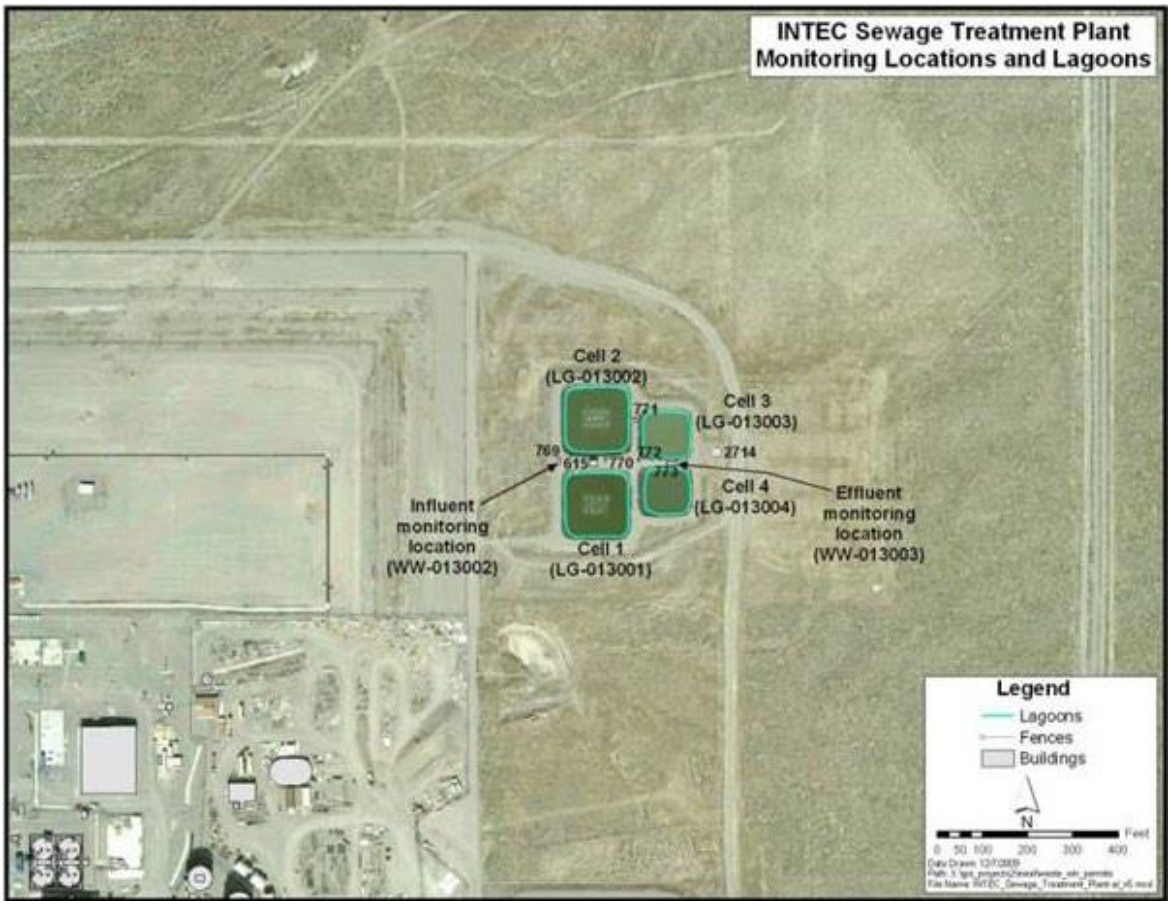

Figure 21. INTEC Sewage Treatment Plant and monitoring locations CPP-769 (WW-013002) and CPP-773 (WW-013003).

3.3.2.2 Service Waste System Description and Operation

The Service Waste System serves all major facilities at INTEC. Industrial wastewater from INTEC operations consists of noncontact cooling water, steam condensates, water treatment effluent (e.g., water-softener regeneration), boiler blowdown wastewater, storm water, and other nonhazardous, non-radioactive liquids. As described in Section 3.1.2.1, municipal wastewater generated at INTEC is treated at the Sewage Treatment Plant and combined with the service waste effluent at Manhole MAH-PHE-SW-106.

The INTEC facilities and processes that could potentially release radioactive contamination to the Service Waste System have controls and barriers that effectively prevent the release of such material. In addition, the operation of a continuous monitoring and diversion system protects the percolation ponds from the potential failure of engineered barriers and controls.

The CPP-753 monitoring station monitors the radioactivity of service waste before it is discharged to the CPP-797. Upon a high-level radiation alarm at CPP-753, the flow is diverted from the CPP-754 diversion station to the service waste diversion collection tank, VES-WM-191, via the CPP-750 Diversion Pump Station (ICP 2013a). The CPP-754 diversion point is downstream from the radiation monitor to allow for the time lag between detection and diversion; thus, radioactive service wastewater does not reach the percolation ponds. If the waste operations distributive control system is out of service, the flow can be manually diverted at CPP-754. In CPP-797, the combined flows are measured, the effluent is monitored for radioactivity, and samples are collected periodically for analyses. CPP-797 provides the last monitoring and sampling of the waste before it is discharged to the percolation ponds. If the concentration of radioactivity in the service waste at CPP-797 exceeds a predetermined set point, an alarm sounds, the flow is manually diverted at CPP-754 to VES-WM-191, and the source of the contamination is located and eliminated.

3.3.3 Sampling Basis and Design

Samples of the effluent to the INTEC New Percolation Ponds are analyzed for radiological and non-radiological constituents to demonstrate compliance with the wastewater reuse permit and DOE orders. As required by the wastewater reuse permit, samples are collected from the influent to the Sewage Treatment Plant (CPP-769), the effluent from the Sewage Treatment Plant (CPP-773), and the combined effluent before discharge to the New Percolation Ponds (CPP-797).

Sample locations are located downstream of the last component stream and are protected from the elements to prevent freezing of the sampling line. Samples of the sewage influent and effluent are collected with two Sigma 900 Max all-weather refrigerated samplers that collect the sample aliquots via a peristaltic pump into a carboy in a refrigerated unit to minimize biological growth. Daily, flow-proportional samples are also collected at CPP-797 using a group of four Masterflex sample pumps.

The wastewater reuse permit requires collection of a 24-hour flow proportional sample (except for total coliform and pH grab samples) every month at CPP-769, CPP-773, and CPP-797 during normal operating conditions. Samples for environmental surveillance monitoring are collected in the same manner as the samples required for compliance with the wastewater reuse permit. Radioactivity analyses of the CPP-797 effluent are performed on flow-proportional samples collected daily and composted over an entire month. Table 12, Table 13, and Table 14 summarize the monitoring performed on the wastewater streams discharged to the INTEC New Percolation Ponds during the period of reuse permit M-130-06.

Table 12. Summary of environmental monitoring performed on the influent to the INTEC Sewage Treatment Plant (CPP-769).

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2017–2021	
				Minimum	Maximum
Biochemical oxygen demand (BOD) (5-day)	Monthly	DEQ	None	9.1	605
Conductivity (µS/cm) (grab)	Monthly	X	None	0.270	6.480
Nitrate+nitrite as nitrogen	Monthly	DEQ	None	ND	3.9
pH (standard units) (grab)	Monthly	X	None	6.82	8.92
Temperature (ºC) (grab)	Monthly	X	None	5.09	25.83

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2017–2021	
				Minimum	Maximum
Total Kjeldahl nitrogen (mg/L)	Monthly	DEQ	None	4.68	204
Total phosphorus, (mg/L)	Monthly	DEQ	None	0.536(J)[c]	24.2
Total suspended solids (mg/L)	Monthly	DEQ	None	23.6	493

a. DEQ = wastewater reuse permit; X = parameter monitored for characterization purposes.
b. Limits from ICP (2018).
c. J indicates that the parameter was positively identified, but the reported value is an estimate. This is because the matrix spike result exceeded the EPA method recovery criteria.

Table 13. Summary of environmental monitoring performed on the effluent from the INTEC Sewage Treatment Plant (CPP-773).

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2017–2021	
				Minimum	Maximum
Non-Metals					
Biochemical oxygen demand (mg/L)	Monthly	DEQ	None	2.90(U)[c]	119
Conductivity (µS/cm) (grab)	Monthly	X	None	0.510	1.269
Conductivity (µS/cm) (composite)	Monthly	X	None	0.617	1.227
Nitrate+nitrite as nitrogen (mg/L)	Monthly	DEQ	None	0.0086(J)[d]	8.26
pH (standard units) (grab)	Monthly	DEQ	None	6.72	9.30
pH (standard units) (composite)	Monthly	X	None	7.12	9.40
Temperature (ºC) (grab)	Monthly	X	None	3.26	27.01
Temperature (ºC) (composite)	Monthly	X	None	3.75	20.10
Total coliform (MPN/100 mL)[e] (grab)	Monthly	DEQ	None	4.1	2827.2
TKN (mg/L)	Monthly	DEQ	None	4.56	74.4
Total phosphorus (mg/L)	Monthly	DEQ	None	1.94	10.3
Total suspended solids (mg/L)	Monthly	DEQ	None	1.20	64
Radionuclides (pCi/L)					
Silver-108m	Semi-annually	DOE	NC[g]	ND[h]	ND
Silver-110m	Semi-annually	DOE	90	ND	ND
Americium-241	Semi-annually	DOE	15	ND	ND
Cerium-144	Semi-annually	DOE	30	ND	ND
Cobalt-58	Semi-annually	DOE	300	ND	ND
Cobalt-60	Semi-annually	DOE	100	ND	ND

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2017–2021	
				Minimum	Maximum
Cesium-134	Semi-annually	DOE	80	ND	ND
Cesium-137	Semi-annually	DOE	200	ND	ND
Europium-152	Semi-annually	DOE	200	ND	ND
Europium-154	Semi-annually	DOE	60	ND	ND
Europium-155	Semi-annually	DOE	600	ND	ND
Potassium-40	Semi-annually	DOE	NC	ND	ND
Manganese-54	Semi-annually	DOE	300	ND	ND
Niobium-95	Semi-annually	DOE	300	ND	ND
Radium-226	Semi-annually	DOE	5[i]	ND	ND
Ruthenium-103	Semi-annually	DOE	200	ND	ND
Ruthenium-106	Semi-annually	DOE	30	ND	ND
Antimony-125	Semi-annually	DOE	300	ND	ND
Uranium-235	Semi-annually	DOE	NC	ND	ND
Zinc-65	Semi-annually	DOE	300	ND	ND
Zirconium-95	Semi-annually	DOE	200	ND	ND
Gross alpha	Semi-annually	DOE	15	ND	ND
Gross beta	Semi-annually	DOE	4 mrem/yr[j]	14.3 ±0.76	28.7±1.16
Strontium-90	Semi-annually	DOE	8	ND	ND

a. DOE = DOE orders for radiation protection; DEQ = wastewater reuse permit; X = parameter monitored for characterization purposes.
b. X = parameter monitored for characterization purposes.
c. U indicates that the parameter was detected above the detection limit in the sample; however, the parameter was also detected in the seed blank. The validator flagged the data as non-detect because the result was <5X the seed blank concentration.
d. J indicates that the parameter was positively identified, but the reported value is an estimate. This is because the value is less than the laboratory reporting limit.
e. MPN = Most probable number.
f. NC = Not calculated.
g. ND = Not detected.
h. The limit is 5 pCi/L if process-derived radium-226 is present in the wastewater.
i. If the gross beta activity in the sample exceeds 15 pCi/L the sample is analyzed for strontium-90.

Table 14. Summary of environmental monitoring performed on the combined effluent discharged to the INTEC New Percolation Ponds (CPP-797).

Analyte	Sampling Frequency	Driver[a]	Screening Level	2017–2021	
				Minimum	Maximum
Non-Metals					
Conductivity (µS/cm) (grab)	Monthly	X	None	0.215	4.20
Conductivity (µS/cm) (composite)	Monthly	DEQ	None	0.058	1.75
Nitrate+nitrite as nitrogen (mg/L)	Monthly	DEQ	10	0.655	9.40
pH (standard units) (grab)	Monthly	DEQ	None	7.33	10.40
pH (standard units) (composite)	Monthly	X	None	7.55	9.66
Temperature (ºC) (grab)	Monthly	X	None	11.24	26.53
Temperature (ºC) (composite)	Monthly	X	None	12.29	26.79
Coliform, total (MPN/100 mL)[e]	Monthly	DEQ	1[f]	1	2419.2
Coliform, fecal (MPN/100 mL)[e]	Monthly	DEQ	1[f]	1	9
Total phosphorus (mg/L)	Monthly	DEQ	None	0.343	2.91
Chloride (mg/L)	Monthly	DEQ	250	7.41	341
Fluoride (mg/L)	Monthly	DEQ	4	0.133	0.313
Total Dissolved Solids (mg/L)	Monthly	DEQ	500	180	906
Metals (mg/L)					
Chromium	Monthly	DEQ	0.1	ND	ND
Manganese	Monthly	DEQ	0.05	ND	0.0213
Radionuclides (pCi/L)					
Silver-108m	Monthly	DOE	NC[g]	ND[h]	ND
Silver-110m	Monthly	DOE	90	ND	ND
Americium-241	Monthly	DOE	15	ND	ND
Barium-137m	Monthly	DOE	NC	ND	ND
Cerium-144	Monthly	DOE	30	ND	ND
Cobalt-58	Monthly	DOE	300	ND	ND
Cobalt-60	Monthly	DOE	100	ND	ND
Cesium-134	Monthly	DOE	80	ND	ND
Cesium-137	Monthly	DOE	200	ND	ND
Europium-152	Monthly	DOE	200	ND	ND
Europium-154	Monthly	DOE	60	ND	ND
Europium-155	Monthly	DOE	600	ND	ND
Potassium-40	Monthly	DOE	NC	ND	84.6 ± 39.0

Analyte	Sampling Frequency	Driver[a]	Screening Level	2017–2021	
				Minimum	Maximum
Manganese-54	Monthly	DOE	300	ND	ND
Niobium-95	Monthly	DOE	300	ND	ND
Radium-226	Monthly	DOE	5[i]	ND	ND
Ruthenium-103	Monthly	DOE	200	ND	ND
Ruthenium-106	Monthly	DOE	30	ND	ND
Antimony-125	Monthly	DOE	300	ND	ND
Uranium-235	Monthly	DOE	NC	ND	ND
Zinc-65	Monthly	DOE	300	ND	ND
Zirconium-95	Monthly	DOE	200	ND	ND
Gross alpha	Monthly	DOE	15	ND	2.91 ± 1.12
Gross beta	Monthly	DOE	4 mrem/yr[j]	ND	8.35 ± 1.01
Strontium-90	Monthly	DOE	8	ND	ND

a. DOE = DOE orders for radiation protection; DEQ = wastewater reuse permit; X = parameter monitored for characterization purposes.
b. Non-radiological limits are from ICP (2018b); radiological limits are from 40 CFR 141.66.
c. U indicates that the parameter was detected above the detection limit in the sample; however, the parameter was also detected in the seed blank. The validator flagged the data as nondetected because the result was <5X the see blank concentration.
d. J indicates that the parameter was positively identified, but the reported value is an estimate. This is because the value is less than the laboratory reporting limit.
e. MPN = Most probably number.
f. An exceedance of the primary constituent standard for total coliform is not a violation. If the primary constituent standard for total coliform is exceeded, analysis for fecal coliform is conducted. An exceedance of the primary constituent standard for fecal coliform is a violation.
g. NC = Not calculated.
h. ND = Not detected.
i. The limit is 5 pCi/L if process-derived radium-226 is present in the wastewater.
j. If the gross beta activity in the sample exceeds 15 pCi/L, the sample is analyzed for strontium-90.

3.3.4 Decision Limits and Actions

The screening levels for discharge to the pond are in Table 13 and Table 14. In the event the reported concentration of a constituent exceeds the corresponding limit, environmental management and facility personnel are notified and an assessment is performed to determine whether additional action is necessary.

3.4 Materials and Fuels Complex

The Materials and Fuels Complex (MFC) is located on approximately 60 acres in the southeastern portion of the INL Site, approximately 35 miles west of Idaho Falls, in Bingham County. MFC consists of buildings and structures for R&D on nuclear technologies, nuclear environmental management, and space radioactive power-source development.

Sanitary wastes are discharged to lined, total-containment evaporative lagoons. Industrial effluent is routed to an unlined pond, as observed in Figure 22. Radioactive liquid waste generated at MFC is containerized and disposed of at an off-Site location.

3.4.1 Materials and Fuels Complex Industrial Waste Pond

3.4.1.1 Drivers for Sampling Program

The industrial effluent discharged to the MFC Industrial Waste Pond (IWP) is sampled to demonstrate compliance with the reuse permits issued by the DEQ. The first reuse permit LA-000160-01 was issued in April 2010 (DEQ 2010b). Permit LA-000160-01 was modified by DEQ in June 2012 to increase the annual hydraulic loading limit to 17 million gallons per year, change the permit name to WRU-I-0160-01, and to correct typographical errors (DEQ 2012b). Permit WRU-I-0160-01 was replaced with permit I-160-02 in January 2017 and issued for a 10-year term (DEQ 2017a). Permit I-160-02 Modification 3 was issued by DEQ in May 2020 to address the elimination of effluent discharges to the Industrial Waste Ditch (commonly referred to as Ditch C) and re-routing the discharge into the Industrial Wastewater Pipeline upstream of the effluent flow monitoring and sampling station, as described below. DEQ reissued permit Modification 3 in September 2020 to correct minor errors (DEQ 2020c).

Environmental surveillance monitoring at the MFC IWP continues to be performed to meet the following requirements:

- DOE O 458.1 (DOE 2013)
- DOE-HDBK-1216-2015 (DOE 2015):

> Groundwater monitoring for CERCLA purposes was discontinued at the end of FY 2022. Groundwater monitoring to demonstrate compliance with the requirements of the Waste Area Group (WAG) 9 Operable Unit (OU) 9-04 Record of Decision commenced in 1998 and was to continue for 20 years (ANL-W 1998). However, the *Operable Unit 9-04 Operations and Maintenance Report for Fiscal Years 2008-2014* (DOE-ID 2015) indicated monitoring data show the remedies have achieved their expected outcomes and formalized the decision to terminate routine CERCLA operations and maintenance (including CERCLA-specific groundwater monitoring) at OU 9-04 after FY 2014. DOE-ID (2015) also indicates groundwater data show no discernible impact from previous or current activities at MFC, and demonstrate that concentrations of organic, inorganic, and radionuclide constituents have never exceeded groundwater or drinking water standards at OU 9-04. DEQ agreed that the monitoring data show no impacts from MFC operations and that the remedies have achieved their expected outcomes. In its review of DOE-ID (2015), DEQ stated, "Since the agencies agree that CERCLA requirements for groundwater, soil, and vegetation monitoring are no longer necessary at OU 9-04, DEQ recommends that DOE utilize the process previously used at WAG 5 to terminate groundwater and O&M monitoring through the Five-Year review process" (DEQ 2015). The *INL Site-wide Institutional Controls, and Operations and Maintenance Annual Report – FY 2015* (ICP 2017) also documents that semiannual groundwater sampling requirements for the ANL-01 IWP would be terminated after FY 2014. Documentation for termination of CERCLA semiannual groundwater monitoring and O&M monitoring via the Five-Year review process was formalized in the *Five-Year Review of CERCLA Response Actions at the Idaho National Laboratory Site – Fiscal Years 2015 – 2019* (DOE-ID 2021). As a result, the last CERCLA-specific groundwater monitoring campaign for the IWP was performed in FY 2022.

Beginning in FY 2023, groundwater monitoring activities for the MFC IWP will be adjusted to discontinue CERCLA-specific monitoring at five MFC wells including:

- Elimination of environmental groundwater monitoring at the CERCLA wells EBR-II #2 and ANL-MON-A-011. These two wells were required for CERCLA only and are not required for reuse permit monitoring.
- Elimination of CERCLA-specific environmental groundwater monitoring at the three remaining monitoring wells specified in reuse permit I-160-02 (ANL-MON-A-012, ANL-MON-A-013, ANL-MON-A-014). These three wells will continue to be sampled to meet reuse permit and DOE environmental surveillance monitoring requirements.

3.4.1.2 Background

The MFC IWP covers approximately three acres and was excavated in 1959. The IWP is located outside the northwest corner of the MFC security fence has a design capacity of 285 MG at a maximum water depth of 13 ft.

Beginning in 2020, the industrial effluent system that discharges to the IWP is now referred to as the Industrial Wastewater Collection System (IWCS) and consists of the combination of pipelines/branches, lift stations, flow meter, automated composite sampler, and associated components. Prior to 2020, the IWCS consisted of two separate systems that discharged independently to the IWP. The West Campus Utility Corridor (WCUC) project completed in May 2020 connected the two separate collection system pipelines and eliminated effluent discharge to the Industrial Wastewater Underground Pipe, which is also known as Ditch C. Reuse permit I-160-02 Modification 3 (DEQ 2020c) accommodates the system changes by eliminating the monitoring requirements for Ditch C due to the termination of discharges to the ditch upon completion of the WCUC project.

The historical names for the two separate collection systems, prior to their connection in 2020, were the ‘Industrial Wastewater Underground Pipe’ and ‘Industrial Waste Pipeline.’ These historical names were undescriptive and became more confusing upon completion of the WCUC project that connected the systems; therefore, the names and descriptions have been updated as described herein and shown in Figure 22. The IWCS has two distinct sections: the IWCS Primary Line (PL) and IWCS Southwestern Boundary Line (SBL). The IWCS PL (formerly the Industrial Waste Pipeline) begins near MFC-774, travels north to and beyond lift station MFC-778A, then turns and travels west to the effluent monitoring station, and eventually discharges to the pond. This section is referred to as the PL because it is the pipeline that collects wastewater from all sources and on which the flow meter and automated sampler are located. The section referred to as the SBL (formerly the Industrial Wastewater Underground Pipe) collects wastewater from sources inside building MFC-768 into a basin located outside the southwest corner of MFC-768, which discharges to an underground pipe running northwest then north into new lift station MFC-803. This new lift station pumps the wastewater through a new pipeline to the north, and then northeast, where it discharges into the PL upstream of the flow meter and automated effluent composite sampler (INL 2022a). The combined IWCS effluent flow from the PL and SBL is measured and sampled at the effluent sampling station prior to discharge into the pond Figure 22.

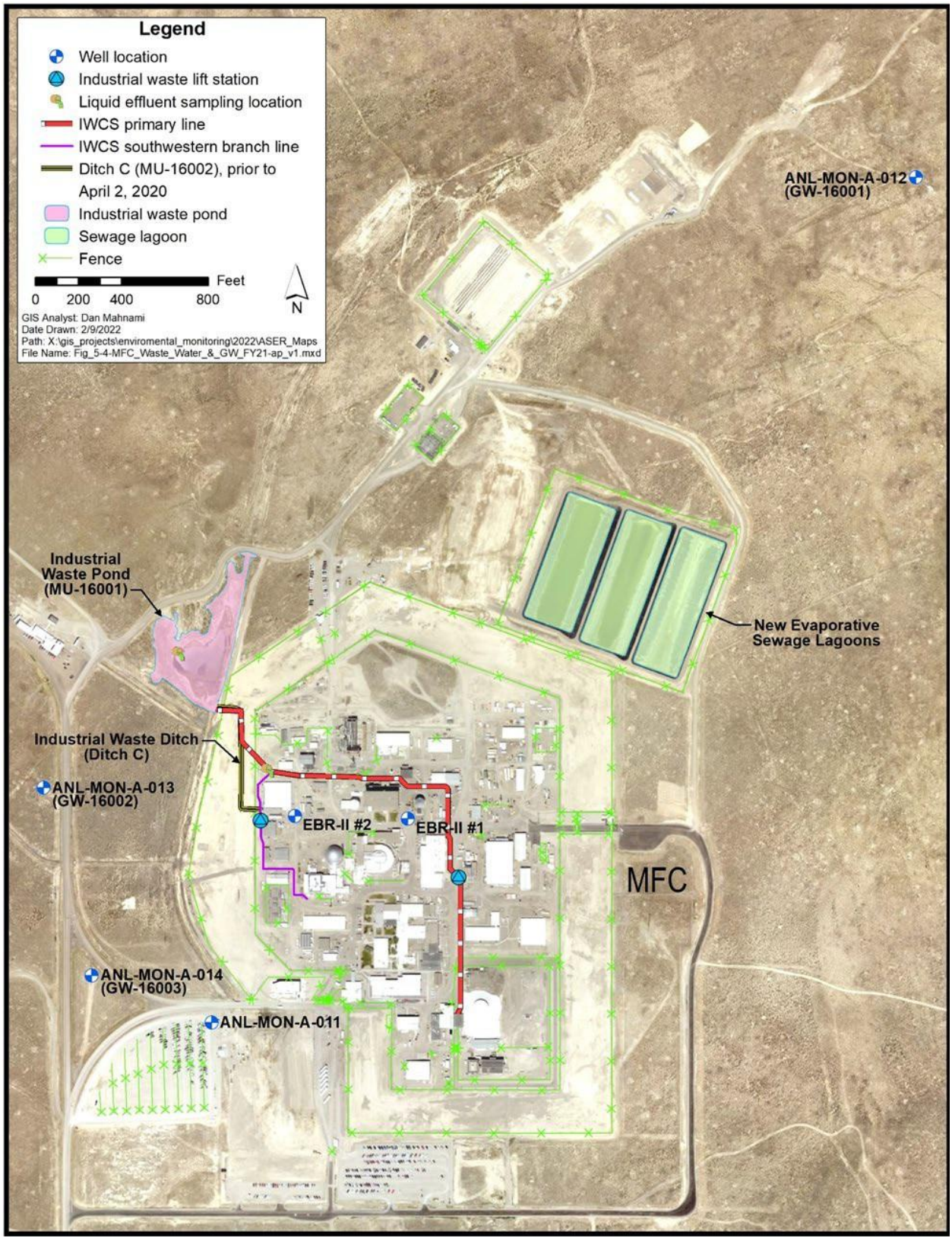

Figure 22. MFC wastewater ponds.

Industrial effluent discharged to the IWP system consists primarily of noncontact cooling water, boiler blowdown, cooling tower drains, and air wash flows. Small volumes of MFC-768 cooling water system blowdown, intermittent reverse osmosis blowdown, and floor drain and laboratory sink discharges are also sent to the IWCS. On occasion, with prior approval, industrial wastewater from MFC facility process holdup tanks discharge to the IWCS.

About 7.4 million gallons of industrial wastewater effluent were discharged to the pond during the 2021 permit year (INL 2021a). The 2017–2021 annual reuse reports indicate IWCS effluent discharge volumes to the pond ranged between 5.6–8.6 million gallons per year, with an average of about 7 million gallons per year.

Sediment samples were collected from the bottom of the pond in the 1980s and again in 1994 (Lee et al. 1997). Cesium-137 was detected at up to 29.2 pCi/gram and determined to be a potential human health risk if use of the pond were discontinued (Lee et al. 1997, DOE-ID 1998b). In the ecological risk evaluation, chromium, mercury, selenium, silver, and zinc were identified as potential threats to burrowing animals if the pond were allowed to dry (DOE-ID 1998b). The maximum metals concentrations in the sediments identified in the ecological risk evaluation are shown in Table 16.

The IWP sediments contained low levels of cesium-137 that posed unacceptable risks to humans (DOE-ID 2007). The pond sediments also contained four inorganics (i.e., chromium, mercury, selenium, and zinc) that posed unacceptable risks to ecological receptors. In 2004, the decision was made to implement the contingent remedy of excavation and disposal rather than phytoremediation at this site because of potential future projects at MFC. The excavation and disposal activities were completed in summer 2004, with the soil being transported to the ICDF. A total of 1,351 tons of soil was removed during the first campaign, and confirmation sampling indicated one hot spot remained for chromium that exceeded the remediation goal. Consequently, a second campaign of excavation and disposal was conducted in November 2004 that removed all the soil from this hot spot down to the basalt, thus eliminating chromium as a COC. The hot spot removal resulted in 136 tons of soil that was transported to the ICDF in November 2004.

The IWP requires institutional controls under CERCLA (site ANL-01) which include warning signs around the site perimeter and generating a notice of site disturbance when disturbing soil within the site. The signs were in good condition during the 2021 inspection (ICP 2022).

3.4.1.3 Sampling Basis and Design

Analytical results for samples collected during the term of the reuse permit LA-000160-01/WRU-I-0160-01, which expired in January 2017, are summarized in Table 15. Note that the screening

release levels at that time were based on potential groundwater contamination assuming a discharge of 26 million gallons per year. The actual annual discharge rates were significantly less, so the screening levels shown in Table 15 are conservative.

Table 15 Summary of effluent monitoring at the Industrial Waste Pipeline and the Industrial Wastewater Underground Pipe during the period of reuse permits LA-000160-01/ WRU-I-0160-01.

Analyte	Driver[a]	Limit[b]	Industrial Waste Pipeline January 2012–December 2016		Industrial Wastewater Underground Pipe January 2012–December 2016	
			Minimum	Maximum	Minimum	Maximum
Metals (µg/L)						
Arsenic	DEQ	77	<1.70	5.66	3.3	10.1
Barium	DEQ	17,000	27.7	47.8	66.6	176
Cadmium	DEQ	7.9	<0.11	<1	<0.11	<1
Chromium	DEQ	150	<2	11.8	3.3	21.7
Iron	GW	18,000	<25	1,710	<25	1,240
Lead	DEQ	290	<0.25	80.9	<0.25	4.8
Manganese	GW	420	<1	22.7	<2.5	105
Mercury	DEQ	39	<0.067	<0.2	<0.067	<0.2
Selenium	DEQ	77	<0.5	6.6	1.04	2.80
Silver	DEQ	1,700	<0.1	6.9	<0.2	<5
Sodium	GW	390,000	17,400	98,600	39,800	131,000
Zinc	DEQ	13,000	5.8	71.0	3.79	364
Anions, Nutrients, and Solids (mg/L)						
Chloride	DEQ	390	17.9	139	39.0	127
Fluoride	DEQ	6.2	0.529	0.753	1.07	2.84
Sulfate	DEQ	390	16.0	24.9	29.5	98.2
Nitrate+nitrite as nitrogen	DEQ	15 (nitrate) 1.5 (nitrite)	1.77	2.94	4.22	12.7
TKN	DEQ	None	<0.033	4.88	<0.1	1.53
Total nitrogen (sum of TKN and nitrate+nitrite, as nitrogen)	DEQ	20c	2.076	4.88	4.533	13.52
Total phosphorus	DEQ	None	<0.017	0.797	0.275	2.97
Total dissolved solids	DEQ	770	181	469	482	1050
Total suspended solids	DEQ	100[c]	<0.57	13.4	0.8	182

a. DEQ = required by wastewater reuse permit; GW = groundwater monitoring parameter required by wastewater reuse permit.
b. Screening release levels calculated for the IWP from INL (2006d) unless otherwise noted.
c. Maximum thirty (30) day average concentration from the industrial wastewater reuse permit.

Table 16. Concentrations of COCs identified in the ecological risk assessment for the IWP sediments.

Metal	Maximum Concentration in Pond Sediment (mg/kg)	Concentration in Pond Water (µg/L)	
		2008	2009
Chromium	11,400	4.2	5
Mercury	6.8	<0.2	<0.2
Selenium	3.3	1.7	0.98
Silver	33	<5	<5
Zinc	5,850	3.6	4

In the permit application to obtain new reuse permit I-160-02 from DEQ (INL 2014b), INL requested the removal of effluent and groundwater monitoring requirements for arsenic, cadmium, chromium, mercury, and silver because the data collected for permit LA-000161-01/ WRU-I-0160-01 indicate these parameters were frequently below laboratory minimum detection levels or an order of magnitude or more below the applicable groundwater quality standards (DEQ 2022b). INL also requested the removal of barium, chloride, selenium, sulfate, and zinc from the new permit because the effluent and groundwater concentrations continued to be detected at low levels well below the groundwater standards. Finally, INL's application requested removal of total nitrogen and total suspended solids (TSS) due to elimination of regulatory standards for these two parameters from the "Recycled Water Rules" (DEQ 2022d).

In addition to the parameters INL requested for the removal from the new reuse permit, DEQ also removed monthly effluent and semi-annual groundwater monitoring requirements for fluoride, lead, TKN, phosphorus, and sodium due to the large number of non-detects, concentrations well below groundwater standards, no or decreasing trends in effluent and groundwater, or no applicable groundwater standard (DEQ 2016). However, the new reuse permit I-160-02 does require limited groundwater monitoring in the first and last year of the permit for chloride, sulfate, sodium, potassium, calcium, magnesium, and alkalinity "to characterize and track key signatures and potential changes to the regional aquifer over time" (DEQ 2016). INL has elected to continue monitoring groundwater for chloride, sulfate, sodium, potassium, calcium, magnesium, and alkalinity on a semiannual basis, instead of the first and last year of the permit, as a best management practice. Additionally, while effluent monitoring of sodium and chloride are not required by permit I-160-02, they also continue to be monitored as a best management practice because they are primary constituents in the reverse osmosis backwash that discharges to the pond. The effluent monitoring results since the issuance of reuse permit I-160-02 in January 2017 are shown in Table 17. As discussed in Section 3.4.1.2, completion of the WCUC Project in May 2020 eliminated effluent discharges from the Industrial Wastewater Underground Pipe (renamed IWCS SBL) in 2020. Beginning in May 2020, the combined effluent flow discharging to the pond is now measured and monitored at the sampling station on the IWCS PL listed in Table 17, in accordance with reuse permit I-160-02 Modification 3 (DEQ 2020c).

The previous reuse permit LA-000160-01/ WRU-I-160-02 required different nitrogen monitoring parameters in effluent and groundwater. The permit required groundwater monitoring for nitrate-nitrogen, while effluent monitoring required nitrite + nitrate-nitrogen. For the new, current permit, I-160-02, DEQ stated its intent was to specify monitoring of the same parameters in both effluent and groundwater (DEQ 2016), so permit I-160-02 changed the groundwater nitrogen monitoring requirement from nitrate-nitrogen to nitrite + nitrate-nitrogen (DEQ 2017a). In addition to the permit-required nitrite + nitrate-nitrogen groundwater monitoring, INL elected to continue to also monitor nitrate-nitrogen as a best management practice to establish the relationship between the two nitrogen parameters in groundwater. Six years of sampling both nitrogen parameters in groundwater have provided enough results to establish that relationship, so the best management practice of monitoring groundwater for nitrate-nitrogen will be discontinued at the end of FY 2022. Beginning in FY 2023, both effluent and groundwater will only be monitored for nitrite + nitrate-nitrogen as required by reuse permit I-160-02.

Table 17. Summary of effluent monitoring at the Industrial Waste Pipeline and the Industrial Wastewater Underground Pipe since the issuance of reuse permit I-160-02.

			IWCS Primary Line[a]		IWCS Southern Boundary Line[b]	
			January 2017–December2021		January 2017–February2020[e]	
Analyte	Driver[c]	Limit[d]	Minimum	Maximum	Minimum	Maximum
Metals (µg/L)						
Iron	DEQ	575	<30	461	<30	220
Manganese	DEQ	135	<1	11.5	<2	11.7
Sodium	GW	120,000	18,300	150,000	27,400	123,000
Anions, Nutrients, and Solids (mg/L)						
Chloride	GW	468	12.0	224	29.8	128
Nitrate+nitrite as nitrogen	DEQ	18.7 (nitrate) 1.87 (nitrite)	1.88	4.23	3.50	15.5
Total dissolved solids	DEQ	936	164	610[f]	314	950

a. The Industrial Waste Pipeline was renamed the IWCS PL in 2020.
b. The Industrial Wastewater Underground Pipe, also known as "Ditch C" in reuse permit I-160-02, was renamed the IWCS Southern Boundary Line (SBL) in 2020.
c. DEQ = required by wastewater reuse permit; GW = groundwater monitoring parameter required by wastewater reuse permit (chloride) or performed as a best management practice (sodium).
d. Screening release levels calculated for the IWP from INL (2018a) unless otherwise noted.
e. The last quarterly effluent sample from the Industrial Wastewater Underground Pipe (Ditch C) occurred in February 2020, just prior to completion of the WCUC Project that connected and re-routed the effluent into the Industrial Waste Pipeline upstream of the existing flow meter and sampling station used for reuse permit monitoring.
f. The maximum TDS result of 610 mg/L from January 2017 – December 2021 excludes the one-time anomalous result of 2, 570 mg/L that occurred in October 2019. The median TDS value from January 2017 – December 2021 is 270 mg/L.

While reuse permit I-160-02 issued in January 2017 (DEQ 2017a) only requires groundwater monitoring at three monitoring wells (e.g., ANL-MON-A-012, ANL-MON-A-013, ANL-MON-A-014) for the constituents listed in the permit, INL continued sampling five wells through FY 2022 (e.g., ANL-MON-A-011, ANL-MON-A-012, ANL-MON-A-013, ANL-MON-A-014, EBR-II #2) for the parameters listed in Table 15 and Table 17 in support of the CERCLA groundwater monitoring requirements for WAG 9. As discussed in Section 3.4.1.1, CERCLA-specific monitoring for WAG 9 and the IWP has been terminated through the Five-Year review process and will not continue after FY 2022.

Beginning in FY 2023, groundwater monitoring activities for the MFC IWP will be adjusted to discontinue CERCLA-specific monitoring at five MFC wells including: (1) elimination of groundwater environmental monitoring at CERCLA wells EBR-II #2 and ANL-MON-A-011; and (2) reduction of monitoring at the three monitoring wells specified in reuse permit I-160-02 (e.g., ANL-MON-A-012, ANL-MON-A-013, ANL-MON-A-014) to only include the reuse permit and DOE environmental surveillance monitoring requirements identified in Section 3.4.1.1.

From at least the late 1980s to 2010, Argonne National Laboratory–West (ANL-W) personnel sampled the IWP monthly from April to October for alpha and beta activity, tritium, gamma-emitting radionuclides, sulfate, phosphate, chloride, and selected metals (Witbeck 1988). The sampling plan was reviewed with the issuance of the industrial wastewater reuse permit LA-000160-01 for the MFC Industrial Waste Ditch and IWP in 2010 (DEQ 2010b). The 2010 wastewater reuse permit-required sampling for anions, solids, TKN, and metals in the effluent discharged to the pond (Table 15), so direct sampling of the pond for non-radionuclides was discontinued in 2010 in lieu of sampling the effluent discharging into the pond. The concentrations of the metals identified in the ecological risk evaluation were deemed to be sufficiently low in the annual pond water samples collected in 2008 and 2009 to discontinue sampling for metals (Table 16).

Table 18 summarizes the current monitoring program at the MFC IWP through calendar year (CY) 2021. The radiological analyte list was originally developed by ANL-W. Samples for gamma spectroscopy, gross alpha, gross beta, and tritium have been collected quarterly. These analyses provide a relatively inexpensive screening for gross radioactivity and a variety of fission and activation products.

Americium-241, plutonium, uranium, and strontium-90 are sampled annually. As noted in the previous version of this document (DOE-ID 2014), rather than attempting to assess each of the numerous facilities and processes at MFC, the sampling program was reviewed with radiation control personnel from MFC. The following changes were recommended:

- Discontinue sampling for curium isotopes. Curium is a transuranic that is relatively rare compared to other transuranic isotopes.
- Discontinue sampling for iron-55, a relatively minor activation product.

The last monitoring event for curium and iron-55 occurred in August 2014. The current analyte list (Table 18) includes the primary nuclides at MFC specifically listed in INL 2010c—americium-241, cesium-137, cobalt-60, plutonium, strontium-90, and uranium. Constituent concentrations were well below the screening release levels from 2017 to 2021 (Table 18).

Table 18. Summary of surveillance monitoring at MFC IWP[a].

Analyte	Sampling Frequency	Driver[b]	Limit	2017–2021	
				Minimum	Maximum
Radionuclides (pCi/L)					
Gamma Spectroscopy	Quarterly	DOE	—	—	—
Silver-108m	—	Not calculated[c]		ND[d]	ND
Silver-110m	—	—	90[c]	ND	ND
Americium-241	—	—	15[c]	ND	ND
Cerium-144	—	—	30[c]	ND	ND
Cobalt-58	—	—	300[c]	ND	ND
Cobalt-60	—	—	100[c]	ND	ND
Cesium-134	—	—	80[c]	ND	ND
Cesium-137	—	—	200[c]	ND	ND
Europium-152	—	—	200[c]	ND	ND
Europium-154	—	—	60[c]	ND	ND
Europium-155	—	—	600[c]	ND	ND
Potassium-40	—	—	None	ND	ND
Manganese-54	—	—	300[c]	ND	ND
Niobium-95	—	—	300[c]	ND	ND
Radium-226	—	—	Naturally occurring[e]	ND	1.01±0.257
Ruthenium-103	—	—	200[c]	ND	ND
Ruthenium-106	—	—	30[c]	ND	ND
Antimony-125	—	—	300[c]	ND	ND
Uranium-235	—	—	66[f]	ND	ND
Zinc-65	—	—	300[c]	ND	ND
Zirconium-95	—	—	200[c]	ND	ND
Gross alpha	Quarterly	DOE	15[e,g]	ND	4.63±0.985
Gross beta	Quarterly	DOE	4 mrem/year[g]	ND	16.7±0.909
Tritium	Quarterly	DOE	20,000[g]	ND	ND
Strontium-90	Annually[h]	DOE	8[g]	ND	ND
Plutonium-238	Annually	DOE	15[c]	ND	ND
Plutonium-239/240	Annually	DOE	15[c]	ND	ND
Plutonium-236	Annually	DOE	15[c]	ND	2.75±0.414
Plutonium-242	Annually	DOE	15[c]	ND	ND

Analyte	Sampling Frequency	Driver[b]	Limit	2017–2021	
				Minimum	Maximum
Plutonium-241	Annually	DOE	Not calculated[c]	ND	ND
Americium-241	Annually	DOE	15[c]	ND	ND
Uranium-233/234	Annually	DOE	186,000[f]	0.868±0.150	1.83±0.259
Uranium-235	Annually	DOE	66[f]	ND	ND
Uranium-238	Annually	DOE	9.9[f]	0.512±0.103	1.070±0.156

a. Table presents the historical quarterly sampling results through 2022. Beginning in 2023 the sampling frequency changes to 3-times per year.
b. DOE = DOE orders for radiation protection.
c. MCL from EPA (2000).
d. ND = not detected. Results are ±1s. Results are shown only for statistically positive detections >3s.
e. The limit is 5 pCi/L if process-derived radium-226 is present in the wastewater.
f. Calculated from the MCL of 30 µg/L. The specific activity for uranium-234 was used to calculate the MCL for uranium-233/234.
g. The Ground Water Quality Rule, IDAPA 58.01.11, specifies a PCS for combined beta/photon emitters of 4 millirems/year EDE. Speciation of the individual radionuclides present would be necessary to determine the equivalent PCS in units of pCi/L. For comparison purposes only, the EPA also specifies a MCL of 4 mrem/year for public drinking water systems and uses a screening level of 50 pCi/L. Public drinking water samples with gross beta activity greater than 50 pCi/L must be analyzed to identify the major radionuclides present.
h. If the gross beta activity in a sample exceeds 15 pCi/L, the sample is analyzed for strontium-90.

At the current average flow of seven million gallons per year, the pond typically has a maximum depth of about 6–8 feet and a wetted perimeter of about 1.5 acres. The residence time of the water in the pond was estimated by dividing the volume of the pond by the flow into the pond. Assuming the pond is an average of 5.5 ft deep, its capacity would be about 2.7 million gallons (e.g., 1 million gallons = 3.069 acre-feet). Using an estimated discharge of seven million gallons per year and ignoring gains for surface runoff and losses to evaporation, the residence time for water in the pond is about five months, which was enough to support the quarterly sampling schedule used through CY 2022.

The pond is typically frozen over during the winter months. Due to the difficulty of obtaining water samples from under the ice-covered pond and the safety concerns for environmental monitoring personnel during the winter sampling event—including walking on the ice, chipping or drilling holes through the ice to access the pond water for sampling, or potentially falling through the ice into the pond—it is recommended that beginning in CY 2023, the pond sampling schedule be changed from quarterly to three times per year, which still falls within the estimated residence time of about five months. The timing of the sampling events will be weather-dependent with the first sample collected in the spring after the ice melts, the second sample during the third quarter (typically July or August), and the third sample in the fall prior to freeze-over.

3.4.1.4 Decision Limits and Actions

The screening levels for discharge to the pond are in Table 17 and Table 18In the event the reported concentration of a constituent exceeds a screening level, environmental management and facility personnel are notified and an assessment is performed to determine whether additional action is necessary. If a reuse permit limit is exceeded, it is reported to the DEQ in accordance with the reporting requirements specified in the reuse permit. Additional samples are collected if warranted.

3.4.2 Materials and Fuels Complex Secondary Sanitary Sewage Lagoon

3.4.2.1 Drivers for Sampling Program

Before 2013, environmental surveillance monitoring at the MFC Secondary Sanitary Lagoon was performed to meet the following requirements:

- DOE O 458.1 (DOE 2013)
- DOE-HDBK-1216-2015 (DOE 2015)
- Comparison to samples collected at the MFC Industrial Waste Pipeline and Industrial Wastewater Underground Pipeline for the reuse permit for the MFC Industrial Waste Ditch and IWP
- Continued monitoring of potential COCs identified during the CERCLA investigation of the pond.

Routine monitoring of the MFC Secondary Sanitary Sewage Lagoons was discontinued in 2012 when the new MFC Evaporative Sewage Lagoons commenced operation (see Section 3.4.3). Refer to the previous version of this document for details on the historical monitoring that was performed (DOE-ID 2014). The Secondary Sanitary Sewage Lagoon system was closed, demolished, and returned to a natural state in 2019 in accordance with the approved Biosolids Management and Closure Plan (DEQ 2019d; INL 2019a; INL 2019b; INL 2019d). The closure included removing the Class A biosolids from the lagoons; cutting and capping lagoon piping; removing synthetic liners where present; ripping the bentonite liners; pushing in the lagoon berms and leveling the site; applying the Class A biosolids at agronomic rates to the closure area; and planting native seed to revegetate the site.

3.4.2.2 Background

The sanitary sewage lagoons were located at the Sanitary Sewage Treatment Facility, north of MFC (Figure 22). The southwest lagoon was used for primary treatment. As the primary lagoon filled, the wastewater cascaded over a divider into the north lagoon, referred to as the Secondary Sanitary Sewage Lagoon, for secondary treatment. The southeast lagoon was used as an emergency overflow and was not in operation after 1965. The two south lagoons were constructed in 1965, and the north lagoon was built in 1974. According to engineering drawings, the three sanitary sewage lagoons covered approximately two acres. The dimensions of the lagoons were approximately 46 × 46 × 2.1 m (150 × 150 × 7 ft) for the SW Lagoon; approximately 15 × 30 × 2.1 m (50 × 100 × 7 ft) for the SE Lagoon; and approximately 38 × 122 × 2.1 m (125 × 400 × 7 ft) for the North Lagoon. The lagoons received all sanitary wastes originating at MFC, except for the Transient Reactor Test Facility, Sodium Process Facility, and the Sodium Components Maintenance Shop. Sanitary waste is discharged from rest rooms, change facilities, drinking fountains, and the cafeteria. The three lagoons were sealed with a 0.32 to 0.63-cm (0.125 to 0.25-in.) bottom bentonite liner and are situated approximately 183 m (600 ft) above the groundwater.

A large leak in the northeast corner of the north lagoon was detected after its construction in 1974. This leak resulted in the loss of more than 1 million gallons of wastewater through fissures that were not sealed by the bentonite. This was rectified by using a 30-mil Hypalon liner over the northeast corner and sealing the seams. Seepage tests performed in 1992 (Braun 1992) estimated a seepage rate of 0.20 in. per day for the primary lagoon and 0.02 in. per day for the secondary lagoon. The seepage tests confirmed that the sanitary lagoons are functioning as evaporative ponds and not as percolating ponds, suggesting that the bentonite and Hypalon liner has remained intact.

Between 1975 and 1981, photo processing solutions were discharged from the Fuel Assembly and Storage Building to the Sanitary Waste Lift Station, which discharged to the lagoons. The manager of the Fuel Assembly and Storage Building during that period estimated that approximately 1.32 Troy ounces of silver were discharged to the Sanitary Waste Lift Station. It has not been confirmed whether the silver was released to the sanitary lagoons or if it remained in the lift station. However, risk calculations show that the estimated silver concentration (68 mg/kg) for the given amount (1.32 Troy oz.) is well below that required to exceed a risk greater than 1E-6 (327 mg/kg). Photo processing was discontinued at the Fuel Assembly and Storage Building in 1981.

Lee et al. (1997) noted that except for an occasional point source of low-level medical radionuclides, there were no known releases of radioactivity into the sewage lagoons. Periodic sampling of the sewage lagoon and a radionuclide detector placed in the lift station (Sanitary Waste Lift Station–788) supplying the sewage lagoons support these conclusions. However, tritium was detected in the lagoon in November 2006, presumably from an incident at the Hot Fuel Examination Facility (HFEF) in October 2006. At MFC, radioactive liquid wastes were treated at the Radioactive Liquid Waste Treatment Facility (RLWTF) prior to its decommissioning. After the RLWTF decommissioning radioactive liquid wastes and decontamination solutions are now containerized and sent offsite for disposal. They are not discharged to the sanitary sewer system.

Because no prior sludge samples were analyzed for metals and radionuclides, seven sludge samples were collected in 1994. The results from this sampling were used in a Track 1 risk evaluation in 1995 (ANL-W 1996), which indicates that the maximum concentrations of arsenic and chromium (i.e., 10.4 mg/kg and 76.4 mg/kg, respectively) exceeded risk-based soil concentrations (i.e., 0.366 mg/kg and 24.9 mg/kg, respectively). The arsenic and chromium were screened from the COCs after the ANL-W sludge concentrations were compared to typical sewage sludge concentrations. This assumes that all the chromium is hexavalent chromium.

The ANL Sewage Lagoons were eliminated from the WAG 9 risk evaluation because it was determined they were not a viable source (Lee et al. 1997). However, it was determined that elevated mercury in the lagoon sediments represented a risk to ecological receptors, so the site was placed in Operable Unit (OU) 10-08 for administrative control (Hain 2005). The Record of Decision (ROD) for OU 10-08 states, “When the ANL-04 lagoons are closed and resampled and risks recalculated, the contingent remedy of removal and disposal from the OU 9-04 ROD will be implemented if the site poses an unacceptable risk. If there is no unacceptable risk, no action will be taken under CERCLA. This OU 10-08 ROD will be modified to formalize the appropriate remedy for ANL-04” (DOE-ID 2009).

An estimated 4.2 million gallons were discharged to the sewage lagoons in 2011 (John Gill, personal communication, 2012). The last effluent samples were collected from the Secondary Sanitary Sewage Lagoons in November 2012. The “Wastewater Rules” (DEQ 2022c) require that all existing wastewater lagoons to have a seepage test by April 15, 2012, and every 10 years after the initial testing. DEQ did not require a seepage test because the Secondary Sanitary Sewage Lagoons were being permanently removed from service and replaced with three new, lined, evaporative Sewage Lagoons in November 2012 (see Section 3.4.3).

3.4.3 Materials and Fuels Complex Evaporative Sewage Lagoons

In November 2012, the MFC sanitary sewage lagoons were replaced with three new, total containment evaporative sewage lagoons (ESLs) located just east of the abandoned lagoons, as observed in Figure 23. The lagoons are lined with a 60-mil high-density polyethylene (HDPE) geo-membrane and a 12-oz nonwoven geotextile underlayment (INL 2013). The liner is anchored around the perimeter of each lagoon in a backfilled anchor trench. At each end of the lagoon and across the middle, liner ballast trenches are included to restrain the liner in these areas and help prevent the liner from lifting during windy conditions when the lagoon is empty.

The MFC ESL collects primarily domestic (nonindustrial) wastewater and some industrial wastewater generated by facilities and operations within the complex. Wastewater is generated from sources such as restrooms, showers, and the cafeteria. Small amounts on noncontact cooling water and condensate from chillers and HVAC systems are also discharged to the ESL (INL 2020b).

The MFC ESLs are a total containment system that relies on evaporation to dispose of the collected 0wastewater. As a result, there is no intended discharge to land or water and the system does not require or have a reuse permit or discharge permit (INL 2020b).

The sampling strategy employed at the MFC Secondary Sanitary Lagoon was employed at the MFC ESL in 2013 per a request from MFC environmental personnel, as observed in Table 19. In September 2013, MFC environmental personnel determined that sampling could be discontinued at the MFC ESL (Gill 2013).

In accordance with the "Wastewater Rules" (DEQ 2022c), seepage tests are performed every 10 years to determine compliance with the allowable seepage rate of 0.125 in./day required for lagoons constructed after April 15, 2007. Seepage tests were performed upon completion of construction of the MFC ESLs and the average seepage rate results for Lagoons 1, 2, and 3 were -0.003 in./day, 0.014 in./day, and 0.000 in./day, respectively (DEQ 2012b). Seepage testing was performed again in 2022. The average seepage rate results for Lagoons 1, 2, and 3 were 0.048 in./day, 0.078 in./day, and 0.046 in./day, respectively (INL 2022b).

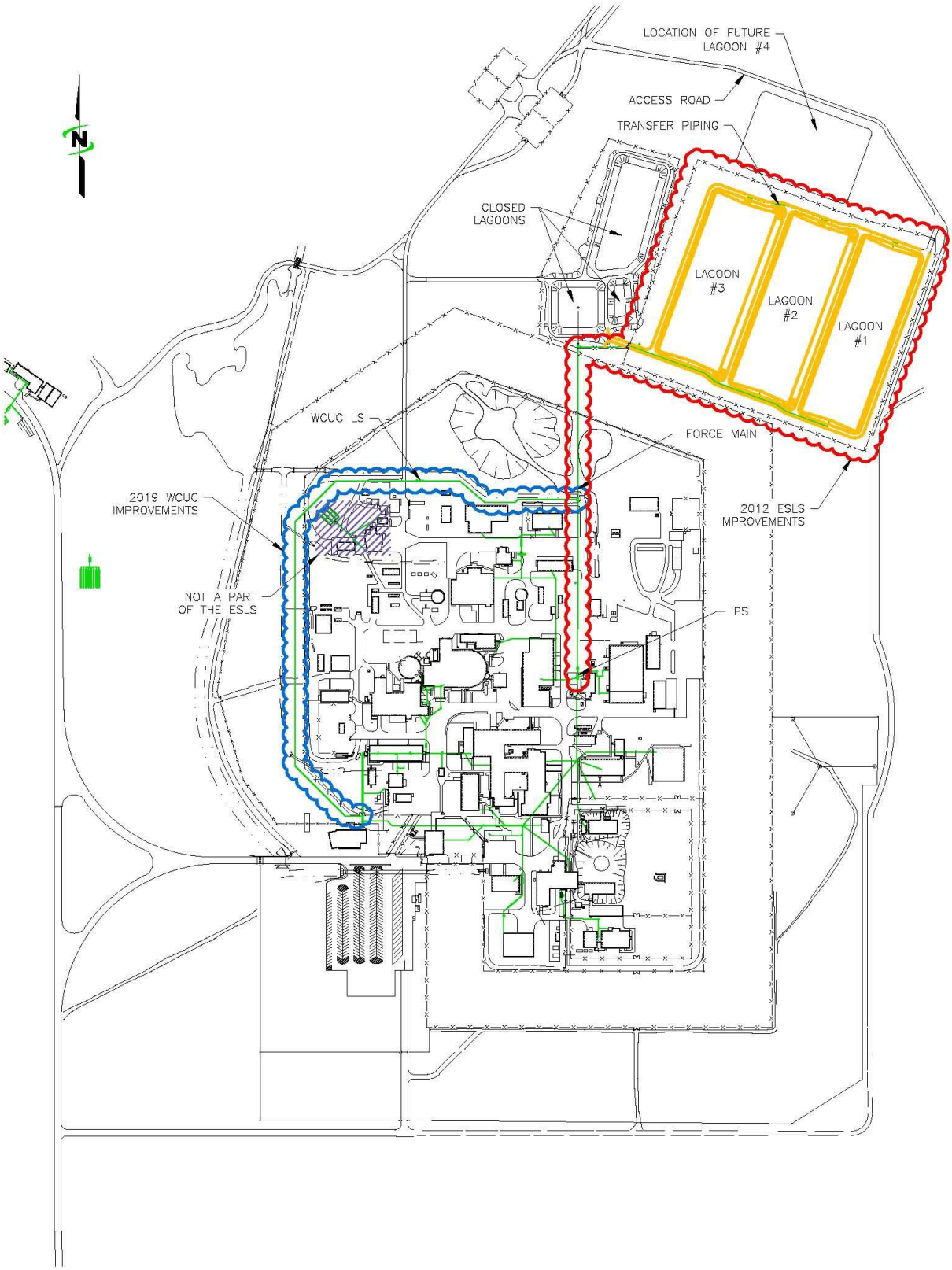

Figure 23. Location of MFC ESLs.

Table 19. Summary of surveillance monitoring at Materials and Fuels Complex ESLs in 2013.

Analyte	Sampling Frequency	Driver[a]	2013	
			Minimum	Maximum
Metals (µg/L)				
Arsenic	Annually	CERCLA, IWRP	10.3	10.3
Barium	Annually	IWRP	81.5	81.5
Cadmium	Annually	IWRP	<1	<1
Chromium	Annually	CERCLA, IWRP	2.6	2.6
Iron	Annually	IWRP	1,270	1,270
Lead	Annually	IWRP	1.7	1.7
Manganese	Annually	IWRP	70	70
Mercury	Annually	CERCLA, IWRP	<0.2	<0.2
Selenium	Annually	IWRP	3.8	3.8
Silver	Annually	IWRP	<5	<5
Sodium	Annually	IWRP	220,000	220,000
Zinc	Annually	IWRP	75.8	75.8
Anions, Nutrients, and Solids (mg/L)				
Chloride	Annually	IWRP	293	293
Fluoride	Annually	IWRP	1.88	1.88
Sulfate	Annually	IWRP	109	109
Nitrate+nitrite as nitrogen	Annually	IWRP	<0.05	<0.05
Total Kjeldahl nitrogen	Annually	IWRP	81.2	81.2
Total phosphorus	Annually	IWRP	12.1	12.1
Chemical oxygen demand	Annually	Treatment effectiveness	1,550	1,550
Total dissolved solids	Annually	IWRP	1,730	1,730
Total suspended solids	Annually	IWRP	670	670
Radionuclides (pCi/L)				
Gamma Spectroscopy	Quarterly	CERCLA, DOE		
Silver-108m	—	—	ND[b]	ND
Silver-110m	—	—	ND	ND
Americium-241	—	—	ND	ND

Analyte	Sampling Frequency	Driver[a]	2013	
			Minimum	Maximum
Cerium-144	—	—	ND	ND
Cobalt-58	—	—	ND	ND
Cobalt-60	—	—	ND	ND
Cesium-134	—	—	ND	ND
Cesium-137	—	—	ND	ND
Europium-152	—	—	ND	ND
Europium-154	—	—	ND	ND
Europium-155	—	—	ND	ND
Potassium-40	—	—	ND	93.8±13.7
Manganese-54	—	—	ND	ND
Niobium-95	—	—	ND	ND
Radium-226	—	—	ND	ND
Ruthenium-103	—	—	ND	ND
Ruthenium-106	—	—	ND	ND
Antimony-125	—	—	ND	ND
Uranium-235	—	—	ND	ND
Zinc-65	—	—	ND	ND
Zirconium-95	—	—	ND	ND
Gross alpha	Quarterly	DOE	ND	ND
Gross beta	Quarterly	DOE	13.8±1.69	96.6±7.24
Strontium-90	Annually[c]	DOE	ND	ND
Tritium	Quarterly	DOE	ND	ND
Plutonium-238	Annually	DOE	ND	ND
Plutonium-239/240	Annually	DOE	ND	ND
Plutonium-236	Annually	DOE	ND	ND
Plutonium-242	Annually	DOE	ND	ND
Plutonium-241	Annually	DOE	ND	ND
Americium-241	Annually	CERCLA, DOE	ND	ND
Curium-242	Annually	DOE	ND	ND

Analyte	Sampling Frequency	Driver[a]	2013	
			Minimum	Maximum
Curium-243/244	Annually	DOE	ND	ND
Uranium-233/234	Annually	CERCLA, DOE	1.78±0.219	1.78±0.219
Uranium-235	Annually	CERCLA, DOE	0.121±0.0502	0.121±0.0502
Uranium-238	Annually	CERCLA, DOE	0.809±0.128	0.809±0.128
Iron-55	Annually	DOE	ND	ND

a. CERCLA = potential CERCLA contaminant of concern for the sewage lagoon or analyte for CERCLA groundwater samples; IWRP = comparison to samples collected at the MFC Industrial Waste Pipeline and the Industrial Wastewater Underground Pipeline for the industrial wastewater reuse permit for the MFC Industrial Waste Ditch and Industrial Waste Pond; DOE = DOE orders for radiation protection.
b. ND = not detected.
c. If the gross beta activity in a quarterly sample exceeds 15 pCi/L the sample is analyzed for strontium-90.

3.5 Radioactive Waste Management Complex Municipal Wastewater Lagoons

RWMC uses a series of four evaporation ponds to manage sewage water emanating from various nonradioactive operations within RWMC. The evaporation ponds are located near the southeast corner of RWMC. They comprise four lagoons. Sewage water is first discharged into Lagoon No. 1, which then overflows into Lagoon No. 2. The overflow from Lagoon No.2 is discharged into both Lagoon No. 3 and Lagoon No. 4. Lagoons 1 and 2 are lined with an impermeable, 60-mil thick, single-ply sheet of HDPE geo-membrane, which is covered by 12 in. of fine grain soil. Lagoons 3 and 4 are lined with 12 in. of polymer-treated clay, which is covered with 6 in. of untreated clay and 6 in. of loose gravel (ICP 2013b).

Successful seepage testing of Lagoons 1 and 2 was completed on June 1, 2021 (ICP 2021). However, the seepage test of Lagoons 3 and 4 failed due to cattle accessing the lagoons. An agreement with DEQ was made that a fence would be installed around the RWMC Sanitary Wastewater Treatment Plant to prevent entry of grazing animals, and the lagoons would be filled to seepage test levels to allow the bentonite liner to self-heal and equilibrate prior to winter. Once the fence was installed and the lagoons had time to heal and equilibrate, a retest of Lagoons 3 and 4 was performed. The retesting of Lagoons 3 and 4 was successfully completed on June 13, 2022 (ICP 2022). The purpose of this testing was to satisfy IDAPA 58.01.16, “Wastewater Rules” (DEQ 2022c), which requires that average seepage rates within sewage lagoons remain below 0.25 in/day (the maximum seepage rate allowed for lagoons built before April 15, 2007). No routine environmental monitoring is performed at the RWMC municipal wastewater lagoons.

3.6 Specific Manufacturing Capability Wastewater Lagoons

3.6.1 Drivers for Sampling Program

Based on historical sampling data and the evaporative characteristics of the lagoons, routine environmental surveillance is no longer performed at the Specific Manufacturing Capability (SMC) facility wastewater lagoons. The lagoons are designed and operated as non-discharging, total containment evaporative lagoons; therefore, the system does not require or have a reuse or discharge permit. To comply with the “Wastewater Rules” (DEQ 2022c) and ensure continued protection of the public and environment, seepage tests are performed periodically at the lagoons. Radiological discharges to the lagoons are not allowed (INEL 1991).

3.6.2 Background

The SMC facility wastewater lagoons consist of three cells that were installed in 1994. The cells are double-lined with two HDPE liners over an 'impermeable' compacted silty clay base (Butler Engineering 1993). Two cells are alternately used for sanitary wastewater: Cell 1 is 230 × 185 ft and Cell 2 is 230 × 440 ft, as shown in Figure 24. The third cell is 230 × 185 ft and used for boiler water.

Use of the lagoons began in 1994 and tied into non-radiological effluent lines from the Loss of Fluid Test Facility (LOFT). File records indicate that the concern was the potential for the new lagoons to be contaminated by effluent from LOFT. Sampling was performed in 1996 and 1997, and the results were summarized as "radioactivity in all samples from the pond was shown to be entirely from outside or natural sources and did not come from LOFT or SMC" (Barg 1997). The lagoons receive only non-radiological process/sanitary wastewater. Radioactively contaminated wastewater at SMC is collected in a separate system and processed in the Waste Treatment Building (TAN-681). No radiological discharges to the SMC lagoons are allowed or expected (INEL 1991).

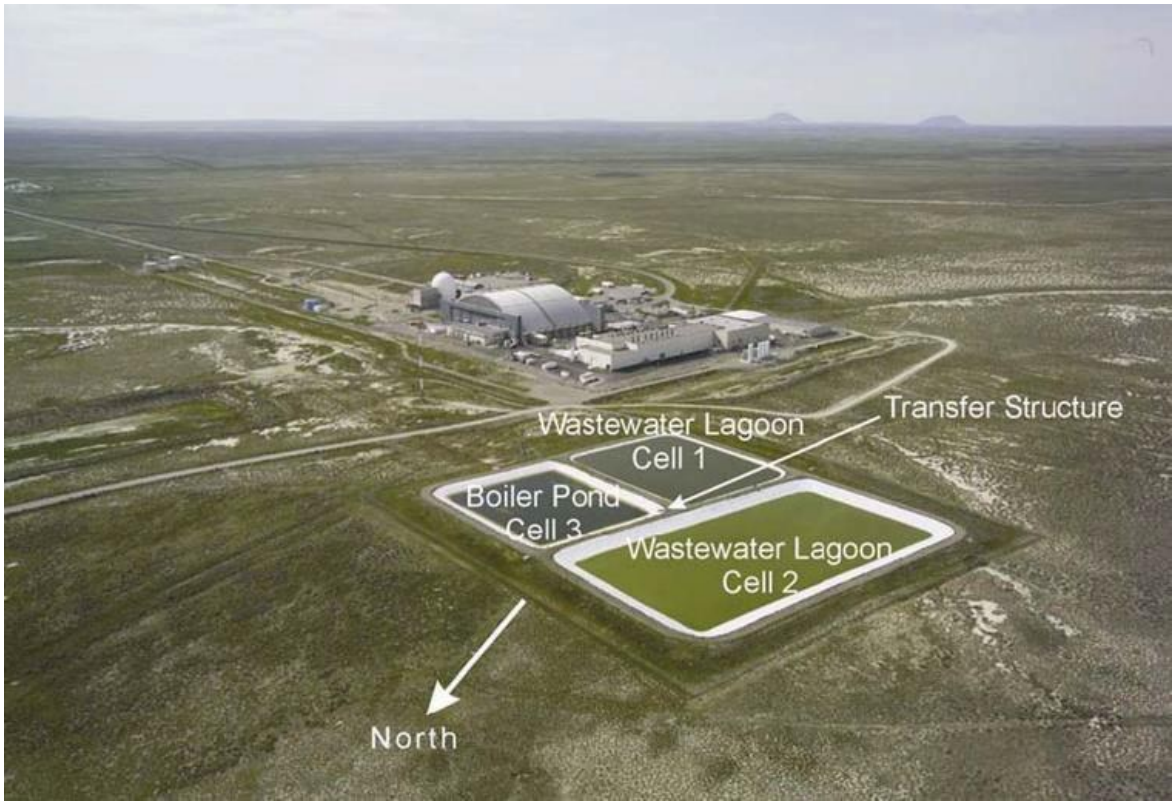

Figure 24. SMC evaporation lagoons.

SMC had an extensive monthly wastewater sampling program for non-radiological constituents when wastewater was discharged to the old LOFT pond. This was partially because "liability for effluent composition from SMC was a major concern between [Babcock and Wilcox] and EG&G" (Jackson 1994a). Sampling throughout that period showed "levels of chemical constituents far below regulatory concern or which would trigger reporting under RCRA or SARA; (this includes radionuclides)." Historical data, combined with the new lagoon design (e.g., evaporative rather than seepage) was the basis for significantly reducing sampling and analysis when discharges to the new lagoon began (Jackson 1994a, 1994b).

Routine sampling and analysis at the new lagoons consisted of quarterly radiological sampling of boiler and sanitary effluents, and supply water. Quarterly sampling occurred until approximately 2002 when sampling was discontinued because of the continued absence of any contamination (above background) and analytical laboratory cost escalation. Radiological sampling was conducted at the SMC lagoons in 2009; results were consistent with background levels (Kirchner 2009).

3.6.3 Sampling Basis and Design

Based on the historical data and the low seepage rates of the ponds, no environmental surveillance samples are collected at the SMC wastewater lagoons.

In accordance with the "Wastewater Rules" (DEQ 2022c), seepage tests are performed every 10 years to determine compliance with the allowable seepage rate of 0.25 in./day required for lagoons constructed before April 15, 2007. Seepage tests were performed at the SMC wastewater lagoons in 2009. The average seepage rates for Lagoons 1, 2, and 3 were -0.018 in./day, 0.012 in./day, and 0.019 in./day, respectively (Harris and Starr 2009). Seepage testing was performed again in 2018 and the average seepage rates for Lagoons 1, 2, and 3 were 0.049 in./day, 0.013 in./day, and 0.040 in./day, respectively (INL 2018b). The seepage rates of the lagoons remain well below the allowable limit of 0.25 in./day.

3.7 Quality Assurance

Liquid effluent monitoring employs an effective QA program to ensure the collection of high-quality data. The QA programs for each contractor are detailed in their respective program- and permit-specific quality assurance documents, for example the Environmental Support and Services Liquid Effluent Monitoring Plan, reuse permit Quality Assurance Project Plans, Statements of Work, and the DOE Consolidated Quality Systems Manual (QSM) for Environmental Laboratories. These plans serve to ensure that all data collected are of known and defensible quality and meet the requirements of all applicable federal and state regulations and DOE orders, specifically DOE O 414.1D Chg 2, EPA QA/R-5, ANSI/ASQC E-4, IDQTF UFP-QAPP and ISO 9000.

The analytical laboratories used for liquid effluent sampling participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) performance-evaluation tests and are certified by the DOECAP-Accreditation Program. Measurements of precision and accuracy in the liquid effluent program are made through the use of field duplicate samples and blind-spiked samples.

4. AIR

4.1 Program Basis

Air monitoring is conducted because air is the primary exposure pathway to humans from contaminants released to the atmosphere from current activities and the resuspension of soil contaminated from INL Site airborne releases or fallout. Humans and terrestrial biota can receive a radiation dose from the inhalation of or external exposure to radionuclides in the air (Figure 7).

Airborne emissions at the INL Site are generated from various facilities during operations, research, and scientific activities. Engineering controls such as high-efficiency particulate air (HEPA) filters, as well as administrative controls, are implemented to prevent, reduce, and/or eliminate air pollutants from reaching the environment. Air surveillance and facility emissions monitoring are completed to assess the adequacy of these controls to protect human health and determine any impact of air pollutants on the environment. This section discusses air surveillance involving the analysis of particulate matter or gaseous radioiodine collected on filters or trapped in a collection medium and not facility emissions monitoring. Emissions from facilities at the INL are monitored and reported in accordance with 40 CFR 61, Subpart H. Annual reports can be obtained on INL's Technical Publications web page (https://inldigitallibrary.inl.gov/SitePages/INL%20Research%20Library%20Digital%20Repository.aspx) and entering "National Emission Standards for Hazardous Air Pollutants" in the title search line.

4.2 Program Drivers

Ambient air monitoring is performed in accordance with the guidance set forth in DOE-HDBK-1216-2015 (DOE 2015) to meet the following regulatory requirements for the environmental surveillance of U.S. Department of Energy (DOE) facilities:

- DOE O 458.1.

Other key drivers include:

- Public perception
- Stakeholder inputs and values
- Nearest resident receptor locations.

4.3 Results of Related Studies

Air sampler locations are currently monitored at various on-Site locations, with additional, duplicate quality control (QC) samplers that are rotated every 2 years. In addition to the on-Site locations, locations outside of the INL Site Boundary are monitored. The locations for Boundary monitoring are Arco, Atomic City, Blue Dome, the Federal Aviation Administration Tower, Howe, Monteview, and Mud Lake, as well as six Distant locations at Blackfoot, Craters of the Moon, Dubois, Idaho Falls, Jackson, and Sugar City. The Jackson station was installed in 2001 in response to stakeholder concerns (Figure 25).

The identity and quantity of radionuclides routinely released from Site facilities is reported annually in the INL NESHAP report for radionuclides (e.g., DOE-ID 2022). The majority of radioactive effluent is in the form of noble gases (e.g., argon, krypton, xenon), which cannot be measured through particulate sampling. Because of this, the impact of Site operations on the surrounding region has been calculated using known amounts of radionuclides released and atmospheric dispersion modeling. INL uses U.S. Environmental Protection Agency (EPA) specified air-dispersion code CAP88-PC to demonstrate compliance with 40 CFR 61, Subpart H. This regulation limits quantities of airborne radionuclides from nuclear facilities. The standard requires that the dose received by any member of the public must be <10 mrem/year. At no time since 1986 (when the EPA standard was adopted) has the dose to the maximally exposed individual (MEI) been calculated to exceed even 10% of the 10 mrem/year standard.

The doses for the past 10 years at the location of the off-Site hypothetical MEI (Frenchman's Cabin until 2019 and Receptor 54 from 2019-present) have not exceeded 1% of the 10 mrem/year dose limit. Since the MEI has moved east to Receptor 54 in 2019, the estimated dose has remained below 1% of the limit. Additionally, the population dose has always been less than 0.01% of that received from the natural background. However, the adoption of the 10 mrem effective dose equivalent (EDE) accentuates the need for fully documented and verified measurements.

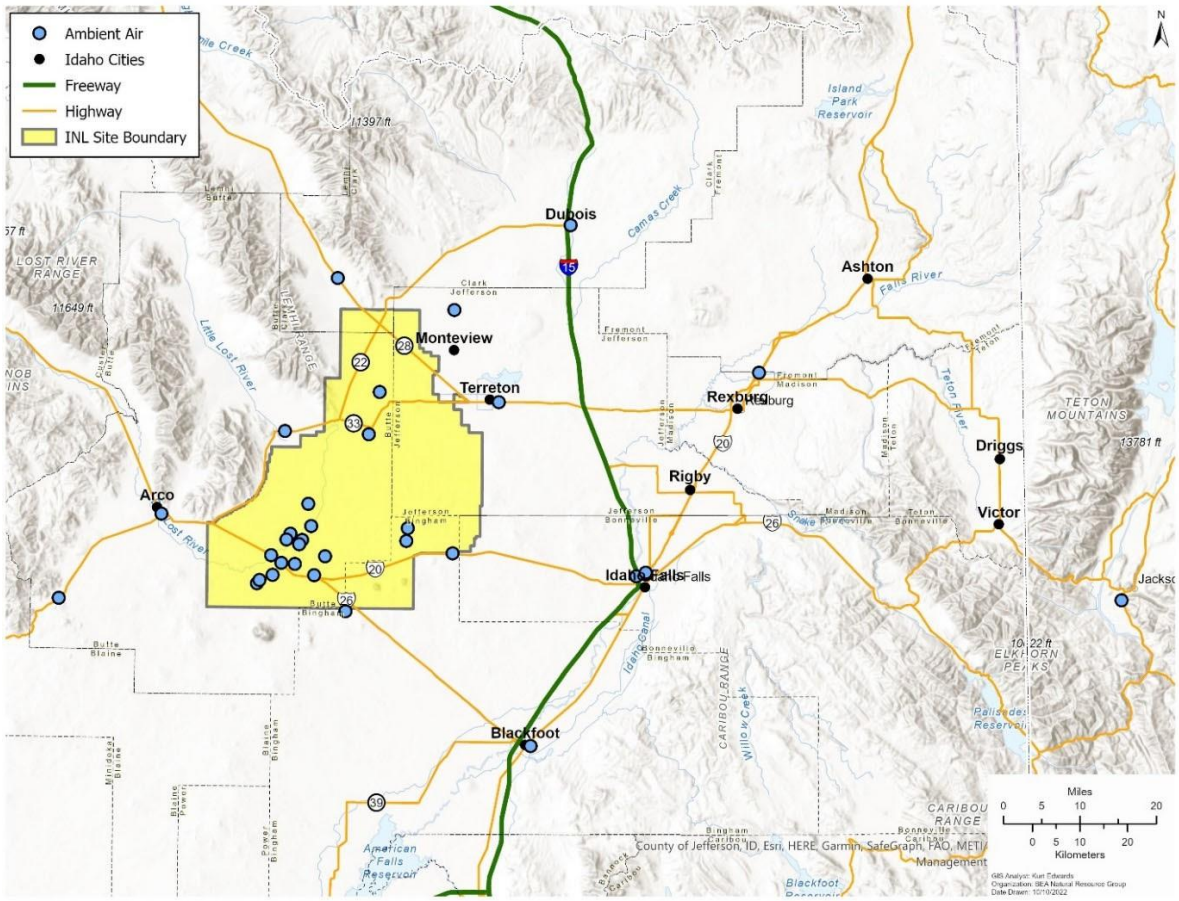

Figure 25. Ambient air monitoring locations.

A recent innovation for modeling at INL with potential national application is the *Development and Demonstration of a Methodology to Quantitatively Assess the INL Site Ambient Air Monitoring Network* (Rood and Sondrup 2014). In this document, Rood and Sondrup develop a methodology and modeling tool that has been used to objectively assess the INL air monitoring network design against established performance objectives. The model takes unit-activity time-integrated concentrations (TICs) at discrete sampler locations (either real or hypothetical), sampler flow rates, sampling times, release quantities, release durations, and minimum detectable activity (MDA) levels as inputs. Using these data, the model has calculated the frequency of detection of the network. Frequency of detection (FD) is defined as the fraction of events that result in a detection at either a single sampler or network of samplers. An event is defined as a release of finite duration that begins on a given day and hour of the year. A detection is recorded if the activity accumulated on or in the measurement device (i.e., a filter) is greater than the MDA. The model steps through each hour of the year, releasing the activity over the release time and calculates the FD for both the individual samplers and the network of samplers. Use of the Rood and Sondrup model has been discussed extensively in *Data Quality Objectives Summary Report Supporting Radiological Air Surveillance Monitoring for the INL Site* (INL 2022).

4.4 Program Goals

The primary goal of the ambient air monitoring program is to determine the status of the INL Site's compliance with applicable public health and environmental quality standards. This is done by confirming emissions control and measurement equipment is functioning, and that diffuse/unmonitored emissions are not causing unacceptable doses at an off-site location.

4.5 Sampling Boundaries

The logistics of implementing the program objectives involve the consideration of spatial and temporal limits, as well as the consideration of practical constraints. Sampling boundaries are discussed in *Data Quality Objectives Summary Report Supporting Radiological Air Surveillance Monitoring for the INL Site* (INL 2022).

High-volume air samplers are deployed at multiple locations both on and off the INL Site. These event air monitors are located at select National Oceanic and Atmospheric Administration (NOAA) weather towers in southeast Idaho (Figure 26). Although the NOAA towers are not located to detect contamination, but to provide weather data, they are the only locations that are currently configured for remote activation of event monitors if an unplanned release occurs. In addition to the fixed locations at NOAA towers, portable event air monitors are staged for deployment. The temporal boundary for an unplanned release depends on the nature and duration of the release. The maximum duration that an event air monitor will be allowed to operate is 24 hours prior to collecting the filter for analysis.

4.6 Sampling Design

The selection of locations, frequency of collection, collection and measurement techniques, and analytical detection and precision goals form the basis of the ambient air monitoring program. The design of the regional air sampling network achieves program goals by using a comprehensive, consistent approach. The overall sampling design (including sampling location placement, collection frequency, flow rates, filter types, analytes, etc.) conforms to DOE-HDBK-1216-2015 (DOE 2015), the accepted federal radiological effluent monitoring and environmental surveillance guide that assists DOE-controlled facilities in running technically defensible programs that meet DOE requirements, as discussed in the following sections.

The environmental surveillance air monitoring program is intended for routine surveillance of environmental concentrations of radionuclides on-Site and in the surrounding region, and not for real-time detection of INL Site facility releases or for regulatory emissions monitoring. Although the routine ambient air monitoring program can provide valuable information if an emergency occurs, it is primarily to confirm that concentrations in ambient air are consistent with the expected level of routine emissions, and to provide an indication of emissions caused by situations that are off-normal, but not necessarily emergencies (Waite 1973). As shown in Rood and Sondrup (2014), the network locations are placed so that there is a high probability of detecting small, short-duration releases.

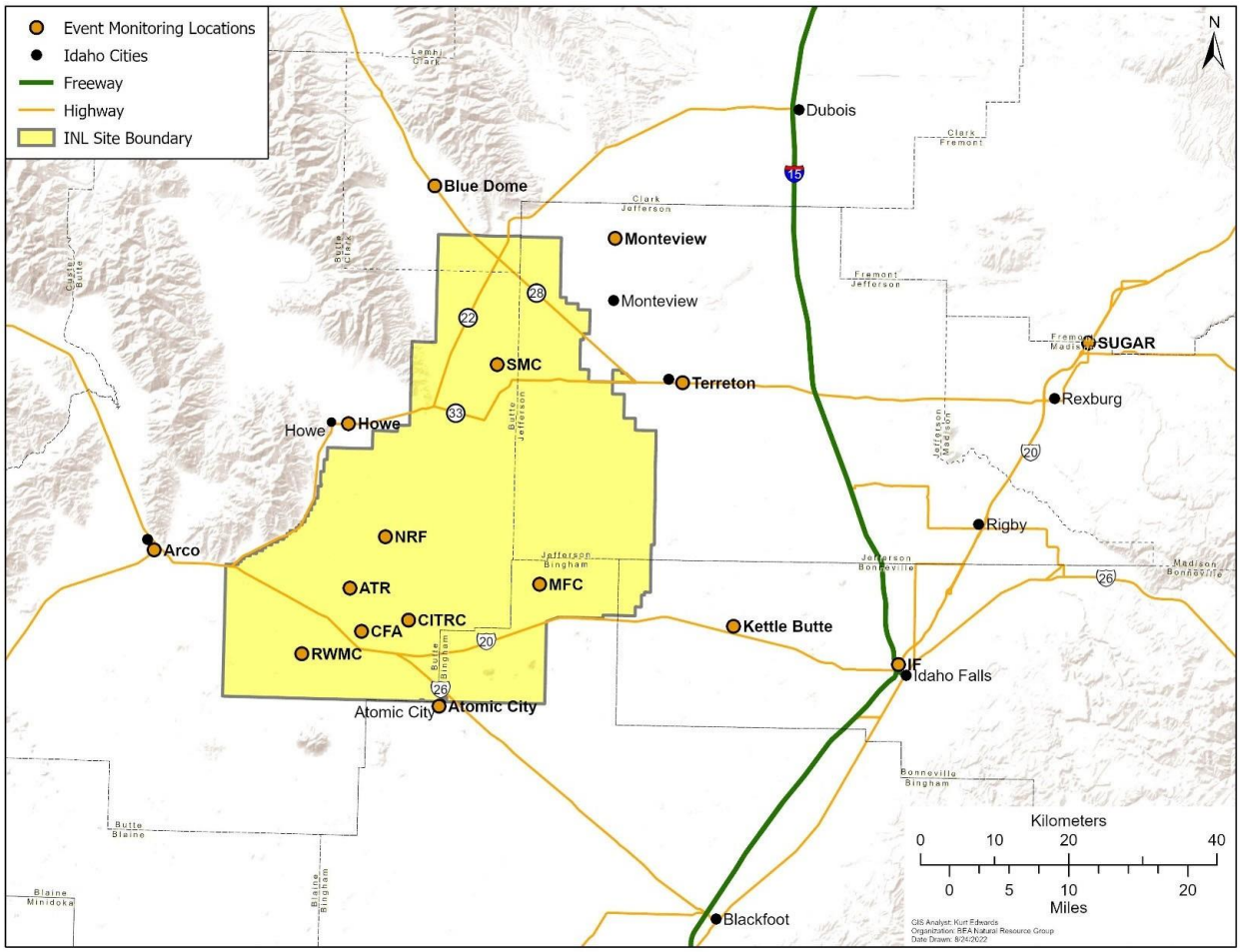

Figure 26. NOAA tower and event monitoring locations.

4.6.1 Sampling Locations

The current regulatory guidance for siting ambient air monitors for surveillance emphasizes expert judgment, the evaluation of planned or potential releases, and the evaluation of long-term meteorological and regional demographic data. Additionally, monitoring locations may be chosen to address stakeholder and community concerns. Prime locations may not be viable due to a lack of electricity. DOE guidance DOE-HDBK-1216-2015 (DOE 2015) for the number and placement of air monitors in a regional monitoring network recommends that a method similar to the one developed by Waite (1973, 1976) may be used. The Waite method incorporates a calculation of weighting factors based on demographic and meteorological data to guide the distribution of air-sampling locations around nuclear facilities. The method is useful for single sources with nearby population centers. However, the maximum applicable population distance is limited to 10 mi, except for very large nuclear facilities. This method clearly has limited applicability for the INL Site, which has multiple facilities spread out over 890 square miles and Distant population centers.

The effectiveness of the ambient air monitoring network with guidance for optimization is discussed in *Data Quality Objectives Summary Report Supporting Radiological Air Surveillance Monitoring for the INL Site* (INL 2022). This network includes monitors at each major on-Site facility in the predominant wind directions several miles from the facilities, as well as in several Distant locations, including the towns of Idaho Falls, Sugar City, and Blackfoot, Idaho; Jackson, Wyoming; and Craters of the Moon National Monument west of Arco, Idaho. In response to the 2010 DOE-HSS assessment, INL placed a low-volume air sampler in Idaho Falls to assess potential impacts from the Idaho National Laboratory Research Center (IRC) and U.S. Department of Energy–Idaho Operations Office (DOE-ID) Radiological and Environmental Sciences Laboratory (RESL) operations on the public. The location is directly south of these facilities between potential release sources and the Idaho Falls population, corresponding with the location of the MEI from operations at IRC (DOE-ID 2022). Subsequently, the methodology developed in Rood and Sondrup (2014) was used to evaluate air monitoring in Idaho Falls, which is discussed in more detail in Appendix A. This evaluation recommended one additional monitor north of the DOE-ID RESL operations building. Results showed that for potential projects coming to INL Site and Idaho Falls facilities, additional modeling was not needed since the current network will detect any alpha, beta, or gamma reading that could result in a dose to the public of 1 mrem/year. All ambient air monitoring network sampling locations are presented in *Data Quality Objectives Summary Report Supporting Radiological Air Surveillance Monitoring for the INL Site* (INL 2022).

The INL Site network of ambient air monitors are assigned to the following groups:

1. Distant samplers: Samplers in this group are used to represent areas of minimal impact from INL Site releases as controls.[a] Criteria used to accept locations into this network are:
   - Samplers are located toward the periphery of the Snake River Plain area surrounding the INL Site, but close enough to be representative of Site conditions. For example, samplers cannot be located in the mountains west of the INL Site because ecological factors that can affect radionuclide transport differ from those associated with the Snake River Plain ecosystem.
   - Samplers encircle the INL Site, ideally at or near population centers.
   - Samplers are located in minimally impacted areas.
2. Boundary samplers: Samplers in this group are used to represent areas that are located off the INL Site but can be impacted by Site releases of radionuclides. The criteria used to accept locations into this network are:
   - Samplers encircle the INL Site to help ensure detection of any emissions that are dispersed beyond the Boundary.
   - Samplers are located near or beyond the INL Site Boundary in areas where members of the public reside and the potential impacts from all INL Site releases are the greatest.
3. On-Site samplers: Samplers in this group are used to represent areas on the INL Site that are most likely to be impacted by all facility emissions. The criteria used to select are:
   - Samplers are located outside individual facility perimeters.
   - Samplers are located in areas that do not conflict with security requirements (e.g., outside fenced-in security areas).
   - Samplers are located on the INL Site at areas that contribute to the overall frequency of detection per Rood and Sondrup (2014).

[a] A control sample is used for comparison to determine if a contaminant of interest is present in a sample of interest. It is collected near the same time and under similar conditions as a sample suspected of containing the contaminant.

In addition to the conditions described above, consideration must be given to the availability of electricity, accessibility during all seasons of the year, and limited access to minimize the possibility of vandalism. The locations that meet all three of these conditions off the INL Site are the NOAA enclosures used for the MESONET meteorological equipment, so therefore, preference was given to NOAA MESONET stations.

Jackson is not representative of the Snake River Plain ecosystem and is not located within the MDIFF mesoscale system; however, this sampling location was established in response to stakeholder concerns in 2001 and should be maintained for that special purpose and not as part of the Distant network as a control location.

4.6.2 Frequency of Sample Collection

The sampling and analysis frequencies are in accordance with DOE-HDBK-1216-2015 (DOE 2015), which suggests that samples be recovered on a fixed frequency, typically 1 to 2 weeks, but no greater than biweekly. It is determined in Rood and Sondrup (2014) that the volume collected in one week is sufficient to detect gross beta activity. The air surveillance program is not limited by physical problems associated with retrieving samples from each location at this frequency. Therefore, samples are collected on a weekly basis.

DOE criteria provide the minimum sample collection and analysis requirements as a function of the EDE to the MEI. For an estimated EDE to the MEI being <1 mrem, as is the case at the INL Site, it is recommended that, at a minimum, the program should consist of:

- The analysis of air particulate samples (collected weekly or biweekly) for total alpha and total beta activity.
- Gamma spectroscopy of an annual air particulate composite.
- Gamma spectroscopy is completed on air samples composited quarterly, rather than annually, for earlier alerts if unusual releases occur. It has been determined that quarterly composited air samples are of sufficient volume that cesium-137 released from the INL Site in excess of normal levels could theoretically be detected in the off-Site environs (Rood and Sondrup 2014).

Alpha spectroscopy, particle size determination, and analyses for noble gases, halogens (radioiodine), and tritium are not considered necessary at the dose level estimated for the INL Site (DOE-HDBK-1216-2015 [DOE 2015]). However, radiochemical analyses of quarterly composited air filters for specific alpha-emitters (e.g., plutonium-238, plutonium-239/240, americium-241, uranium-234, uranium-238) and specific beta-emitters (e.g., strontium-90, chlorine-36) are performed on some samples. This is because these radionuclides were ranked as one of the top contributors to dose calculated for compliance with NESHAP, and because they have been detected historically on air filters. Past detections are likely due to fallout from previous weapons testing, in the case of strontium-90, or resuspension of soil previously contaminated by plutonium and americium-241.

The ambient air-monitoring program uses charcoal cartridges to collect ambient air samples for iodine-131 analysis on a weekly basis. Radioiodine is monitored because of the potential for releases of radioiodine from the ATR or an unplanned release.

Weekly gross alpha and gross beta analyses are performed on the particulate filters in gas flow proportional counters. Filter analysis is delayed for five days to allow for naturally occurring radon and thoron decay products to decay. Charcoal cartridges are screened using gamma spectroscopy within three days of collection to measure iodine-131 before it decays (the half-life is eight days.) At the end of each quarter, the particulate filters from each location are composited. All composites are then analyzed for gamma-emitting radionuclides. Selected sample composites are analyzed for strontium-90 or actinides (e.g., plutonium-238, plutonium-239/240, americium-241, chlorine-36, uranium-234, uranium-238) each quarter on a rotating basis.

4.6.3 Sampling Methods

According to DOE-HDBK-1216-2015 (DOE 2015), air particulate sampling for gross alpha, gross beta, and gamma spectroscopy is the minimum monitoring required if the annual EDE is <1 mrem to the MEI. Sample collection for radioiodine is recommended if the EDE is >1 mrem and <5 mrem to the MEI. Although estimated dose contributions to the MEI are much smaller than this range, radioiodine is sampled because it is a good indicator of a nuclear event, such as a potential unplanned INL Site release or the reactor accident at Fukushima. Low-volume samplers are used because of their durability and reliability and their capability of pulling the air volume needed for monitoring radioactive materials potentially released by INL Site operations (see the discussion about sample volume and minimum detectable activity [MDA] in Section 4.6.2).

Low-volume air samples are typically used throughout the DOE system for regional air monitoring. The INL contractor performs air monitoring using microprocessor-controlled low-volume air samplers consisting of oil-less carbon-vane vacuum pumps and constant air-flow regulators that pull air at approximately 2 cfm through a combination head holding a 2-in. paper filter and a charcoal cartridge. Each sample inlet is positioned in the breathing zone for adults in accordance with the recommendations in DOE-HDBK-1216-2015 (DOE 2015). The regional component of the ambient-monitoring program low-volume air samplers consists of a dual membrane filter and cartridge holder, a vacuum gauge, a Gast rotary vacuum pump, and microprocessor-controlled data loggers. These samplers can maintain air flow up to 4 cfm (113 L/min) through a set of two filters: (1) a non-woven, nylon-backed polyvinyl acrylonitrile support membrane prefilter (e.g., Gelman Versapor-1200); and (2) an activated-charcoal cartridge (SAIC/RADēCO™ BG-300). The membrane prefilter has a pore size of 1.2 µm and an efficiency of greater than 99% for particles >0.3 µm in diameter. This approximately encompasses the range (0.1 to 3 µm) of the optimum size of particles for deposition in the upper respiratory system and meets the efficiency criteria in DOE-HDBK-1216-2015 (DOE 2015). The filter also retains a high percentage of smaller particles that can be inhaled. The BG-300 cartridge has more than a 99% collection efficiency for methyl iodide at pump flow rates of 1 cfm, about 96% collection efficiency at 2 cfm, and about 92% collection efficiency at 3 cfm (see http://www.radecoinc.com/index.php?option=com_content&view=article&id=23&Itemid=47). TheB-300 cartridge collection efficiency drops to about 85% at 4 cfm. The sample flow rate is limited to≤3 cfm because of the relatively steep drop in efficiency above this rate (Figure 27).

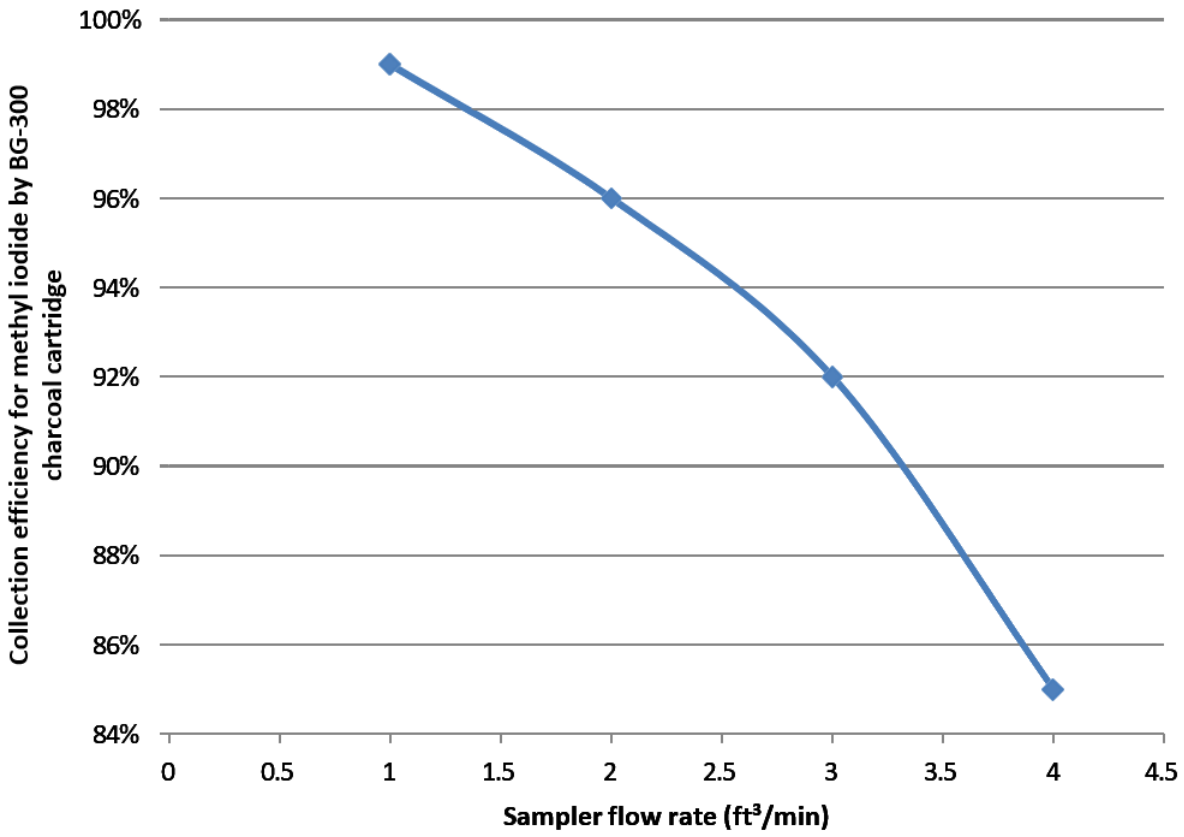

Figure 27. Collection efficiency of charcoal cartridges as a function of air sampler flow rate.

Gross beta activity is detected in virtually all membrane filters collected. This is because the median background concentration is easily detected by proportional counters. The median background measured in the vicinity of the INL Site is approximately 2.5E-14 µCi/mL, which is approximately 1.6E-05 µCi, assuming a week's collection at a rate of 2 cfm. The laboratory MDA is 4.28E-7 µCi per filter, which is easily achieved by all air flow rates on a weekly basis. The median activities per filter are 1.43E-5 µCi, 1.78E-5 µCi, and 2.14E-5 µCi at 2, 2.5, and 3 cfm, respectively. The detectable gross beta activity is thus not limited by the flow rate used. However, the counting statistics for gross beta activity are improved by increasing the flow rate and, thus, the volume of air collected. Using the methods outlined in Boothe et al. (2008), the theoretical 96% standard deviation (SD) associated with counting beta activity collected on filters at various flow rates is plotted in Figure 28. The percent SD increases with the increasing flow rate, but almost levels off at around 3 cfm.

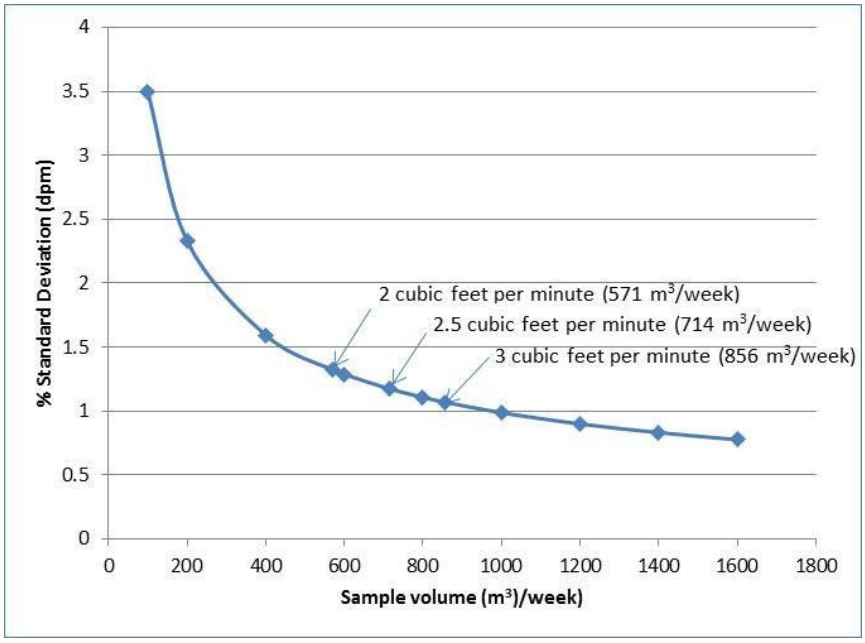

Figure 28. Percent theoretical SD for gross beta counting versus sample volume.

4.6.4 Analytical Methods

The DOE Environmental Measurements Laboratory (EML) Procedures Manual, HASL-300, has served as a significant resource for the development of laboratory. Analytical methods have been further refined by the individual laboratories contracted by the program to meet the required detection limits, which are based on the detection of concentrations per mrem at the locations of the MEIs.

The approximate MDAs listed in Table 20 are based on *a priori* calculations that, following an actual analysis, determine the minimum detection limit specifically for that analysis.

Table 20. Approximate MDAs for radionuclides in quarterly composited air filters.

Approximate Sample Size	Radionuclide	MDA (pCi/mL)
	Americium-241	2.02e-11
40 filters	Plutonium-238	2.02e-11
	Plutonium-239/240	2.02e-11
40 filters	Strontium-90	1.35e-10
40 filters	Cesium-137[a]	1.35e-10
40 filters	Uranium 234	6.74e-10
	Uranium 238	6.74e-10
40 filters	Chlorine-36	6.74e-11
40 filters	Zinc-65	6.74e-10

a. Representative gamma-emitter. Any measurable gamma-emitting radionuclide present in the sample may be detected.

4.7 Radionuclides Assessed

During 2014 to 2021, the airborne dose from INL Site operations was estimated by EPA air-dispersion code CAP88-PC to range from 0.008 to 0.067 mrem/year for the MEI just off the INL Site. The top contributors (i.e., those isotopes contributing greater than 95% of the total dose) to the dose are shown in Table 21. Those radionuclides routinely contributing (i.e., ≥3 years in the 5-year period) to 95% of the dose are recommended for routine analysis, except for Ar-41, tritium, and I-129.

Table 21. Percent radionuclide contributions to total dose, estimated by CAP88-PC, for NESHAP at an MEI location (Receptor 54) and recommended inclusion in an air monitoring program.

Radionuclide	2014	2015	2016	2017	2018	2019	2020	2021	Included in routine analysis?	Comments
H-3	28.5%	33.7%	23.4%	30.3%	22.4%	2.0%	1.7%	1.1%	No	Collected in precipitation and air moisture.
Am-241	22.9%	28.1%	7.2%	5.5%	0.5%	<1%	<1%	<1%	Yes	—
Sr-90	14.3%	6.6%	12.7%	14.3%	14.8%	<1%	<1%	<1%	Yes	—
Pu-239	8.9%	5.6%	4.4%	2.7%	0.6%	<1%	<1%	<1%	Yes	—
I-129	8.5%	11.2%	19.2%	8.7%	10.4%	<1%	<1%	<1%	No	Long-lived radionuclide that accumulates and is more easily detected in soil.[b]
Ar-41	8.4%	7.6%	11.8%	21.3%	15.9%	<1%	<1%	<1%	No	Gas cannot be collected by a particulate filter.
Cs-137	3.5%	3.2%	12.3%	6.1%	23.2%	56.2%	55.2%	54.7%	Yes	Other gamma-emitting radionuclides may also be detected by gamma spectrometry.
Co-60	0.6%	0.2%	4.5%	6.9%	4.8%	<1%	<1%	<1%	No	—
C-14	0.7%	0.7%	1.8%	1.6%	5.5%	<1%	<1%	<1%	No	—
U-238	<1%	<1%	<1%	<1%	<1%	20.1%	15.7%	16.3%	Yes	—
U-234	<1%	<1%	<1%	<1%	<1%	7.7%	8.0%	8.3%	Yes	—
Cl-36	0%	<1%	<1%	<1%	<1%	6.3%	5.8%	6.0%	Yes	—
Zn-65	<1%	<1%	<1%	<1%	<1%	3.4%	6.3%	7.0%	No	—
I-131	<1%	<1%	<1%	<1%	<1%	0.2%	3.4%	0.3%	No	—
U-235	<1%	<1%	<1%	<1%	<1%	0.4%	0.4%	3.6%	No	—
TOTAL	96.3%	97.0%	97.4%	97.5%	98.2%	96.2%	96.5%	97.3%	—	—

a. Not considered if does not routinely contribute to 95% of the dose (i.e., more than three times in 5 years) or for reasons presented in "Comments".

b. Iodine-129 cannot easily be measured on an air filter using low-energy gamma spectrometry due to the long half-life (15.7 million years) and small amount present. Mass spectrometry, an expensive method, is typically used on environmental samples. Because historical INL Site releases (approximately 0.2 Ci, according to R.C. Morris, unpublished report) have been deposited in the INL Site environment, primarily in soil, it would be more appropriate to measure iodine-129 in soil.

As discussed previously, argon-41 is a noble gas and cannot be measured through particulate sampling. It is best measured as part of the external radiation exposure program. Tritium is collected in atmospheric moisture and precipitation and is discussed in Section 5.

4.8 Quality Assurance

The surveillance program employs an effective quality assurance (QA) program to ensure the collection of high-quality data. The QA programs are detailed in their respective documents, for example, the Environmental Monitoring Services QA Project Plan (QAPjP) and on-Site Environmental Support and Services Monitoring Services Surveillance Plan. These plans serve to ensure that all data collected are of known and defensible quality and meet the requirements of all applicable federal and state regulations and DOE orders, specifically DOE O 414.1D Chg 2, ASME NQA-1-2000, EPA QA/R-5, ANSI/ASQC E-4, IDQTF UFP-QAPP, and ISO 9000.

The analytical laboratories participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) performance-evaluation tests, and some are certified by the DOECAP-Accreditation Program. Measurements of precision and accuracy in the air sampling program are made through the use of duplicate air samplers, recounts of air filters, blanks, and blind-spiked samples.

4.9 Decision Limits and Actions

Per DOE O 458.1, DOE radiological activities must be conducted so that exposure of members of the public to ionizing radiation will: not cause a total effective dose (TED) exceeding 100 mrem (1 mSv) in a year, an equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year, or an equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose. This does not include doses from radon and its decay products in air, doses received by patients from medical sources of radiation, dose from background radiation, or dose from occupational exposure.

INL contractor gross alpha and beta data from 2006 to 2017 were used to calculate the 99%/95% upper tolerance limits (UTLs) for gross alpha, gross beta, americium-241, plutonium-238, plutonium-239/240, and strontium-90, as shown in Table 22 (INL 2017). Beginning in October 2022, the INL contractor will begin performing analysis on chlorine-36, uranium-234, uranium-235, uranium-238, and zinc-65. Due to not having any historic data associated with these nuclides, UTLs cannot be established. A conservative action level of any detection greater than 3σ will be used until UTLs can be established. Note that a gross alpha or gross beta concentration exceeding a UTL in Table 22 does not necessarily mean that the result is outside of the normal range. For example, gross alpha concentrations are highest in August and lowest in March. So, if the UTL is exceeded in August, the concentration may still be well within the normal range. Whereas, if it is exceeded in March, closer examination may be required. For the specific radionuclides, the data used were from June 2013 through December 2020. Because more than 50% of the observations were non-detects, the larger of the maximum observed detection or the MDA was used as the decision limit for each radionuclide.

If radionuclides concentrations are detected potentially exceeding background levels the following actions are taken:

- Determine if the concentration is an anomalous measurement by comparison with historical data, meteorological conditions, other contractor data, communication with the analytical laboratory, and other actions.
- If verifiable, inform DOE-ID and determine if any further action is needed.

Table 22. Gross alpha and beta action levels for the INL contractor.

	Decision Limit (uCi/mL)
Gross Alpha	5.60E-15
Gross Beta	6.27E-14
Americium-241	7.90E-17
Plutonium-238	2.65E-17
Plutonium-239/240	1.29E-16
Strontium-90	4.19E-16
Chlorine-36	>3σ
Uranium-234	>3σ
Uranium-235	>3σ
Uranium-238	>3σ
Zinc-65	>3σ

5. PRECIPITATION AND ATMOSPHERIC MOISTURE

5.1 Program Basis

Tritium, with a half-life of about 12 years, is an important radionuclide because it is a radioactive form of hydrogen, which combines with oxygen to form tritiated water. The most common forms of tritium are tritium gas and tritiated water (ANL 2007). The environmental behavior of tritiated water is like that of water, and it can be present in surface water, precipitation, and atmospheric moisture.

Therefore, the monitoring programs at the Idaho National Laboratory (INL) Site sample surface water (see Chapter 7), atmospheric moisture, and precipitation to assess this isotope. The purpose of sampling precipitation and atmospheric moisture at the INL Site is to monitor tritium in air at and around the INL Site in order to help establish background levels and determine any trends that might reflect INL Site releases.

The present environmental tritium level is governed globally by three main sources: (1) naturally-produced tritium, (2) tritium from nuclear explosions and nuclear facilities, and (3) consumer products (Uchrin et al. 1993). Tritium occurs naturally due to cosmic rays interacting with atmospheric gases. Cosmic rays interact with nitrogen-14 or deuterium and a form tritium and carbon-12. These are primarily interactions that happen in the upper atmosphere and the tritium falls to earth as rain.

Tritium was released to the atmosphere during the test phase for hydrogen bombs. These very low natural levels were insignificant in comparison to concentrations that were several orders of magnitude higher. Since then, tritium levels have progressively decreased due to washout processes and the admixture of moisture from the oceans (see http://www.naweb.iaea.org/napc/ih/documents/userupdate/description/Precip1.html). The amount of tritium present in the environment, as a result of nuclear weapons testing in the mid-1950s and early 1960s, peaked in 1963 and has been decreasing ever since.

Anthropogenic sources such as the nuclear fuel cycle, fusion test experiments, and military and industrial use of tritium inject the isotope into the atmosphere (Uchrin et al. 1993). Tritium is released to the environment from the INL Site and is important in terms of potential radiological dose (Rood and Sondrup 2014). The doses calculated for tritium from 2014 to 2021 ranged from 1 to 34% of the total dose estimated at the MEI location for the National Emission Standards for Hazardous Air Pollutants (NESHAP) reports (e.g., DOE-ID 2021b). This broad range in dose contribution can be attributed to the shift in maximally exposed individual (MEI) location. Prior to 2019, tritium was the primary dose driver, accounting for 28% of total dose on average. After the MEI shift, contributions from tritium account for less than 2% of total dose.

The measurement of tritium concentrations in precipitation and atmospheric moisture may help: (1) distinguish tritium concentrations in background from those associated with INL operations, and (2) determine the impact, if any, of tritium released from the INL Site on offsite residents. Other isotopes could be addressed as well in precipitation and atmospheric moisture samples. However, the INL on-Site monitoring and environmental surveillance programs effectively address the presence of other isotopes through the air, soil, and environmental radiation programs. These methods are effective for isotopes other than tritium because of their particulate nature. Tritium is primarily present in water, both liquid and vapor (ANL 2007); hence, this is the basis for sampling this medium for tritium.

5.2 Program Drivers

Sampling of precipitation and atmospheric moisture is performed on and around the INL Site to meet the following requirements and criteria for environmental surveillance of DOE facilities:

- DOE O 458.1
- DOE Handbook Environmental Radiological Effluent Monitoring and Environmental Surveillance (DOE 2015), which updates and supersedes Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T) (DOE 1991).

Other key drivers of the ambient air surveillance program include stakeholder inputs and values.

The DOE Handbook (DOE 2015) is an implementation guide for DOE O 458.1. Since air is a primary exposure pathway to humans from radionuclides released to the atmosphere, the DOE Handbook states that air sampling should be conducted to evaluate potential dose to populations from inhaled or ingested radionuclides or from immersion in a cloud of gas. For facilities that release tritium to the air, air-sampling techniques should employ methods that collect moisture from the air. The DOE Handbook recommends that rainwater surveillance should be included in the evaluation of the airborne pathway. This is especially important for the tritium pathway because tritium in the atmosphere, resulting from natural and man-made sources other than the INL Site, can be washed out of the atmosphere and deposited at ground-level locations. For this reason, the DOE Handbook recommends that rainwater sampling be co-located with air, vegetation, and soil surveillance locations.

Per the Order, DOE radiological activities must be conducted so that exposure of members of the public to ionizing radiation (from all pathways) will not cause a total effective dose (TED) exceeding 100 mrem (1 mSv) in a year. The dose from the air pathway shall not exceed 10% (10 mrem) of the primary dose limit (100 mrem). Dose from background radiation is excluded.

The DOE Handbook recommends that air sampling and analysis be performed as part of environmental sampling conducted to protect the environment and the public. According to sample collection/analysis criteria presented in Table 6-2 of the DOE Handbook, tritium should be sampled for and analyzed if the TED is estimated to be equal to or greater than 1 mrem.

Dose calculations made using U.S. Environmental Protection Agency (EPA) air-dispersion code CAP88-PC (EPA 2020 for releases from the INL Site for the past 10 years (2012 to 2021) show an annual TED ranging from 0.008 to 0.067 mrem/year to a hypothetical individual living at the location of maximum radionuclide concentration (DOE-ID 2021b). The estimated dose has not exceeded 1 mrem in the period from 2012-2021. As such, routine surveillance for tritium is not indicated. However, to ensure the detection of tritium originating from the INL Site in the air well before dose standards are approached, routine monitoring should be conducted around the INL Site. This assures public protection.

5.3 Results of Related Studies/Surveillance

The earliest records on file for precipitation and atmospheric moisture sampling around the INL Site are in 1968 (AEC 1969) and the mid-1970s (DOE-ID 1991). Tritium in snow, rain, and stream water was being evaluated as a research and development (R&D) project (AEC 1969). Tritium in atmospheric moisture has been measured in Idaho Falls, at the Experimental Field Station (EFS), and at Van Buren Boulevard (on the INL Site) since 1976 (DOE-ID 1991). Development of the system was reported in the 1970 report (AEC 1971); some limited sampling may have been done before 1973.

Currently, the program includes atmospheric moisture monitors located at the following—two on the INL Site at the EFS and Van Buren Boulevard; two at the Boundary locations in Atomic City and Howe; and three at Distant locations at the Craters of the Moon National Monument and two in Idaho Falls. The atmospheric moisture samplers collect moisture from the atmosphere using a column of molecular sieve material contained in the apparatus. Air passes through the columns at the rate of between 100–150 cm^3/min. This collection frequency may range from two weeks during the summer periods up to ten weeks during cold weather (DOE-ID 2014). In addition to the requested detection limits, the number and placement of monitoring locations were evaluated (Rood and Sondrup 2015) and concluded that the current monitoring setup is adequate to detect a dose of 0.0192 mrem in a week to an offsite individual or 1 mrem in a week to an onsite shepherd/rancher grazing livestock onsite. In that report, a hypothetical network was also evaluated, which also concluded that a release of tritium of the quantities that would yield a dose of 0.0192 mrem and 1 mrem for the resident and shepherd/rancher scenario would be detected.

Precipitation samples are also collected to measure tritium washed from the air. One location on the INL Site (EFS); two at Boundary locations (Howe and Atomic City); and one at a Distant location (Idaho Falls), will serve as a control or background sampler (Figure 29). The Idaho Falls station is operated as a part of the EPA RadNet Program, the results of which can be found at http://www.epa.gov/enviro/facts/radnet/index.html.

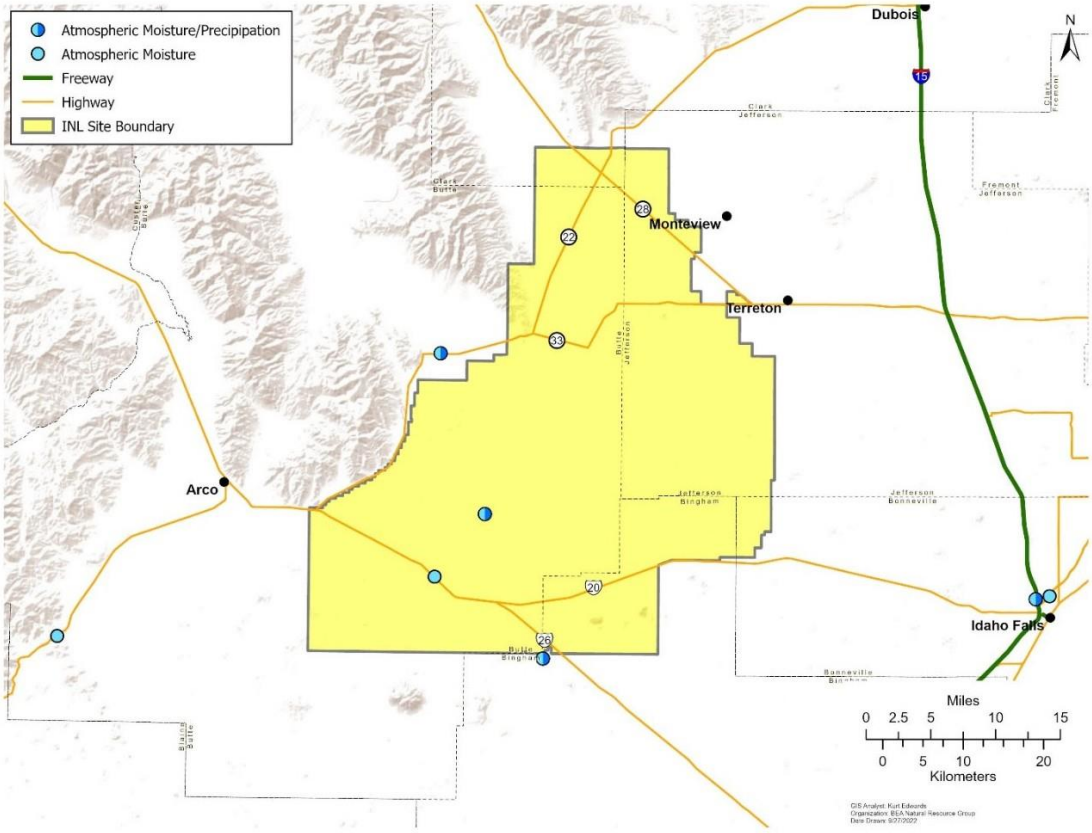

Figure 29. Current precipitation and atmospheric moisture sampling locations.

Beginning with calendar year 2011, the monitoring results for the locations shown in Figure 29 were analyzed in Atmospheric Moisture and Precipitation Monitoring Data Quality Objectives (INL 2022).

Tritium concentrations were frequently detected above the 3σ level and are shown in Figure 30. The concentrations appear to be cyclic, with highs in the spring/summer and lows in the fall/winter. A regression analysis was performed over the years. A decreasing trend over time can still be detected even though it is confounded somewhat by the existence of the cyclical trend. This ability to detect a negative trend is important because a linear regression analysis performed over a shorter period may erroneously conclude a significant positive or negative trend, when in fact, it is a portion of the cyclical trend. The confidence intervals for the slopes in Figure 30 overlap, and from this, it can be concluded that there is no difference in the rate of change in tritium measurements for atmospheric moisture and precipitation. The decreasing trend is thus most likely due to the decay and dilution of tritium present in the atmosphere as a result of nuclear weapons testing.

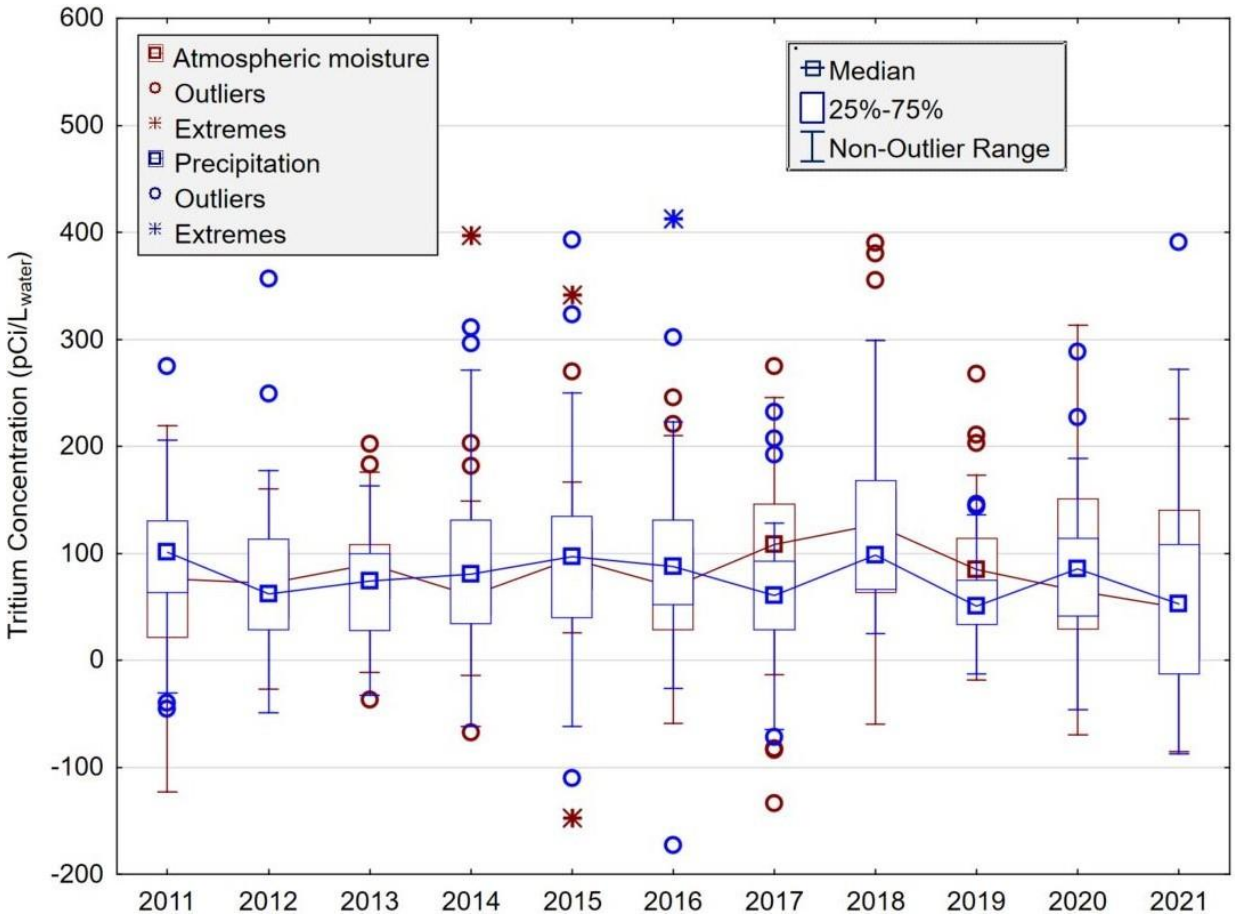

Figure 30. Tritium concentrations in atmospheric moisture and precipitation samples from 2011 to 2021.

Although it appears in Figure 30 that tritium concentrations in atmospheric moisture and precipitation are indistinguishable, statistical testing is needed to formulate any conclusions with confidence. The data were found to have no discernable distribution, and for this reason, the nonparametric Mann-Whitney U Test was employed. The test results indicate no difference between tritium concentrations measured in atmospheric moisture and precipitation samples collected from 2011 to 2021. This helps confirm that the source of tritium measured in the samples is most likely due to ambient sources (i.e., nuclear weapons testing fallout and natural production).

Annual tritium concentrations in atmospheric moisture and precipitation have no discernable statistical distribution, so nonparametric statistical methods were used to assess both sets of data (DOE-ID, 2021a). To summarize the results, box plots were constructed of annual tritium concentrations measured in atmospheric moisture (as water) and precipitation samples collected by the ESER contractor for the past 10 years, as can be seen in Figure 30. The results appear to be similar for each year. A statistical comparison of both sets of data using the nonparametric Wilcoxon Matched Pairs Test shows there are no differences between median annual tritium concentrations measured in atmospheric moisture and in the precipitation samples. Because low levels of tritium exist in the environment at all times as a result of cosmic ray reactions with atmospheric gases in the upper atmosphere and the decreasing influence of fallout from nuclear weapons testing in the atmosphere, as well as tritium concentrations that do not appear to differ between the precipitation and atmospheric moisture samples, the source of tritium measured in precipitation and atmospheric moisture is most likely of natural origin and past nuclear tests, and not from INL Site releases (DOE-ID, 2022a).

5.4 Program Goals

The primary aim of precipitation and atmospheric sampling is to obtain data about the concentration of tritium in the environment to:

- Assess impacts to public health and the environment
- Verify that radiological doses related to the precipitation and atmospheric moisture exposure pathways are quantifiable and as low as reasonably achievable as required by DOE-HDBK-1216-2015 (DOE 2015)
- Provide baseline data to quantify contaminant level changes caused by fugitive or accidental releases of INL Site radiological materials.

The results of environmental surveillance will demonstrate if radionuclides have been transported off-Site and provide data to assess the impacts to human populations.

5.5 Sampling Boundaries

The logistics of implementing the program objectives involves the consideration of spatial and temporal limits, as well as a consideration of practical constraints. The DOE regulatory guidance for environmental surveillance, as presented in DOE (2015), addresses the dose to an individual at the INL Site Boundary and a 50-mile population. For this reason, the regional tritium precipitation and atmospheric moisture surveillance program focuses on the area within 50 miles of any site facility, particularly in areas that are in the predominant downwind direction of the Site (Figure 31). It considers long-term meteorology and receptor populations.

Releases from the Site can occur at any time during the year. For this reason, precipitation and atmospheric moisture sampling is conducted on a continual basis. The average mean detectable activity in tritium for precipitation and atmospheric moisture in environmental surveillance samples was 5.25E-8 µCi/mL (ISU 2011).

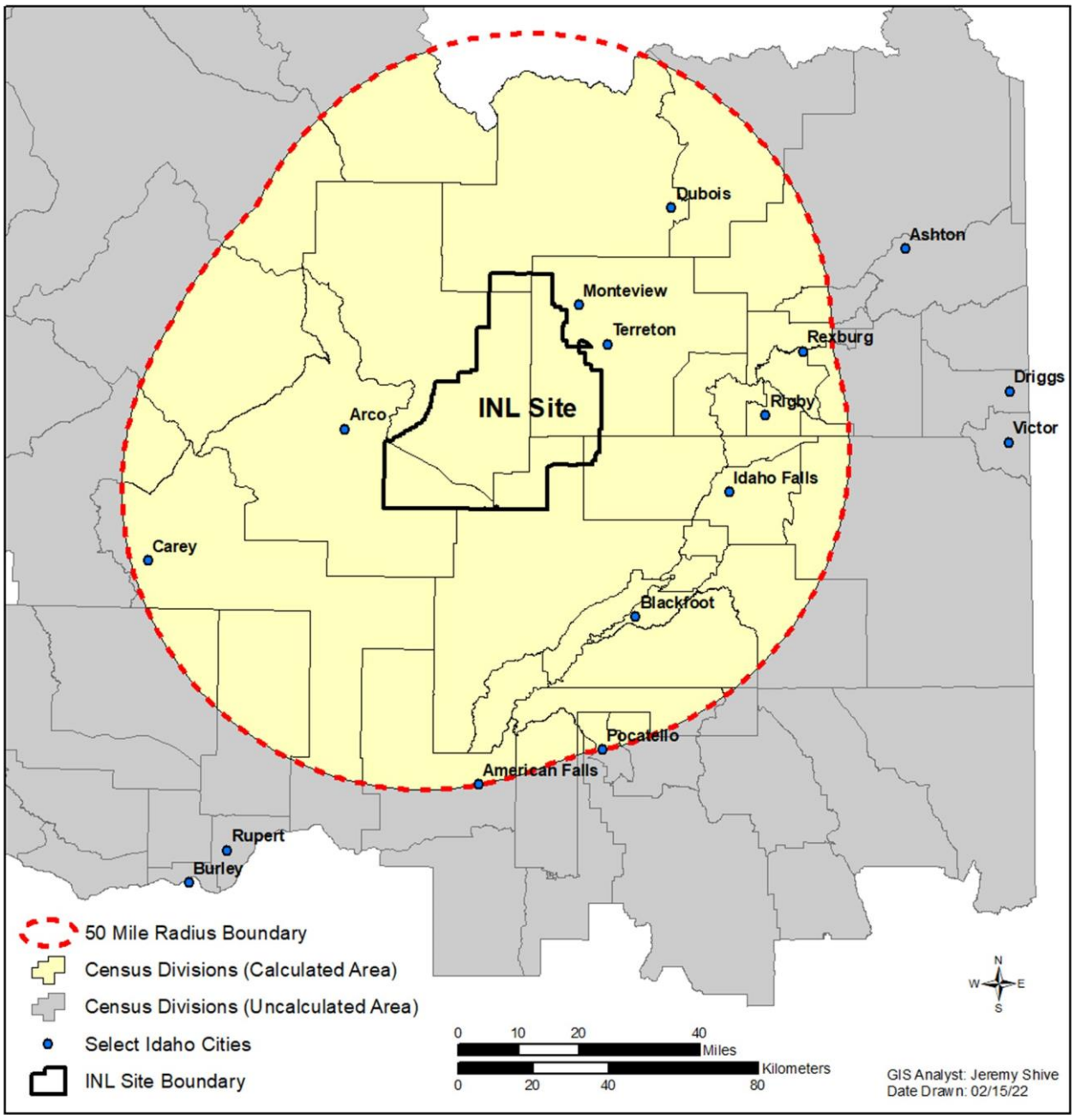

Figure 31. The region within 80 km (50 miles) of INL Site facilities. Census divisions used in the 50-mile population dose calculation are shown.

5.6 Sampling Design

Atmospheric moisture monitoring and precipitation sampling is conducted in accordance with the criteria of DOE (2015). In addition, the design considers experience with the current environmental surveillance program, results of historical monitoring, and professional judgment.

5.6.1 Sampling Locations

As with air sampling, the INL contractor evaluated potential atmospheric moisture and precipitation sampling locations using the air-dispersion modeling technique documented in Rood and Sondrup (2014). Historical NESHAP data show that most tritium is released from the Advanced Test Reactor (ATR) and the Idaho Nuclear Technology and Engineering Center (INTEC). The airborne concentrations resulting from a unit release of tritium from ATR and INTEC generally reflect southwest-northwest dispersion patterns. The model also demonstrates that the maximum offsite dispersion value is located between the southwest INL Site Boundary and the Great Southern Butte (Frenchmans Cabin); however, no power exists there to run a sampler pump, so it will not be included in the sampling design. Atomic City and Howe are communities that are located downwind of INL Site operations and/or are situated in areas of maximum projected offsite concentrations and close to the INL Site Boundary and will be included in the program. EFS is located onsite downwind of INTEC and ATR. It appears to be within or near the highest projected air-dispersion concentrations making it a good choice for on-Site monitoring. Idaho Falls is a good off-Site location because it does not appear to be impacted by the dispersion of tritium and can easily and readily be accessed by the INL contractor after a precipitation event. The EPA also has a precipitation collector here. Thus, an atmospheric moisture sampler and a precipitation sampler are placed at each of four locations: Atomic City, EFS, Howe, and Idaho Falls. Although there are more particulate air monitoring stations, additional atmospheric moisture and precipitation monitoring stations are not warranted. This is because the calculated dose for INL Site releases is less than 0.1 mrem. While, ideally, the samplers would be placed at each air monitoring station, the additional expense and time needed to collect and process the samples is not justified.

The locations are summarized in Table 23.

Table 23. Sampling locations on and around the INL Site.

Medium	Frequency of	Area of Potential Maximum Impact on the INL Site[a]	Likely Offsite Areas of Potential Background[b]	Areas of Minimum or Unlikely Impact
Precipitation	When collection bottle has 50 mL available	EFS	Howe and Atomic City	Idaho Falls
Atmospheric Moisture	When collection column is saturated	EFS	Howe and Atomic City	Idaho Falls

a. Near to projected location of maximum onsite impact downwind of INTEC and ATR. A particulate air monitor is located here.
b. The projected location of maximum offsite impact (Frenchmans Cabin) has no power available and cannot serve as a monitoring site.

5.6.2 Frequency of Sample Collection

Because of the ubiquitous nature of tritium (Uchrin et al. 1993) and its rapid dissipation, sampling should be conducted constantly. Precipitation sampling is dependent on the amount of rain or snowfall between collection periods. A 50-mL sample is required for laboratory analysis. Rain collection buckets will be checked after each precipitation event in Idaho Falls, because access there is easy and timely.

Distant locations will be checked weekly during the weekly air sample collection. Atmospheric moisture columns will be collected when saturated. Sample duration will range between 2 and 10 weeks, depending upon relative humidity and temperature. The sample columns will be changed when the column is expended as indicated by the color of the indicating molecular sieve, which changes from blue to a buff color when moisture is adsorbed.

5.6.3 Sampling Methods

Environmental tritium can be found in two forms: tritiated molecular hydrogen gas and tritiated water vapor. In terms of exposure potential, tritiated water vapor yields a dose equivalent approximately 25,000 times that of tritium gas for the same concentration (ISO 1975). Thus, air sampling techniques should employ methods that collect moisture from the air (DOE 2015). This is the basis for sampling both precipitation and atmospheric moisture for tritium. The current sampling methods meet this basis.

The INL contractor collects precipitation samples weekly when available at one location on the INL Site (EFS); two at the Boundary locations (Howe and Atomic City); and one at a Distant location (Idaho Falls), will serve as a control or background sample. Precipitation is collected monthly at Idaho Falls for EPA RadNet monitoring (see http://www.epa.gov/radnet) and a subsample is taken by the INL contractor for analysis (DOE-ID 2022a).

Atmospheric moisture is collected to monitor for tritium in air at the following: two on the INL Site (EFS and Van Buren Boulevard); two at the Boundary locations (Atomic City and Howe); and two at Distant locations (Craters of the Moon National Monument and Idaho Falls). The samplers collected moisture from the atmosphere using a column of molecular sieve material contained in the apparatus. A molecular sieve was chosen for its ability to effectively adsorb water vapor at a relative humidity as low as 1% and its ability to retain moisture at elevated temperatures. Air samplers for atmospheric moisture sampling provide a constant airflow through the sample column. An indicating agent that changes color with moisture saturation is included in the molecular sieve to aid the sampler in determining when the sample column is nearing saturation. Air passes through the columns at the rate of 130 standard cubic centimeters per minute (SCCM). Columns are changed when a sufficient quantity of moisture has been collected to obtain a 20-ml sample. This collection frequency may range from 2 weeks during the summer to 10 weeks during cold weather (DOE-ID 2022b).

5.6.4 Analytical Methods

Tritium in water samples is measured using the standard method of counting the sample in a liquid scintillation counter (EPA 1987). The minimum detectable concentration (MDC) is typically <100 pCi/L (or 1E-7 µCi/mL). Another method involves using an electrolytic enrichment method with a much lower MDC of 10 to 14 pCi/L. This is an expensive and time-consuming process. Moreover, the standard method is sufficient to measure background concentrations, historically measured in water samples.

5.7 Quality Assurance

An effective quality assurance (QA) program ensures that the collection of high-quality data is in place. QA programs are detailed in the Environmental Monitoring Services QA Project Plan (QAPjP), which ensures all data collected are of known and defensible quality and meet the requirements of applicable federal and state regulations and U.S. DOE orders, specifically DOE O 414.1D Chg 2, ASME NQA-1-2000 (ASME 2008), EPA QA/R-5 (EPA 2001), and ANSI/ASQC E-4 (ANSI/ASQC 1994). The analytical laboratory participates in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) and performance evaluation tests.

5.8 Decision Limits and Actions

Years of monitoring air moisture and precipitation show that DOE dose limits have never been exceeded or even approached. The surveillance program thus will look for instances when results deviate from historical trends. The following approach will be used to assess new data:

1. Append the results to the data file containing historical results and continue the trend analysis as shown in Figure 30. If a detected concentration of tritium lies outside the projected 95% confidence interval:
    - Determine if the concentration is an anomalous measurement.
    - If verifiable, assess the potential dose to humans using the radionuclide concentration measured minus the average concentration measured in samples collected from locations of minimum potential impact and the dose calculation methodology described in DOE-ID (2014). This is a very conservative calculation.
    - If the estimated dose to humans is above the Action Level of 1 mrem (1% of regulatory limit of 100 mrem), then inform DOE-ID for potential corrective actions.
2. At the end of the year:
    - Determine if the trends are still decreasing.
    - If a trend is increasing, review INL Site source terms and determine, through modelling, if increasing concentrations due to INL Site releases are indicated.
    - Conduct statistical tests to determine if differences exist between tritium in precipitation and atmospheric moisture, and between locations.

If radionuclides are above background and exceed historical levels, assessors will determine whether the concentration is an anomalous measurement by one of the following methods:

- Review of historical monitoring results at that location to see if the measurement is consistent with past monitoring results
- Consulting with other INL Site surveillance components and the Idaho Department of Environmental Quality INL Oversight Program
- Review to determine if this location is affected by recent activities or events
- Review of any other factors that may have contributed to the result.

If the concentration is verified, it may signal the need for further action dependent upon the concentration level and/or a trend showing elevated concentrations over a period of time.

6. EXTERNAL ENVIRONMENTAL RADIATION

6.1 Program Basis

External environmental radiation should be monitored as it is one of the critical pathways of exposure for population groups living within the vicinity of U.S. Department of Energy (DOE) nuclear facilities (Denham 1979). External environmental radiation surveillance is conducted to monitor the critical environmental pathways identified in Sections 2.1, "Air," and 2.3, "Soil;" and presented in Figure 7 and Figure 14, respectively. Direct radiation monitoring is also a more feasible approach to determining the impact of short-lived gases rather than by sampling and analysis (DOE 2015). That is, any large increase in the release of short-lived gases, or any other radionuclide from INL Site facilities could be correlated with increases in exposure rates. Although historical measurements generally show that background levels and DOE regulatory limits are not exceeded in the environment around the INL Site, monitoring direct radiation with environmental dosimeters is relatively easy, inexpensive, and provides usable confirmatory data. It is also useful for determining natural external radiation from terrestrial and cosmic sources. External environmental radiation monitoring personnel perform semi-annual external exposure monitoring (DOE-ID 2010a) to meet the recommendations set forth in DOE-HDBK-1216-2015 (DOE 2015).

6.2 Program Drivers

External-exposure monitoring is performed on and around the INL Site to meet the following regulatory requirements and guidance for environmental surveillance of DOE facilities:

- DOE O 458.1.

Other key drivers include:

- Public perception
- Stakeholder inputs and values
- Nearest resident receptor locations.

6.3 Results of Related Studies/Surveillance

Measurements of the dose from operations at the INL Site have been conducted since 1951. The equipment used to measure the dose has developed and changed with technology improvements. During normal operations performed at the INL Site, dose to the public has been almost immeasurable as compared to background environmental radiation. Because background environmental dose varies depending on site specific factors, such as elevation and soil types, measurements of dose at facilities will be compared with historical measurements at these facilities to determine whether changes have occurred. The following summarizes the technology development and typical results.

Background 24-hour readings of external exposure were first made in 1951 across the INL Site using small, detachable ionization chambers installed at the Experimental Breeder Reactor I (EBR-I) Site, Central Facilities Area (CFA), and the Meteorological Station at Midway (Singlevich et al. 1951).

Intermittent testing of film badges began in 1959, and a continuous program started in 1960 (AEC 1960). Badges were placed at 118 locations along highways traversing the INL Site and at various agricultural areas in the surrounding perimeter. The badges were collected and read monthly. The average total dose for the year was <160 mrem for gamma radiation from all sources of radiation, including terrestrial and cosmic.

Film badges were replaced by thermoluminescent dosimeters (TLDs) during the fourth quarter of 1966 (AEC 1966). At each monitoring location, a dosimeter containing five individual Harshaw TLD-700 chips was placed 1 m above the ground. TLDs measure penetrating radiation (e.g., gamma plus beta radiation >200 keV). TLDs were chosen as a better measurement method of long-term low-dose accumulation.

In 2010, testing of the optically stimulated luminescence dosimeter (OSLD) manufactured by Landauer, Inc., began at locations On-Site. The OSLD also measures ambient ionizing radiation. OSLDs and TLDs are similar in that both dosimeters respond to the absorption of energy from ionizing radiation by trapping electrons that are excited to a higher energy band. However, unlike TLDs, where exposure to heat releases these electrons, the trapped electrons in the OSLD are released by exposure to green light from a laser.

A comparative field study of TLDs and OSLDs occurred at the INL Boundary and Distant sampling locations beginning 2012. During the first year, there was a high correlation between the TLD and OSLD results, although there was a small bias attributed to differences in the technology use (DOE-ID 2013, Appendix B).

Monitoring results from the Direct Radiation Program have consistently shown since inception that the measured radiation near the INL Boundary and at Distant locations is indistinguishable from background radiation calculated from terrestrial and cosmic sources (see Section 7.3 in the 2013 ASER as an example, DOE-ID 2014). This indicates that INL Site operations do not contribute any measurable amount of radiation dose at those Boundary or Distant locations. Monitoring at locations within the INL Site boundary primarily shows similar results; measured radiation is indistinguishable from background. At some monitoring locations immediately adjacent to facilities on the desert, such as the northeast corner of Idaho Nuclear Technology and Engineering Center (INTEC) (ICPP O-27 and ICPP O-28),and east of Radioactive Waste Management Complex (RWMC) (RWMC O-41), results consistently show either elevated or slightly elevated radiation measurements. These elevated measurements have been attributed to previous wind-blown deposition or to temporary activities inside the facilities (see DOE ASERs).

Appendix C of Data Quality Objectives Supporting the Environmental Direct Radiation Monitoring Program for the Idaho National Laboratory Site Revision 2 presents the direct radiation monitoring results for all monitored locations beginning with calendar year 2012 (INL 2022). Results from earlier years are available in previous Annual Site Environmental Reports (ASERs).

6.4 Program Goals

The overall goal of the Environmental Direct Radiation Monitoring Program is to determine the radiation dose in areas where the public and non-affected workers may be present and potentially affected by radiation from INL activities and ascertain if this dose is within the historical trends for the applicable areas. This requires not only external radiation monitoring around specific facilities, but also on the INL Site Boundary and at Distant locations up to 50 miles outside of the INL Site boundary to assess the movement of radioactive contaminants.

6.5 Sampling Boundaries

The sampling boundaries for the External Environmental Radiation Monitoring Program were determined in *Data Quality Objectives (DQOs) Supporting the Environmental Direct Radiation Monitoring Program for the Idaho National Laboratory Site* (INL 2015). Boundaries include both the physical and temporal boundaries.

External environmental radiation monitoring is used to determine the radiation dose from INL Site activities. The area of interest is limited to areas within the INL Site boundary and a 50-mile radius extending from the Site boundary per DOE guidance (DOE 2015). This area of interest has been divided into three regions and then further divided into smaller areas within each of the regions to ensure that any concerning dose measurements are properly identified. The three regions are:

- On-Site Region: Areas on the desert west of Idaho Falls and INL facilities located within Idaho Falls
- Boundary Region: At or near the Site boundary
- Distant Region: Limited to a 50-mile radius of the Site.

The regions are discussed in detail in *Data Quality Objectives (DQOs) Supporting the Environmental Direct Radiation Monitoring Program for the Idaho National Laboratory* (INL 2022) along with identifying individual sampling locations within each sampling area. The On-Site Region is further divided into sampling areas for those facilities that are within the INL Site boundary. The direct radiation DQO includes the handling of monitoring results from DOE facilities in Idaho Falls with On-Site monitoring. The Distant Region is subdivided into sampling areas by cities within that region. The three regions and associated sampling areas are shown in Figure 32 for On-Site Region located at the INL Site, Table 24 for areas within each of the three primary sampling regions and Figure 33 for Boundary and Distant locations.

The temporal boundaries for the external environmental radiation monitoring are encompassed by the time between the first dose measurements collected at a facility, which may have been as early as the 1960s, up until the dose is no longer measured under this program. External environmental radiation monitoring will continue as long as the site is operational under DOE. This is likely to be as long as

100 years into the future. The number of monitoring locations at a specific sampling area and the length of time that a particular sampling area is measured can vary depending on changes in conditions or activities in that particular sampling area.

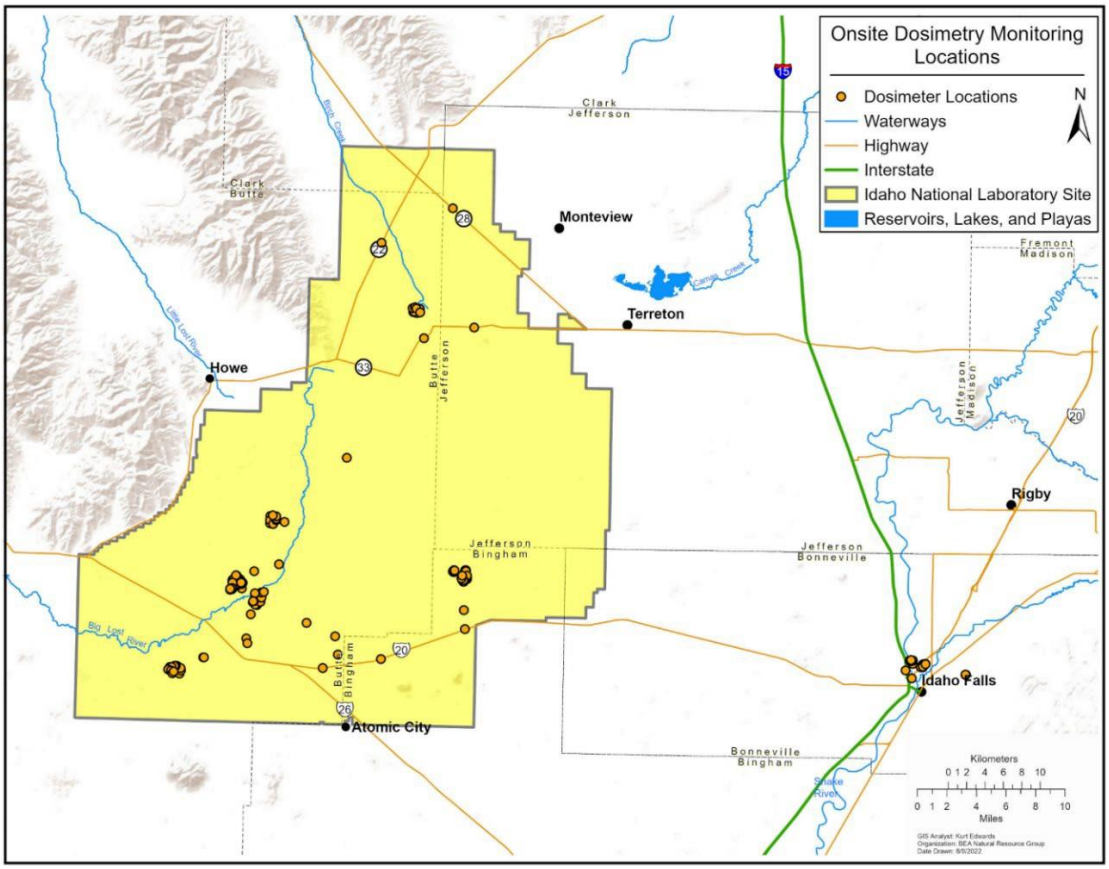

Figure 32. Sampling areas included within the On-Site Region, located at the INL Site.

Table 24. Sampling areas within each of the three primary sampling regions.

Areas Within the Site Boundary and in Idaho Falls	Areas Near the Site Boundary	Areas Outside of the Site Boundary
ARA[e]	Arco	Aberdeen
ATR[e]	Atomic City	Blackfoot
CFA[e]	Birch Creek Hydro[b]	Craters of the Moon[c]
EBRI[e]	Blue Dome	Dubois
EFS[e]	Howe	Jackson
Haul E	Monteview	Minidoka[d]
Haul W	Mud Lake	Roberts
Highway 20	RRL3[e] Frenchmans Cabin	Sugar City
Highway 22	RRL5[e] East Butte	—
Highway 28	RRL6[e] Grant Road	—
Highway 33	RRL17[e] Monteview	—
INTEC[e]	RRL24[e] Howe	—
Lincoln Boulevard	—	—

Areas Within the Site Boundary and in Idaho Falls	Areas Near the Site Boundary	Areas Outside of the Site Boundary
MFC[e]	—	—
NRF[e]	—	—
PBF[e]	—	—
RHLLW[e]	—	—
RWMC	—	—
SMC[e]	—	—
TREAT[e]	—	—
IF-603[e] (IRC)[a, e] IF-616 (WCB)[a, e] IF-627 (SAF)[a, e] IF-638 (Physics Building)[a, e] IF-665 (CAES)[a, e] IF-670 (BCTC)[a, e] IF-675 (PINS)[a, e] IF-688B[a, e] IF-689[a, e] IF-IDA[a, e] IF-IRC[a, e] Idaho Falls[a, c] O-10		

a. Facility located in Idaho Falls.
b. Also known as Reno Ranch.
c. Background location.
d. Also known as the Idaho Youth Ranch.
e. Acronyms: ARA: Auxiliary Reactor Area, ATR: Advanced Test Reactor, BCTC: Bonneville County Technology Center, CFA: Central Facilities Area, CAES: Center for Advanced Energy Studies, EBRI: Experimental Breeder Reactor I, EFS: Experimental Field Station, IF: Idaho Falls, IF-IDA: NOAA/INL Mesonet location, INTEC: Idaho Nuclear Technology and Engineering Center, IRC: INL Research Center, MFC: Materials and Fuels Complex, NRF: Naval Reactors Facility, PBF: Power Burst Facility, PINS: Portable Isotopic Neutron Spectroscopy, RHLLW: Remote-Handled Low Level Waste, RWMC: Radioactive Waste Management Complex, SAF: System Analysis Facility, SMC: Specific Manufacturing Capability, TREAT: Transient Reactor Test (TREAT) Facility, RRL: resident receptor location, WCB: Willow Creek Building.

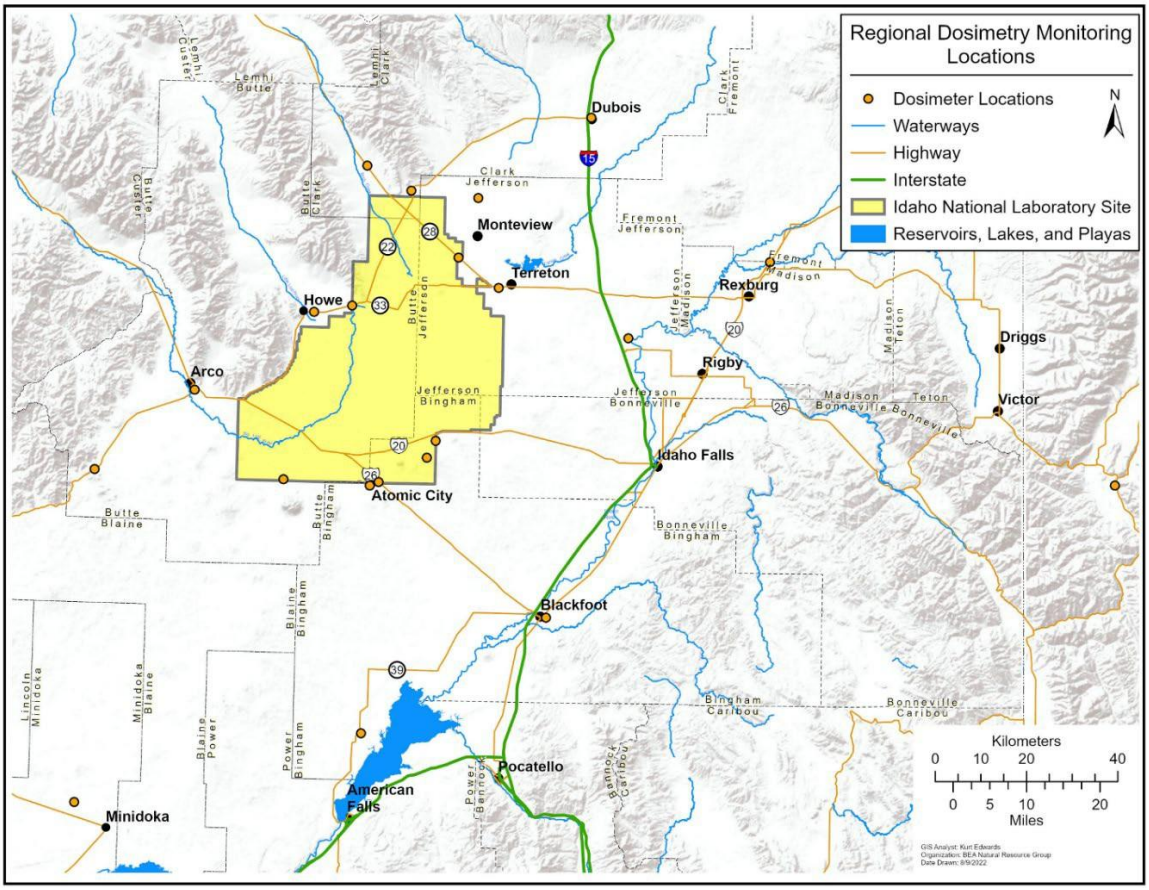

Figure 33. Boundary and Distant sampling areas.

6.6 Sampling Design

6.6.1 Sampling Locations

There have been changes in direct radiation monitoring locations over time as facility mission and operations have changed. Boundary and Distant locations have been more consistent, in part because On-Site locations were changed as facility use changed. The number and location of dosimeters for monitoring external radiation were determined in *Data Quality Objectives (DQOs) Supporting the Environmental Direct Radiation Monitoring Program for the Idaho National Laboratory* (INL 2022).

The number of samples required within specific sampling areas was determined based on the proximity of the area to radiological activities, the ability to compute appropriate statistical measures, and the physical characteristics of the location. Required minimum number of samples for the various types of facilities and locations are as follows:

- Sampling areas that are used to monitor On-Site facilities where radiological activities are taking place require a minimum of eight sampling locations, not including duplicates. Eight samples are required to compute and maintain an upper tolerance limit for the area. Area characteristics or other motivators may indicate that more than eight monitoring locations are warranted.
- Sampling areas that are not close to radiological activities, either within the INL Site boundary or outside of the INL Site boundary, may be maintained with one monitoring location. It may be merited to place more than one dosimeter at such areas because of physical characteristics, historical information, public interest, or other reasons.

The previous paragraphs provide a minimum number of monitoring locations for each type of sampling area, but do not indicate where dosimeters should be located or how to determine if more than the minimum number is warranted.

HDBK-1216-2015 states, “Selection of the indicator locations for external exposure monitoring should be based on expected sources of external radiation—noble gas plumes, soil-deposited atmospheric particulates released from the site, On-Site radiation-generating facilities or large radiation sources, or potential routes of waste transport from the site—and the local population distribution and prevailing wind directions” (DOE 2015).

Data Quality Objectives (DQOs) Supporting the Environmental Direct Radiation Monitoring Program for the Idaho National Laboratory (INL 2015) presents a methodology for determining sample locations and also presents the chosen sampling locations for each sampling area. Consideration was given to the following factors when determining sampling locations:

- Location of radiation sources
- Location of highest potential dose
- Prevailing wind directions
- Knowledge of facility features and activities
- Presence of low volume air monitoring locations
- Proximity to INL transportation routes
- Location suitable for background readings
- Location Distant from INL that has potential for impact from INL radiation.

Additional sampling locations may be added to the current list as new programs are established at the INL or if a specific event occurs that warrants additional sampling. Existing sampling locations may be modified if the above listed factors for an area or location change. The above listed sample size justification and location methodology will be used for additional areas or for the reassessment of existing areas, if necessary.

6.6.2 Frequency of Sample Collection

The criteria in DOE-HDBK-1216-2015 (DOE 2015) state that dosimeters should be exposed long enough, typically one calendar quarter, to produce a readily detectable dose. All external environmental radiation dosimeters will continue to be collected biannually to allow for a long-term, low-dose accumulation.

6.6.3 Sampling Methods

At each monitoring location, dosimeters are placed 1 m above the ground and suspended to prevent shielding from the post. The date and time of placement are recorded for the dosimeters (OSLD/neutron) when deployed. After the approximately 6-month sampling interval, the dosimeters are collected, and the date and time of collection are recorded.

6.6.4 Analytical Methods

Dosimeters collected from On-site, Boundary, or Distant locations, are sent to Landauer, Inc., for reading.

6.7 Quality Assurance

An effective quality assurance (QA) program ensures that the collection of high-quality data is in place. QA programs are detailed in the Offsite Environmental Surveillance Program QA Project Plan (QAPjP). This plan ensures that all data collected are of known and defensible quality and meet the requirements of applicable federal and state regulations and U.S. DOE orders, specifically DOE O 414.1D Chg 2, ASME NQA-1-2000 (ASME 2008), EPA QA/R-5 (EPA 2001), and ANSI/ASQC E-4 (ANSI/ASQC 1994).

6.8 Decision Limits and Actions

The approach to defining decision limits and actions is documented in *Data Quality Objectives (DQOs) Supporting the Environmental Direct Radiation Monitoring Program for the INL Site* (INL 2022). A summarization of the approach is presented in the paragraphs that follow.

The trend for each sampling area will be estimated using appropriate control charts depending on the number of measurements collected in the applicable sampling area. Figure 34 provides an example of Control Charts for the RWMC O-41 location. The various charts establish a baseline and upper and lower limits. For sampling areas where only one measurement is collected, a moving range chart will be constructed for the same purpose.

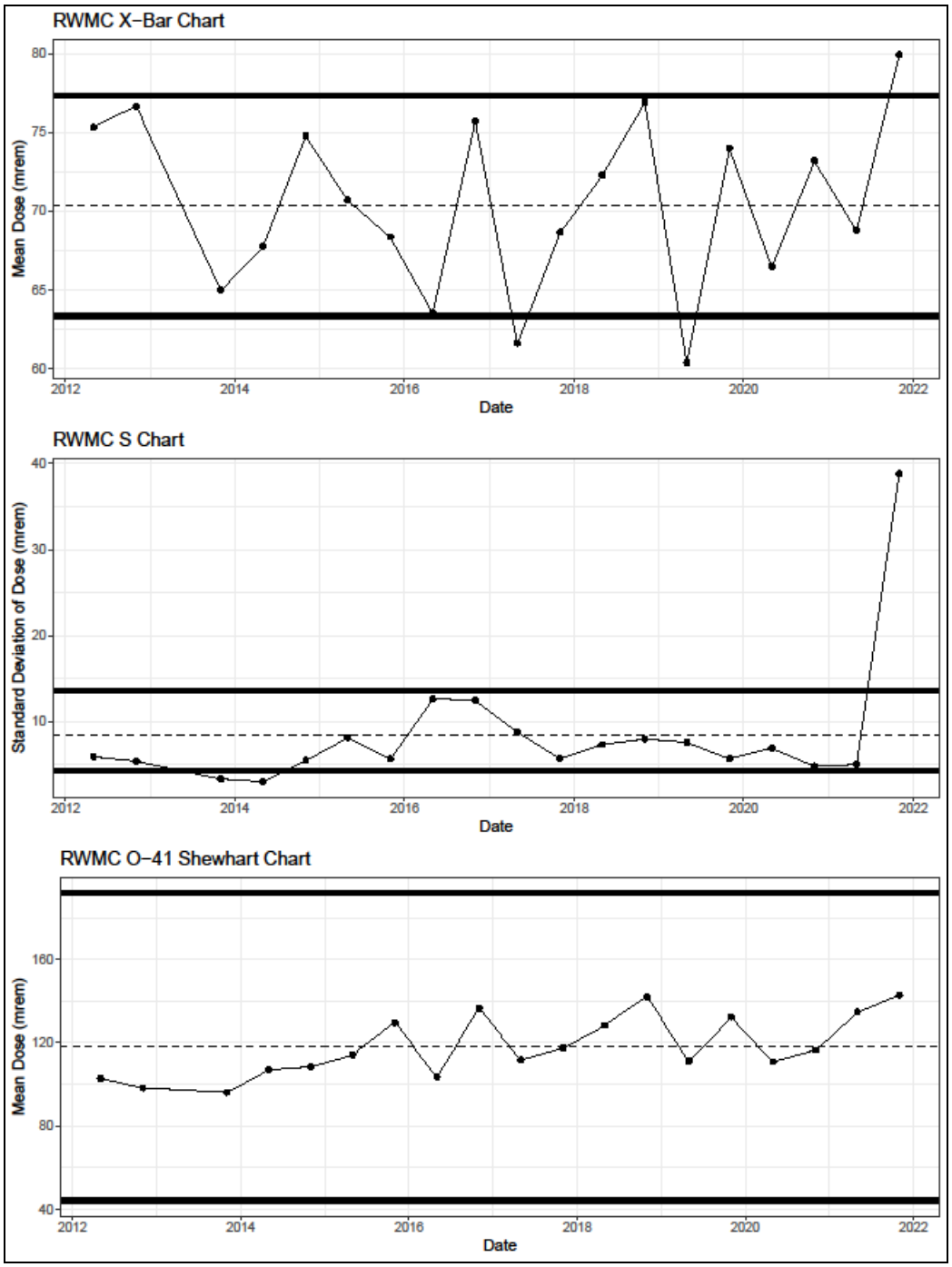

Figure 34. Example Control Charts for location RWMC O-41.

The 95th percentile of the background values will be estimated using a 95%/95% upper tolerance limit calculation of background values. The background calculation is an estimate that is anticipated to be greater than 95% of the population with 95% confidence. It provides a threshold value for individual measurements that can quickly alert data users to potentially high readings of dose. Historical data has been used to compute a 95%/95% background value for each sampling area. Background values are presented in Table 25. It is important that a background value is sampling area-specific because each sampling area can have very different dose levels.

The following actions will be taken for changes in trend scenarios:

- If a single dose measurement is greater than the 95th percentile for that sampling area (as measured by the 95%/95% background value), then the measurement will be closely examined in the context of the other measurements obtained in that sampling area, activities in the area since the previous sampling event, and the control charts used to map the trend for that sampling area. This information will be used to provide context for the measurement and determine whether it is truly a cause for concern. Otherwise, the measurement will be considered within the normal variation of doses for that subunit.
- If the mean or variation of doses for one or more sampling areas exceed the control limit for the associated control charts, or if the trend is within bounds and indicates the process may be out of control, trends for the other sampling areas, including the background, will be examined to provide additional context for the change in trend. Information about the sampling area that may affect the dose readings will also be obtained and examined to provide context for the change in trend. The comprehensive set of information will be used to determine what, if any, additional action is needed.
- Neutron monitoring at town locations is performed specifically at facilities with the potential to emit neutrons or facilities where neutrons are generated. These facilities in Idaho Falls are IF-675 (Portable Isotopic Neutron Spectroscopy System [PINS]), IF-670 (Bonneville County Technology Center [BCTC]), IF-652A (Lindsay Building), and adjacent to IF-638 (Physics Laboratory). Because the background level for neutrons is essentially zero, any detectable neutron dose would be considered a reason for further investigation.
- On-Site neutron dose monitoring occurs at the Transient Reactor Test (TREAT) facility.

Table 25. Direct radiation 6-month background values for areas within the INL Site boundary.

Area	Background Value (UTL in mrem)	Area	Background Value (UTL in mrem)
Within INL			
ARA	80.2	IF-670	67.1
ATR	121	IF-675 (PINS)	63.0
CFA	81.3	IF-688	62.6
EBR I	91	IF-IDA	62.7
EFS	81.0	IF-IRC	67
Haul E	80.6	INTEC	146.9
Haul W	83.8	INTEC SW	347
Hwy 20	76.7	INTEC NE	230.2
Hwy 22	68.1	Lincoln	83.3
Hwy 28	64.5	MFC	87.5
Hwy 33	71.0	NRF	79.2
Idaho Falls	71.5	PBF	79.6
IF-603	61.8	RHLLW	80.5
IF-616	74.6	RWMC	88

Area	Background Value (UTL in mrem)	Area	Background Value (UTL in mrem)
IF-627	65.2	RWMC O-41	154.0
IF-638	66.4	SMC	79.8
IF-665	66.2	TREAT	81.4
Boundary			
Arco	74.0	Frenchmans Cabin	73.4
Atomic City	74.0	Grant Road	81.2
Birch Creek Hydro	65.2	Howe	67.4
Blue Dome	63.9	Monteview	72.0
East Butte	104	Mud Lake	77.2
Outside INL			
Aberdeen	77.1	Jackson	71.5
Blackfoot	66.1	Minidoka	65.8
Craters of the Moon	75.3	Roberts	79.2
Dubois	62.6	Sugar	88.9

7. SURFACE AND DRINKING WATER

7.1 Program Basis

The surface water and groundwater pathways to humans are not considered to be the critical dose pathways from the Idaho National Laboratory (INL) Site (see Section 2.2). However, the public perceives drinking water and surface water to be, after air, two of the most important surveillance media to be monitored (MWH 2002). For this reason, off-Site surface and drinking water should be sampled.

Off-Site and on-Site surface water is collected when available from natural and man-made sources such as rivers, streams, ponds, lakes, or irrigation sources. Drinking water is collected from a municipal water source that has been through a water treatment facility or a well (Mud Lake) used for drinking water. In southeastern Idaho, the public/drinking water source is primarily derived from groundwater.

On-Site drinking water is sampled at specific drinking water/production wells and distribution/manifold systems for analytes and frequencies driven directly by state and federal regulations, per the Safe Drinking Water Act. Drinking water parameters are regulated by the State of Idaho under authority of the Safe Drinking Water Act (40 CFR 141; 40 CFR 142). Parameters are sampled according to a 9-year monitoring cycle, which identifies the specific classes of contaminants to monitor at each drinking water source, and the frequency. Parameters with primary maximum contaminant levels (MCL) must be monitored at least once every three years. Parameters with secondary maximum contaminant levels (SMCLs) are monitored every three years based on a recommendation by the United States (U.S.) Environmental Protection Agency (EPA) (40 CFR 143). Many parameters require more frequent sampling during an initial period to establish a baseline; subsequent monitoring frequency is determined from the baseline results.

7.2 Off-Site Program Drivers

Environmental surveillance monitoring of radioactivity in surface and drinking water is performed on and around the INL Site to meet the following regulatory requirements and guidance for environmental surveillance of U.S. Department of Energy (DOE) facilities:

- DOE O 458.1 (DOE 2011)
- DOE-HDBK-1216-2015 (DOE 2015).

Other key drivers include:

- Public perception regarding where and what to monitor
- Stakeholder inputs and values
- Potential environmental risks posed by contaminants originating from the INL Site.

7.3 On-Site Program Drivers

All active INL drinking water systems (i.e., potable water supplied to personnel) are sampled according to their classification as required to show compliance with regulations. Sampling, data analysis, data management, and analytical results are managed in compliance with the applicable regulations listed in the following:

- 40 CFR 141, "National Primary Drinking Water Regulations"
- 40 CFR 142, "National Primary Drinking Water Regulations Implementation"
- 40 CFR 143, "National Secondary Drinking Water Regulations"
- 42 U.S.C. § 300f et seq., "Safe Drinking Water Act (1974)"
- DOE O 458.1, "Radiation Protection of the Public and the Environment" (2011)
- IDAPA 58.01.08, "Idaho Rules for Public Drinking Water Systems" (2022).

7.4 Off-Site Related Studies/Surveillance

Two main sources of water could potentially be contaminated from activities on the INL Site: (1) the Eastern Snake River Plain Aquifer (ESRPA), and (2) the Big Lost River (BLR). The ESRPA is a primary source of regional drinking water and supplies irrigation water to a large, regional agricultural and aquaculture economy. Most of the basalt lava flows that host the aquifer and comprise the overlying vadose zone are very porous and permeable. The subsiding Eastern Snake River Plain (ESRP) and the high elevations of the surrounding recharge areas comprise a large drainage basin that receives enormous amounts of precipitation and feeds high-quality groundwater into the aquifer. Numerous studies suggest the hydraulic gradient of the ESRPA is to the south/southwest (Figure 35), with velocities ranging from 0.5 to 6.1 m/day (2 to 20 ft/day) (DOE-ID 2011). This velocity is much faster than most studied aquifers and is attributed to the ESRP architecture and porous media.

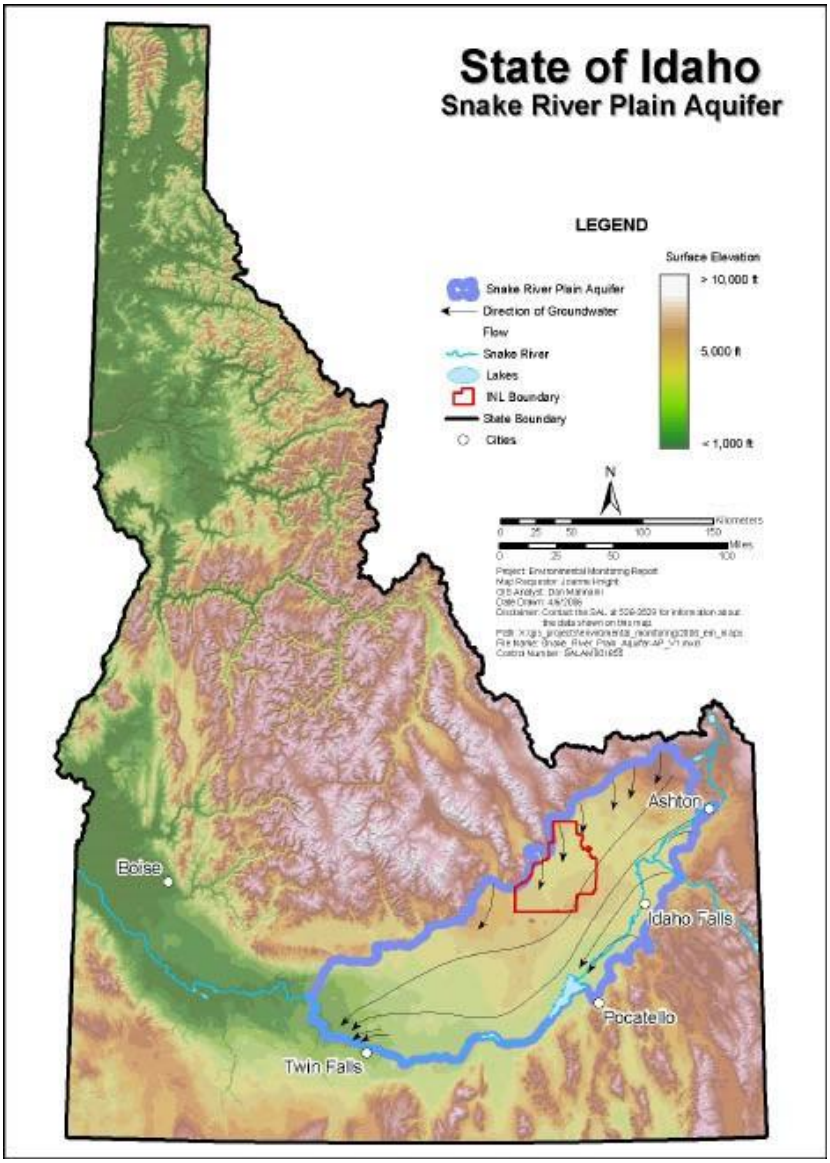

Figure 35. Location of INL Site in relation to ESRPA.

Historic waste-disposal practices have produced localized areas of contamination in the ESRPA beneath the INL Site (DOE-ID 2011). Idaho Nuclear Technology and Engineering Center (INTEC) used direct injection as a disposal method up to 1984. This wastewater contained elevated concentrations of tritium, strontium-90, and iodine-129. Injection at INTEC was discontinued in 1984, and the injection well sealed in 1989. When direct injection ceased, INTEC wastewater was directed to shallow percolation ponds where the water infiltrated into the subsurface. Disposal of low- and intermediate-level radioactive waste solutions to the percolation ponds ceased in 1993 with the installation of the Liquid Effluent Treatment and Disposal Facility. The old percolation ponds were taken out of service and closed. The new INTEC percolation ponds went into operation in August 2002.

The Advanced Test Reactor (ATR) Complex, formerly known as the Test Reactor Area (TRA) and the Reactor Technology Complex (RTC), also had a disposal well, but primarily discharged contaminated wastewater to a shallow percolation pond. The ATR shallow percolation pond was replaced in 1993 by a flexible, plastic Hypalon-lined evaporative pond to stop the input of radioactive wastewater to groundwater.

Tritium has formed the largest plume of any of the radiochemical pollutants at the INL Site because tritium is equivalent in chemical behavior to hydrogen, which is a key component of water. The configuration and extent of the tritium contamination area, based on the most recently published U.S. Geological Survey (USGS) data, are shown in Figure 36 (Bartholomay et al. 2020). The area of elevated tritium concentrations near the Central Facilities Area (CFA) likely represents water originating at INTEC some years earlier when larger amounts of tritium were disposed. This source is further supported by the fact that there are no known sources of tritium contamination to groundwater at CFA.

Two monitoring wells downgradient of the ATR Complex (USGS-065) and INTEC (USGS-114) have continually shown the highest tritium concentrations in the aquifer over the past 20 years, as can be seen in Figure 37. For this reason, these two wells are considered representative of maximum concentration trends in the rest of the aquifer. The concentration of tritium in USGS-065 near the ATR Complex decreased from 1,600 ± 90 pCi/L in 2020 to 1,380 ± 90 pCi/L in 2021; the tritium concentration in USGS-114, south of INTEC, increased slightly from 3,912 ± 173 in 2020 to 4,280 ± 150 pCi/L in 2021.

The Idaho primary constituent standard for tritium (20,000 pCi/L) in groundwater is the same as the EPA MCL for tritium in drinking water. The values in Wells USGS-065 and USGS-114 dropped below this limit in 1997 as a result of radioactive decay (tritium has a half-life of 12.33 years), ceased tritium disposal, advective dispersion, and dilution within the aquifer. A 2015 report by the USGS (Davis et al. 2015) indicated that water quality trends for tritium in all but one well at the INL Site showed decreasing or no trends, and the well that showed the increasing trend changed to a decreasing trend when data through 2018 were analyzed (Bartholomay et al. 2020).

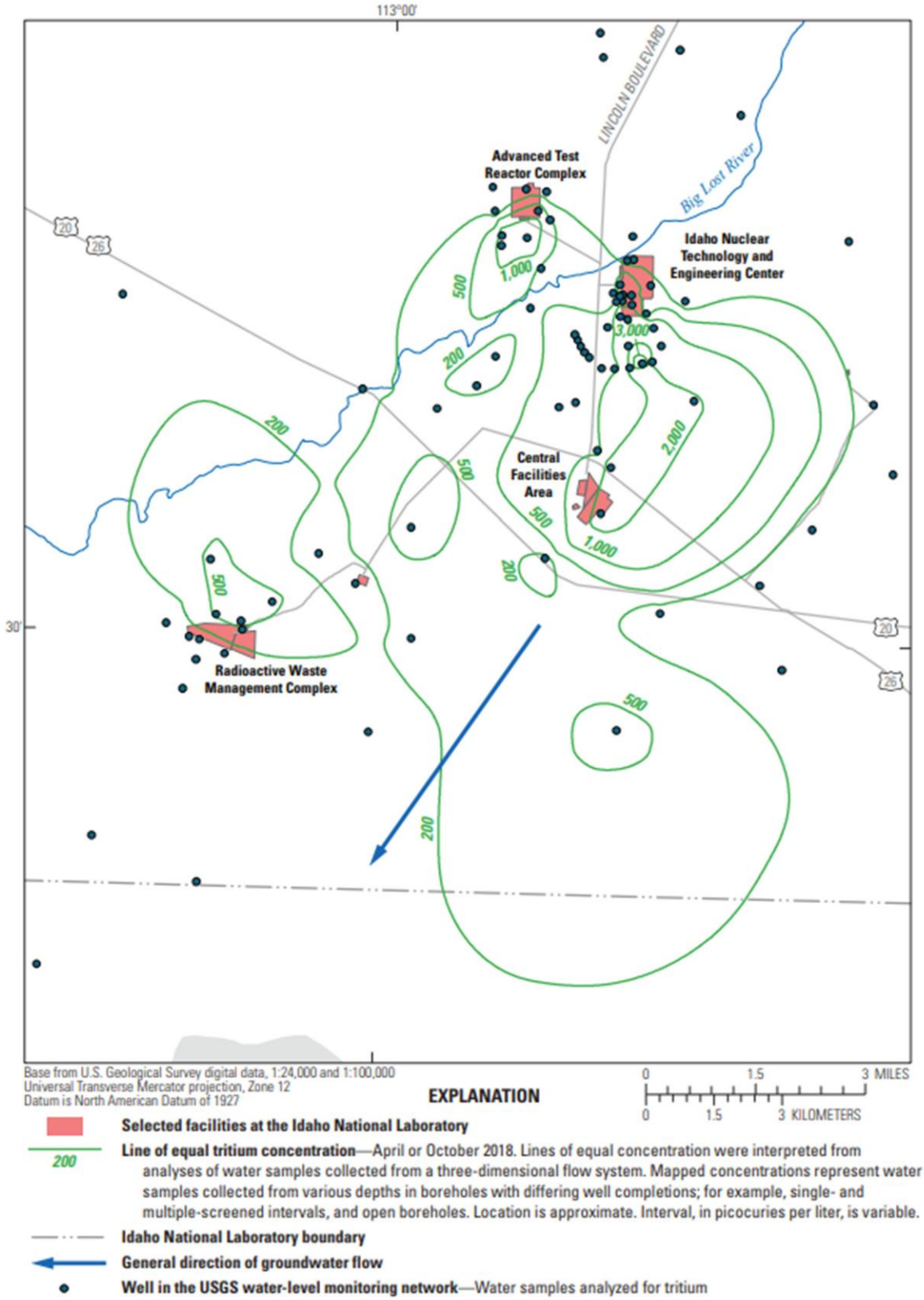

Figure 36. Distribution of tritium in the ESRPA on the INL Site in 2018 (Bartholomay et al. 2020).

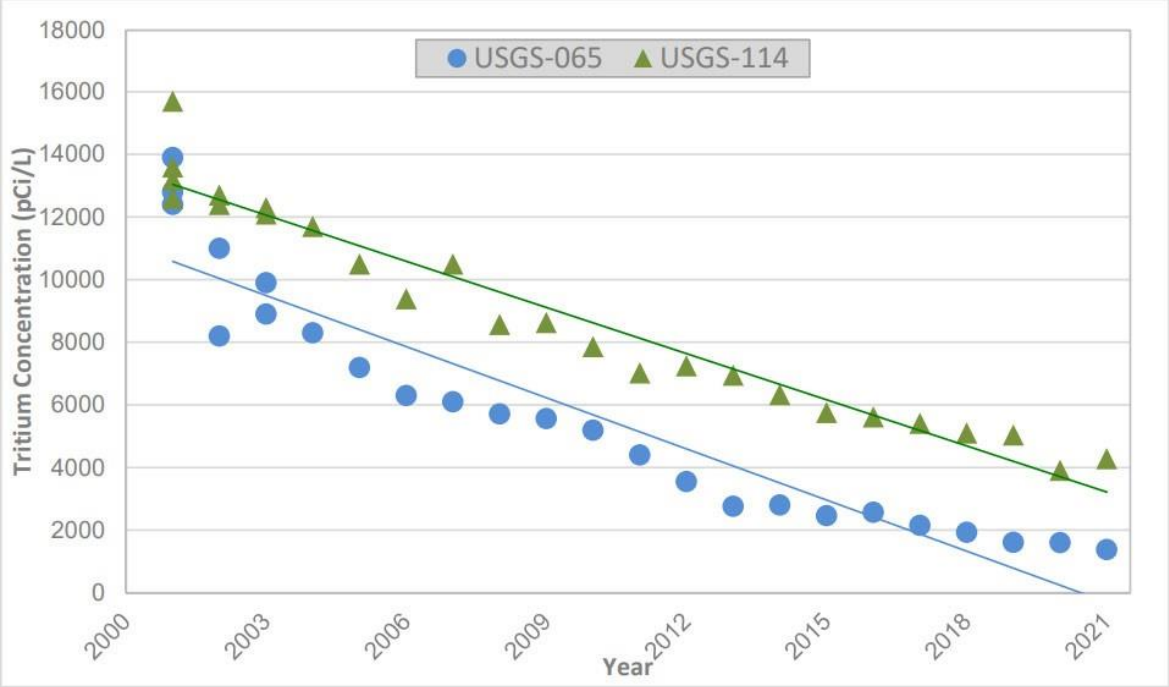

Figure 37. Long-term trend of tritium in wells USGS-065 and USGS-114 (2000-2021) (DOE-ID 2022).

Presently, strontium-90 is the only radionuclide that continues to be detected by the Idaho Cleanup Project (ICP) Core contractor and the USGS above the primary constituent standard in some surveillance wells between INTEC and CFA, and at Test Area North (TAN). The configuration and extent of strontium-90 in groundwater, based on the latest published USGS data, are shown in Figure 38 (Bartholomay et al. 2020). The contamination originates at INTEC from the historical injection of wastewater. No strontium-90 was detected by USGS in the ESRPA near the ATR Complex during 2021. All strontium-90 at the ATR Complex was disposed to infiltration ponds, in contrast to the direct injection that occurred at INTEC. At the ATR Complex, strontium-90 is retained in surficial sedimentary deposits, interbeds, and perched groundwater zones. The area of strontium-90 contamination from INTEC is approximately the same as it was in 1991.

The strontium-90 trend over the past 20 years (e.g., 2001–2021) in Wells USGS-047, USGS-057, and USGS-113 is shown in Figure 39. Concentrations in Well USGS-047 have varied through time, but indicate a general decrease. Concentrations in Wells USGS-057 and USGS-113 also have generally decreased during this period. The variability of concentrations in some wells was thought to be due, in part, to a lack of recharge from the BLR that would dilute the strontium-90. Other reasons may include increased disposal of other chemicals into the INTEC percolation ponds, which may have changed the affinity of strontium-90 on soil and rock surfaces, causing it to become more mobile (Bartholomay et al. 2000). A 2015 report by the USGS (Davis et al. 2015) indicated that water quality trends for strontium-90 in all but two perched water wells at the INL Site showed decreasing or no trends.

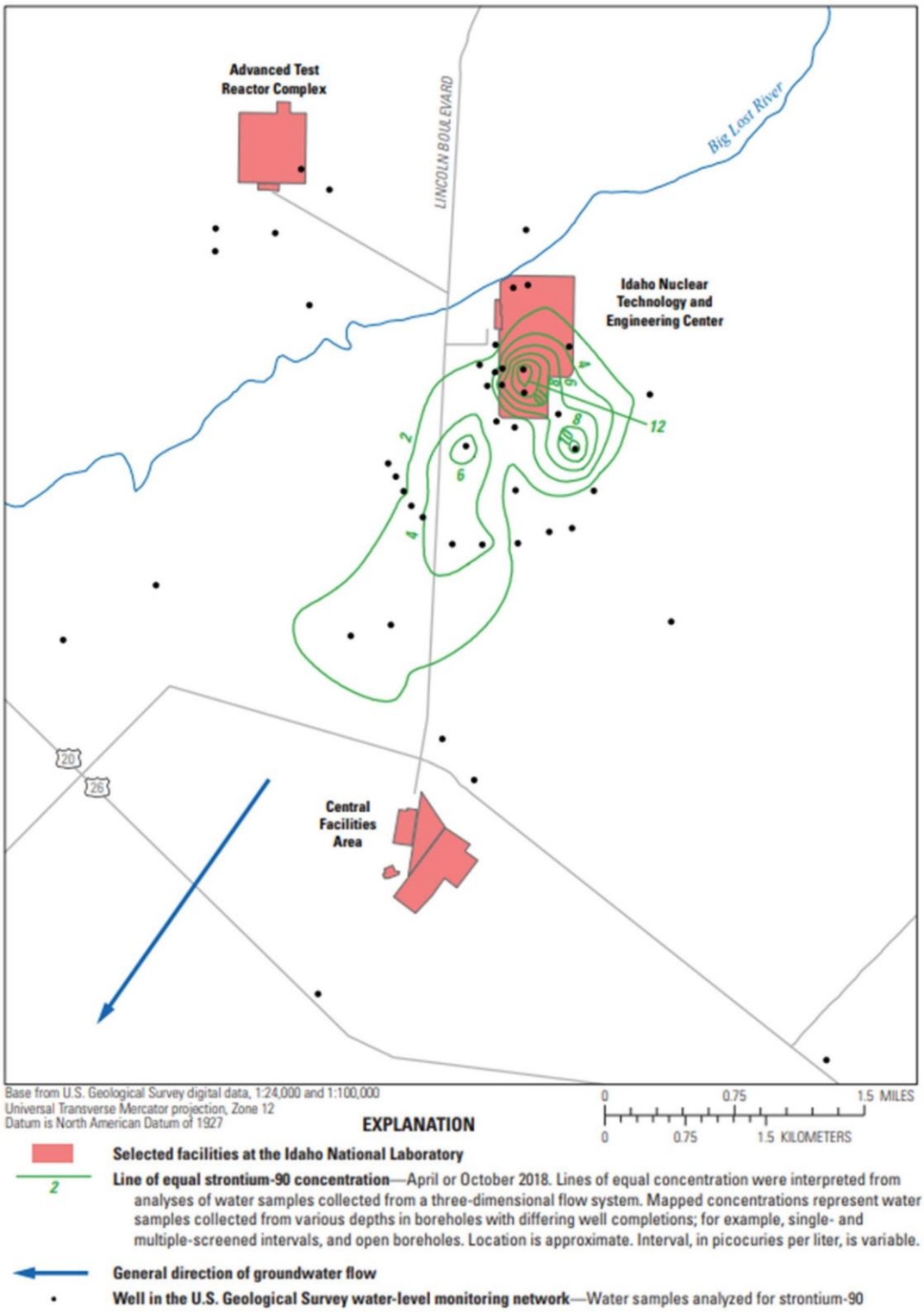

Figure 38. Distribution of strontium-90 in the ESRPA on the INL Site in 2018 (Bartholomay et al. 2020).

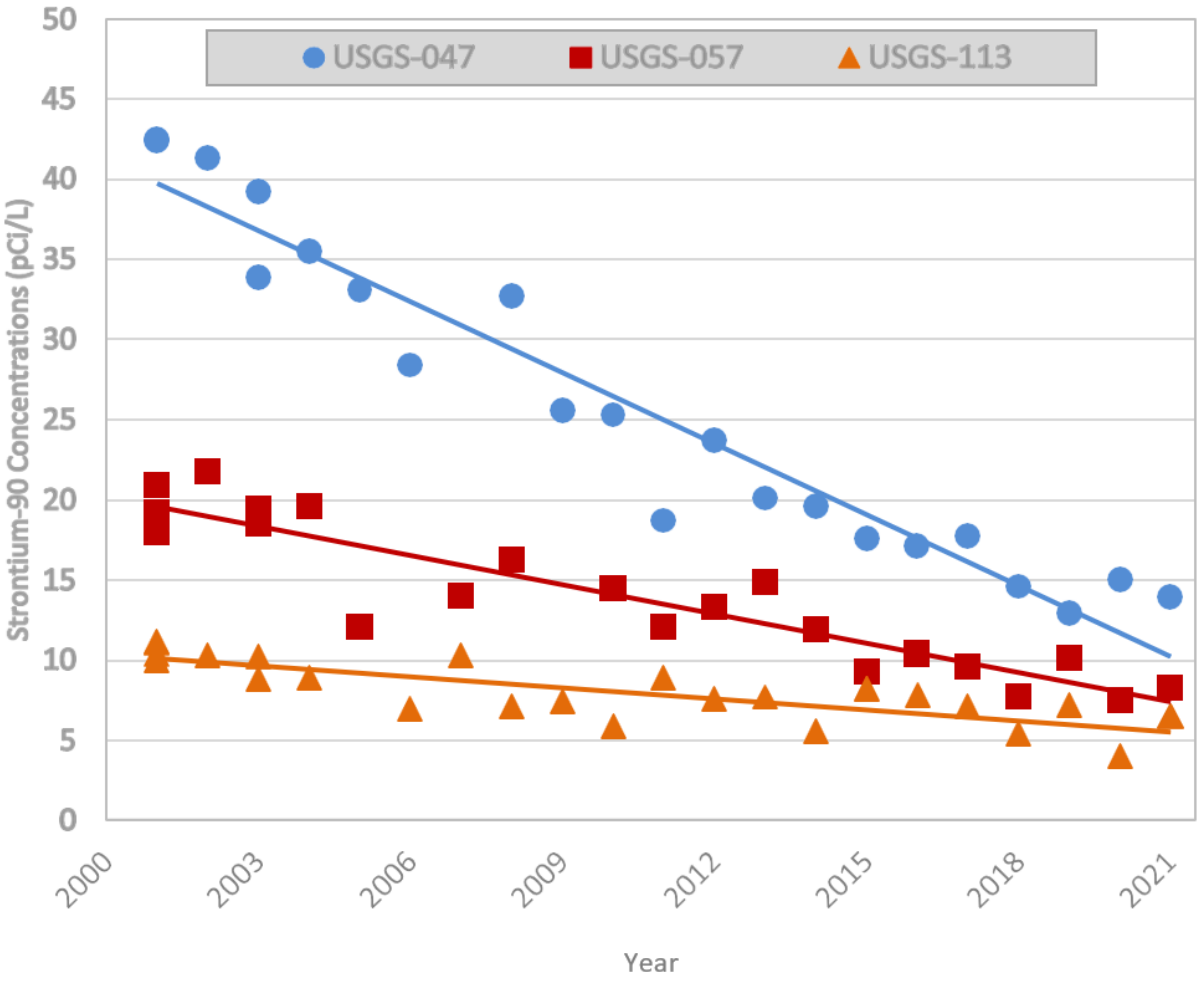

Figure 39. Long-term trend of strontium-90 in wells USGS-047, USGS-057, and USGS-113 (2000-2021) (DOE-ID 2022).

Periodically, the USGS has sampled for iodine-129 in the ESRPA. Monitoring programs from 1977, 1981, 1986, 1990, 1991, 2003, 2007, 2011, and 2012 were summarized in Mann et al. (1988), Mann and Beasley (1994), and Bartholomay (2013). The USGS sampled for iodine-129 in wells at the INL Site in the fall of 2017 and collected additional samples in the spring of 2018. Average concentrations of 15 wells sampled in 1990–1991, 2003, 2007, 2011–2012, and 2017–2018 decreased from 1.15 pCi/L in 1990–1991 to 0.168 pCi/L in 2017–2018. The maximum concentration in 2011 was 1.02 ± 0.04 pCi/L in a monitoring well southeast of INTEC. The concentration in that same well in 2017 decreased to 0.877 ± 0.032 pCi/L. The drinking water standard for iodine-129 is 1 pCi/L. Concentrations around INTEC showed slight decreases from samples collected in previous sample periods, and the decreases are attributed to discontinued disposal, as well as dilution and dispersion in the aquifer. The configuration and extent of iodine-129 in groundwater, based on the 2017–2018 USGS data, are shown in Figure 40 (Maimer and Bartholomay, 2019).

The BLR is an intermittent, ephemeral body of water that flows only during periods of high spring runoff and when the Mackay dam, which impounds the river upstream of the INL Site, releases water. The river enters the INL Site about 7.5 miles west of the public rest stop on U.S. Highway 20/26, flows north through the INL Site, and enters a depression where the water flows into the ground, called BLR Sinks. The river emerges about 100 miles (160 km) away at Thousand Springs near Hagerman and at other springs downstream of Twin Falls. The BLR watershed includes the Little Lost River, BLR, Birch Creek, and associated tributary channels, playas, and sinks. No streams or rivers flow from within the Site to locations outside the Boundary; in most years, the channels of the BLR system on the INL Site are dry.

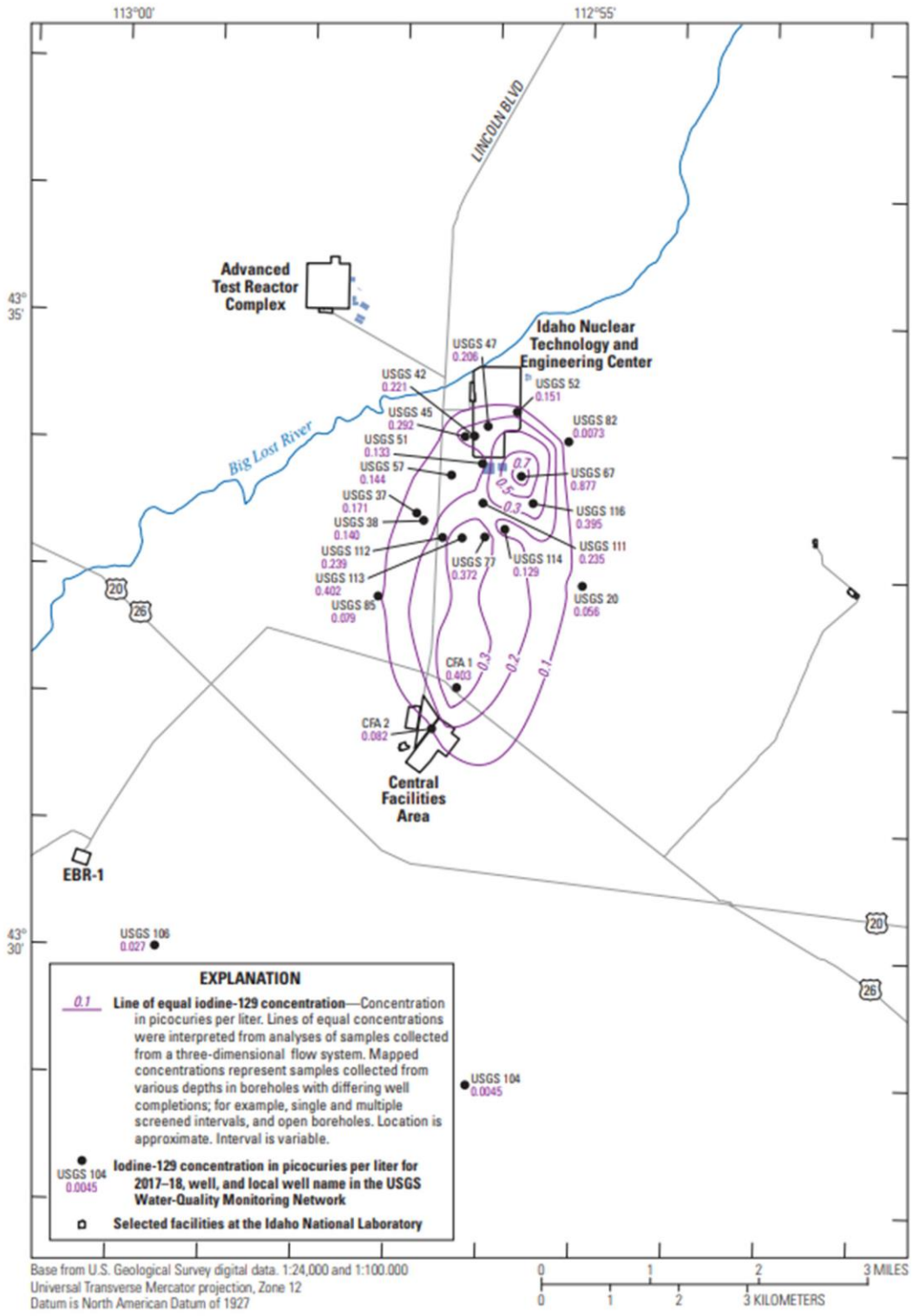

Figure 40. Distribution of iodine-129 in the ESRPA on the INL Site in 2017–2018 (Maimer and Bartholomay 2019).

Initial monitoring of groundwater wells and surface water off the INL Site in surrounding communities was conducted in 1951 to establish an upper limit of natural radioactivity (Singlevich et al., 1951). Samples were obtained in the communities of Midway, Taber, Idaho Falls, Blackfoot, Pocatello, Dubois, Arco, and from wells at farmhouses, particularly in the region between the INL Site and the Snake River in the direction of the Thousand Springs area. In addition, samples were taken in streams, rivers, lakes, and springs of the region. Thirty-one locations were sampled, and the samples were analyzed for gross beta-emitters, plutonium and uranium mixture, uranium (six samples), and radon (six samples) using various radiochemical and counting techniques. Unfortunately, the exact locations of many of the samples were not documented and a complete picture of trends could not be established.

However, it could be concluded from the found samples that the natural uranium content is higher in the vicinity of Thousand Springs on the Snake River than it is at the INL Site. This phenomenon is still observed in current samples.

Extensive routine monitoring of off-Site wells began in 1952 and continued through 1965 with 27 to 32 locations sampled on a bi-monthly to quarterly basis per year. The sample stations were generally located at communities around the INL Site and areas southwest of the INL Site in the direction of groundwater flow. Samples were analyzed for gross alpha and beta activity. The analytical detection limit for gross beta activity, 1.5E-7 µCi/mL, was considered to provide assurance that any strontium-90 contribution, which would be less than 25% of any total fission product activity detected, would be well below 4.5E-8 µCi/mL, the maximum permissible concentration for this isotope. Tritium was added to the analytes in 1961 because a study of test wells around INTEC and the ATR Complex indicated the presence of tritium. The detection level for tritium, 4E-6 µCi/mL, was not exceeded in off-Site samples from 1961 to 1963. After 1963, only gross beta was reported (AEC 1964) until 1968, when tritium reporting was resumed mid-year (AEC 1968).

Because the above detection limit was not exceeded, the number of off-Site groundwater sample locations was reduced to 12 in 1966. This decision was based on a thorough review of previous monitoring results. Since routine sampling began in 1952, no evidence was found of any INL Site contribution to the natural activity in the off-Site water (AEC 1966). The 1966 samples were collected at 10 communities surrounding the INL Site—Arco, Howe, Monteview, Terreton, Menan, Idaho Falls, Taber, Atomic City, Carey, and Aberdeen—and two down gradient communities, Shoshone and Minidoka, in 1968. Samples were collected semi-annually and analyzed for gross alpha and gross beta activities. In addition to the groundwater samples, two surface water samples were collected from the Snake River at Idaho Falls and Bliss. Tritium analysis was added in July 1968. At that time, the minimum detectable activities for gross alpha, gross beta, and tritium were 3E-9 µCi/mL, 5E-9 µCi/mL, and 4E-7 µCi/mL, respectively. The USGS added two additional wells in 1978 along the southern Boundary of the INL Site to provide better coverage of the aquifer to the south of major facilities, because on-Site water sampling indicated that the tritium plume had moved to within 3 miles (5 km) of the Site Boundary. At that time, the USGS conducted most of the groundwater monitoring on-Site and at a few locations beyond the southern and western Boundaries. The environmental surveillance program remained essentially the same until the second half of 1989, when three surface water locations in the Magic Valley area near Twin Falls and points west were added.

Conducting co-sampling with the State of Idaho Department of Environmental Quality (DEQ), the INL Oversight Program will continue for comparative purposes and public interest. The DEQ has co-sampled seven locations off-Site since 1994. This includes three surface water sampling locations in the Magic Valley (e.g., Buhl, Hagerman, Twin Falls) and four drinking-water locations (e.g., Minidoka, Shoshone, Atomic City, Mud Lake). The off-Site water-monitoring program changed little through 2006. The historical data were then reviewed, and it was concluded that no evidence showed that the INL Site contributed to radioactivity in the off-Site samples. The off-Site drinking water and surface water program was suspended in 2007.

The program was reintroduced in 2010 at the direction of DOE-ID because of stakeholder interest. The sampling design was amended based on a review of the historical data and other program drivers. In addition, sampling of the BLR on the INL Site was initiated when water was present both on and around the INL Site. The changes are discussed in Section 7.10.1.

7.5 On-Site Locations

Monitoring locations currently consist of ten active drinking water systems that are monitored on a routine basis (see Table 26). Depending on the specific regulatory requirements, the samples are collected either at the wellhead, at the manifold, or from the point of entry to the distribution system after any treatment.

Table 26 lists the monitoring locations for the ten drinking water systems. Since all of these water systems are public water systems (PWSs), their data is listed on the DEQ's PWS Switchboard at www.deq.idaho.gov.

Table 26. Drinking water wells at INL Site.

Facility/Area	Well	Building No.
ATR Complex/RHLLW	Wellfield[a,b]	TRA-696
CFA	Well No. 1[a]	CFA-651
	Well No. 2[a]	CFA-642
CITRC	Well No. 1[a]	PBF-602
	Well No. 2[a]	PBF-614
EBR-I	Well	EBR-711
Gun Range	Well	B21-607
Main Gate	Well	B27-605
MFC	Well[a]	MFC-754
	Well	MFC-756
TAN/CTF	Well No. 1[a]	TAN-632
	Well No. 2[a]	TAN-639
RWMC	Well	WMF-603
INTEC	Well No. 1[a]	CPP-04
	Well No. 2[a]	ICPP-POT-A-012

a. Wells No. 5 and No. 2317 are monitored as a wellfield.
b. ATR Complex wells No. 1, 3, and 4 are used as backup drinking water wells.

All INL and ICP Core drinking water systems were well below regulatory limits for drinking water or there were no detections. See Table 27 for a summary of drinking water sampling results in 2021. All water systems were sampled for nitrates and all values were less than the MCL of 10 mg/L. The highest nitrate values were 3.57 mg/L at CFA and 2.20/2.26 mg/L at MFC well #1/2, respectively. INL did not detect nitrates at the ATR Complex, Critical Infrastructure Test Range Complex (CITRC), Experimental Breeder Reactor I (EBR-I), Gun Range, Main Gate, TAN/Contained Test Facility (CTF), the Radioactive Waste Management Complex (RWMC), or INTEC. Samples for total trihalomethanes (TTHMs) and haloacetic acids (HAA5) were collected at the ATR Complex, CFA, Materials and Fuels Complex (MFC), TAN/CTF, RWMC, and INTEC. All results were below the MCL of 80 ppb for TTHMs, and no HAA5s were detected in any INL PWS.

Table 27. INL drinking water results (2021).

CONSTITUENT	MCL (units)	ATR COMPLEX 6120020	CFA 6120008	CITRC 6120019	EBR-I 6120009	GUN RANGE 6120025	MAIN GATE 6120015	MFC 6060036	TAN CTF 6120021	RWMC PWS 6120018	INTEC PWS 6120012
RADIOLOGICAL SURVEILLANCE MONITORING											
Gross Alphaa	15 pCi/L	NDb	ND	ND-3.05	ND	ND	ND	ND-4.68	ND	2.08 – 3.15	ND
Gross Betaa	50 pCi/L screening or 4 mrem	ND	4.254.28	ND-5.65	ND-2.68	2.432.72	ND	1.9410.5	2.502.67	ND - 2.87	1.88 –2.88
Tritiuma	20,000 pCi/L	ND	2,3102,640	ND	ND	ND-284	ND	ND	ND	ND	ND
Iodine-129c	1 pCi/L	—	ND	—	—	—	—	—	—	—	—
COMPLIANCE MONITORING											
Nitrate	10 mg/L	ND	3.57	ND	ND	ND	ND	2.20/2.26	ND	ND	ND
Total trihalomethanes	80 ppb	ND	5.0	NAc	NA	NA	NA	2.8	1.3	1.5	ND
Total coliform	2 or more present	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
E. coli	Present	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
HAA5s	60 ppb	ND	ND	NA	NA	NA	NA	ND	ND	ND	NA
SOCs/VOCsd	SOCs varies, 5 ppb for most VOCs	ND	ND	NA	NA	NA	NA	ND	ND	ND	ND

a. Range of results (minimum – maximum) presented.
b. ND = not detected.
c. NA = not applicable based on water system classification.
d. SOCs = synthetic organic compounds and VOCs = volatile organic compounds.

7.6 Off-Site Program Goals

Off-Site water-monitoring sites are sampled to examine trends of INL Site contaminants and other general groundwater quality indicators, and to verify DOE monitoring results. Specific program objectives derived from these objectives and other drivers include:

- Measure background concentrations of radionuclides in surface and drinking water
- Measure concentrations in drinking and surface water at locations that could be impacted by routine INL Site operations
- Determine INL Site contributions of waterborne radionuclides to the environment
- Detect and report trends in measured concentrations of waterborne radionuclides
- Compare measured concentrations to reference levels based on derived concentration standards (DCSs) tabulated in DOE-STD-1196-2011, "Derived Concentration Technical Standard" (DOE 2011a)
- Determine environmental alert levels and any potential radiological doses exceeding the reporting limit
- Prepare a comprehensive analysis of surveillance results in the Annual Site Environmental Report (ASER).

7.7 On-Site Program Goals

On-Site monitoring is conducted to help protect the health of workers and visitors at INL by ensuring that consumed water does not expose anyone to contaminants posing an unacceptable risk and to show compliance with state and federal regulations.

7.8 Off-Site Sampling Boundaries

Sites sampled include groundwater locations (wells and springs) and surface water locations (streams). Ample groundwater sample sites have been selected to aid in identifying INL Site impacts on the ESRPA. These are categorized as upgradient or downgradient wells. Upgradient locations are not impacted by INL Site operations and are considered representative of background groundwater quality conditions. Downgradient locations are south of the INL Site in the direction of groundwater flow from potential sources of INL Site contamination. These locations provide trends in water quality

down-gradient of INL and include wells and springs used for irrigation, public water supply, livestock, domestic, and industrial purposes. Surface water stations include select locations on the BLR and the Snake River. The BLR stations provide information on soil contaminants potentially entrained by the river flowing through the INL Site.

7.9 On-Site Sampling Boundaries

Drinking water systems at INL have been defined as transient noncommunity or nontransient noncommunity water systems. CITRC, EBR1, Gun Range, and Main Gate, are classified as transient noncommunity water systems. ATR Complex, CFA, INTEC, MFC, RWMC, and TAN / CTF are classified as nontransient noncommunity water systems. It is required that monitoring be performed according to the classification of the water system to comply with regulations. The regulations for sampling vary based on the system classification, the initial system startup date, and the monitoring schedule released by DEQ.

7.10 Sampling Design

7.10.1 Off-Site Sampling Locations

A review of the monitoring data collected through 2006 showed that samples collected at the locations selected for the drinking and surface water program have yielded gross alpha, gross beta, and tritium results that are well below regulatory concern and DOE guidance (DOE 2015) and do not indicate any movement of waterborne radioactive contamination from the INL Site to the public. For this reason, the program was redesigned primarily to address the public interest in drinking and surface water. In general, the changes are to:

- Sample drinking water from a public water source at U.S. Highway 20/26 rest area, which is the only public water source located close to the mapped tritium plume from the INL Site.
- Sample drinking water from a public water source at Howe because it is near the INL Site Boundary and near the BLR Sinks.
- Sample drinking water from a public water source at Craters of the Moon, which is distant from the INL Site and can be compared, as a background sample, with other currently collected samples. Craters of the Moon is also an area of public concern because of its relatively pristine setting.
- Sample Idaho Falls drinking water from a public water source because it is a populated area distant from the groundwater plume. This location is sampled for the EPA RadNet Program; thus, results can be compared with another federal agency.
- Add a bottled water control sample for comparison with drinking water samples.
- Continue the surface water sampling on the BLR through the INL Site because it has the potential to carry contaminated soil to the BLR Sinks. Gamma spectroscopy of these samples for cesium-137 and other gamma-emitting radionuclides was added because it is a soil contaminant at the INL Site.
- Sample surface water at Birch Creek for comparison with BLR samples.
- Eliminate other locations that offer no scientific insight into the surface water/drinking water pathway. These include:
    - Drinking water from a public source located at Aberdeen, Arco, Blackfoot (Moreland), Carey, Fort Hall, Monteview, Roberts, and Taber, which are not located downgradient of the INL Site
    - Surface water at Bliss, which is downgradient of the Thousand Springs area
    - Surface water at Idaho Falls, which is not downgradient of the INL Site.

The final drinking water and surface water sampling design is presented in Table 28 and shown in Figure 41 and Figure 42.

Table 28. Current drinking and surface water monitoring program design.

DRINKING WATER PROGRAM			
LOCATION	SAMPLING FREQUENCY	RADIONUCLIDE ANALYSIS	SAMPLING BASIS
Atomic City	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program; other environmental surveillance sample(s) collected here.
Control sample (bottled water)	Semiannual	Gross alpha/beta, tritium	For quality assurance (QA) purposes.

DRINKING WATER PROGRAM			
LOCATION	SAMPLING FREQUENCY	RADIONUCLIDE ANALYSIS	SAMPLING BASIS
Craters of the Moon	Semiannual	Gross alpha/beta, tritium	Distant location for comparison with other samples
Howe	Semiannual	Gross alpha/beta, tritium	Near the INL Site boundary and the BLR Sinks - could potentially be downgradient.
Idaho Falls	Semiannual	Gross alpha/beta, tritium	Distant from INL plume for comparison with downgradient samples; EPA samples here.
Minidoka	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program.
Mud Lake	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program; other environmental surveillance sample(s) collected here.
Public rest stop on Highway 20/26	Semiannual	Gross alpha/beta, tritium	Only public drinking water site located close to the mapped tritium plume from the INL Site.
Shoshone	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program.
SURFACE WATER PROGRAM			
LOCATION	SAMPLING FREQUENCY	RADIONUCLIDE ANALYSIS	SAMPLING BASIS
Big Lost Riverb	Dependent on flow	Gross alpha/beta, tritium, specific gamma	Only surface water going through INL Site; could contact contaminated soils.
Birch Creek (Control)	Semiannual	Gross alpha/beta, tritium, specific gamma	Background for comparison with BLR.
Buhl (Clear Springs)	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program.
Hagerman (Bill Jones Fish Farm)	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program.
Twin Falls (Alpheus Springs)	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program: BLR emerges here.

a. Semiannual = May and November sampling campaigns.
b. At Highway 20/26 rest stop, Lincoln Blvd by INTEC, Experimental Field Station (EFS), Lincoln Blvd by the Naval Reactor Facility (NRF), and BLR Sinks, when water is available.

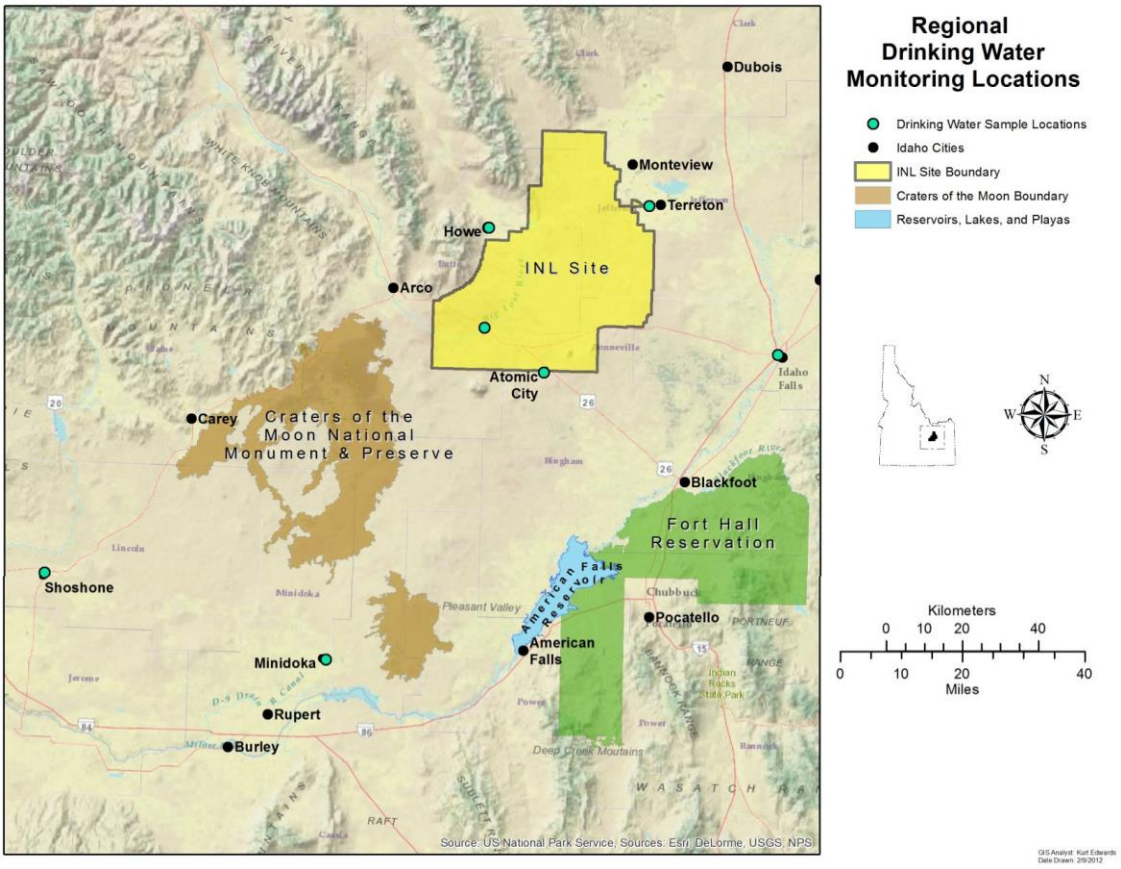

Figure 41. Regional drinking water monitoring locations.

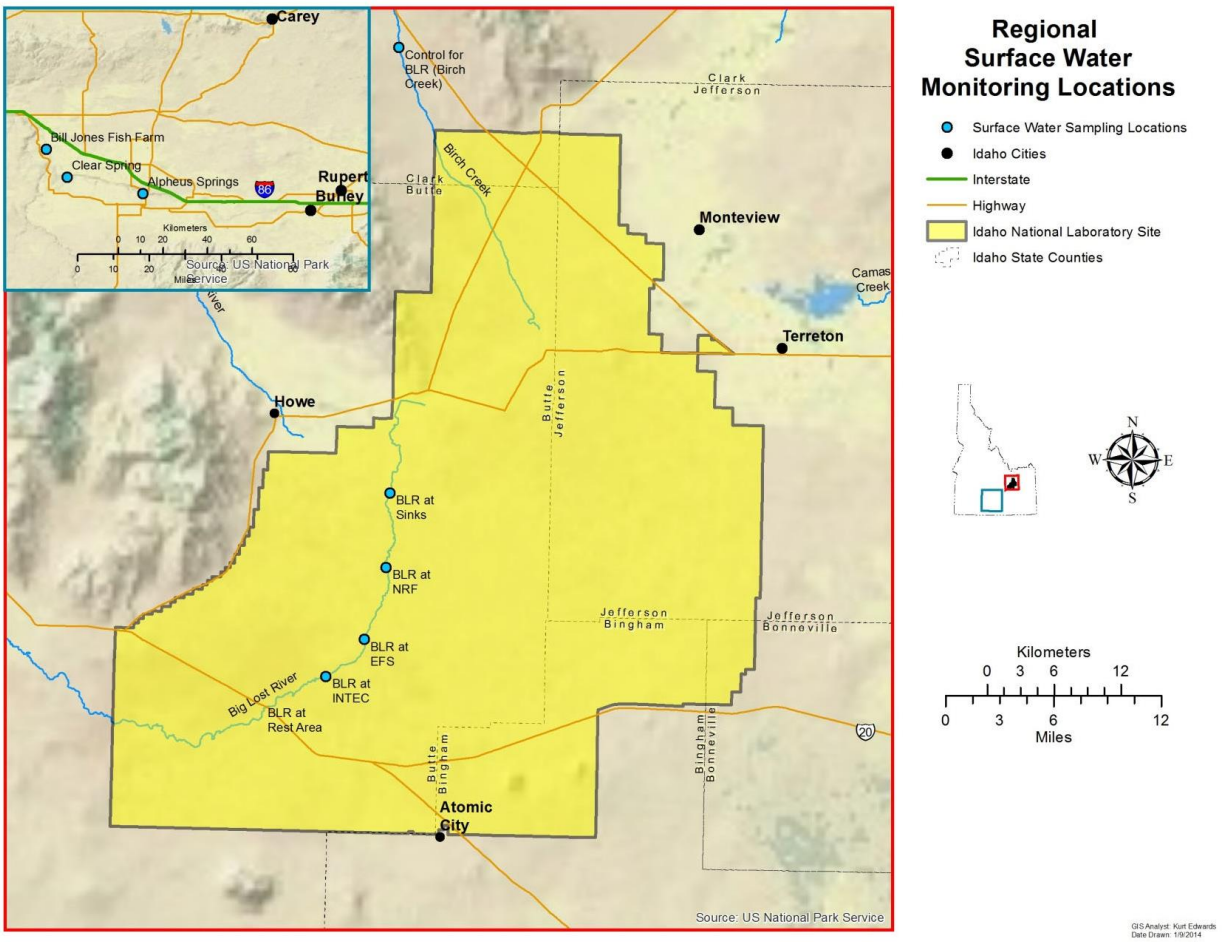

Figure 42. Regional surface water monitoring locations.

7.10.2 Frequency of Sample Collection

The frequency of collection and analysis that has been followed in past programs was semiannually conducted in May and November. This coincides with the DEQ INL Oversight Program's sampling frequency and with that used historically for comparison purposes.

The BLR is sampled when and if it is flowing in the spring and fall.

7.10.3 Sampling Methods

Samples are collected and preserved using the methods recommended in DOE-HDBK-1216-2015 (DOE 2015) and the EPA (1987) and documented in sample collection procedures. Sample sizes are such that program minimum detectable activity (MDA) levels are achieved.

7.10.4 Analytical Methods

The standard analytical method to determine gross alpha and gross beta activities in drinking water is the use of gas-proportional counters (EPA 1987). The sample is first reduced in volume though drying and then plated onto a planchet, which is counted in the counter. The volume and counting time are determined by the desired MDC. The MDC for gross alpha activity is approximately 1 pCi/L (1E--9 µCi/mL) and for gross beta activity is approximately 1.5 pCi/L (1.5E--9 µCi/mL).

Tritium in water samples is measured using the standard method of counting the sample in a liquid-scintillation counter (EPA 1987). The MDC is typically <100 pCi/L or 1E--7 µCi/mL. The State of Idaho DEQ INL Oversight Program analyzes some of its samples using an electrolytic enrichment method with a much lower MDC of 10 to 14 pCi/L. This is expensive and time-consuming. Moreover, the standard method is sufficient to measure background concentrations as measured historically in water samples.

Surface water samples collected from the BLR are also analyzed for gamma-emitting radionuclides using gamma spectrometry. The MDA for cesium-137 is approximately 2 pCi/L (2E--9 µCi/mL).

7.10.5 On-Site Sampling Locations, Frequencies, and Analytes

Depending on the specific regulatory requirements, samples are collected either at the wellhead, at the manifold, or at the point of entry to the distribution system after any treatment. Compliance sampling locations, analytes, and frequencies for all INL drinking water systems can be found at https://www2.deq.idaho.gov/water/monitoringschedulereport.

Surveillance monitoring is conducted more frequently than regulations require, for example more frequent bacteriological analysis may be completed at specific locations because of historical problems with bacteriological contaminants.

7.11 Battelle Energy Alliance (BEA) Off-Site Radionuclides Assessed

Tritium is a naturally occurring radioactive form of hydrogen that is produced in the atmosphere when cosmic rays collide with air molecules. Tritium has also been produced historically by INL Site activities. The environmental behavior of tritiated water is like that of water, and it can be present in drinking and surface water. Tritium is therefore analyzed in all water samples collected off the INL Site.

Gross alpha and gross beta activities are measured in surface and drinking water for screening purposes and as indicators of naturally occurring radionuclides and strontium-90, which is a beta-emitter that was historically injected into the aquifer. Additionally, gamma-emitting radionuclides, particularly cesium-137, are included for BLR samples because INL Site surface soils may be historically contaminated with gamma-emitting radionuclides. The MCL for gross alpha established in the *National Primary Drinking Regulations* (40 CFR 141) is 15 pCi/L. Historical results have never approached this level and to conduct analyses routinely for americium-241, plutonium-238, and plutonium-239/240 is not warranted. However, if any samples exceed historical levels for gross alpha, specific isotopic analyses may be performed to ascertain if americium-241, plutonium-238, and plutonium-239/240 or naturally occurring radionuclides—primarily radium and uranium—resulted in exceeding the historical levels.

7.12 Quality Assurance

The off-Site environmental surveillance program employs an effective quality assurance (QA) program to ensure the collection of high-quality data. The program is detailed in the Environmental Monitoring Services QA Project Plan (QAPjP), which serves to ensure that all data collected are of known and defensible quality, and to meet the requirements of all applicable federal and state regulations and DOE orders, specifically DOE O 414.1A, ASME NQA-1-2000, EPA QA/R-5, ANSI/ASQC E-4, IDQTF UFP-QAPP, and ISO 9000.

Measurements of precision and accuracy in the drinking water program are made using replicated water samples, recounts of samples, blanks, and blind spiked samples.

The on-Site programmatic goals and QA/quality control (QC) requirements are detailed in DOE-ID-11088, *Idaho National Laboratory Environmental Monitoring Plan* (DOE 2021), and in PLN- 8530, *Idaho National Laboratory Drinking Water Monitoring Plan* (INL 2020). Both documents ensure data collection of known and defensible quality and ensure INL meets state and federal requirements.

7.13 Decision Limits and Actions

DOE radiological activities (DOE 2011b) must be conducted so that exposure of members of the public to ionizing radiation will not cause a total effective dose (TED) exceeding:

- 100 mrem (1 mSv) in a year
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year
- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose.

The results of 60 years of environmental monitoring of drinking and surface water around and down gradient of the INL Site show that DOE dose limits have never been exceeded or even approached. Thus, the off-Site environmental surveillance program looks for instances when background or historical measurements are exceeded. The program has developed action levels for the laboratory to use as criteria to notify us if an unusual result is observed. The action levels were developed based on an assessment of the last 2004-2013 data. The action levels developed for off-Site water samples are shown in Table 29.

Table 29. Off-Site action levels for radionuclides in surface and drinking water.

Radionuclide	Surface Water	Drinking Water
Gross Alpha	3E--9 µCi/mL	3E--9 µCi/mL
Gross Beta	1.3E--8 µCi/mL	1.3E--8 µCi/mL
Tritium	3E--7 µCi/mL	3E--7 µCi/mL
Cesium-137	$>3\sigma$[a]	[b]

a. σ is the counting uncertainty reported with each result.
b. Not analyzed for this constituent.

If the measurement at any location exceeds the action level, the following actions will be taken:

- Whether the concentration is an anomalous measurement is determined by one of the following methods:
  - Review historical monitoring results at that location to see if the measurement is consistent with past monitoring results
  - Consult with other INL Site surveillance components and the Idaho DEQ INL Oversight Program
  - Review whether this location is affected by recent activities or events
  - Review any other factors that may have contributed to the result.
- If the concentration is verified, it may need further action dependent upon the concentration level and/or a trend showing elevated concentrations over a period of time.

For the on-Site program IDAPA 58.01.08 provides regulatory limits that define maximum drinking water concentrations that protect human health. It incorporates by reference the federal limits in 40 CFR 141 143. IDAPA 58.01.08 requires that INL drinking water must meet the State of Idaho regulations to be in compliance.

8. SOIL

8.1 Program Basis

As stated in Section 6.9 of DOE-HDBK-1216-2015, "Soil provides an integrating medium that can account for contaminants released to the atmosphere, either directly in gaseous effluents or indirectly from resuspension of on-Site contamination" (DOE 2015). Soil sampling is a useful approach to determine the accumulation of initially airborne radionuclides that have been deposited on the ground and generally serves as a supplementary role in environmental surveillance monitoring programs (Gallegos 1995; Hardy and Krey 1971; DOE 1997). Soil sampling is, however, of questionable value in attempting to estimate small increments of deposition over a period of a few years or less (DOE 1997). Soil sampling and analysis should be used to evaluate the long-term accumulation trends to estimate environmental radionuclide inventories (DOE 2015) and to establish baseline inventories of radionuclides in the soils.

The Environmental Soil Monitoring Program at Idaho National Laboratory (INL) monitors levels of radionuclides in soils within INL Site Boundary and surrounding areas. The program uses historical data, atmospheric dispersion and deposition modeling, and ambient air data to determine the requirements for routine soil sampling around INL facilities and in areas within 50 miles of the INL Site Boundary.

8.2 Program Drivers

Sampling of soil is performed on and around the INL Site to meet the following requirements and criteria for environmental surveillance of U.S. Department of Energy (DOE) facilities:

- DOE O 458.1, "Radiation Protection of the Public and the Environment," (DOE 2013)
- DOE-HDBK-1216-2015 (DOE 2015), which updates and supersedes the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T) (DOE 1991).

Other key drivers of the ambient air surveillance program include stakeholder inputs, concerns, and values.

8.3 Results of Related Studies/Surveillance

The INL Site has a long history of operation that includes various large-scale experiments and large user facilities such as reactors. The primary sources of historical soil contamination were operating reactors, radioactive material management, processes such as calcining, and unplanned releases to native soil, as when the Subsurface Disposal Area of the Radioactive Waste Management Complex (RWMC) was flooded in 1962 and 1969. Soil sampling has been performed at the INL Site for decades to evaluate facility contributions to environmental levels of man-made radionuclides. In 1970, the United States (U.S.) Department of Energy–Idaho Operations Office (DOE-ID) Radiological and Environmental Sciences Laboratory (RESL) established a routine program for collecting surface soils (0 to 5 cm and 5 to 10 cm) both on and around the INL Site. At that time, RESL established extensive on-Site soil sampling grids outside facilities. RESL also established Boundary and Distant off-Site locations during this process to serve as background sites. Between 1970 and 1978, RESL sampled these on-Site grids extensively, and then reduced the on-Site sampling frequency to a 7-year rotation, and off-Site to every 2 years. RESL analyzed all samples (both on- and off-Site) for gamma-emitting radionuclides. In addition, the surface component (0 to 5 cm) of the off-Site samples was analyzed for strontium-90 and alpha-emitting radionuclides (americium-241 and isotopes of plutonium). However, current operations are significantly reduced, many of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites have been remediated, and all but one reactor has been shut down. In addition, years of sampling and analyses that characterized the nature and extent of the contamination in these areas show slowly declining trends in the concentrations of short-lived man-made radionuclides.

Before 1963, the U.S. and other countries conducted more than 500 atmospheric nuclear weapons tests. Surface soils worldwide contain traces of radionuclides caused by fallout from these tests. The INL Site can generate airborne emissions from various facilities during operations, research, and scientific activities that can also be deposited on the soil. Engineering controls, such as high-efficiency particulate air (HEPA) filters and administrative controls to prevent the introduction of and reduce and/or eliminate air pollutants from the environment are implemented. Air surveillance and facility emissions monitoring are conducted to assess the adequacy of these controls to protect human health and determine any impact of air pollutants on people and the environment. Past INL Site activities have also contaminated soil in defined locations that can be detected above the worldwide fallout background. The largest of these locations include low-level radionuclide-contaminated surface-soil areas centered on Idaho Nuclear Technology and Engineering Center (INTEC) and SL-1 that are elongated in predominant wind directions. These contamination areas on-Site have been evaluated and, in some cases, remediated by the CERCLA program, the remaining contamination has been modeled and is not considered a significant source term for, or potential contributor to, accumulation in Distant locations.

Years of data collected and evaluated by the DOE-ID RESL showed that radionuclide concentration ranges across the Site, in specific locations and regionally, were consistent with previous years for long-lived isotopes (e.g., uranium and plutonium) or were decreasing for shorter-lived isotopes (e.g., cobalt-60), and that cesium-137 was the most prevalent isotope.

Recent modeling of current emission rates indicates that radionuclide concentrations in soils will not show measurable accumulation for hundreds to millions of years in most cases (INL 2015). The one exception is potentially measurable contamination of soil immediately downwind of RWMC within 7 years from continual ground-level releases of transuranic radionuclides. Therefore, except in the vicinity of RWMC, routine monitoring of soils is of minimal value in evaluating long-term accumulation of small, predictable deposits over time. Because the likelihood of accumulation is low at current emission rates, it is more useful to use air or direct radiation measurement if an unplanned release occurs as an indicator to when radionuclides may be depositing in soils.

8.4 Program Goals

The goal of the Environmental Soil Monitoring Program at INL is to monitor levels of radionuclides in soils within the INL Site Boundary and surrounding areas. The program involves collecting soil samples around INL facilities and in areas within 50 miles of the INL Site Boundary.

The primary aim of soil sampling is to obtain accurate data representing the level of soil contamination of a specific site; however, the ultimate objective is to:

- Establish baseline concentration and action levels near facilities and at Distant areas
- Assess long-term accumulation trends away from the facilities and estimating environmental radionuclide inventories
- Assess threat to public health or welfare or to the environment
- Define the extent of contamination
- Safeguard the environment
- Use the data generated as a database to substantiate compliance to local, regional, and national laws and regulations.

8.5 Sampling Boundaries

8.5.1 Physical Boundaries

The physical boundaries of the study include areas within the INL Site Boundary, as well as the 50-mile radius surrounding the INL Site per DOE guidance (DOE 2015). This area has three divisions:

- Near-Facility (RWMC)
- Mid-Range (Rest Area, Experimental Field Station)
- Distant (numerous), limited to a 50-mile radius of the Site.

The divisions are discussed in more detail in *Data Quality Objectives (DQOs) Supporting the Environmental Soil Monitoring Program for the INL Site* (INL 2022) along with an identification of the individual sampling locations within each sampling area. The Near Facility area includes sampling locations at RWMC because it is the only facility on INL modeled to have potential measurable deposition in the time frame of decades as opposed to centuries or millennia for the other facilities. The areas to be sampled at RWMC were chosen from a previously established grid sampled by the DOE-ID RESL beginning in the 1970s. The RWMC data can be used to represent all Site facilities as a worst-case for potential soil deposition and data will allow for monitoring of concentration trends in the area.

Mid-Range sampling includes two locations at a distance from facilities that were identified through deposition modeling as areas of high deposition potential if an unplanned release occurs. These locations at the U.S. Highway 20/26 Big Lost River Rest Area and the Experimental Field Station (EFS) also have collocated air monitors for data comparison. Boundary and Distant sampling includes locations near the INL Site Boundary (e.g., Arco, Atomic City, Blue Dome, Federal Aviation Administration [FAA] Tower, Frenchmans Cabin, Receptor 54, Howe, Monteview, Mud Lake [two locations], and Reno Ranch) and locations near Distant communities (Blackfoot, Carey, Idaho Falls, and St. Anthony). The locations in this region are, with a few exceptions, those established by RESL in 1970. (The Crystal Caves location has been removed because it is within the Craters of the Moon Monument expanded boundary and cannot be disturbed.) Frenchmans Cabin was added because it was previously the location of the maximally exposed individual (MEI) in National Emission Standards for Hazardous Air Pollutants (NESHAP) dose assessments until 2019 when the MEI was updated to Receptor 54 (DOE-ID 2022). Because three decades of measurements at the Boundary and Distant locations show that radionuclides in these soils are the result of deposition of fallout particulates, it is reasonable to continue sampling at these locations to continue following the historically established trends within that region.

The types of sampling areas are shown below in Table 30. Figure 43 presents the soil sampling areas in the regions. Figure 44 shows the near-facility sampling locations at RWMC.

Table 30. Sampling areas within the Near-Facility, Mid-Range, and Distant Regions.

Near-Facility	Mid-Range	Boundary/Distant
RWMC	Rest Area EFS	**Boundary** Arco (Butte City) Atomic City FAA Tower Frenchmans Cabin Receptor 54 Howe Monteview Mud Lake #1 Mud Lake #2 Reno Ranch **Distant Communities** Blackfoot (Moreland) Carey (Craters of the Moon) St. Anthony

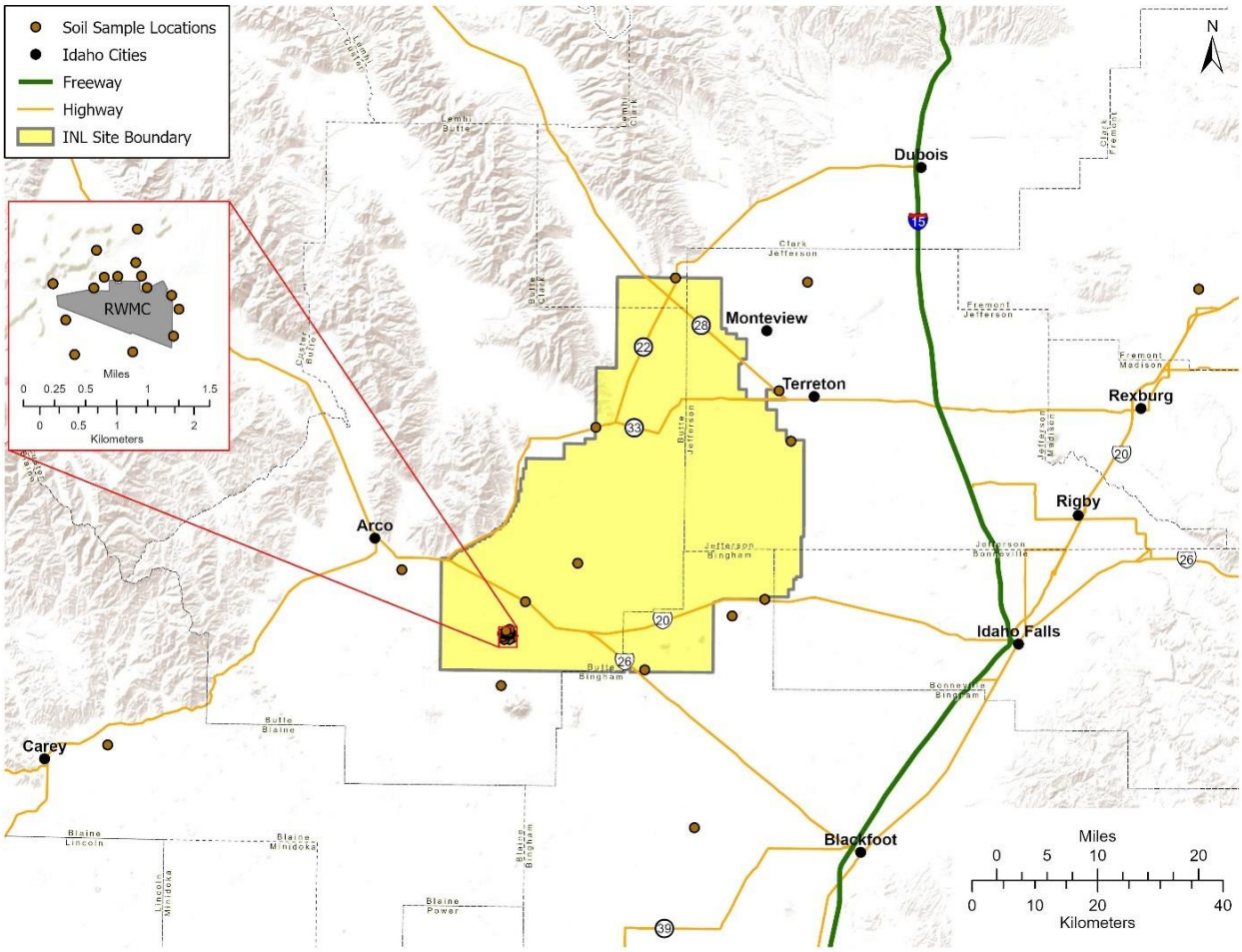

Figure 43. Soil sampling locations.

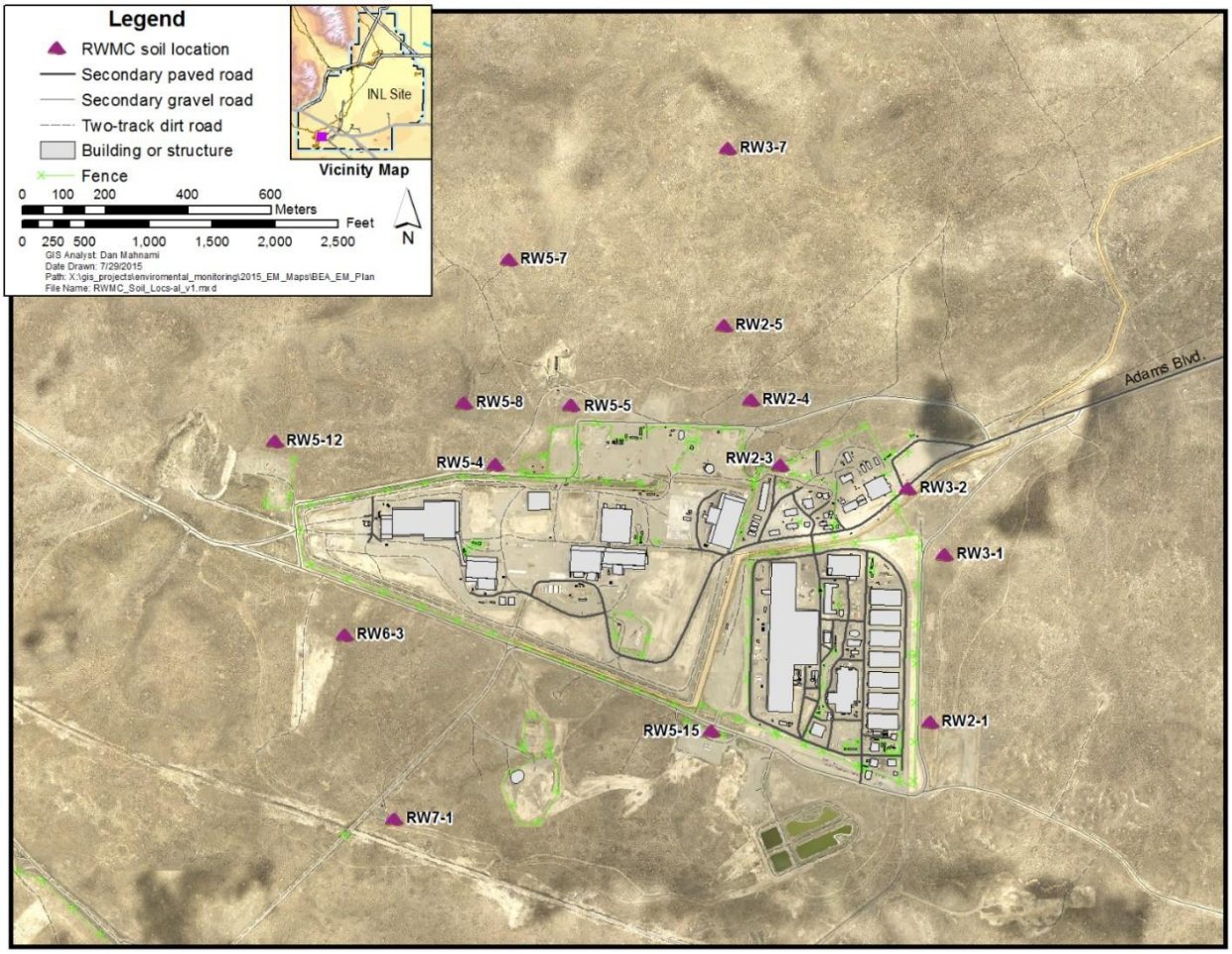

Figure 44. Near facility sampling locations at RWMC.

8.5.2 Temporal Boundaries

The temporal boundaries for soil monitoring are encompassed by the time between soil sample collection at a location, which may have been as early as the 1970s, up until when soil monitoring is no longer measured under this program. It is anticipated that soil monitoring will continue as long as the Site is operational under DOE, which is likely to be long as 100 years into the future. The number of monitoring locations at a specific sampling area and the length of time that a particular sampling location is measured can vary depending on changes in conditions or activities in that particular sampling location. Thus, as conditions and activities change at the Site, the DQO will need to be revised to adjust the monitoring program approach to changes in operations.

8.5.3 Practical Considerations

Practical constraints on collecting data are access to the private property where samples are to be collected off the site, the lack of undisturbed surface soil (e.g., some air monitor locations), the cost of sampling and analysis, and the time needed to collect and analyze samples. When possible, soil sampling locations should be placed at points corresponding to air sampling locations to allow for the comparability of data.

Following an acute release of a contaminant or an accident at a specific facility, surface soil sampling can be used to define the contamination contours or distribution pattern. This would require sampling only the top 5 cm of soil, including the vegetation. In-situ gamma spectrometry can also be used to screen for surface deposition (before soil sampling) or used as the primary means of measurement if the deposited radionuclides are photon-emitters and if the soil concentration depth profile is known through previous sampling (NCRP 1999).

Sampling techniques used in evaluating acute releases are more Site-dependent and methods used for fallout deposition may not be appropriate. Differences in the methods are dictated by the nature of the distribution of the contaminant in the soil, the range of particle sizes, and the generally higher levels of releases. Soil sampling in locally contaminated areas, such as Rocky Flats, can be inventoried by Environmental Measurements Laboratory (EML) methods where the contaminant was initially made airborne in micron size particles from the source (Hardy and Krey 1971). Direct collections of deposition of airborne material are much more specific and yield more information with respect to the time when contamination occurred. There is no standard method to sample for availability of a contaminant in the soil for resuspension. The direct measurement of the airborne contaminant is the only sound approach to the problem of evaluating exposure to resuspended material (DOE 1997).

8.6 Sampling Design

Modeling has indicated that radionuclides of concern will not deposit on INL Site surface soils at rates that would result in concentrations distinguishable from the background for many years at any air sampling location. Sampling at a 1- to 3-year frequency, as recommended by DOE-HDBK-1216-2015 (DOE 2015), may not produce a statistically defensible trend analysis because the rate of routine deposition is too small. Because of the large uncertainties in sampling and the inherent variability in soil, estimating short-time increments of deposition history or deposition changes of small degrees is not recommended (DOE 1997). However, past and present monitoring data is also used to characterize areas of interest to maintain baseline concentrations and trends of such areas.

8.6.1 Sampling Locations

Sampling will be conducted to determine long-term deposition trends and to provide a baseline for key areas in and around the INL. DOE-HDBK-1216-2015 (DOE 2015) suggests sampling in locations that meet the following criteria:

- Samples should be collected and analyzed from areas near the operational activities and effluent release points
- Samples should be collected and analyzed from areas within the INL Site Boundary where radioactive material may accumulate due to air or water dispersion
- Samples should be collected and analyzed from areas beyond the Site Boundary where members of the public may be exposed to radioactive materials.

The Near-Facility, Mid-Range, and Boundary/Distant sample locations encompass these criteria.

Specific sampling locations are identified in INL 2022. Additionally, sampling locations are in areas of likely deposition from sourced terms based on modeling. As illustrated in Figure 45 and Figure 46, soil sampling locations are within the predominant wind and highest potential concentration areas. Wind roses and atmospheric dispersion calculations provide useful guidance in selecting appropriate soil sampling locations (DOE 1997). Additionally, where appropriate, soil sampling locations are collocated with air monitoring locations to provide comparability of data.

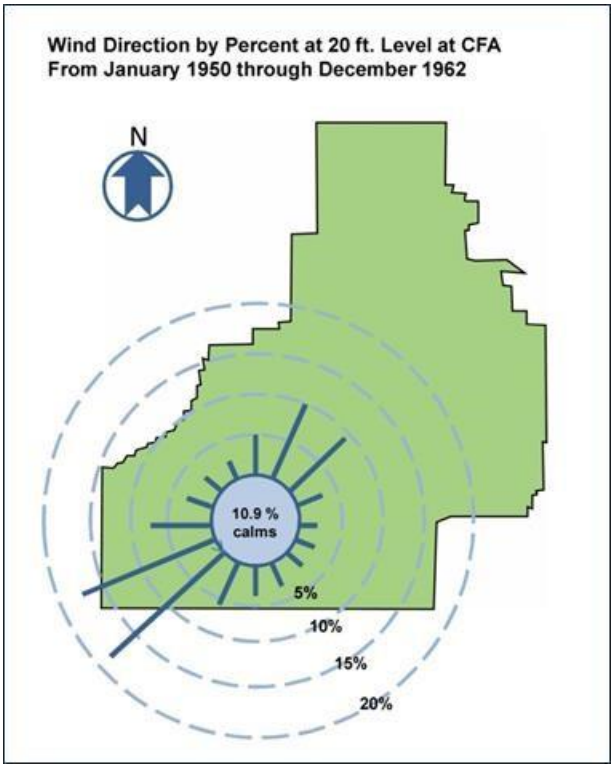

Figure 45. Predominant wind directions on INL Site (Clawson, Start, and Ricks 1989). Direction is the direction from which the wind is blowing.

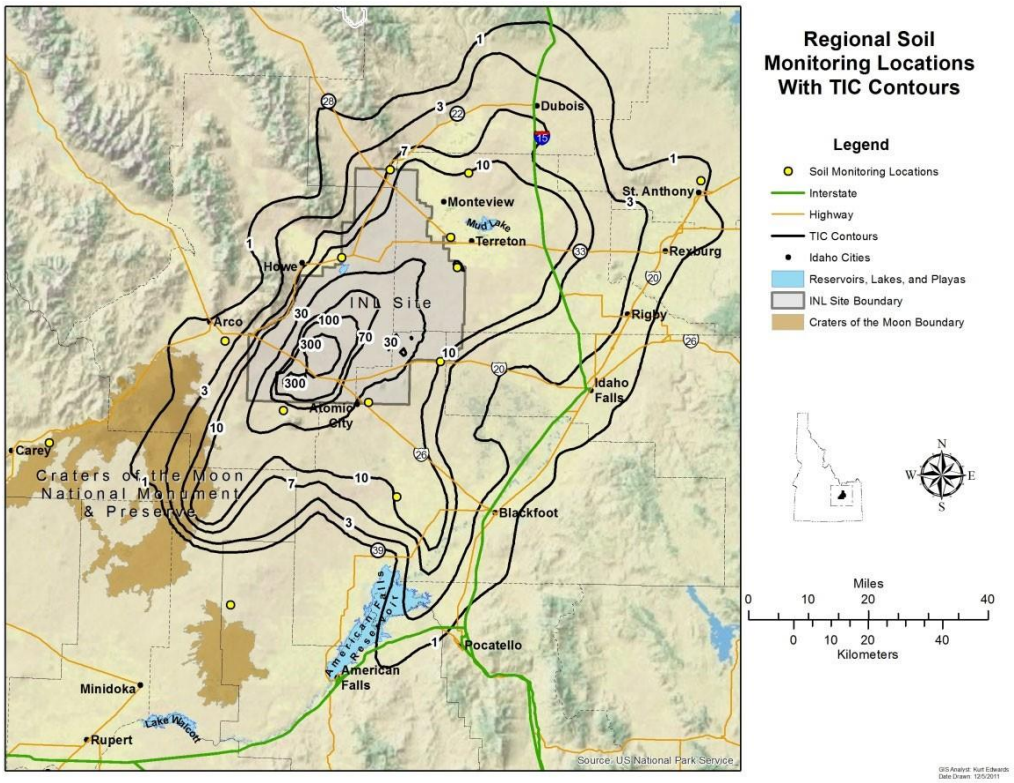

Figure 46. Off-Site soil monitoring locations with air-concentration isopleths.

8.6.2 Frequency of Sample Collection

DOE-HDBK-1216-2015 states, “Environmental surveillance measurements may be performed occasionally when the potential dose is low but should be performed at least every 5 years” (DOE 2015). Based on historical data and deposition modeling included in *Data Quality Objectives Supporting the Environmental Soil Monitoring Program for the INL Site* (INL 2022), the annual sampling frequency is technically unjustifiable for soils because the examination of 40 years of data shows that the concentrations of radionuclides in these soils are aged fallout products. The longer-lived radionuclide concentrations should remain constant unless soils are disturbed. Cesium-137 and strontium-90 will continue to decrease with time. The decreasing trends are not statistically observable over short periods (i.e., every 2 years), but rather require longer periods to distinguish the trends from natural variability in soil samples. In addition, atmospheric dispersion modeling shows that off-Site soil concentrations from INL sources will never be distinguishable from background. For this reason, a 5-year sampling regime has been selected to maintain baseline and confirm observed trends in each region. When monitoring global fallout, short-term changes in radiation concentrations are generally small compared to the variability in the local radionuclide distribution (DOE 1997). Soil samples will be collected during each sampling event. If a major unplanned release is detected on the INL Site, select locations on the Site Boundary may be sampled in response if it is believed, through modeling or air monitoring, that the location may be affected.

8.6.3 Physical Soil

Each physical soil sample is a composite of five cores from one of two depths: 0 to 5 cm and 5 to 10 cm. All samples are analyzed for gamma-emitting radionuclides; samples from the 0- to 5-cm depth are also analyzed for strontium-90 and transuranics (e.g., plutonium-238, plutonium-239/240, americium-241). Samples are taken from the corners and center of a 10-m grid at each sample location.

The five samples from 0 to 5 cm and 5 to 10 cm are composited in separate containers and oven-dried at the analytical laboratory for analysis. Only the top 5 cm is analyzed for all radionuclides. Previous studies have shown that more than 90% of existing fallout contamination is contained within this depth. The 5 to 10 cm depth is typically analyzed for cesium-137 only.

Due to distance, low predicted concentrations, and low precipitation (8-in. annually) sampling the top 10 cm of soil every five years will permit sufficient data to determine if:

- Radionuclides from the INL Site reach Distant locations
- Radionuclides build-up in soil over time
- Radionuclides exceed historical values
- Soil concentrations of these radionuclides in Distant locations exceed federal guidance levels (EPA 1993)
- Soil concentrations pose a hazard to the public or biota.

Samples are normally submitted for analysis when all of the samples for a year have been collected and processed (once annually). Optionally, samples may be submitted in smaller groups as they are prepared, particularly those samples being analyzed for gamma spectrometry.

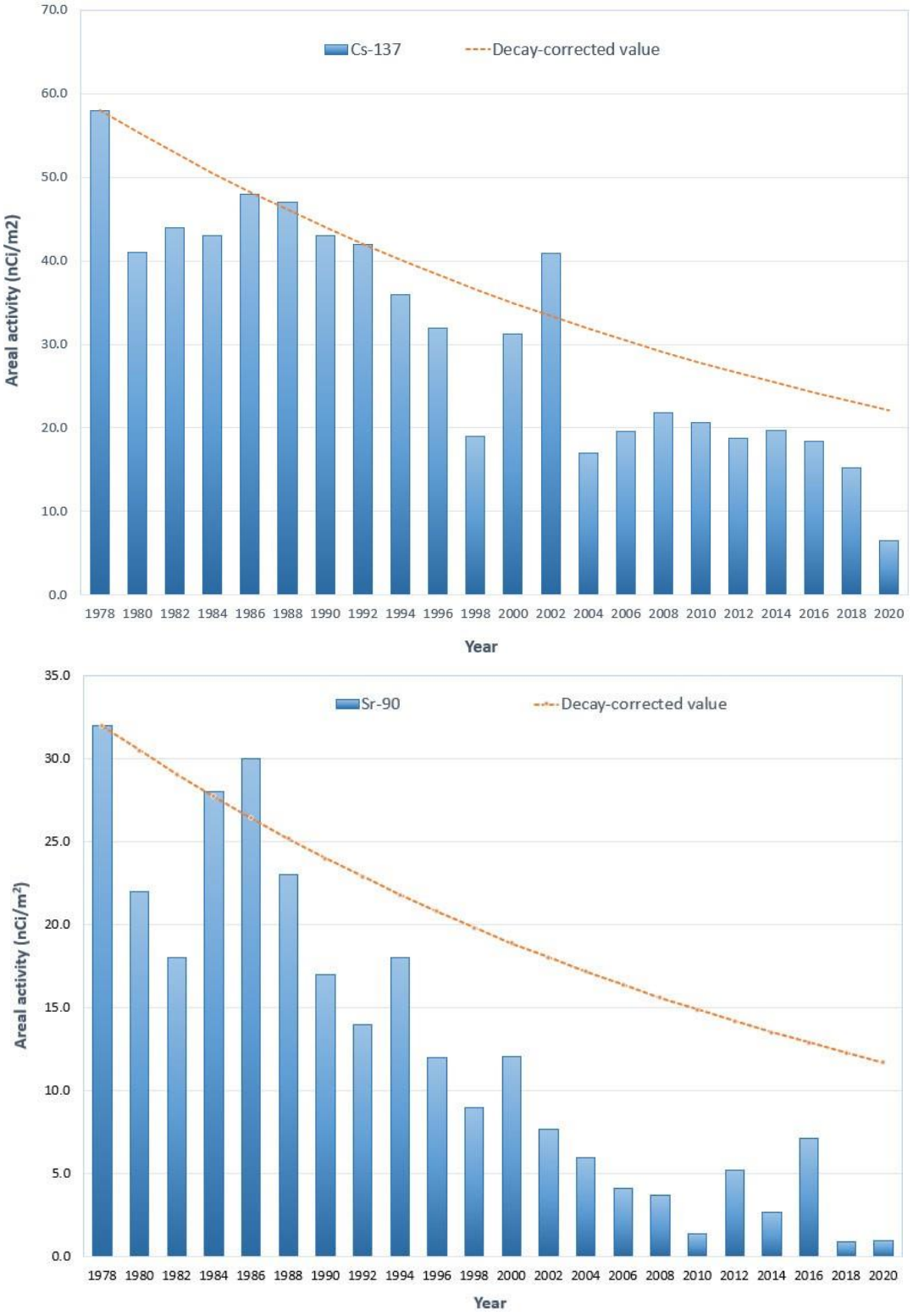

Figure 47. Historical radionuclide concentrations in soils outside the INL Site Boundary.

8.6.4 Analytical Methods

Physical soil samples are analyzed in the laboratory for gamma-emitting radionuclides using gamma spectrometry. Subsamples are placed in small vials for analyzing strontium-90 and transuranics. The radionuclides of interest are separated chemically and then counted using a beta spectrometer for strontium-90 and alpha spectrometer for transuranics. The separation methods were developed using the DOE EML procedures manual (HASL-300), which may be found at http://www.orau.org/ptp/PTP%20Library/library/DOE/eml/hasl300/HASL300TOC.htm.

8.7 Radionuclides Assessed

Air is considered to be the most critical pathway from the INL Site to off-Site receptors (DOE 2015; DOE-ID 2022a; NCRP 2010). Surface soil can become contaminated with radionuclides by deposition of airborne particles released from INL Site activities.

Information on current radiological effluents is contained in the most recent INL Site NESHAP report, *National Emission Standards for Hazardous Air Pollutants—Calendar Year 2022 INL Report for Radionuclides*, referred to hereafter as the NESHAP Report (DOE-ID 2022b). Using data from the 2014 to 2021 NESHAP reports, the radionuclides that contribute at least 1% of the total estimated dose for a total of 96% of the total estimated dose over the 8-year period are summarized in Table 31. Estimated doses to the MEI during this period ranged from 0.008 to 0.0067 mrem. Tritium and argon-41 are not considered in the soil sampling program because they are not particulates that can be deposited.

Table 31. Radionuclides that are important in terms of radiological dose based on the 2014-2021 NESHAP reports (DOE-ID 2022b).

Radionuclide[a]	Average Percentage of Total Dose (2014–2021)[b]
Cesium-137	26.8
Tritium (vapor)	17.9
Argon-41 (gas)	8.4
Strontium-90	8.1
Americium-241	8.0
Iodine-129	7.3
Uranium-238	6.5
Uranium-234	3.0
Plutonium-239	2.8
Chlorine-36	2.3
Cobalt-60	2.2
Zinc-65	2.1
Carbon-14	1.4
Total	96.8

a. Unless otherwise indicated, radionuclide is assumed to be in a particulate form.
b. Dose estimated using EPA air dispersion code CAP88-PC (Versions 4.0 and 4.1), INL Site meteorological data, and NESHAP source terms.

8.8 Quality Assurance

The quality assurance (QA) programs are detailed in the Environmental Monitoring Services QA Project Plan (QAPjP) and the Environmental Support and Services Monitoring Services Surveillance Plan (INL 2016a).

8.8.1 Physical Soil

QA and quality control (QC) samples are analyzed in addition to field samples and provide information on the variability and usability of environmental sample results. They assist in identifying the origin of analytical discrepancies to help determine how the analytical results should be used. They are used mostly to validate analytical results. Field replicated, collocated, background, and rinsate blank samples are the most commonly collected field QA/QC samples. Performance evaluation, matrix spike, and matrix spike duplicate samples, either prepared for or by the laboratory, provide additional measures of control for the data generated. QA/QC results may suggest the need for modifying sample collection, preparation, handling, or analytical procedures if the resultant data do not meet Site-specific QA objectives.

8.9 Decision Limits and Actions

Per DOE O 458.1, DOE radiological activities must be conducted so that exposure of members of the public to ionizing radiation will: not cause a total effective dose (TED) exceeding 100 mrem (1 mSv) in a year, an equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year, or an equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose. This does not include doses from radon and its decay products in air, doses received by patients from medical sources of radiation, dose from background radiation, or dose from occupational exposure.

A background level has been computed for each near-facility area and distant region to establish the baseline. Individual measurements obtained during sampling events can be compared to the background level to alert the monitoring program that a background level has been exceeded. The background level assumes a parameter of the 99^{th} percentile of all radionuclide concentrations in the soil. Thus, the 99/95% upper tolerance limit (UTL) has been used as the estimate for the background level. This is the level such that 99% of the concentrations will be less than the background level with 95% confidence. The data obtained from future sampling events may be compared to the appropriate set of background levels to determine if any of the measurements exceed the established background level. If the background level is exceeded, the sample will be further investigated to assess the reason for the larger value. It is assumed that 1% of the concentrations will exceed the background level. Thus, a single measurement that exceeds the background level does not necessarily indicate an unusually high amount of that radionuclide in the area. Once the data obtained from a sampling event have been examined and compared to the background levels, the background level will be updated using the new data to ensure that the baseline profile remains current. Table 32 shows the background levels for each of the areas in the near-facility area and distant regions.

The results of soil monitoring should indicate if radionuclides have been transported off-Site and used to assess what the impacts are to human populations. They should also indicate if biotic populations have been impacted. The results require further assessment when they:

- Exceed background levels
- Demonstrate an increasing trend over time.

Table 32. Background levels (UTLs)[a] for near-facility and distant areas (INL,2016b).

Radionuclide	Am-241 (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239/240 (pCi/g)	Sr-90 (pCi/g)
INL Site Facilities					
ARA	0.401	133	0.025	0.0577	57
ATR	0.49	223	0.0116	0.0728	1.349
INTEC	0.9	40	0.387	0.73	14.9
MFC	0.008	1.99	0.01	0.0487	0.953
RWMC	8.4	3.54	0.058	2.57	2.47
TAN	0.086	23.8	0.014	0.029	1.754
Boundary/Distant Sites					
Atomic City	0.0278	1.012	0.0227	0.0573	0.734
Blackfoot	0.0405	2.697	0.154	0.239	0.398
Butte City	0.0942	1.248	0.0337	0.0487	0.56
Carey	0.0556	0.963	0.0447	0.0671	0.534
FAA Tower	0.0356	1.623	0.0743	0.0829	0.806
Frenchman's Cabin	Insufficient data to compute a background value				
Howe	0.01	0.7	0.0119	0.0353	0.67
Monteview	0.0194	1.11	0.035	0.0477	0.268
Mud Lake	0.0875	0.624	0.0514	0.0892	0.335
Blue Dome/Birch Creek Hydro	0.0268	1.583	0.0144	0.0677	0.911
St. Anthony	0.0422	1.758	0.0857	0.0954	0.948

a. The 99/95% upper tolerance limit
b. ARA = Auxiliary Reactor Area
c. ATR = Advanced Test Reactor
d. FAA = Federal Aviation Administration
e. INTEC = Idaho Nuclear Technology and Engineering Center
f. MFC = Materials and Fuels Complex
g. RWMC = Radioactive Waste Management Complex
h. TAN = Test Area North

9. AGRICULTURAL (FOOD) PRODUCTS

9.1 Program Basis

Historical and current INL Site releases of radionuclides could enter the food chain via air or soil. Agriculture products could become contaminated by radionuclides released from INL Site facilities that are transported off-Site by wind and deposited in soil and on plant surfaces. This is important as approximately 45% of the land surrounding the INL Site is used for agriculture (DOE-ID 1995). In addition, many residents maintain home gardens that could be impacted by INL Site releases.

Animals could also eat contaminated crops and soil and in turn transfer radionuclides to humans through the consumption of meat and milk. Livestock uses off the INL Site include the production of sheep, cattle, hogs, poultry, and dairy cattle (Bowman et al. 1984).

Determining radionuclide concentration in the diet or individual food items constitutes an important element of an integrated program of radiological surveillance and assessment. Food is analyzed to determine: (1) the level of contamination at the point of production; or (2) the level of intake of the contaminant for the consumer or a particular population group (DOE 1997). For surveillance purposes on the INL Site, the first factor is most applicable due to the low levels of anticipated contamination and the distances of major population zones from the INL Site. One method of food monitoring is to sample individual foods at the point of production. This is most useful for relating contamination to local conditions of fallout, soil content, or farming practice (DOE 1997). The geographic area to be sampled is relatively small. This sampling system is used, for example, by the U.S. Food and Drug Administration (FDA) in their program of food monitoring near power reactors (FDA 2004; Stroube and Jelinek 1985).

The purpose of the Agricultural Products Monitoring Program at the INL Site is to monitor radionuclides in agricultural products that could be consumed by individuals living in areas surrounding the INL Site.

9.2 Program Drivers

Sampling of agricultural foodstuffs is performed on and around the INL Site to meet the following requirements and the criteria for environmental surveillance of DOE facilities:

- DOE O 458.1, "Radiation Protection of the Public and the Environment" (DOE 2013)
- DOE-HDBK-1216-2015, "Environmental Radiological Effluent Monitoring and Environmental Surveillance" (DOE 2015), which updates and supersedes the "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance" (DOE-EH-0173T) (DOE 1991).

Other key drivers of the ambient air surveillance program include stakeholder inputs and values.

As specified in DOE-HDBK-1216-2015, representative samples of the pathway-significant agricultural products grown at locations surrounding the Site should be collected and analyzed for radionuclides potentially present from Site operations. These samples should be collected in at least two locations: (1) the place of expected maximum radionuclide concentrations; and (2) a background location unlikely to be affected by radionuclides released from the Site (DOE 2015).

Additionally, cow milk—and in certain localities, goat milk—is widely consumed by all age groups. Therefore, milk is frequently one of the most important foods contributing to the radiation dose if dairy animals are pastured near a nuclear site. If dairy herds or 'family' cows (or goats) are present in the vicinity of the site, representative milk samples should be taken and analyzed for radionuclides potentially present from Site operations. The frequency of sampling will depend on the magnitude of the radiation doses potentially received via this source. No particular sampling techniques are required, other than toguard against cross-contamination and souring or curdling of the milk. For the levels of contamination expected at most DOE sites, a 4 L sample is necessary to achieve the required detection level. However, for goat's milk, a 1 L sample may be all that can be obtained, especially from a single goat. Meat is typically not considered good indicator material because of the time delay for the transfer of radionuclides from the point of release through vegetation to beef, pork, and poultry.

DOE-HDBK-1216-2015 also recommends vegetation sampling. Vegetation includes three categories: vegetables, grains, and fruit (DOE 2015). If vegetation (i.e., vegetables, grains, and fruit) is not one of the contributing pathways involved in determining the dose to humans from the site, native vegetation can be used as indicator species. Collection and analysis of vegetation samples can serve three useful purposes: (1) evaluating the potential radiation doses received by people consuming such vegetation; (2) estimating the possible concentrations in meat, eggs, and milk from animals consuming contaminated forage (and resultant radiation doses to consumers of the animal products); and (3) monitoring trends in environmental contamination and possible long-term accumulation of radionuclides.

DOE-HDBK-1216-2015 recommends that agricultural product sampling and analysis be performed as part of environmental sampling conducted to protect the environment and the public (DOE 2015).

According to the sample collection/analysis criteria presented in Table 6-2 of DOE-HDBK-1216-2015, if the total effective dose (TED) is estimated to be between 1 and 5 mrem, then sufficient surveillance (at least annually) should be conducted to provide reasonable assurance that the doses are within this range. Above 5 mrem, routine sampling should be conducted on those foods and radionuclides contributing at least 90 percent of the ingestion. If the TED is between 1 and 0.1 mrem, then periodic surveillance (at least every 5 years) should be performed to ensure that radionuclides are behaving in the environment as expected.

Dose calculations made using U.S. Environmental Protection Agency (EPA) air-dispersion code CAP88-PC (EPA 2020) for releases from the INL Site for the past eight years (2014 to 2021) show an annual TED ranging from 0.008 to 0.067 mrem/year to a hypothetical individual living at the location of maximum radionuclide concentration (DOE-ID 2022). The estimated dose has not exceeded 1 mrem in the period from 2014-2021. As such, routine surveillance of agricultural products is not indicated.

However, to ensure the detection of radionuclides originating from the INL Site in foodstuffs well before dose standards are approached, annual monitoring should be conducted around the INL Site. This assures protection of the public.

9.3 Related Studies/Surveillance

The earliest records on file for agricultural sampling around the INL Site are from a 1966 annual report (AEC 1968). The report states that “all samples collected in 1966 were found to be below applicable AEC guide values.” Agricultural sampling has continued with current and historical results (DOE-ID 2011) being comparable to those reported more than 40 years ago (AEC 1968).

The current agricultural program, locations, and sampled media shown in Figure 48 were developed historically to fulfill several recommendations of DOE Regulatory Guide 0173T (DOE 1991), which preceded DOE-HDBK-1216-2015 (DOE 2015):

- Pathway significant agricultural products grown and collected within 10 miles of the INL Site
- The samples are collected in at least two locations: (1) the place of expected maximum radionuclide concentrations; and (2) a ‘background’ location unlikely to be affected by radionuclides released from the Site
- If dairy herds or ‘family’ cows (or goats) are present in the vicinity of the site, representative milk samples should be taken and analyzed for radionuclides potentially present from Site operations.

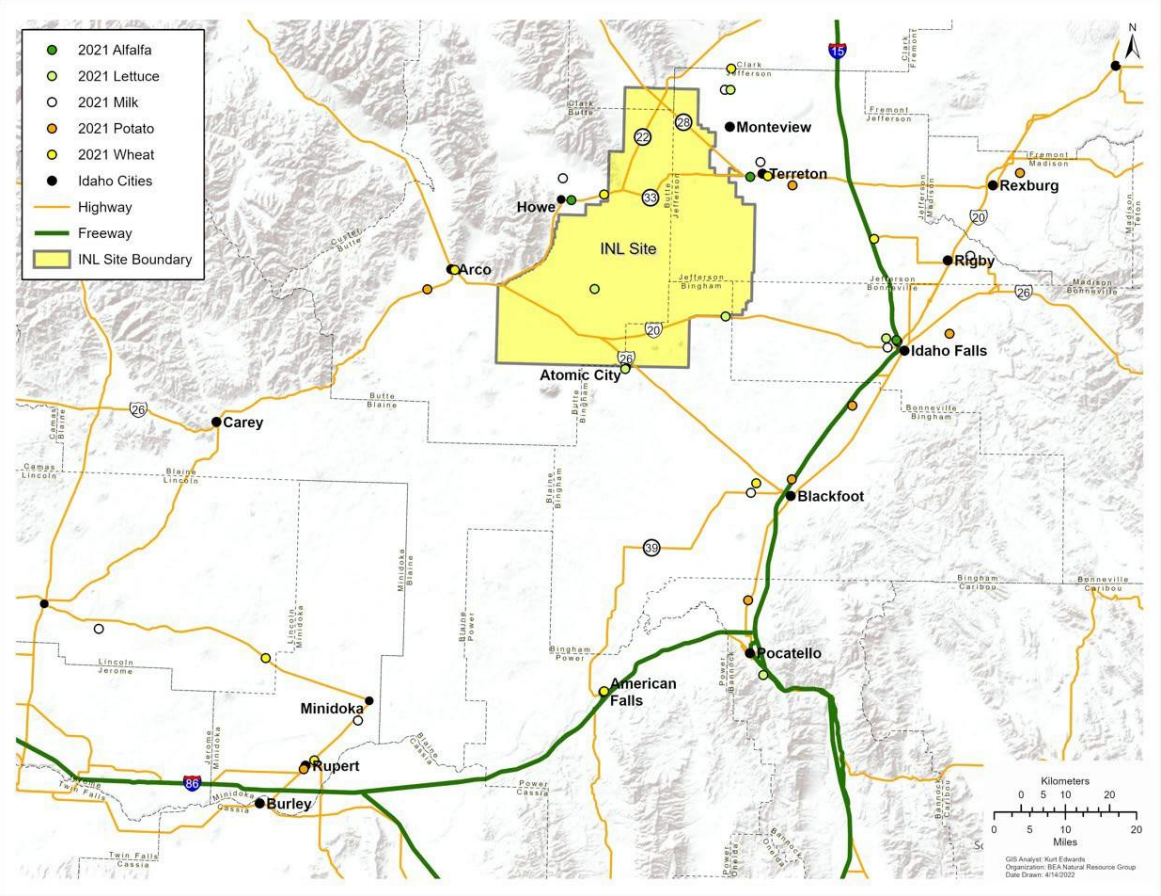

Figure 48. Agricultural product sampling locations in 2021.

According to DOE-HDBK-1216-2015 (2015), meat samples are not good indicator materials due to the time delay for transfer of radionuclides from the point of release through vegetation to beef, pork, and poultry. With a few exceptions, radiation doses from meat ingestion are considered secondary. This was confirmed by gamma analysis of meat, liver, and thyroid samples collected from sheep grazing on and off the INL Site prior to 2007. While cesium-137 was sometimes detected in sheep grazing on-Site, the calculated ingestion doses were far below the guidelines recommended by DOE.

In order to better assess the potential dose pathways for local livestock and game animals, the *Independent Oversight Assessment of Environmental Monitoring at the Idaho National Laboratory Site* (DOE-HSS 2010) recommended that locally grown alfalfa and native vegetation in grazing allotments on the INL Site, as observed in Figure 49, be sampled with the highest potential to be impacted based on known isopleths and wind rose data (Figure 50). Ideally, this location would be along the southern INL Site Boundary; however, there are no agriculture activities in this area (Figure 49). Instead, a routine collection of alfalfa samples from a farm near the northwest INL Site Boundary (near where milk is also collected) was initiated in 2011. Elk forage (grasses and forbs) samples were also collected in 2011 from areas known to be frequented by elk based on radio collar information (GSS 2012). Samples were obtained from an area north of MFC, from around RWMC, and from a control area near Craters of the Moon National Monument. These were analyzed for gamma-emitting radionuclides because cesium-137 is sometimes detected in game animal samples. No man-made gamma-emitting radionuclides were detected, and therefore, routine sampling of elk forage was not incorporated in the agricultural product surveillance program.

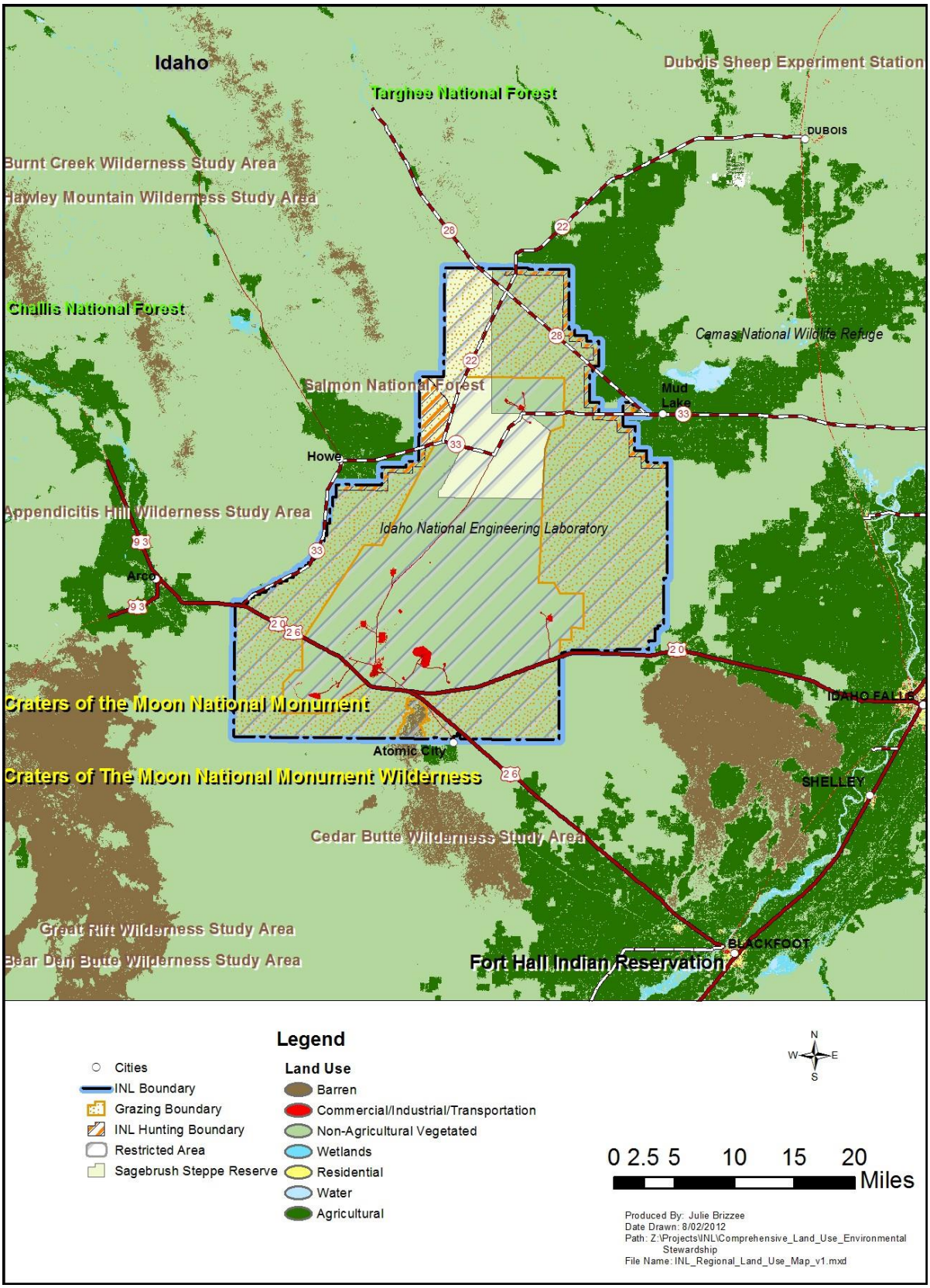

Figure 49. Land use at the INL Site.

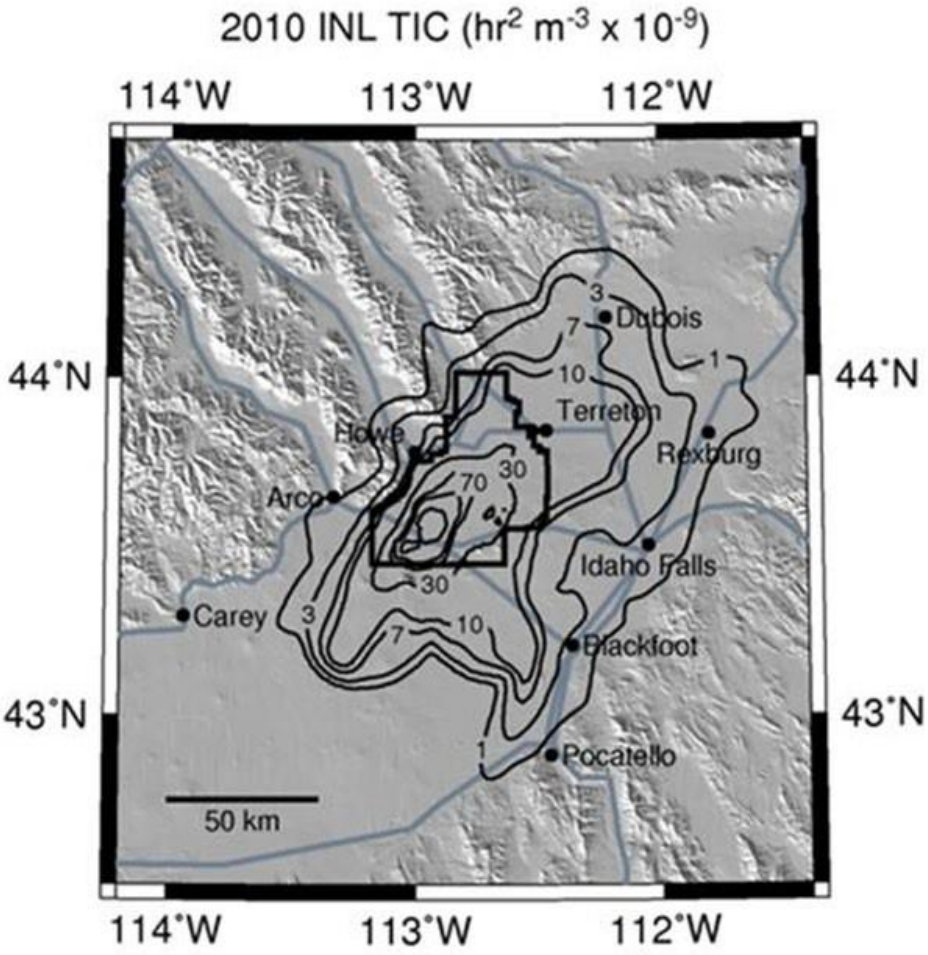

Figure 50. Time-integrated concentrations based on National Oceanic and Atmospheric Administration (NOAA) meteorological monitoring data at the INL Site (DOE-ID 2011).

Cesium-137, strontium-90, and tritium, which are identified as important contributors to ingestion dose, have been historically detected in agricultural product samples (e.g., milk, potatoes, wheat, alfalfa) collected around the INL Site (DOE-ID 2014). During 2014 to 2021, strontium-90 was the most frequently detected radionuclide in all agricultural products, whereas cesium-137 was not detected. The source of strontium-90 and cesium-137 in agricultural products is most likely atmospheric fallout from past weapons testing.

Iodine-129 has not been detected in regional agricultural products because it is not routinely analyzed due to the expense of analysis. According to several Annual Site Environmental Reports (ASERs)

(Hoff et. al 1991; Hoff et al. 1992; Hoff et al. 1993; Mitchell 1994; Mitchell et al. 1995; Mitchell et al. 1996), approximately 3.6 Ci of iodine-129 were released through 1995 from a 69-m stack located at the Idaho Nuclear Technology and Engineering Center (INTEC). From 1996 to 1999, the Environmental Science & Research Foundation (ESRF) sampled sagebrush, grass-forb, litter, small mammals, and four soil compartments to estimate the total iodine-129 inventory on the INL Site (Morris 2000). The results were never published (Morris and Soto, unpublished data), but were shared with the Environmental Surveillance, Education, and Research (ESER) program (Morris 2003). The ESRF collected three samples each of four soil layers, litter, sagebrush, grass and forbs, and small mammal samples at each of 16 locations on and near the INL Site for iodine-129 analysis. Although a preliminary study, it was estimated that most of the current inventory of iodine-129 on the INL Site resides southwest of INTEC,

and is the highest in litter and the lowest in deep soil. This unpublished study also approximated that around 6% of the total inventory released to the environment remains at the INL Site. They hypothesized that the rest was transported off-Site after release from the stack. The iodine-129 concentration in forbs and grasses collected just south of the INL Boundary and north of the Big Southern Butte, where the highest concentrations have been modeled to occur off-Site, averaged 1.8 pCi/kg. Iodine-129 concentrations in litter and upper soil at the same location averaged 4.2 and 1.2 pCi/kg, respectively. If grazing cattle consumed forage at the area of maximum projected concentration, the dose to an individual eating meat from those cows would be 1.1E-03 mrem, as calculated using methodology described in the *Idaho National Laboratory Site Environmental Report, Calendar Year 2013* (DOE-ID 2014). If a game animal were to access the area of highest iodine-129 concentration (6.7 pCi/kg) southwest of INTEC, the dose to an individual eating meat from this animal would be 4.2E-03 mrem. If milk cows foraged downwind near the northeast INL Site Boundary, where grass and forbs averaged 0.30 pCi/kg, the estimated dose from drinking milk from those cows would be 3.5E-04 mrem. If lettuce grown in this area contained the same concentration as grass and forbs, the dose to a human from eating the contaminated lettuce would be 2.2E-02 mrem. Thus, ingestion of iodine-129 may be insignificant and, given the expense of the analysis, should not be analyzed routinely in the Agricultural Products Monitoring Program. Instead, a special study that continues the ESRF study (Morris 2003) would be more appropriate.

Statistical analyses of strontium-90 concentrations in lettuce and milk samples collected historically indicate no differences in strontium-90 results between areas of expected maximum concentrations and Distant locations. In the case of lettuce, data collected prior to 2011 are not considered comparable to more recent data because the current laboratory uses different methodology to prepare and analyze lettuce, resulting in lower detection limits. The results from 2011 to 2013 were normally distributed with a mean of 61 pCi/kg, a minimum of -3 pCi/kg, a maximum of 164 pCi/kg, and a 95% confidence interval from 49 to 74 pCi/kg. There is no statistical difference, using a student *t* test, between the on-Site/Boundary (e.g., the Experimental Field Station [EFS], Atomic City, Arco, Federal Aviation Administration [FAA] Tower, Howe) and the Distant (e.g., Blackfoot, Carey, Idaho Falls, Sugar City) results measured from 2011 to 2013. Strontium-90 is undetectable in control samples of lettuce purchased from a grocery store. This possibly reflects the method used to grow the lettuce, such as hydroponics.

The current agricultural program, locations, and sampled media fulfill several recommendations of DOE-HDBK-1216-2015 (DOE 2015) where:

- Sampling considers pathway-significant agricultural products grown and collected at locations surrounding the INL Site
- The samples are collected in at least two locations: (1) the place of expected maximum radionuclide concentrations; and (2) a ‘background’ location unlikely to be affected by radionuclides released from the INL Site
- If dairy herds or ‘family’ cows (or goats) are present in the vicinity of the site (e.g., within 10 miles), representative milk samples are taken and analyzed for radionuclides potentially present from Site operations
- The sampling considers representative vegetation (e.g., fruits, grains, vegetables).

9.4 Program Goals

The primary aim of agricultural product sampling is to get accurate data about the concentration levels of INL Site-related radionuclides in agricultural products consumed by humans and farm animals to evaluate potential public health and environmental impacts from INL Site operations. The sampling that the environmental surveillance program conducts must evaluate the potential pathways of exposure to radionuclides in off-Site agricultural products by:

- Determining whether INL Site-related radionuclides reach off-Site receptors in this pathway
- Distinguishing these radionuclides as background, fallout, or within historical levels previously measured resulting from INL Site operations
- Determining when agricultural product radionuclide concentrations in off-Site locations exceed or are approaching regulatory limits
- Identifying when agricultural product concentrations in off-Site locations pose a hazard to the public. In support of these objectives, the program is designed to insure that:
- The dose received by a representative member of the public through ingestion is less than 10 mrem (or 10% of the primary dose limit) from the ingestion of foods containing radionuclides released from the INL Site
- Radionuclides of concern in agricultural products collected around the INL Site can be measured at minimum detectable concentrations equivalent to least 20% (1 mrem) of the DOE-HDBK-1216-2015 (DOE 2015) reference dose (5 mrem).

9.5 Sampling Boundaries

9.5.1 Physical

As stated in DOE-HDBK-1216-2015 (DOE 2015), samples should be collected from locations surrounding the INL Site. It also recommends that vegetation sampling and milk sampling (from goats or cows) be selected among locations in the potentially impacted vicinity of the site (i.e., one sample at the highest annually average air concentration and in each area that where the estimated dose exceeds 5 mrem/year). At a minimum, representative agricultural product samples should be collected in at least two locations: (1) the place of expected maximum radionuclide concentrations; and (2) a ‘background’ location unlikely to be affected by radionuclide emissions released from the INL Site. Milk samples should be as representative of the location of interest as possible (i.e., not commercially available processed milk).

Where warranted, and based on Site-specific considerations, DOE-HDBK-1216-2015 (DOE 2015) acknowledges that it may be necessary for individual DOE sites or facilities to conduct sampling at extended distances from the site.

9.5.2 Temporal

Annual sampling of fruits, grains, and vegetables should occur during harvest periods when sufficient sample sizes are available.

For milk, DOE-HDBK-1216-2015 (DOE 2015) recommends that at a minimum, one background and one potentially affected location be sampled at least annually. For iodine-131 analysis, sampling should be at least biweekly during the local grazing season. For longer-lived radionuclides, such as strontium-90, iodine-129, and cesium-137, quarterly composite samples are usually adequate.

Although there is no DOE guidance for sampling of animal feed, it makes sense to collect alfalfa samples after the first harvest, when the hay is relatively green and is most likely to represent the fastest period of growth and nutrient uptake.

9.6 Sampling Design

Per DOE-HDBK-1216-2015 (DOE 2015), samples will be taken from locations surrounding the INL Site, as shown previously in Figure 48. Sampling plots are selected to represent areas within this area as well as representing locations that may receive the highest concentrations from wind-distributed radionuclides (Figure 50). To assess distribution distances and impacts of radionuclides from INL Site operations, agricultural samples are taken from areas outside of the 10 mile radius recommended by DOE-EH-0173T (DOE 1991) (Table 33).

Table 33. Acreage of major crops harvested on land surrounding the INL Site (USDA 2017).

County	Total Harvested Cropland	Wheat	Barley	Potatoes	Sugar Beets	Orchards	Oats	Silage Corn	Forage[a]
Bingham	345,521	135,883	19,764	67,297	21,872	17	32	2,859	92,724
Bonneville	172,674	49,387	68,414	16,708	—[b]	19	211	4,220	28,922
Butte	69,677	9,060	11,726	1,068	—	—	347	251	47,224
Clark	34,733	7,273	2,615	195	—	—	—	1,460	23,190
Jefferson	202,560	43,318	40,084	30,961	—	6	77	5,168	81,980

a. Land used for all hay, haylage, grass silage, and greenchop.
b. Signifies no acreage or data withheld to avoid disclosing data for individual farms.

Radioactive material concentrates in vegetation as a result of deposition onto plant foliage and from uptake of activity deposited on the ground. Contaminated irrigation water can also impact vegetation, but contaminated groundwater is not a significant pathway at the INL Site (DOE-ID 2014).

DOE-HDBK-1216-2015 (DOE 2015) recommends that vegetation from three categories be sampled: vegetables, grains, and fruit. It is recommended that vegetables be sampled at local farms or family gardens. Leafy, green vegetables are preferred because of the relatively large surface areas exposed to deposition and the fact that almost the entire plant is consumed. In addition, vegetable/soil radionuclide transfer factors are greater for leafy vegetables than for other kinds of food, such as root vegetables, fruits, and grains (Wang et al 1993). Vegetable samples should be collected at the area of maximum projected concentration.

Based on the total acreage farmed for wheat in southeast Idaho, the program should focus on this grain, although it is not grown in the location of maximum modeled concentrations. In addition, grains grown for human consumption do not tend to concentrate radionuclides, as evidenced by past ESER monitoring (DOE-ID 2014). However, wheat has been sampled historically and is of some interest to residents living southwest of the INL Site (MWH 2002). For these reasons, wheat should be sampled where available.

Potatoes are also of interest to members of the public in Idaho and other states where Idaho potatoes are consumed. Although potatoes do not tend to concentrate radionuclides and there are none grown commercially in the areas of maximum predicted concentrations, they have been sampled historically and are of interest to the public consuming them. For these reasons, potato sampling should continue.

Given the small acreage devoted to orchards around the INL Site, as well as the fact that DOE-EH-0173T (DOE 1991) states it is normally not necessary to sample fruit, fruit should not be sampled.

Milk is an important food product in southeast Idaho, as there are many dairies in the area. Although there is not a dairy at the area of maximum concentration, there are dairies in other areas where concentrations are higher than background levels (i.e., Howe and Terreton). Given the historical detection of strontium-90 and tritium in milk collected around the INL Site, most likely from atmospheric fallout or natural sources, milk should be collected. When fresh milk is not available, analytical results of analysis of leafy vegetables or fresh forage can be used to calculate radionuclide concentrations in milk.

Meat has been demonstrated to be of secondary importance in the agricultural food chain; therefore, it should not be sampled. However, in order to better assess impacts on farm and game animals, DOE-HSS recommended locally grown alfalfa and native vegetation in grazing allotments on the INL Site (Figure 49) be sampled with the highest potential to be impacted. Although man-made radionuclides have not been detected via gamma analysis of previously collected samples, alfalfa, or native forbs should be collected at areas of higher predicted concentrations for the analysis of strontium-90 concentrations.

In summary, samples representing grain, vegetables, milk, and vegetation likely to be grazed by farm animals (i.e., alfalfa) will be sampled.

9.6.1 Sampling Locations

Air dispersion modeling, using CALPUFF and INL Site meteorological data measured from 2006 to 2008, was performed to develop data quality objectives (DQOs) for radiological air surveillance for the INL Site using the methodology documented in Rood and Sondrup (2014). The same methodology was used to discern deposition patterns. For deposition, it was assumed that the particulates have a geometric mean diameter of 1 micron and a geometric standard deviation of 1.5 microns. Based on historical National Emission Standards for Hazardous Air Pollutant (NESHAP) data, the Advanced Test Reactor (ATR) Complex and INTEC were selected as the major sources of particulates containing cesium-137, iodine-129, and strontium-90. Most radionuclides are released from ATR via a stack and from INTEC via ground-level emissions. The dispersion and deposition patterns resulting from these sources reflect the southwest/northeast wind patterns typical of the INL Site. In INL/MIS-22-68866, *Data Quality Objectives Summary Report Supporting Agricultural Products Monitoring* (INL 2022), it was concluded that where the deposition and dispersion patterns (Rood and Sondrup 2014), agricultural activity (Figure 49), and resident locations (Figure 50) overlap, the areas of maximum potential impact for agricultural products are located along the southern (Atomic City), western (Howe), and northeastern (Mud Lake/Terreton) INL Site boundaries (Figure 51). The CALPUFF model also demonstrates that the maximum offsite deposition value is located between the southwest INL Site Boundary and the Great Southern Butte (Frenchmans Cabin). However, there is no agricultural activity at this location.

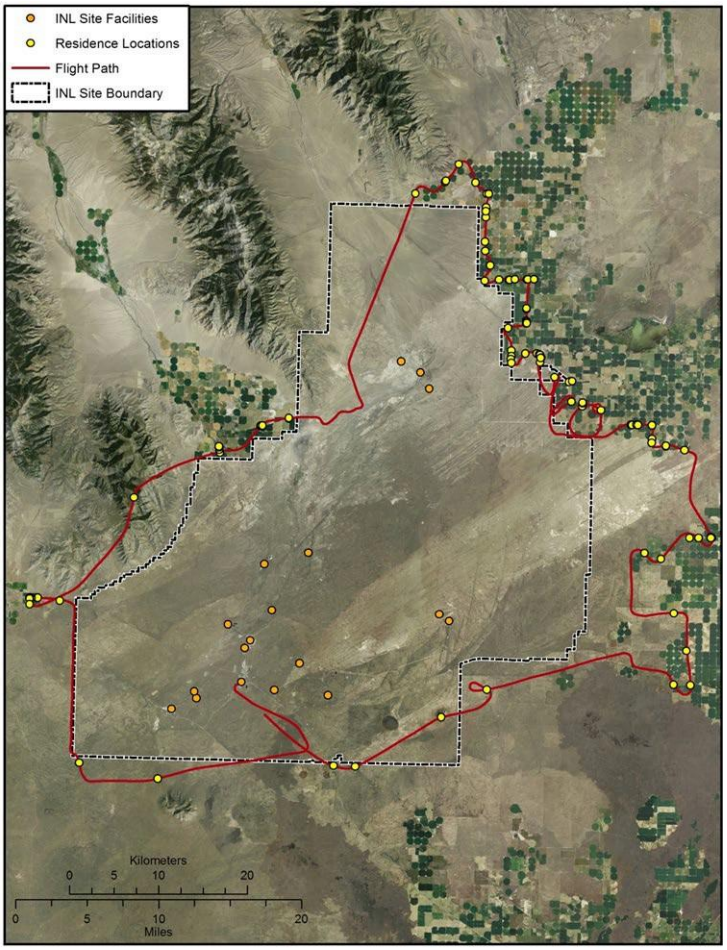

Figure 51. Distribution of residences around the INL Site. The flight path shown was conducted in 2001.

9.6.2 Frequency of Sample Collection

The representative food samples and frequency of collection for agricultural monitoring are shown in Table 34. Wheat and potatoes are crops that have been collected in the past due to public interest.

Although radionuclides of interest (e.g., strontium-90, cesium-137) have not been frequently detected in the past, the collection process is not difficult and gamma analysis is relatively inexpensive to perform. Wheat and potatoes will thus be collected in the region to provide assurance to the public that the INL Site has not impacted commercial production of these staple crops. Because wheat and potatoes are rotated seasonally, the areas where they will be collected are variable, depending on availability.

Collection of the remaining agricultural food products (e.g., lettuce, milk) at the area of maximum concentration is not possible due to the fact that no agricultural land use occurs here. Although there is not a dairy at the area of maximum concentration, there are dairies in other areas where concentrations are modeled to be higher than background levels (e.g., Howe, Terreton). Alfalfa will be collected at Howe (e.g., the Boundary), Terreton/Mud Lake (e.g., downwind), and Idaho Falls (e.g., Distant) for comparison and to help clarify the forage to milk pathway at these locations.

Table 34. Sampling locations around the INL Site.

Medium	Frequency of Collection	Area of Potential Maximum Impact	Likely Areas of Potential Impact Above Background	Areas of Minimum or Unlikely Impact
Green, leafy vegetables	Annual	NA[a]	Howe, Terreton, and Atomic City	Idaho Falls, Blackfoot, and Rupert. More at other locations, if available
Wheat	Annual	NA	Howe, Terreton, if available	Three or more Distant locations, where available
Potatoes	Annual	NA	Howe, Terreton, if available	Three or more Distant locations, where available
Milk	Weekly at Rigby and Terreton; Monthly at all others	NA	Howe and Terreton (not available at Atomic City)	Dietrich, Rigby, and Rupert
Forage-Alfalfa	Annual	NA	Howe and Terreton/Mud Lake	Idaho Falls

a. NA = Not applicable because agricultural product is not grown or produced at this location.

9.6.3 Sampling Methods

Lettuce samples are collected from locations bordering the INL Site and at locations Distant from the INL Site (Figure 48). Samples are collected annually from local gardens and analyzed for gamma-emitting radionuclides and strontium-90. The environmental surveillance program also uses portable self-contained lettuce planters at the sampling locations in Atomic City, EFS (on-Site), the FAA Tower, Monteview, and Howe. These locations are relatively remote and have no access to water, requiring that a self-watering system be developed. This method allows for the placement and collection of lettuce at areas previously unavailable to the public (i.e., on the INL Site). The planters are set out in the spring with lettuce grown from seed. This method also allows for the accumulation of deposited radionuclides on the plant surface throughout the growth cycle. Lettuce samples are processed, dried, and sent to analytical laboratories.

Wheat samples are collected annually from local growers at approximately ten locations around the INL Site (Figure 48) and one outside the state of Idaho. The samples are collected from combines, trucks, or grain elevators. The samples are sent to analytical laboratories and analyzed for gamma-emitting radionuclides and strontium-90.

Potato samples are collected annually from local potato growers at approximately eight locations around the INL Site (Figure 48) and at least one location outside of Idaho. The samples are processed and sent to analytical laboratories for analysis for gamma-emitting radionuclides and strontium-90.

Milk is collected weekly at two dairies—one located in Rigby and another located in Terreton. Milk is also collected monthly at six dairies outside of and within 50 miles of the INL Site Boundary (Figure 48). Samples are sent to analytical laboratories for analysis for gamma-emitting radionuclides, tritium, and strontium-90.

9.6.4 Analytical Methods

Radionuclides of concern will be analyzed according to Table 35. All agricultural products will be analyzed for gamma-emitting radionuclides (such as iodine-131 and cesium-137). Green, leafy vegetables, forage, and milk will be analyzed for strontium-90 because this radionuclide has been detected historically in these media. Only milk will be analyzed for tritium as it is easy to analyze for in liquids and has been detected in milk in the past. Milk will be collected and analyzed more frequently at Terreton (a downwind, Boundary location) and Rigby (a Distant, 'background' location). Currently, milk is collected weekly from Terreton and Rigby.

Table 35. Radionuclides and frequency of analysis.

Medium	Tritium	Strontium-90	Gamma Analysis
Green, leafy vegetables	No	Annually	Annually
Wheat	No	Annually	Annually
Potatoes	No	Annually	Annually
Milk - Terreton and Rigby - All other locations	 Biannually Biannually	 Biannually Biannually	Weekly Monthly
Forage	No	Annually	Annually

Potato and lettuce samples are processed, dried, milled, placed in small vials, and sent to the analytical laboratories for analysis for strontium-90 and gamma-emitting radionuclides (e.g., cesium-137). Forage samples are dried and milled and analyzed for gamma-emitting radionuclides (e.g., cesium-137). Wheat samples are sent to the laboratories for the same analyses, but are not dried or milled. Milk is sent to the laboratories in 2-L containers for analysis for gamma-emitting radionuclides (e.g., iodine-131 and cesium-137) and for strontium-90. Half of the samples are also analyzed for tritium.

The sample volumes and counting times are driven by the desired minimum detection limits, as shown in Table 36.

Table 36. Detection limits for radionuclides in agricultural product samples.

Medium	Approximate Sample Size	Radionuclide	MDA (pCi per sample)	MDC (pCi/L or pCi/kg)
Milk	1 L 2 L 1 L	Strontium-90 Iodine-131 Hydrogen-3	0.2 2.0 100	0.2 1.0 100
Potato	15 g 500 g	Strontium-90 Cesium-137	0.98 4.0	65 8.0
Lettuce	5 g 12 g	Strontium-90 Cesium-137	0.33 1.8	65 150
Wheat	5 g 500 g	Strontium-90 Cesium-137	0.33 4.5	65 9.0
Forage	5 g 12 g	Strontium-90 Cesium-137	0.33 1.8	65 150

9.7 Radionuclides Assessed

Although there are several more radionuclides, it is impractical and cost-prohibitive to perform complete analyses on all of them. The primary pathways contributing to the majority of doses to the maximally exposed individual (MEI), and the radionuclides associated with them, have been calculated by EPA air-dispersion code CAP88-PC (EPA 2020) for the annual NESHAP report (DOE-ID 2022). The results indicate that inhalation is a major exposure pathway for transuranics such as americium and plutonium; immersion is a major pathway for noble gases; and food represents a major pathway for cesium-137, strontium-90, iodine–129, and tritium. This is consistent with conclusions made in DOE-HDBK-1216-2015 (DOE 2015) that radionuclides of potential significance in vegetation and milk include tritium, strontium-89, strontium-90, iodine-129, iodine-131, and cesium-137.

Therefore, radionuclides that contribute significantly to dose and are readily taken up by the body should be assessed. Radiological analyses historically performed on agricultural products collected near the INL Site are (DOE-ID 2011):

- Gamma spectrometry in all media (with cesium-137 being the gamma-emitter of interest)
- Gamma spectrometry of alfalfa
- Strontium-90 in potatoes, grain, and lettuce
- Strontium-90, tritium, and iodine-131 in milk.

Strontium-90 is an important radionuclide because it behaves like calcium and can deposit in bones. Strontium-90, like cesium-137, is produced in high yields from nuclear reactors or detonations of nuclear weapons. It has a half-life of 28 years and can persist in the environment. Strontium tends to form compounds that are soluble, as compared to cesium-137, and are therefore comparatively mobile in ecosystems (DOE-ID 2011). About 8% of the ingested activity remains in the body after 30 days, and this decreases to about 4% after 1 year. This activity is mainly in the skeleton. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (in the pore spaces between soil particles). Concentration ratios are typically even higher (110 times the concentration in solution) in clay soil (ANL 2007).

Cesium-137 (gamma spectrometry), the predominant gamma-emitter and largest gamma contributor to dose for waterfowl (Halford, Millard, and Markham 1981), assuming it behaves similarly no matter which media it is from, is chemically analogous to potassium in the environment and behaves similarly. It has a half-life of about 30 years and tends to persist in soil and, in soluble form, can readily enter the food chain through plants. It is widely distributed throughout the world from historic nuclear weapons detonations from 1945 to 1980 and has been detected in all environmental media at the INL Site.

Regional sources of cesium include releases from INL Site facilities and resuspension of previously contaminated soil particles (DOE-ID 2011). Cesium tends to concentrate in muscles because of their relatively large mass. Like potassium, cesium is excreted from the body fairly quickly. In an adult, 10% is excreted with a biological half-life of 2 days, and the rest leaves the body with a biological half-life of 110 days. Clearance from the body is somewhat quicker for children and adolescents. This means that if someone is exposed to radioactive cesium and the source of exposure is removed, much of the cesium will readily clear the body along the normal pathways for potassium excretion within several months.

Iodine is an essential nutrient element and is readily assimilated by cows eating plants containing the element. Iodine-131 is of particular interest because it is produced by nuclear reactors or weapons, is readily detected, and along with cesium-134 and cesium-137, can dominate the ingestion dose regionally after a severe nuclear event such as the Chernobyl accident (Kirchner 1994). Iodine-131 has a short

half-life (8 days) and therefore does not persist in the environment. Iodine can be taken into the body by eating food, drinking water, or breathing air. It is a constituent of thyroid hormone and, as such, is a required element for humans. Iodine is readily taken into the bloodstream from both the lungs and the gastrointestinal tract (essentially 100%) after inhalation and ingestion. Upon entering the bloodstream, 30% is deposited in the thyroid, 20% is quickly excreted in feces, and the remainder is eliminated from the body within a short time (per simplified models that do not reflect intermediate redistribution) (ANL 2007).

Tritium, with a half-life of about 12 years, is an important radionuclide because it is a radioactive form of hydrogen, which combines with oxygen to form tritiated water. The environmental behavior of tritiated water is like that of water, and it can be present in surface water, precipitation, and atmospheric moisture. Tritium is formed by natural processes, as well as by reactor operation and nuclear-weapons testing. Tritium enters the food chain through surface water that animals drink, as well as in plants that contain water (DOE-ID 2011). Tritium can be taken into the body by drinking water, eating food, or breathing air. It can also be taken in through the skin. Nearly all (up to 99%) inhaled HTO can be taken into the body from the lungs, and then distributed to all tissues through circulating blood. Ingested tritium oxide is also almost completely absorbed, moving quickly from the gastrointestinal tract to the bloodstream. Within minutes, the inhaled HTO can be found in varying concentrations in body fluids, organs, and other tissues. Skin absorption of airborne tritium oxide can also be a significant route of uptake, especially for exposure to high concentrations of tritiated water vapor, as could occur under conditions of high humidity during hot weather, because of the normal movement of water through the skin. For someone immersed in a cloud of airborne HTO, the uptake by absorption through the skin would be about half that associated with inhalation. No matter how it is taken into the body, tritium is uniformly distributed through all biological fluids within 1 to 2 hours. Tritium is eliminated from the body with a biological half-life of 10 days, the same as for water. During the time it is in the body, a small fraction of the tritium is incorporated into easily exchanged hydrogen sites in organic molecules (ANL 2007).

9.8 Quality Assurance

An effective QA program to ensure the collection of high-quality data is in place. The program is detailed in the Environmental Monitoring Services QA Project Plan (QAPjP), which serves to ensure that all data collected are of known and defensible quality, and to meet the requirements of all applicable federal and state regulations and DOE orders, specifically DOE O 414.1A, ASME NQA-1-2000 (ASME 2008), EPA QA/R-5 (EPA 2001), and ANSI/ASQC E-4 (ANSI/ASQC 1994).

9.9 Decision Limits and Actions

For detected radionuclides showing concentrations above the average background level and exceeding the historical range for the past five years:

- Determine if the concentration is an anomalous measurement.
- If verifiable, assess the potential dose to humans using the radionuclide concentration measured minus the average concentration measured in samples collected from locations of minimum potential impact and the dose calculation methodology described in *Idaho National Laboratory Site Environmental Report, Calendar Year 2021* (DOE-ID 2022a). This is a very conservative calculation.

If the estimated dose to humans is above the action level of 1 mrem (1% of regulatory limit of 100 mrem) then inform DOE-ID for potential corrective actions. If detected radionuclides are above background and exceed historical levels, a determination of whether the concentration is an anomalous measurement will be made using one of the following methods:

- Review historical monitoring results at that location to see if the measurement is consistent with past monitoring results.
- Consult with the Idaho Department of Environmental Quality (DEQ) INL Oversight Program.
- Review to determine if this location is affected by recent activities or events (e.g., Fukushima fallout event).
- Review any other factors that may have contributed to the result.

If the concentration is verified, it may signal the need for further action dependent upon the concentration level and/or a trend showing elevated concentrations over time. Further investigation may include performing a calculation of the highest potential dose to humans using the conservative method of employing maximum radionuclide concentrations, or comparing detected concentration levels to other federal standards, such as the FDA's derived intervention levels, as was done during the Fukushima accident (FDA 2004).

10. BIG GAME ANIMALS

10.1 Program Basis

Before 1984, no elk were known to reside on the Idaho National Laboratory (INL) Site; but by 1990, more than 200 elk were documented to be frequenting the Site (Peek and Comer 2000) and continue to do so today (Whiting 2010). Pronghorn (Hoskinson 1977) and deer (Reynolds et al. 1986) migrate through or reside on the INL Site as well. Both elk and pronghorn are known to be associated with radioactively contaminated areas and/or facilities on the INL Site and migrate from the INL Site (Hoskinson 1977; Long, Idaho State University [ISU], Personal Communication 2012). Therefore, some animals from the INL Site could be harvested by hunters because hunting is permitted up to 0.5 mile inside the northeast border and up to 3 miles inside the northwest border of the INL Site. Some animals may also migrate long distances from the INL Site (Long 2013) and could be harvested by hunters. Therefore, the development of the data quality objectives (DQOs) for the INL Site Big Game Animal Monitoring Program was used to establish the technical basis for this component (INL 2022c). The DQO process followed the U.S. Environmental Protection Agency (EPA) DQO process (EPA 2006).

Because these animals have historically been documented to uptake some level of radioactive contaminants (Markham et al. 1982, Markham and Halford 1985, Markham et al. 1980, Markham, Halford and Autenrieth 1980), the sampling of big game is important to ascertain the potential impacts of these contaminants on the animals themselves, as well as the humans potentially consuming them.

10.2 Program Drivers

Monitoring INL Site big game animals fulfills:

- Regulatory requirements for assessing the movement of radionuclides from the INL Site
- Regulatory requirements for assessing the protection of the public and environment
- Regulatory requirements for assessing the impacts to biota
- A responsibility to address public concern regarding the movement of INL Site-produced radionuclides off-Site
- A responsibility to address public concern that big game animals harvested near the INL Site may contain radionuclide concentrations above background levels.

10.3 Results of Related Studies/Surveillance

Vegetation contaminated by radionuclides released from INL Site facilities, including buried waste areas (Warren 1999), could be consumed by big game animals. Big game have been documented on the INL Site for decades, and a sampling program was established in the early 1970s (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford, and Autenrieth 1980). Analyses indicated that big game could become contaminated with radionuclides and could not only receive a radiological dose themselves, but also potentially provide a dose to persons consuming them (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford and Autenrieth 1980). Thus, INL Site Operations could potentially impact big game coming in contact with radioactive-waste areas or contaminated areas outside of waste areas, as well as moving contaminants off-Site and being harvested and consumed by the public. This makes a valid basis for sampling big game from the INL Site to assess the radionuclide concentrations. These data enable a biota dose assessment to evaluate impacts on biota foraging and watering on the INL Site using Site waste ponds, as well as providing data to humans consuming big game potentially containing these radiological contaminants (INL 2022c).

Historically, big game were observed and specifically collected by the Idaho Department of Fish and Game for the U.S. Department of Energy–Idaho Operations Office (DOE-ID) near INL Site Facilities (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford, and Autenrieth 1980). This occurred through 1978. No big game samples were collected in 1979; the collection of road-killed animals began in 1980 (DOE-ID 1981).

In 2011, at the recommendation of the 2010 DOE-HSS assessment of the INL Site Environmental Monitoring Program (DOE-HSS 2010), vegetation samples were collected at areas frequented by elk (Figure 52). The sampled vegetation species were known elk forage species based on field observations. Biased samples were collected from areas with the highest soil concentrations by the on-Site contractor near Radioactive Waste Management Complex (RWMC) on the west side of the INL Site and analyzed for gamma and transuranic radionuclides. Water samples were also collected near the Materials and Fuels Complex (MFC) on the east side of the INL Site and analyzed for gamma radionuclides (Figure 52).

Control samples were collected near Craters of the Moon National Monument as well (Figure 52). None of the gamma or transuranic results exceeded the action level, which is defined as exceeding 3 sigma (σ). This may indicate that vegetation and water from MFC may not be a significant pathway in distributing radionuclides to big game animals.

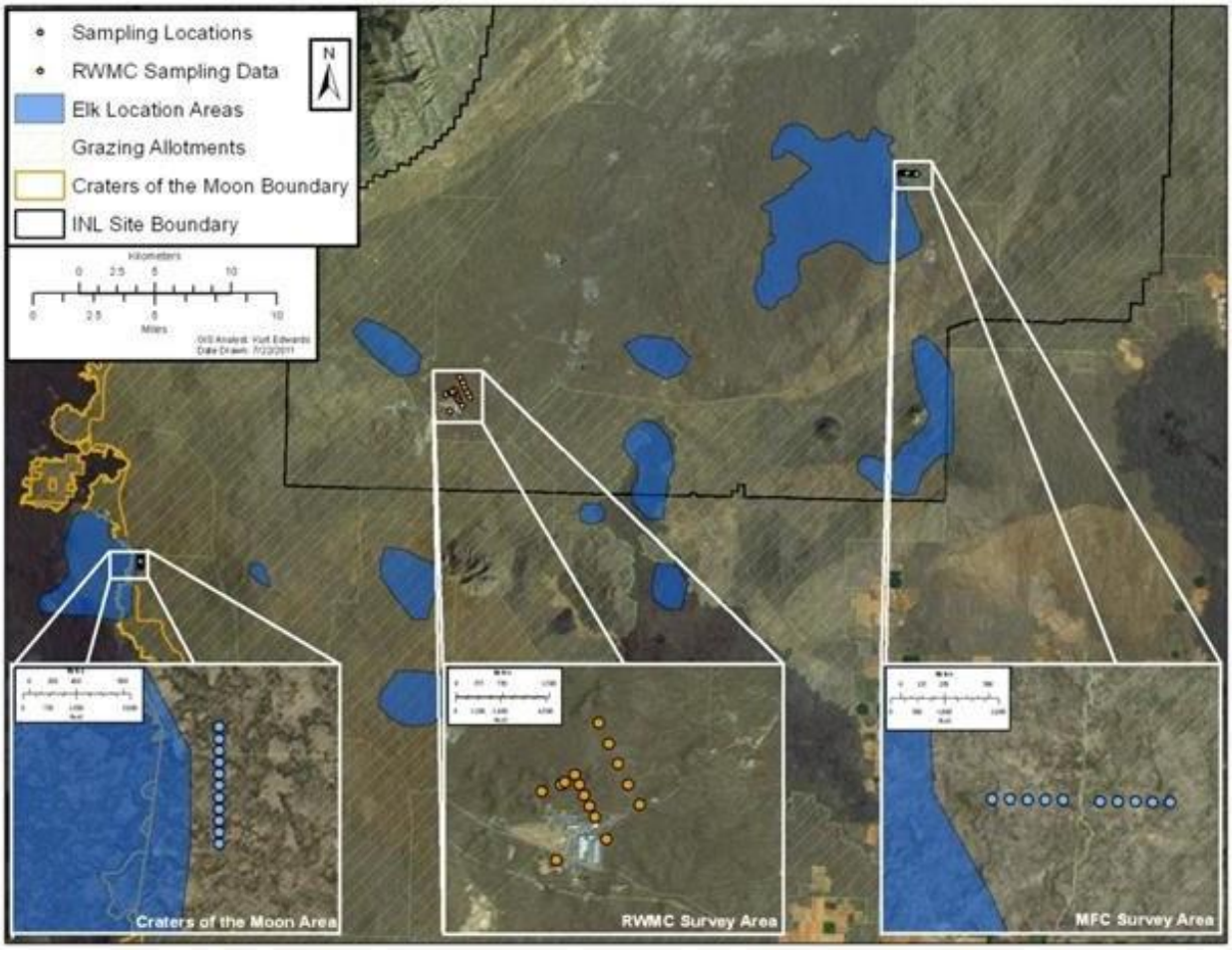

Figure 52. Elk forage sampling locations.

Because of limited water resources on the INL Site, radioactive waste ponds could provide a pathway for the ingestion of radionuclides by big game animals. To ascertain this, cameras were placed at the MFC Industrial Waste Pond. The video observations indicated that all big game species (e.g., elk, pronghorn, mule deer) on the INL Site used the pond as a water source. In Figure 53, the water is on the right. One elk is standing in the water, while another can be seen drinking. However, as described above, no detectable gamma or transuranic radionuclides were present in MFC water samples. MFC water results showed the detection of two uranium isotopes that the environmental surveillance program did not analytically assess: uranium-233/234 and uranium-238. Uranium-238 is a naturally-occurring radionuclide, as is uranium-234. Uranium-233, however, is man-made. The concentrations shown previously in Table 19 are not above the 3 σ error criteria and would be termed as undetected for analyses or evaluation. In addition, the ingestion transfer coefficient of ingestion to beef muscle is 2×10^{-4} (Baes et al. 1984), thus making uranium undetectable in big game samples. Therefore, the continued analysis of water from MFC or adding uranium isotopes to the analytical suite for big game is not justifiable (INL 2022c).

Preliminary data from a current elk telemetry study on the INL Site indicates elk move substantial distances across and outside the INL Site and come in close contact with INL Site facilities, as shown in Figure 53, Figure 54, and Figure 55.

Figure 53. Camera recording of wildlife activity around the MFC Industrial Waste Pond.

Map 1

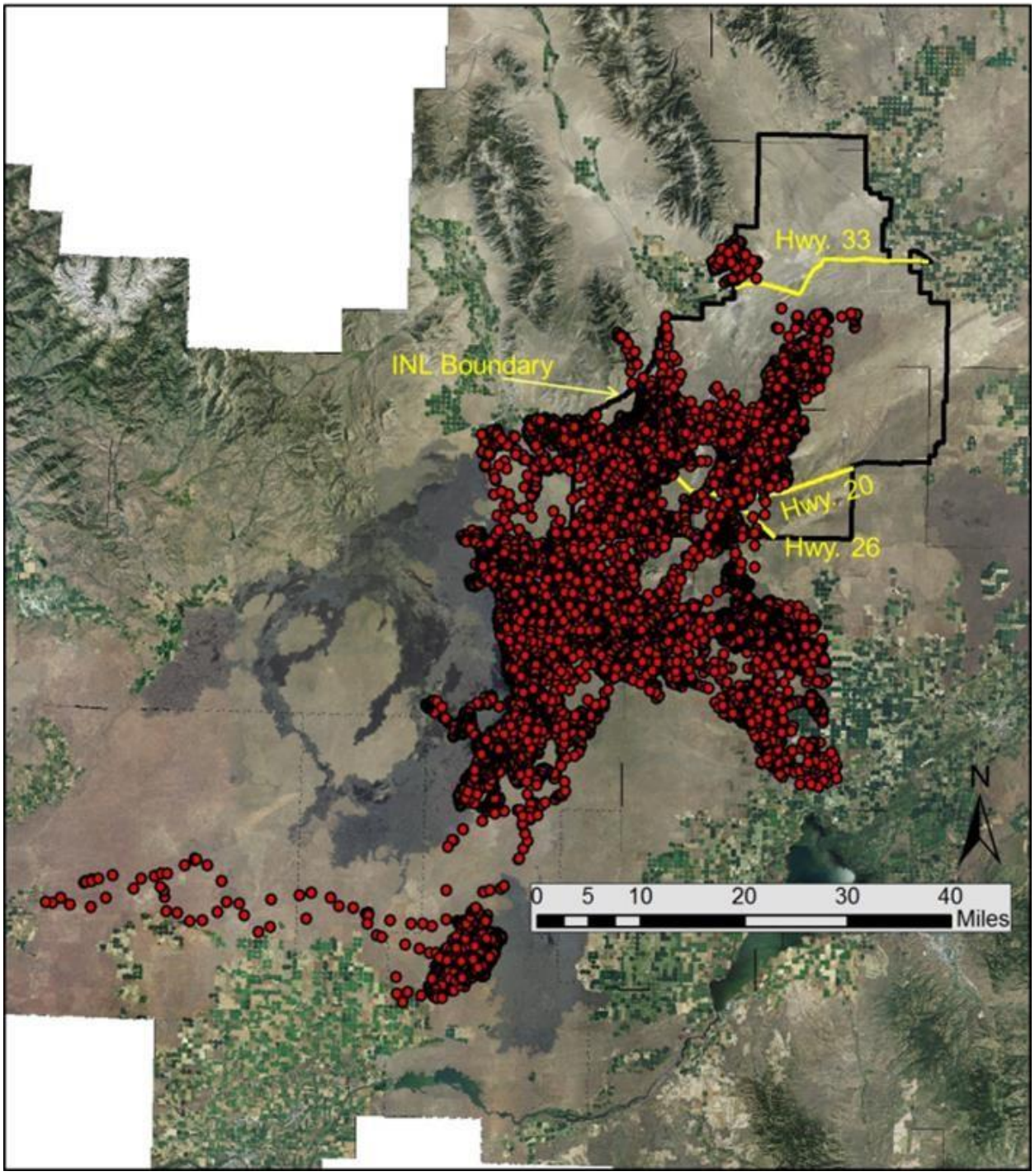

Figure 54. Elk movements on and around the INL Site.

Map 2

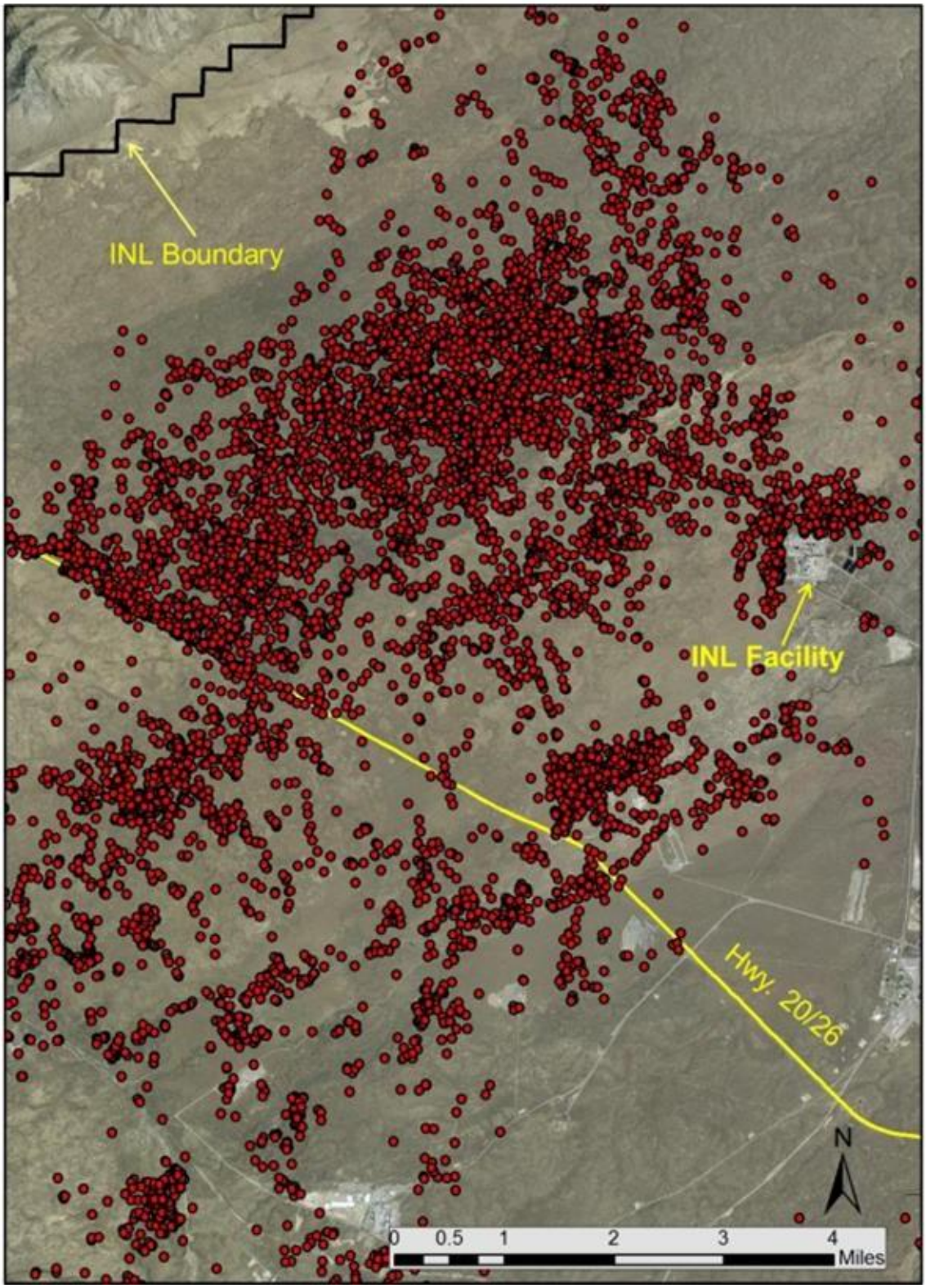

Figure 55. Elk movements near INL Site facilities.

10.4 Program Goals

If radionuclide concentrations in environmental media or site biota sampling data (applying appropriate media- and radionuclide-specific transfer factors for media to game animal) indicate that a human could receive a dose of no more than 1 mrem/year through the consumption of game animals, then intensive sampling of game animals may not be warranted (DOE 2005). However, random, opportunistic sampling—as is currently performed by the environmental surveillance program—is based on public concern. This sampling, which is largely centered on game killed on-Site in collisions with vehicles, provides verification that dose from INL Site big game animals is well below regulatory and health guidelines (INL 2022c).

Previous studies and data document that big game do uptake radionuclides present on the INL Site (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford, and Autenrieth 1980). Big game receives doses from radionuclides ingested or present externally from their use of the INL Site (Markham et al. 1982; Markham, Halford, and Autenrieth 1980). Some big game are migratory and move off-Site, while others travel considerable distances (Long, ISU, personal communication 2012; Hoskinson and Tester 1980; Reynolds 1984; Comer 2000). Members of the public consume big game and could potentially harvest big game that has used the INL Site (Markham et al.

1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford, and Autenrieth 1980).

The U.S. Department of Energy (DOE)-established general public dose limit is 100 mrem/year; the DOE-established dose guideline for terrestrial animals is 0.1 rad/day (DOE 2002, DOE 2011). Sample collection and analysis provide data to verify that radiological doses related to the game-animal exposure pathways remain low and quantifiable as required by DOE-HDBK-1216-2015 (DOE 2015). Data further provide assurance to consumers of game animals from the INL Site that the degree of contamination caused by site operations and cleanup activities is monitored and documented in publicly available reports (e.g., the ASER) and provide data baseline to quantify contaminant level changes due to fugitive or accidental releases of INL Site radiological materials (INL 2022c).

10.5 Sampling Boundaries

Because of the mobility and diversity of habitat big-game use, samples should be taken within the Boundary of the INL Site. Samples should be taken from animals known to frequent areas of contamination, which will be compared to background samples that should be collected at least 25 miles from the INL Site (INL 2022c).

10.6 Sampling Design

The sampling design must assess and determine whether radionuclides attributable to past and current INL site releases are measurable, above background, in potential forage and water sources used by big game animals and in big game animals that currently use the INL Site and migrate off-Site. Based on the above discussions of vegetation and water analyses, it is not technically justifiable to continue sampling these media to assess contaminant uptake in big game animals. Specific sampling of vegetation and water may be warranted after a known release of radionuclides from INL Site facilities should either of the following occur:

- If levels of radionuclides measured in these big game animals represent a dose to the animal population that exceeds biota dose limits
- If levels of radionuclides measured in big game animals produce a dose to a human consuming the animal that exceeds human dose limits.

Based on the historical and recent data on radionuclide uptake and animal movement, the most technically feasible design would collect big game known to access or use contaminated areas on the INL Site. Big game monitoring will continue so long as there is potential for these animals to access contaminated areas, vegetation, and/or water on the INL Site. However, it is recommended that all historical big game radionuclide monitoring data be evaluated to determine if continued monitoring of radionuclide uptake in big game animals on the INL Site is technically defensible. Perhaps the frequency of sampling should be reduced or stopped completely. A key factor to consider during this assessment will be stakeholder concerns (INL 2022c).

10.6.1 Frequency of Sample Collection

At least three samples must be collected annually for a minimal statistically significant number. Samples will be collected opportunistically as roadkill.

10.6.2 Sampling Methods

The method chosen for sampling involves opportunistically collecting big game that are accidentally killed on INL Site roads. This provides a level of randomness that may be comparable to harvesting an animal by hunting. Sampling involves the collection of muscle, liver, and thyroid tissues of the road-killed animal.

10.6.3 Analytical Methods

An analysis of the collected tissue samples involves grinding and blending the samples for homogeneity. This analysis detects gamma-emitting radionuclides and iodine-131 in thyroid tissues through gamma spectrometry.

10.7 Radionuclides Assessed

Only gamma spectrometry will be completed for game-animal muscle and liver tissue. Cesium-137 is the predominant gamma-emitter and largest gamma contributor to dose for waterfowl (Halford, Millard, and Markham 1981), assuming it behaves similarly no matter which faunal medium it is from and is chemically analogous to potassium in the environment (INL 2022c). Thus, it behaves similarly. It has a half-life of about 30 years and tends to persist in soil. In soluble form, it can readily enter the food chain through plants. It is widely distributed throughout the world from historic nuclear weapons detonations, which occurred between 1945 and 1980, and has been detected in all environmental media at the INL Site. Regional sources include releases from INL facilities and resuspension of previously contaminated soil particles (DOE-ID 2011). Cesium tends to concentrate in muscles because of its relatively large mass. Like potassium, cesium is excreted from the body quickly. This means that the body of someone who is exposed to radioactive cesium will readily be cleared along the normal pathways for potassium excretion within several months once the source of exposure is removed.

Iodine-131 will be assessed in thyroid tissues primarily to assess the biota dose to game animals. Iodine is an essential nutrient element and is readily assimilated by cows eating plants containing the element (INL 2022c). Iodine-131 is of particular interest because it is produced by nuclear reactors or weapons, is readily detected, and—in addition to cesium-134 and cesium-137—can dominate ingestion dose regionally after a severe nuclear event, such as the Chernobyl accident (Kirchner 1994). Iodine-131 has a short half-life of eight days, and therefore does not persist in the environment. Iodine can be taken into the body by eating food, drinking water, or breathing air. It is a constituent of thyroid hormone and, as such, is a required element for humans. Iodine is readily taken into the bloodstream from both the lungs and the gastrointestinal tract (essentially 100%) after inhalation and ingestion. Upon entering the bloodstream, 30% is deposited in the thyroid, 20% is quickly excreted in feces, and the remainder is eliminated from the body within a short period of time per simplified models that do not reflect intermediate redistribution (ANL 2007).

10.8 Quality Assurance

The quality of sample analysis is assured in a variety of ways. The laboratory that is used will be experienced in the analysis of biota and must participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) performance evaluation tests for biota and show acceptable performance.

The minimum detection limit of the most likely detected gamma-emitting radionuclide (cesium-137) must be below the concentration measured in background samples. At least three samples must be collected for a minimal statistically significant number of samples, which will be compared with background samples that must be collected at least 25 miles off the INL Site (INL 2022c).

10.9 Decision Limits and Actions

DOE radiological activities (DOE 2011; INL 2022c) must be conducted so that exposure of members of the public to ionizing radiation will not cause:

- A TED exceeding 100 mrem (1 mSv) in a year.
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year.
- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose excepting:
  - Dose from radon and its decay products in air (radon is regulated separately under Paragraphs 4.f. and 4.h.[1][d] in DOE O 458.1 and under 40 CFR 61, Subparts Q and T).
  - Dose received by patients from medical sources of radiation, and by volunteers in medical research programs.
  - Dose from background radiation.
  - Dose from occupational exposure under U.S. Nuclear Regulatory Commission (NRC) or agreement state license or to general employees regulated by 10 CFR 835 and DOE O 458.1.

The results of years of environmental monitoring around the INL Site show that DOE dose limits have never been exceeded or even approached off the INL Site. Thus, the surveillance program looks for instances when background or historical measurements are exceeded. Action levels for the laboratory have been developed to use as criteria to immediately notify personnel if an unusual result is observed. The action levels were developed based on an assessment of the last 10 years of data (unpublished ESER assessment). The action level developed for large game animals for cesium-137 is 1.5E-08 µCi/g.

If cesium-137 is detected above background and exceeds the action level, the highest potential dose to humans will be determined using the conservative technique of calculating maximum radionuclide concentrations. The highest potential dose to the biota will be similarly calculated using a graded approach. Additional monitoring, determination of change in the source term, and an attempt to determine whether the animal had spent considerable time near contaminated areas are permissible.

If the dose to big game is above biota dose limits (DOE 2002; DOE 2011), then a Site-specific biota dose assessment will be conducted involving problem formulation, analysis, and risk characterization protocols similar to those recommended by the EPA (1998).

11. WATERFOWL

11.1 Program Basis

Waterfowl use the Idaho National Laboratory (INL) Site waste ponds and can potentially become contaminated with radionuclides and receive a dose from those radionuclides. Waterfowl are hunted and consumed by humans who could receive a dose from ingestion of radionuclides in waterfowl tissues.

Therefore, radionuclide concentrations in waterfowl tissues should be assessed and the basis for this assessment was determined using data quality objectives (DQOs) for the INL Waterfowl Monitoring Program (INL 2022a). The DQO process followed the seven-step U.S. Environmental Protection Agency (EPA) DQO process (EPA 2006).

11.2 Program Drivers

Monitoring INL Site waterfowl fulfills:

- Regulatory requirements for assessing the movement of radionuclides from the INL Site
- Regulatory requirements for assessing the protection of the public and environment
- Regulatory requirements for assessing the impacts to biota
- A responsibility to address public concern regarding the movement of INL Site-produced radionuclides off-Site.
- DOE Order 458.1 and supporting guidance document (DOE 2011).

11.3 Results of Related Studies/Surveillance

Water containing radionuclides has been disposed of on the INL Site in several lined or unlined ponds for decades. These ponds offer an attractive environment to many species of wildlife that may, in turn, uptake and remove those radionuclides off-Site (Warren, Majors, and Morris 2001; Halford, Millard, and Markham 1981). Waterfowl have been documented using many of the radioactive wastewater ponds on the INL Site, and a sampling program was established in the early 1970s (Warren, Majors, and Morris 2001; Halford, Millard, and Markham 1981; Halford, Markham, and Dickson 1982; Halford, Markham, and White 1983; Morris 1993). Analyses indicated that waterfowl became contaminated with radionuclides both internally and externally and could not only receive a radiological dose themselves, but also potentially provide a dose to persons consuming them (Halford, Millard, and Markham 1981).

Thus, INL Site operations could potentially impact waterfowl coming into contact with radioactive waste ponds. The impacted waterfowl could then move contaminants off-Site and be harvested and consumed by the public. Therefore, there is a valid basis for sampling waterfowl from INL Site radioactive waste ponds to assess the radionuclide concentrations. These data enable a biota dose assessment to evaluate the impacts on biota using these ponds and provide data on humans consuming waterfowl with these radiological contaminants (INL 2022a).

Previous studies have indicated that waterfowl uptake a variety of radionuclides from the ponds, but the levels have decreased substantially over the years (Warren, Majors, and Morris 2001) because of decommissioning of some ponds and the reduction of radionuclide concentrations in the effluents sent to these ponds. Wastewater ponds are still present on the INL Site and are visited by migratory waterfowl. Waterfowl provide a logical and accessible media for determining biotic uptake of radionuclides, assessing biota dose, evaluating potential movement of radionuclides off-Site, and evaluating dose to man from the consumption of waterfowl.

11.4 Program Goals

The goals of waterfowl sampling and assessment are to evaluate the impacts to waterfowl and off-Site human population from radioactive contaminants in waterfowl tissue attained at the INL Site. Previous studies and data document waterfowl uptake radionuclides from these wastewater ponds (Warren, Majors, and Morris 2001; Halford, Millard, and Markham 1981; Halford, Markham, and Dickson 1982; Halford, Markham, and White 1983; Halford and Markham 1984; Markham et al. 1988; Morris 1993). Waterfowl receive doses from radionuclides ingested or present externally from their use of the INL Site wastewater ponds (Halford, Markham, and Dickson 1982; Halford, Markham, and White 1983; Halford and Markham 1984; Markham et al. 1988).

Waterfowl are migratory and move off-Site, some considerable distances. Members of the public consume waterfowl and could potentially harvest waterfowl that have used the INL wastewater ponds (Halford, Millard, and Markham 1981; Warren, Majors, and Morris 2001).

The DOE-established dose limit for the general public is 100 mrem/year and the DOE-established technical standard for aquatic animals is 1 rad/day (DOE 2002; DOE 2011). Data obtained from sample collection and laboratory analysis for INL Site-related radionuclides are used to verify that radiological doses related to the waterfowl exposure pathways are quantifiable and remain in compliance with DOE and other applicable radiation standards and requirements as recommended by DOE-HDBK-1216-2015 (DOE 2015). Data also provide assurance to the consumers of waterfowl from the INL Site that the degree of contamination caused by site operations and cleanup activities is monitored and documented in publicly available reports (e.g., the Annual Site Environmental Report [ASER]) and establish a baseline to quantify contaminant level changes due to fugitive or accidental releases of INL Site radiological materials.

11.5 Sampling Boundaries

Sampling is to be conducted on the INL Site at the Advanced Test Reactor (ATR) Complex evaporation pond, which is used by waterfowl and are potentially contaminated from historic and/or current liquid effluents (INL 2022a). The ATR Complex evaporation pond is lined; waterfowl are not taken from this pond to prevent damage to the lining. INL Environmental Monitoring Services procedures (INL 2022b) instruct that no birds are to be collected directly from or over contaminated ponds. Instead, waterfowl are collected from the sewage ponds adjacent to the lined pond. Based on historical observations and data, the probability of waterfowl collected at the sewage ponds having used the adjacent radioactive waste ponds is reasonable and provides a representative assessment of the contaminant uptake (Warren, Majors, and Morris 2001; Morris 1993).

Radionuclides released to ponds are primarily gamma-emitting due to fission and activation products of nuclear reactors (INL 2022a). Because of the high biological elimination rates of radionuclides (Halford, Markham, and White 1983) and migratory patterns (Warren, Majors, and Morris 2001), background waterfowl should be collected north, east, and southeast of the INL Site Boundary (birds are migrating from the north and moving south and southwest [Warren, Majors, and Morris 2001]). The highest numbers of waterfowl at contaminated ponds occur during the spring and fall migratory period (Warren, Majors, and Morris 2001). Therefore, the highest probability of harvest by a hunter would occur during the fall migratory/hunting season.

11.6 Sampling Design

Sampling is limited to INL Site unlined wastewater ponds. Samples are collected by shooting.

Waterfowl samples are collected by INL Security personnel with firearms training. Background samples will be obtained from locations at least 25 miles off the INL Site. These samples will be collected by area hunters (INL 2022a).

Waterfowl monitoring will continue until there are no radioactive wastewater ponds accessible to waterfowl on the INL Site. If new facilities are constructed with a radioactive-wastewater pond, waterfowl monitoring will be initiated after use by waterfowl is determined.

11.6.1 Frequency of Sample Collection

Samples will be collected annually during the fall waterfowl migration (INL 2022a). At least three samples must be collected from each location for a minimal statistically significant number of samples. Samples will be collected during the fall because that is when contaminated birds could be harvested.

11.6.2 Analytical Methods

Analysis of sampled waterfowl carcasses proceeds by first dividing them into edible tissue, external tissue (e.g., skin, feathers, feet, bill), and the remainder. The edible tissue can be used for ingestion doses, the external tissue indicates external contamination, and the remainder adds to the overall inventory.

Tissues will be ground and blended for homogeneity, then analyzed by gamma spectrometry for gamma-emitting radionuclides and by yttrium-90 separation for strontium-90. Alpha spectrometry will be used to determine the presence and levels of transuranics (INL 2022a).

11.7 Radionuclides Assessed

Although up to 29 different radionuclides have been detected in waterfowl tissues collected from INL Site radioactive waste ponds (Halford, Millard, and Markham 1981), it is impractical and cost-prohibitive to perform complete analyses on them all. Therefore, radionuclides that contribute significantly to the dose and are readily taken up by the body were assessed. Radionuclides historically assessed in waterfowl collected on INL Site ponds are (INL 2022a; INL 2022b):

- Cesium-137 (the primary gamma-emitter of interest), by gamma spectrometry.
- Strontium-90, by yttrium-90 separation.
- Transuranics (plutonium-238, plutonium-239/240, and americium-241), which were selected because they are often measured in INL Site effluents (DOE-ID 2011) and are of concern to stakeholders.

Strontium-90 is an important radionuclide because it behaves like calcium and can deposit in bones. Strontium-90, like cesium-137, is produced in high yields from nuclear reactors or detonations of nuclear weapons. It has a half-life of 28 years and can persist in the environment. Strontium tends to form compounds that are soluble, in contrast to cesium-137, and is therefore comparatively mobile in ecosystems (DOE-ID 2011). About 8% of the ingested activity remains in the body after 30 days, which decreases to about 4% after 1 year. This activity is mainly in the skeleton. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (in the pore spaces between the soil particles). Concentration ratios are typically even higher (e.g., 110 times the concentration in solution) in clay soil (ANL 2007).

Cesium-137, the predominant gamma-emitter and largest gamma contributor to dose for waterfowl (Halford, Millard, and Markham 1981) assuming it behaves similarly no matter which media it is from, is chemically analogous to potassium in the environment and behaves similarly. It has a half-life of about 30 years and tends to persist in soil. In soluble form, it can readily enter the food chain through plants. It is widely distributed throughout the world from historic nuclear weapons detonations and has been detected in all environmental media at INL. Regional sources include releases from INL Site facilities and the resuspension of previously contaminated soil particles (DOE-ID 2011). Cesium tends to concentrate in muscles due to their relatively large mass. Like potassium, cesium is excreted from the body quickly.

In an adult, 10% is excreted with a biological half-life of 2 days, while the rest leaves the body with a biological half-life of 110 days. Clearance from the body is somewhat quicker for children and adolescents. This means that the body of someone who is exposed to radioactive cesium will readily be cleared along the normal pathways for potassium excretion within several months once the source of exposure is removed.

Plutonium and americium were dispersed worldwide from atmospheric testing of nuclear weapons conducted during the 1950s and 1960s. The fallout from these tests left very low concentrations of plutonium and americium in soils around the world, per EPA Radiation Protection (see http://www.epa.gov/radiation/radionuclides/). Accidents and other releases from weapons production facilities have caused localized contamination. Americium oxide is the most common form in the environment. Average americium-241 levels in surface soil are about 0.01 pCi/g. Americium is typically quite insoluble, although a small fraction can become soluble through chemical and biological processes. It adheres very strongly to soil, with americium concentrations associated with sandy soil particles estimated to be 1,900 times higher than in interstitial water (e.g., the water in the pore spaces between the soil particles); it binds more tightly to loam and clay soils, so those concentration ratios are even higher. At U.S. Department of Energy (DOE) sites, such as Hanford, americium can be present in areas that contain waste from the processing of irradiated fuel (ANL 2007). Americium can be taken into the body by eating food, drinking water, or breathing air.

Gastrointestinal absorption from food or water is a likely source of internally deposited americium in the general population. After ingestion or inhalation, most americium is excreted from the body within a few days and never enters the bloodstream; only about 0.05% of the amount taken into the body by ingestion is absorbed into the blood. After leaving the intestine or lung, about 10% clears the body. The rest of what enters the bloodstream deposits about equally in the liver and skeleton where it remains for long periods, with biological retention half-lives of about 20 and 50 years, respectively (per simplified models that do not reflect intermediate redistribution). The amount deposited in the liver and skeleton depends on the age of the individual, with a fractional uptake in the liver increasing with age. Americium in the skeleton is deposited uniformly on cortical and trabecular surfaces of bones and slowly redistributes throughout the volume of mineral bone over time.

About 10,000 kg of plutonium were released to the atmosphere during weapons tests. Average plutonium levels in surface soil from fallout range from about 0.01 to 0.1 pCi/g. Accidents and other releases from weapons-production facilities have caused greater localized contamination. The most common form in the environment is plutonium oxide. Plutonium is typically very insoluble, with the oxide being less soluble in water than in ordinary sand (quartz). It adheres tightly to soil particles and tends to remain in the top few centimeters of the soil as the oxide. In aquatic systems, plutonium tends to settle out and adhere strongly to sediments, again remaining in the upper layers. Typically, one part of the plutonium will remain in solution for every 2,000 parts in sediment or soil. A small fraction of plutonium in soil can become soluble through chemical or biological processes, depending on its chemical form.

While plutonium can bioconcentrate in aquatic organisms, data have not indicated that it biomagnifies in aquatic or terrestrial food chains. When plutonium is inhaled, a significant fraction can move from the lungs through the blood to other organs, depending on the solubility of the compound. Little plutonium (about 0.05%) is absorbed from the gastrointestinal tract after ingestion, and little is absorbed through the skin following dermal contact. After leaving the intestine or lung, about 10% clears the body. The rest of what enters the bloodstream deposits about equally in the liver and skeleton where it remains for long periods, with biological retention half-lives of about 20 and 50 years, respectively, per simplified models that do not reflect intermediate redistribution. The amount deposited in the liver and skeleton depends on the age of the individual, with a fractional uptake in the liver increasing with age. Plutonium in the skeleton deposits on the cortical and trabecular surfaces of bones and slowly redistributes throughout the volume of mineral bone with time.

Other radionuclides present in INL Site waste ponds include cesium-134 and iodine-131 and these may warrant consideration for dose assessment due to their biological uptake and contribution to the overall dose (Halford, Markham, and Millard 1981). Both have relatively short half-lives (e.g., 2.1 years for cesium-134 and 8 days for iodine-131) and do not pose a long-term dose hazard. However, at least a periodic assessment of these isotopes may be warranted to ascertain if they are major contributing factors to dose relative to the other isotopes being assessed.

11.8 Quality Assurance

The quality of sample analysis is assured in a variety of ways. The laboratory that is used will be experienced in the analysis of biota and must participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) performance evaluation tests for biota and show acceptable performance.

The minimum detection limit of the most likely detected gamma-emitting radionuclide (cesium-137) must be below the concentration measured in background samples. At least three samples must be collected for a minimal statistically significant number of samples, which will be compared with background samples that must be collected at least 25 miles off the INL Site (INL 2022a).

11.9 Decision Limits and Actions

The results of environmental surveillance identify whether radionuclides have been transported off-Site and allow us to assess what the impacts are to human populations. The results require further assessment when they:

- Exceed background measurements
- Demonstrate an increasing trend over time
- Result in an estimated dose to a member of the public that approaches regulatory limits.

DOE radiological activities (DOE 2011; INL 2022a) must be conducted so that exposure of members of the public to ionizing radiation will not cause:

- A total effective dose (TED) exceeding 100 mrem (1 mSv) in a year.
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year.
- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose excepting:
    - Dose from radon and its decay products in air (radon is regulated separately under Paragraphs 4.f. and 4.h.[1][d] in DOE O 458.1 and under 40 CFR 61, Subparts Q and T).
    - Dose received by patients from medical sources of radiation, and by volunteers in medical research programs.

- Dose from background radiation.
- Dose from occupational exposure under U.S. Nuclear Regulatory Commission (NRC) or agreement state license or to general employees regulated by10 CFR Part 835, and DOE O 458.1.

If the detected radionuclides are above background and exceed historical levels, per the action levels shown in Table 37, a determination of whether the concentration is an anomalous measurement will be made. If the concentration is verified, the highest potential dose to humans will be calculated using the conservative method of employing maximum radionuclide concentrations. These calculations will be used to assess the highest potential dose to biota, using a graded approach. In turn, this assessment will be used to determine whether the dose to humans is above the regulatory limits or the action levels listed in Table 37.

Table 37. Action levels for radionuclides in biota.

Radionuclide	Action Level
Cesium-137	3.5E-7 µCi/g
Iodine-131	Positive detection >3 σ
Strontium-90	1.0E-7 µCi/g
Plutonium-238	Positive detection >3 σ
Plutonium-239/240	Positive detection >3 σ
Americium-241	Positive detection >3 σ

If the dose to humans is approaching or above regulatory limits or above the action levels listed above, then further investigation and action may be warranted. These may include additional monitoring, a determination of change in source term and an attempt to determine if the sample animal had spent considerable time on the source pond. If the dose to waterfowl is above biota dose limits (DOE 2002; DOE 2011), then a Site-specific biota dose assessment will be conducted involving problem formulation, analysis, and risk characterization protocols similar to those recommended by the EPA (1998). The program will then consider methods to discourage waterfowl from using the ponds.

12. IDAHO CLEANUP PROJECT WASTE MANAGEMENT FACILITIES

12.1 Program Basis

It is the policy of the U.S. Department of Energy (DOE) to conduct suitable environmental monitoring programs to determine whether the public and the environment are adequately protected during DOE operations and whether those operations are in compliance with DOE and other applicable Federal, State, and local radiation standards and requirements. It is also DOE policy that monitoring and surveillance programs be capable of detecting and quantifying unplanned releases and meet high standards of quality and credibility. It is DOE's objective that all DOE operations properly and accurately measure radionuclides in ambient environmental media (DOE 2015).

DOE O 435.1 establishes requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of DOE pursuant to the Atomic Energy Act of 1954 (DOE 1999). The objective of this Order is to ensure that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety, and the environment. The Order requires that radioactive waste management facilities, operations, and activities meet the environmental monitoring requirements of DOE O 458.1 (DOE 2013), which captures the environmental monitoring requirements formerly documented in cancelled DOE O 5400.1 and DOE O 5400.5.

Environmental surveillance is conducted for all waste management facilities at the Idaho National Laboratory (INL) Site. Currently, environmental monitoring waste management operations occur in the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) and Idaho Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF) at Idaho Nuclear Technology and Engineering Center (INTEC). Radiological surveillance and monitoring at the INL Site radioactive waste management facilities are essential to meet the environmental monitoring requirements of DOE orders. The development of a technical basis for surveillance and monitoring activities ensures the most efficient and effective sampling processes, methods, and media are used.

12.2 Program Drivers

Environmental surveillance monitoring at Idaho Cleanup Project (ICP) waste management facilities is performed in the vicinity of those facilities according to the following DOE requirements:

- DOE O 435.1 (DOE 1999)
- DOE M 435.1-1 (DOE 1999)
- DOE O 458.1 (DOE 2011)
- DOE-HDBK-1216-2015 (DOE 2015).

12.3 Environmental Dose Pathways

During routine operations at INL Site facilities, radioactive materials are released to the environment. Various environmental processes may transport these materials from the INL Site to nearby populations off the INL Site. These processes include wind, flowing water in the surface or subsurface, and the movement of biota. The environmental pathways were ranked for the INL Site and can be applied to waste management facilities, as well as determining the environmental media to be monitored. Based on the analysis presented in Section 2 of this document, the following are monitored in proportion to the relative ranking of the transport pathway involved for ICP waste management facilities:

- Air at ICDF and RWMC
- Surface water at RWMC
- Penetrating radiation monitoring (gamma surface surveys) at RWMC and ICDF.

Most of the monitoring program at ICP is directed at characterizing airborne releases, mostly from resuspension of radioactive materials fugitive dusts. Groundwater monitoring is not included in routine environmental surveillance at waste management facilities, but is conducted by other organizations and programs, including the U.S. Geological Survey (USGS), CERCLA, and a Resource Conservation and Recovery Act (RCRA) post-closure permit.

The ICP contractor ceased soil sample collection in 2017 because the areas where the samples had been collected at RWMC were heavily disturbed (e.g., construction, subsidence fill-in, gravel road base), samples had been collected well beyond the expectations of the 1992 Monitoring Activities Review panel, and all sample results were well below established environmental concentration guides. The ICP contractor also ceased the collection of biota samples in 2018 since availability of samples had diminished due to construction activities and weed treatment associated with fire prevention, and many years of data indicated radionuclide concentrations were well below levels of concern for animals who may encounter or consume the vegetation.

12.4 Program Objectives

The ICP Environmental Surveillance Program has the following general objectives:

- Support the overall programmatic objectives of the INL Site Environmental Monitoring Program
- Comply with applicable DOE requirements regarding environmental surveillance
- Identify trends in concentrations of radioactivity in environmental media near ICP waste management facilities and concentrations of contaminants in environmental media near ICP facilities
- Provide indications of confinement integrity at ICP radioactive waste storage and disposal facilities
- Make environmental surveillance data available to the U.S. Department of Energy–Idaho Operations Office (DOE-ID), other federal agencies, INL Site contractor personnel, State of Idaho officials, and other programs conducting activities, such as performance assessment, pathways analyses, dose estimation, and site environmental report preparation
- Collect data in support of special studies.

Environmental surveillance programs and their components are determined on a site-specific basis by the field organization. Consequently, the ICP Environmental Surveillance Program mission does not include all aspects of environmental surveillance, but only those components that have been identified by DOE-ID environmental programs as appropriate to the operations conducted at the INL Site. The technical objectives provided in this section for each specific activity are designed to meet the aspects of the ICP Environmental Surveillance Program addressed by that activity.

12.4.1 Ambient Air Monitoring

The specific objectives of ambient air monitoring are as follows:

- Determine concentrations of radionuclides in ambient air in the vicinity of ICP waste management facilities and at appropriate background locations
- Detect and report significant trends in measured concentrations of airborne radionuclides
- Compare measured concentrations of radionuclides to reference levels based on derived concentration guides for the public given in DOE O 458.1
- Measure the ambient air concentrations of radionuclides if a nonroutine or unmonitored release occurs
- Report comparisons of measured concentrations to reference levels based on derived concentration guides for the public given in DOE O 458.1.

12.4.2 Surface Water Sampling

The specific objectives of surface water sampling are as follows:

- Determine concentrations of radionuclides in any surface waters with the potential of leaving RWMC
- Report comparisons of measured concentrations against reference levels based on derived concentration guides for the public given in DOE O 458.1
- Detect and report significant trends in measured concentrations of radionuclides in surface waters with the potential of leaving RWMC.

12.4.3 Radiation Monitoring

The specific objectives of radiation monitoring are as follows:

- Characterize direct radiation levels at specific points of interest at ICP waste management facilities.
- Detect and report significant trends in measured levels of penetrating radiation.

12.5 Program Design

In addition to the DOE drivers previously discussed, the program design is based upon the data quality objective (DQO) process described in Section 7 of PLN-720 (ICP 2020). The primary concern is that the design meets the criteria and constraints established in Stages I and II of DQO development.

Resources used for guidance in the design stage include regulatory requirements and guidance specific to data collection systems, current technical references, and technical peer review.

12.5.1 Sampling Locations

12.5.1.1 Ambient Air

Airborne materials from RWMC and ICDF are predominantly fugitive dusts with small amounts of sorbed radionuclides. The general approach to monitoring an area source, such as the fugitive dusts at RWMC and ICDF, is to monitor around the periphery of the facility. As such, monitors were located in predominant wind paths from disposal activities to ensure a high probability of detection (Bryan 1991). The series of samplers that monitor for particulates around the RWMC SDA are shown in Figure 56. A control location is situated north of Howe, as seen in Figure 57. This location was selected because it is close enough to be representative of the area being monitored and yet in an area that would not be influenced by INL Site activities. Airborne particulates are also monitored downwind of the ICDF, as observed in Figure 58. The Howe site is also used for the ICDF control location.

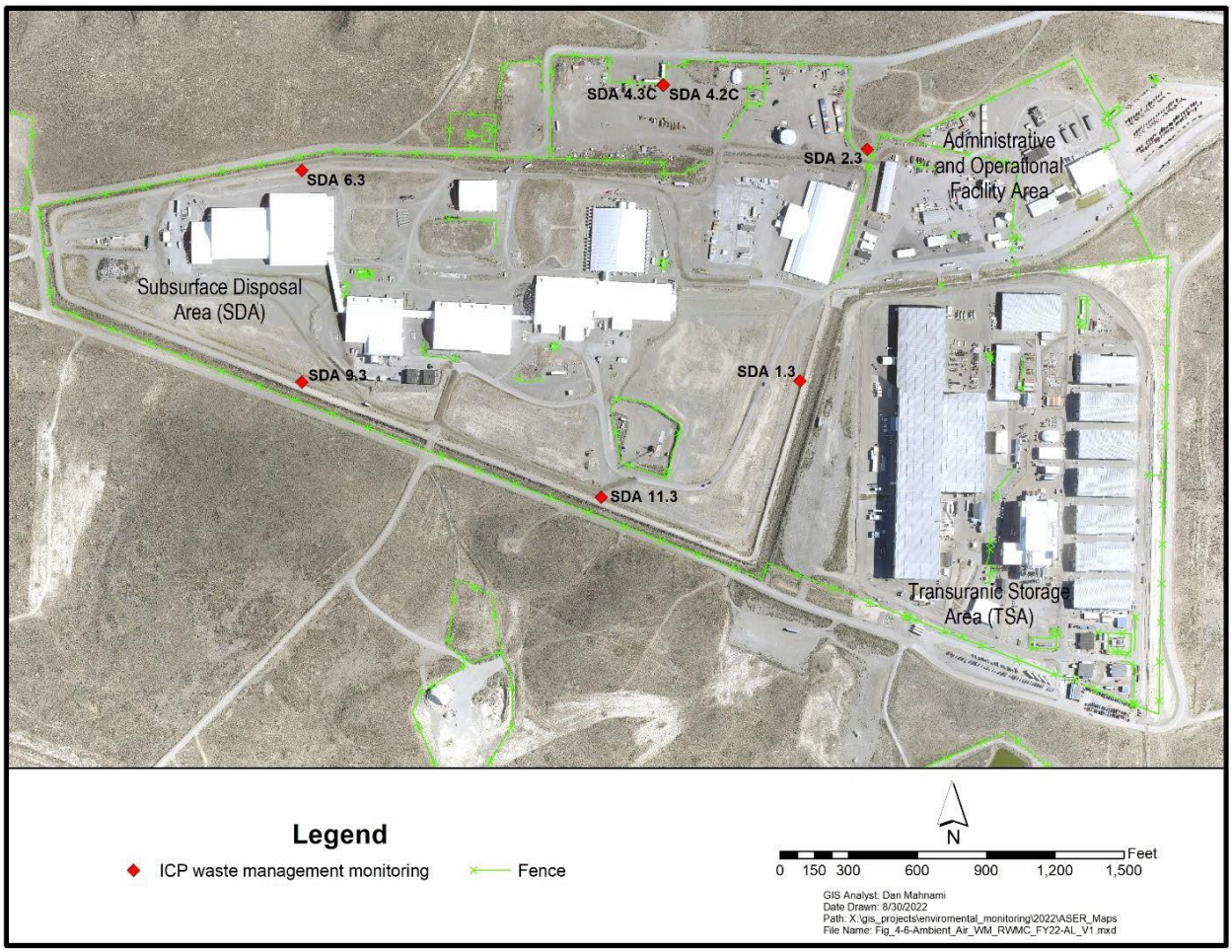

Figure 56. Locations of low-volume air samplers at the RWMC SDA.

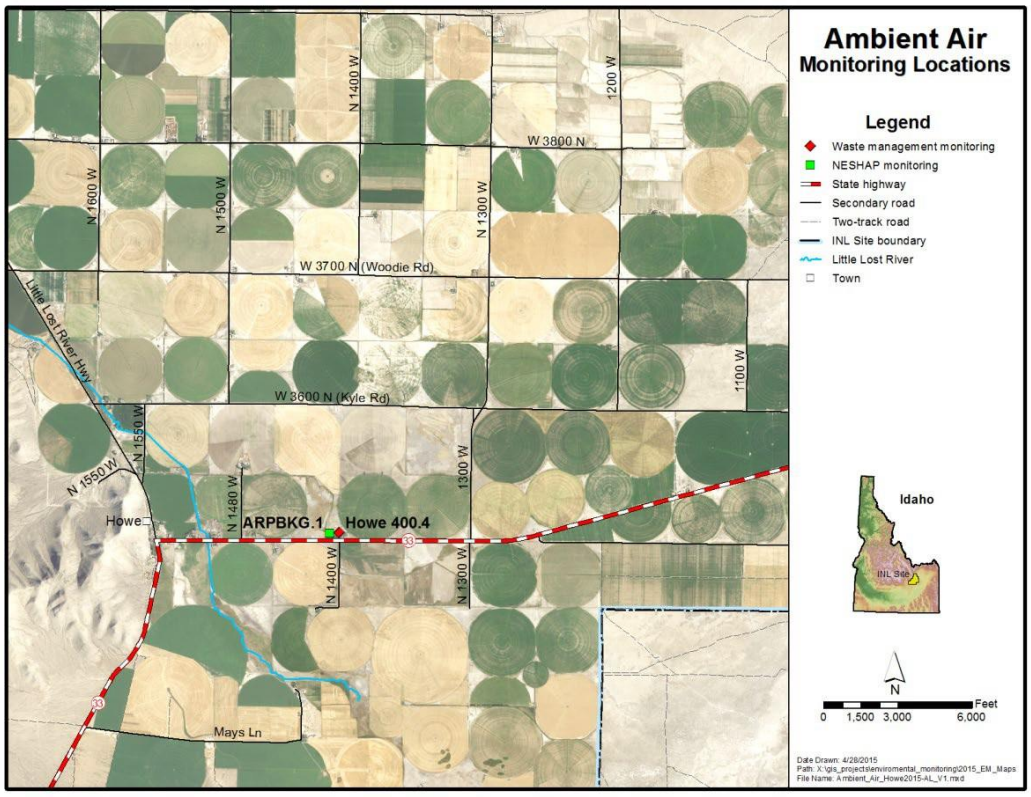

Figure 57. Background ambient air monitoring location in Howe.

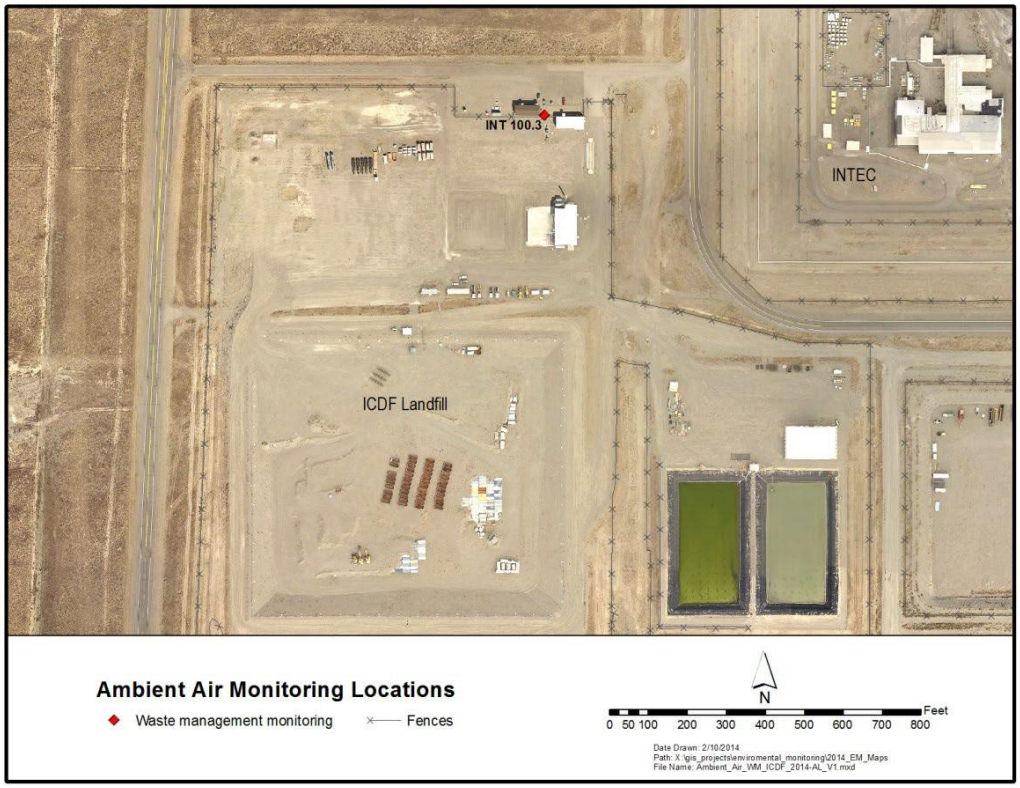

Figure 58. Locations of low-volume air samplers at ICDF.

12.5.1.2 Surface Water

Radionuclides could be transported outside the boundary of RWMC via surface water run-off, which occurs at the SDA only during periods of snowmelt or heavy precipitation. At these times, water runs off the SDA into a lift station that pumps water into a canal and carries outside run-off that has been diverted around RWMC. Samples are collected semiannually at the lift station if available or after heavy rainfall or snowmelt, as observed in Figure 59.

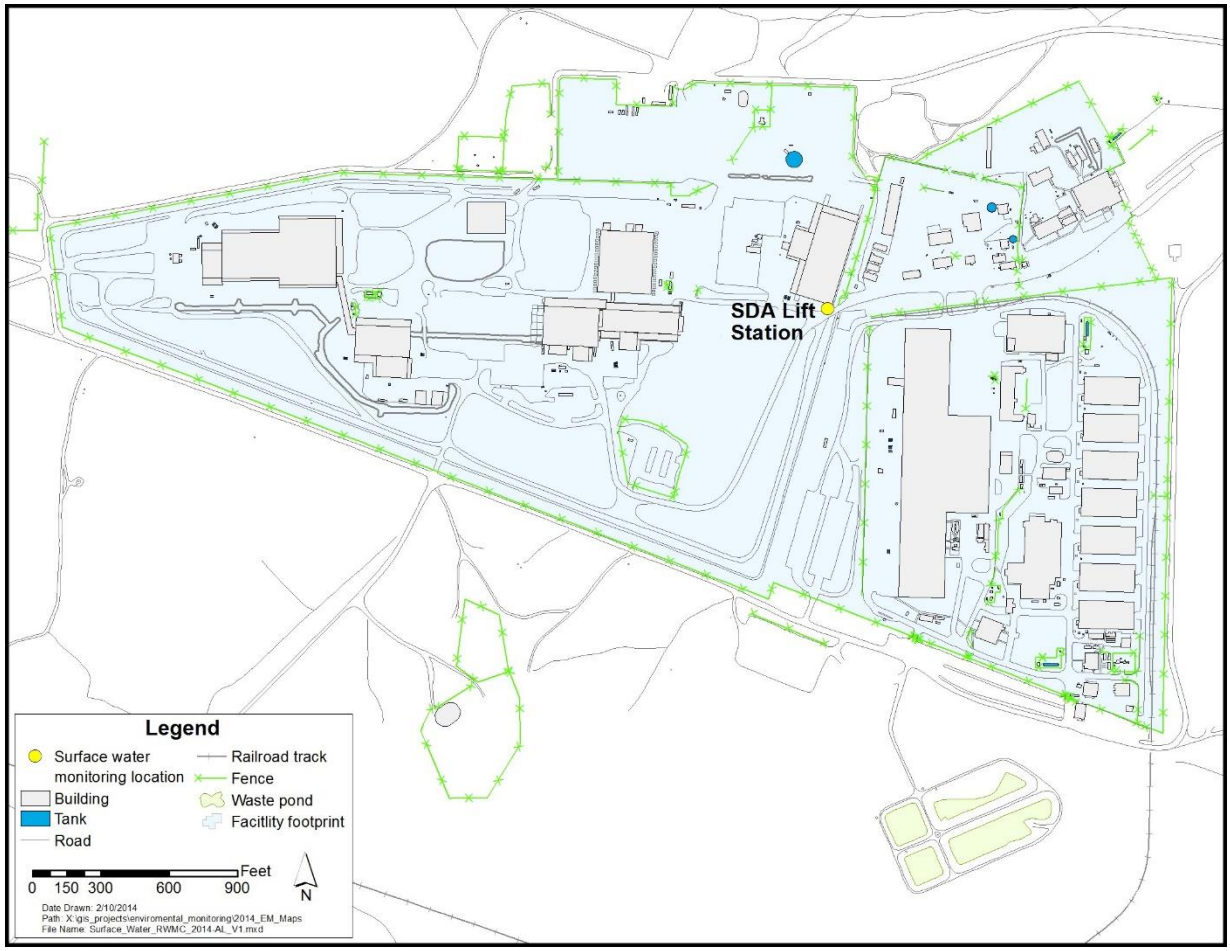

Figure 59. Surface water sampling location at the RWMC SDA.

12.5.1.3 Surface Radiation Monitoring

Surface radiation surveys are conducted annually at the RWMC SDA and ICDF to detect soils that have become contaminated with gamma-emitting radionuclides. The survey is performed with a global positioning radiometric scanner (GPRS) system mounted on a four-wheel drive vehicle. Soil surface radiation surveys complement air sampling conducted at RWMC and ICDF.

12.5.1.4 Frequency of Sample Collection

Collection frequencies are shown in Table 38. The sampling and analysis frequencies follow the recommendations in DOE-HDBK-1216-2015 (DOE 2015), DQOs, and past project reviews. Any changes or additions to the current program are driven by changes in operation and periodic procedure reviews.

Table 38. ICP Environmental Surveillance Program activities.

Media	Analysis	Collection Frequency	Location		Description
			INL (on-Site)	Distant	
Air	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]	Semimonthly Composited Monthly Composited Quarterly	RWMC SDA (see Figure 56)	NA	Seven SP[b] air samplers operate at 0.17 m^3/min (includes one control and one replicate, excludes one blank).
	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]	Semimonthly Composited Quarterly Composited Quarterly	NA	Howe (see Figure 57)	One SP air sampler operates at 0.17 m^3/min.
	Gross alpha Gross beta Gamma spectrometry Radiochemistry	Semimonthly Composited Quarterly Composited Quarterly	ICDF (see Figure 58)	NA	One SP air sampler operates at 0.17 m^3/min.
Surface Water	Gamma spectrometry Radiochemistry[a,]	Semiannually, depending on precipitation	RWMC SDA (see Figure 59)	NA	Surface run-off samples from SDA and control location.
Surface Radiation	External radiation levels	Annually	RWMC SDA	NA	Surface gamma radiation—truck-mounted GPRS[d] gamma-radiation detector system.

a. Analysis for Am-241, plutonium-238, plutonium-239/240, uranium-235, uranium-238, and strontium-90.
b. SP—suspended particulate.
c. Exact number of samples may vary due to availability.
d. GPRS—global positioning radiometric scanner.

12.5.1.5 Sampling Methods

Monitoring activities are performed using the methods described below for each media area.

Ambient Air

Ambient air sampling is performed using SPR-107, *Waste Management Low-Volume Suspended Particulate Air Monitoring*. Suspended particulate samples are collected every two weeks using low-volume air samplers drawing air through a 4-in. Gelman Versapor-3000 filter at a flow rate of approximately 6 ft^3/min. At the time of filter change-out, pertinent data are recorded from the sampler, including total volume, elapsed time, flow rate, and sample time. Filters are shipped to the analytical laboratory for gross alpha and gross beta analyses of each biweekly sample. Samples are composited by location and analyzed monthly for gamma-emitting radionuclides and quarterly for americium-241, plutonium-238, plutonium-239/240, uranium-235, uranium-238, and strontium-90. Low-volume air samples are collected from seven locations at RWMC, one location at INTEC, and a control location off-Site northwest of RWMC in Howe.

Surface Water

Surface water sampling is performed using SPR-213, *Surface Water Sampling at Radioactive Waste Management Complex*. Water levels at the SDA lift station are visually observed to determine if sufficient water has collected for sampling. Surface water samples are collected semi-annually when surface water is present or as requested by facility personnel. Samples also may be collected after significant rainfall or when weather warms up enough to cause snowmelt. If sufficient water is present, a 4-L sample is collected using a disposable bailer or a peristaltic pump. Water level is measured in inches at the time using a measuring stick. Samples are submitted to the analytical laboratory for gamma spectroscopy analyses and radiochemistry analyses for americium-241, plutonium-238, plutonium-239/240, uranium-235, uranium-238, and strontium-90.

Surface Radiation

Surface radiation monitoring is performed using TPR-6525, *Surface Radiation Surveys Using the Global Positioning Radiometric Scanner*. A vehicle-mounted GPRS system (Rapiscan Model GPRS-111[b]) was used to conduct soil surface gross gamma radiation surveys at the SDA and the ICDF to detect trends in measured levels of surface radiation. The GPRS system consists of two scintillator gamma detectors, housed in two separate metal cabinets, and a Trimble[1] global positioning system (GPS) receiver all mounted on a rack located above the front bumper of a pickup truck. The detectors are about 36 in. above the ground. The detectors and the GPS receiver are connected to a system controller and a laptop computer located inside the cabin of the truck. The GPRS system software displays the gamma counts per second from the detectors and the latitude and longitude of the system in real-time on the laptop screen. The laptop computer also stores the data files collected for each radiometric survey. During radiometric surveys, the pickup truck is driven 5 mph (7 ft./second) and the GPRS system collects latitude, longitude, and gamma counts per second from both detectors. Data files generated during the radiological surveys are saved and transferred to the ICP spatial analysis laboratory for mapping after the surveys are completed. The maps indicate areas where survey counts were at or near background and areas where survey counts are above background. Maps of areas that have been radiometrically surveyed for several years can be compared from one year to the next to determine whether radiological trends exist in specific areas and if there is a need for further action.

The SDA is approximately 100 acres in size and usually requires several days to survey all accessible areas within its boundary. The areas surveyed within the SDA may vary from year to year depending on the placement of Accelerated Retrieval Project (ARP) facilities and subsidence within the SDA. Areas at the ICDF that are surveyed with the GPRS system are the earthen embankments and roads surrounding the ICDF landfill and ICDF evaporation ponds, and the land area in between the landfill and evaporation ponds. The ICDF area generally requires 1-1/2 to 2 days for completion.

12.5.1.6 Analytical Methods

The analytical methods and parameters meet the detection levels required in the task order statement of work with the laboratory and are based on requirements in PLN-720, *Environmental Surveillance Program Plan*.

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[b] PRODUCT DISCLAIMER—References to any specific commercial product, process, or service by tradename, trademark, manufacturer, or otherwise, do not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with ICP.

12.5.2 Radionuclides Assessed

12.5.2.1 Ambient Air

Because the radionuclides shown in Table 39 are included in the source term, it is recommended that routine analysis and trending of these radionuclides must continue to fulfill the requirements of DOE O 435.1. These radionuclides have been detected over previous years at waste management facilities, and the details of these detections have been reported in Annual Site Environmental Reports (ASERs).

Table 39. Select radionuclides considered for routine analysis.

RWMC	INTEC
Americium-241	Americium-241
Gamma-emitting	Gamma-emitting
Plutonium-238	Plutonium-238
Plutonium-239/240	Plutonium-239/240
Strontium-90	Strontium-90

Radiochemical analyses are conducted of quarterly composited air filters for strontium-90, americium-241, and plutonium-239/240. Americium-241 and plutonium-239/240 were detected a few times in the INTEC filters and more frequently in SDA filters collected from 2012 to 2022.

Plutonium-238 is occasionally detected in filters from RWMC. These detections are expected because soil in the northwest corner and vicinity of the SDA has been shown to be contaminated with transuranic radionuclides from past flooding events.

Gamma spectroscopy of the composite air filters are analyzed for those radionuclides that are typically associated with the source term in the waste stream. Europium-152 was detected in one filter at RWMC, but not at INTEC, during the past 10 years.

The biweekly air filters are analyzed for gross alpha/beta activity for screening purposes. Figure 60 presents the average results for gross beta activity in filters from 2012 to 2022. Gross beta activity has been detected in almost all filters collected, indicating background levels. The seasonal pattern of results (lowest in the spring and summer and highest in the fall and winter) also confirm this because inversion conditions typically occur during these seasons. In addition, the RWMC and INTEC results appear to track each other closely. Any changes in pattern or unusually high results can be investigated further to determine if a specific radionuclide or radionuclides are present at higher levels than expected. If an abnormal trend is identified, additional investigations are initiated, and actions taken if warranted. For this reason, the measurement of gross activity should continue.

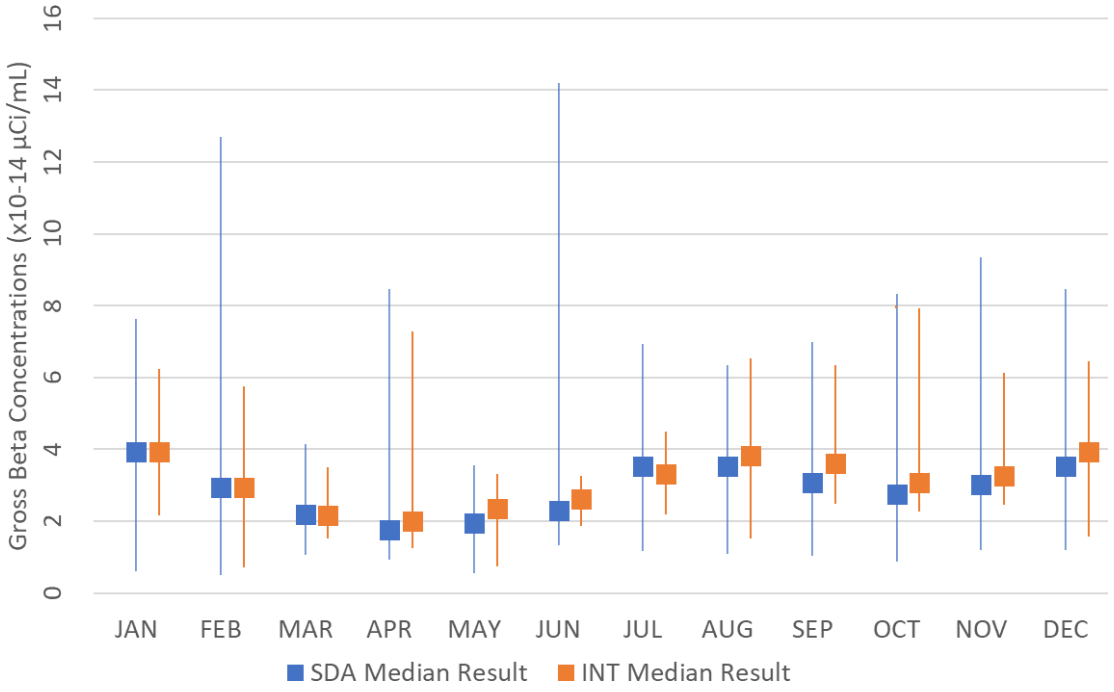

Figure 60. Median biweekly gross beta concentrations in air filters collected at RWMC and INTEC (2012–2022).

12.5.2.2 Surface Radiation

Because these surveys are concerned with detecting and reporting trends and characterizing radiation levels, surface radiation surveys take measurements of gross gamma radiation within the SDA and ICDF. No measurements of specific gamma-emitting radionuclides are made.

12.5.2.3 Surface Water

Strontium-90 and transuranic radionuclides have been detected in surface water samples have been collected since 2008. Strontium-90 and other man-made gamma/alpha-emitting radionuclides should be continued to be analyzed for because the source term contains these radionuclides and has a potential for release outside of RWMC.

12.6 Quality Assurance

The quality assurance (QA) program developed by the ICP Environmental Surveillance Program is found in PLN-720, *Environmental Surveillance Program Plan*.

QA objectives (QAOs) are qualitative and quantitative specifications for the quality of data. They include an evaluation of acceptable conformance with established sampling procedures and criteria for evaluating the results of analyses of QA/quality control (QC) samples. QAOs provide a continuing measure of performance for the activity.

The EPA has identified the following five areas relating to QAOs, sometimes referred to as the PARCC parameters:

- Precision
- Accuracy
- Representativeness
- Completeness
- Comparability.

Three of the five PARCC parameters lend themselves to quantitative measures of data quality for ICP environmental surveillance. They are precision, accuracy, and completeness. The remaining two, representativeness and comparability, are addressed in qualitative terms.

The Environmental Surveillance Program evaluates precision and accuracy of measurements using QC samples. The precision and accuracy of measurements are evaluated using field duplicates and spiked environmental samples. Periodic reviews of procedures and field operations are conducted to assess the representativeness and comparability of data. Various QC processes designed to evaluate the PARCC of data are integrated in the detailed procedures of the project.

12.7 Decision Limits and Actions Levels

Action levels have been established, where appropriate. These levels can be found in the program plan and in applicable procedures. Decision limits are specified by conservative guidelines and action levels established for the monitoring programs. Based on the regulatory driver for waste management facilities (DOE O 435.1), data trending is used as the basis and justification for actions when necessary.

Appendix A

Environmental Monitoring and Surveillance at Idaho Falls Facilities

Environmental surveillance is being performed at Idaho National Laboratory (INL) facilities located in Idaho Falls, Idaho, to meet the requirements of DOE-HDBK-1216-2015, "Environmental Radiological Effluent Monitoring and Environmental Surveillance," and to address stakeholder concerns. Because the potential dose and risks are low from Idaho Falls facilities, the resources necessary to complete a full technical basis or pathways analysis for in-town facilities is not warranted. Environmental monitoring is being performed at the following Idaho Falls facilities with the potential for radiological emissions: the INL Research Center (IRC) Complex, the Bonneville County Technology Center (BCTC), and the Portable Isotopic Neutron Spectroscopy System (PINS) Laboratory.

A-1. IDAHO NATIONAL LABORATORY RESEARCH CENTER COMPLEX

A-1.1 Air Monitoring

Small quantities of radionuclides may be released at the INL Research Center (IRC) Complex, a partially developed 35-acre site located on the north side of Idaho Falls (Figure A-1), which is the only Idaho Falls location with estimated radiological air emissions. For National Emission Standards for Hazardous Air Pollutants (NESHAP), estimated emissions were calculated for the following facilities:

- IF-603, IRC Laboratory Building
- IF-611, National Security Laboratory
- IF-638, IRC Physics Laboratory
- IF-683, Radiological and Environmental Sciences Laboratory (RESL).

The IRC Laboratory Building consists of over 60 laboratories that are dedicated to research in robotics, genetics, biology, chemistry, metallurgy, physics, and modeling and computational science. Other disciplines may include earth sciences and environmental engineering, biotechnology, physical systems modeling, systems engineering, intelligent automation and remote systems, applied engineering, nuclear science, materials processing, chemical separations and processing, and sensing and diagnostics. Fundamental and applied research and development (R&D) serves government agencies, private companies, universities, and nonprofit organizations. The U.S. Department of Energy–Idaho Operations Office (DOE-ID) RESL prepares radiological performance-testing samples at IF-683. RESL began operations at IF-683 in the third quarter of 2011. Prior to 2011, compliance with the NESHAP 10-mrem dose standard at IRC was demonstrated by use of the possession limits in 40 CFR 61, Appendix E.

Using assumed release fractions of existing inventory to have been released to the air at IRC from 2019 to 2021 (DOE-ID 2022), <1 Ci of radioactivity was calculated each year.

Table A-1 summarizes the releases that contribute at least 1% of the annual total dose calculated for the maximally exposed individual (MEI), which is located in sector 10 of the IRC. The estimated annual dose for 2019 to 2021 was 0.0099, 0.0115, and 0.0062 mrem/year, respectively (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

In response to a 2010 assessment conducted by the U.S. Department of Energy–Office of Health, Safety, and Security (DOE–HSS), a low volume air sampler was placed in Idaho Falls to assess the potential impacts from operations at the IRC Complex (Figure A-2). The location is directly south of IF-683, corresponding to the approximate vector for the MEI, based on the NESHAP modeling using

U.S. Environmental Protection Agency (EPA) air-dispersion code CAP88-PC (Figure A-3). At this location, samples are collected and analyzed as described in Section 4.6.2 and analyzed for the radionuclides as described in Section 4.6.4.

Figure A-1. Receptor locations and sector configuration used for IRC NESHAP modeling are shown, along with 2021 estimated dose values. MEI is located in sector 10. All emissions are modeled as collocated sources at IF-683, otherwise referred to as DOE-ID RESL (Overin and Sondrup, 2022).Table A-1. Estimated radiological air emissions at the IRC Complex that contributed at least 1% of calculated total dose to MEI during any year (2019–2021) (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

Radionuclide	Source	Estimated Annual Emissions (Ci)			Contribution to Total Dose at e MEI (%)		
		2019	2020	2021	2019	2020	2021
Iodine-125	IF-611	1.00E-03	1.00E-03	—	36.2%	32.1%	0.4%
	IF-683	3.81E-09	9.91E-08	4.88E-08			
Plutonium-239	IF-683	1.32E-07	1.32E-07	1.32E-07	15.9%	13.7%	25.5%
Americium-241	IF-683	1.03E-07	1.02E-07	1.02E-07	10.4%	8.9%	16.4%
Xe-133	IF-603	4.05E-01	5.10E-01	—	8.6%	9.7%	16.4%
	IF-611	1.29E-04	2.50E-05	4.63E-01			
Plutonium-238	IF-683	7.96E-08	7.90E-08	7.83E-08	8.8%	7.5%	13.9%
Cesium-134	IF-603	1.17E-06	3.76E-06	9.37E-07	5.9%	16.4%	7.8%
	IF-683	3.50E-08	2.50E-08	2.57E-08			
Radium-226	IF-683	7.53E-08	7.53E-08	7.53E-08	3.6%	3.2%	5.9%
Cesium-137	IF-603	2.49E-07	1.59E-07	9.40E-08	3.6%	2.2%	2.9%
	IF-683	7.51E-08	7.34E-08	7.18E-08			
Uranium-233	IF-683	1.64E-07	1.64E-07	1.64E-07	1.3%	1.1%	2.1%
Uranium- 232	IF-683	3.24E-08	3.21E-08	3.18E-08	1.3%	1.1%	2.0%
Actinium-227	IF-683	5.75E-09	5.57E-09	5.39E-09	1.0%	0.9%	1.6%
Barium-133	IF-683	4.09E-07	3.83E-07	3.59E-07	0.7%	0.6%	1.1%
Strontium-90	IF-683	7.38E-08	7.21E-08	7.04E-08	0.6%	0.5%	1.0%

Figure A-2. Location of new low-volume air sampler at IRC.

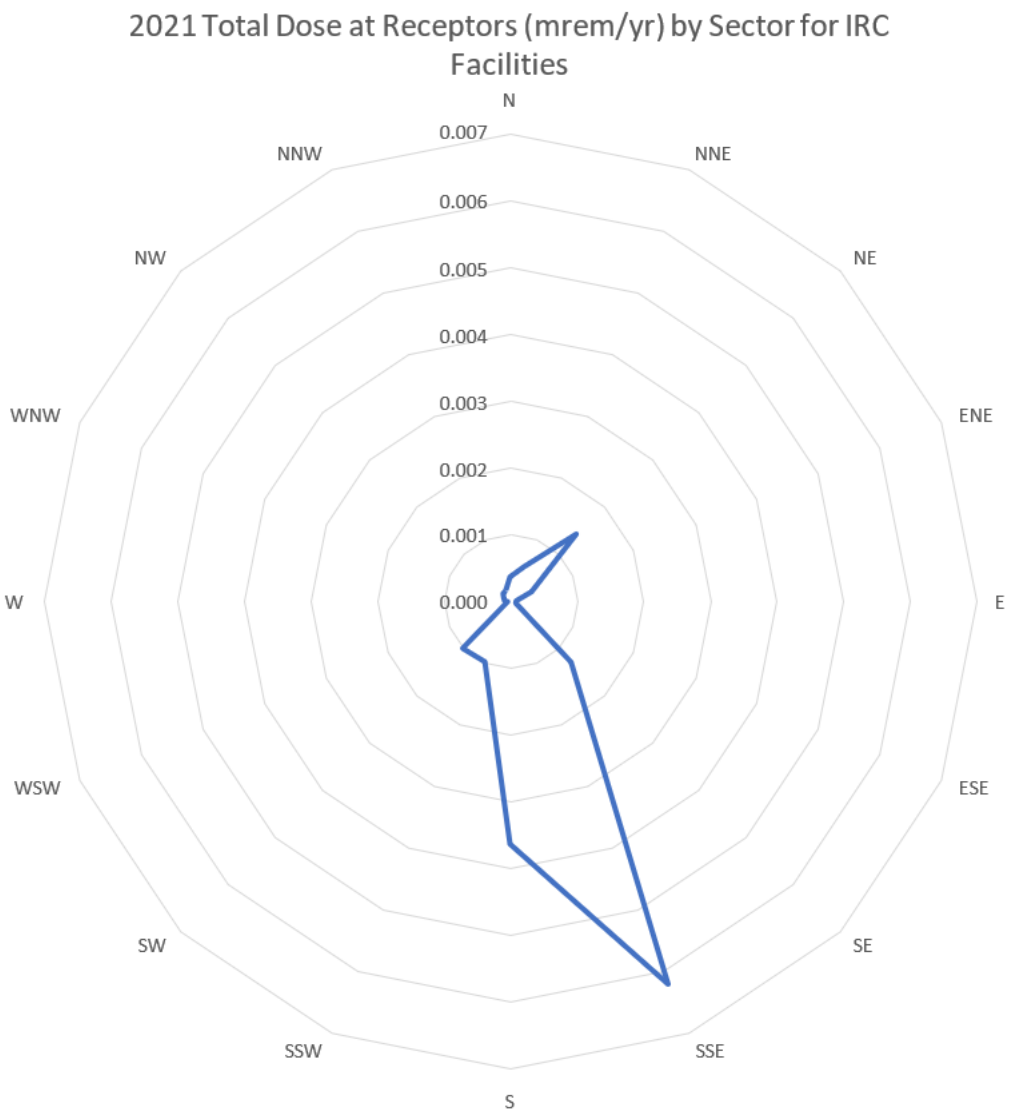

Figure A-3. Radar chart showing 2021 modeled dose (mrem/year) per sector for IRC facilities at NESHAP receptor locations.

A-1.2 Liquid Effluent Monitoring

A-1.2.1 Background

A meeting was held with City of Idaho Falls personnel on December 5, 2006, to determine which facilities in Idaho Falls required an Industrial Wastewater Acceptance Permit (IWA) from the City of Idaho Falls (City of Idaho Falls 2007). The City of Idaho Falls determined it would not issue permits to the minor facilities in Idaho Falls occupied by INL because the facilities did not meet the criteria for the issuance of an IWA (City of Idaho Falls 2007, Smith 2009). These facilities include:

- Energy Storage Technology Lab (IF-605)
- Records Storage Building (IF-663)
- Willow Creek (IF-616/617)

- Engineering Research Office Building (IF-654)
- Firewater Pump House #2 (IF-731)
- Technical Support Building and Technical Support Annex (IF-604A and B)
- Idaho National Lab Administration Building (IF-606)
- North Boulevard Annex (IF-613)
- May Street North (IF-614) (no longer in use)
- May Street South (IF-615) (no longer in use)
- Bus Dispatch (IF-631) (no longer in use)
- North Holmes Laboratory (IF-639)
- North Yellowstone Laboratory (IF-651)
- Bonneville County Technology Center (IF-670)
- Idaho Innovation Center (IF-673) (no longer in use)
- International Way Building (IF-674).

City of Idaho Falls personnel determined that an IWA would not be required for the Energy Systems Laboratory (ESL: IF-685) (Lewis 2012). Representatives from the City of Idaho Falls were informed that no radiological work would be performed at the Research and Education Laboratory (REL) and determined that the facility, later renamed the Energy Innovation Laboratory (IF-688), would not require an IWA (Lewis 2013a, 2013b).

The City of Idaho Falls determined that an IWA was required for the IRC Complex (City of Idaho Falls 2007). The expired 2013 and current 2018 IWA permits retain the same buildings, which include the following (City of Idaho Falls 2013; City of Idaho Falls 2018):

- Radiological and Environmental Sciences Office (IF-601)
- INL Research Center (IRC) Office Building (IF-602)
- IRC Laboratory Building (IF-603)
- National Security Building (IF-611)
- Systems Analysis Facility (IF-627)
- IRC Physics Laboratory (IF-638)
- IRC Chemical Storage Facility (IF-655)
- INL Engineering Demonstration Facility (IF-657)
- Fire Water Pump House #1 (IF-732).

The estimated discharge to the City of Idaho Falls sewer system from IRC is about 30,000 gallons per day (gpd) (INL 2018b). Most of the wastewater discharged to the sewer is process water (about 23,000 gpd) from the remainder includes approximately 2,400 gpd of cooling water and 4,600 gpd sanitary water.

There are over 60 small laboratories in the IRC Laboratory Building that contain utility sinks and floor drains (sealed where practical) that drain to the city sewer. Unlike a production facility, IRC typically uses very small quantities of chemicals.

A meeting was held with a representative of the City of Idaho Falls Sewer Department to determine whether a Wastewater Acceptance Permit would be required when the DOE-ID RESL moved into IF-683 in 2011. Based on the information provided, the City of Idaho Falls determined the new RESL building did not meet any of the criteria of a significant industrial user or categorical industrial user and would not require a permit (Henricksen 2009). The evaluation of potential radionuclide discharge to the Idaho Falls sewer developed by RESL and presented at the meeting with the City of Idaho Falls Sewer Department is shown in Table A-2.

Table A-2. Potential discharge to Idaho Falls publicly-owned treatment works from the DOE-ID RESL.

Radionuclide	Drinking Water MCL's (pCi/L)	DOE-ID RESL Sample Concentration (pCi/L)	DOE-ID RESL Impact to POTW assume 1% loss RESL Sample (pCi)	Monthly Facility Discharge estimated 10,000 L/month (pCi/L)
Americium-241	15	17	0.17	0.000017
Cobalt-57	1,000	511	5.11	0.000511
Cobalt-60	100	465	4.65	0.000465
Cesium-137	200	180	1.80	0.000180
Iron-55	2,000	1,300	13.00	0.001300
Manganese-54	300	396	3.96	0.000396
Plutonium-238	15	23	0.23	0.000023
Plutonium-239	15	23	0.23	0.000023
Strontium-90	8	195	1.95	0.000195
Technetium-99	900	391	3.91	0.000391
Uranium-234	NA	75	0.75	0.000075
Uranium-238	NA	78	0.78	0.000078
Zinc-65	300	368	3.68	0.000368
Tritium	20,000	8,900	89.00	0.008900

A-1.2.2 Sampling Program

The wastewater discharged to the City of Idaho Falls sewer from the IRC is sampled by City of Idaho Falls personnel (INL 2009) to meet the requirements of the City of Idaho Falls Industrial Waste Acceptance Permit (Table A-3; City of Idaho Falls 2018). In addition, daily pH measurements are recorded by INL at the IRC pH building retention tank (IF-705) and submitted monthly to the City of Idaho Falls. During 2018 and 2019, the results were all within the limits established by the permit.

Among other things, the permit prohibits "wastewater containing any radioactive wastes or isotopes except as specifically approved by the Director in compliance with applicable State or Federal regulations."

Table A-3. Monitoring requirements in the City of Idaho Falls Wastewater Acceptance Permit for IRC.

Parameter	Sampling Frequency	Sample Type	Permit Limit	2010-2011	
				Minimum	Maximum
pH	discretion of City of Idaho Falls	Grab	5.0–9.0	Not reported	Not reported
Biochemical Oxygen Demand (mg/L)	discretion of City of Idaho Falls	Grab	None	Not reported	Not reported
Total Suspended Solids (mg/L)	discretion of City of Idaho Falls	Grab	None	Not reported	Not reported
Flow	discretion of City of Idaho Falls	water meter	None	Not reported	Not reported
pH	Daily (INL)	retention tank at IF-705	5.0–9.0	6.66	8.12
pH	semiannual[a]	Grab	5.0–9.0	Not reported	Not reported
Arsenic (mg/L)	semiannual[a]	Composite	0.04	<0.0001	<0.0001
Cadmium (mg/L)	semiannual[a]	Composite	0.26	<0.00003	<0.00003
Chromium (mg/L)	semiannual[a]	Composite	2.77	<0.0002	<0.0002
Copper (mg/L)	semiannual[a]	Composite	1.93	0.03	0.072
Cyanide (mg/L)	semiannual[a]	Composite from grab samples	1.04	<0.002	<0.005
Lead (mg/L)	semiannual[a]	Composite	0.29	<0.00008	<0.00008
Mercury (mg/L)	semiannual[a]	Composite	0.002	<0.00005	<0.00005
Molybdenum (mg/L)	semiannual[a]	Composite	None	0.001	0.063
Nickel (mg/L)	semiannual[a]	Composite	2.38	<0.0008	<0.0008
Selenium (mg/L)	semiannual[a]	Composite	None	<0.0002	<0.0002
Silver (mg/L)	semiannual[a]	Composite	0.43	<0.00003	<0.00003
Zinc (mg/L)	semiannual[a]	Composite	0.90	0.027	0.078

a. In addition to the semiannual samples the City of Idaho Falls commonly collects one or two unscheduled samples per year. The results of the unscheduled samples are included in the data summarized in this table.

Einerson (1996) concluded, “It is not recommended that sampling for radionuclides be done [at IRC] since there is virtually no potential for radionuclide contamination. This is because under normal operations, radionuclide sources are either sealed or containerized.” Einerson (1996) further states, “Monthly self-monitoring at this location is not recommended based on the low probability of exceeding a limit.”

Routine discharges to IRC sinks and drains are limited to unregulated and nonhazardous material. Administrative controls have been instituted at the laboratories to control discharges from the sinks to maintain compliance with sewer permit requirements (INL 2018b). The laboratory sinks are posted with a notice of the sewer discharge limits, including the prohibition of radioactive isotopes. The limits are also specified in laboratory procedures. Engineering controls, such as plugging the floor drains in the laboratories, have also been utilized. In addition, there is a 2,000 gallon retention tank that can be used to contain the effluent if a pH excursion or inadvertent release of a prohibited material occurs (INL 2021a). Administrative controls, training requirements, and the spill-notification procedure for IRC are located at INL (2018a).

The 2010 DOE–HSS assessment stated, "The ability to demonstrate compliance with the provisions of DOE O 5400.5 can only be achieved through sampling and/or radionuclide quantity limits low enough to ensure the derived concentration guide (DCGs) cannot be exceeded based on concentration calculations using average facility-specific discharge volumes" (DOE–HSS 2010). This issue was evaluated by calculating effluent concentrations assuming the entire inventory of sources used at IRC in 2021 was lost to the sanitary sewer over a period of one year. DOE O 458.1 cancelled 5400.5 in 2011, and derived concentrations standards (DCSs) from DOE (2011) replaced the DCGs as guidance for the design and conduct of radiological environmental protection programs at DOE facilities. The DOE Derived Concentration Technical Standard (DOE 2011) states that for known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding DCS must not exceed 1.0 (DOE 2011). The calculated concentrations were compared to the DCSs and added to ensure the sum was less than one (Table A-4). The sum was only 0.0003; therefore, no monitoring is required at IRC. The source-term calculations will be reviewed whenever there is a significant change in the representative source term at the IRC and evaluated to determine if monitoring is recommended.

Table A-4. Comparison of IRC inventory used in 2021 to DCSs for water ingestion, assuming entire inventory used is released in the estimated annual effluent for a 1-year period (41,450,000 L).

Radionuclide	Inventory (µCi)	Effluent Concentration if Inventory Released over 1 Year (µCi/L)	DCS for Water Ingestion (µCi/L)	Ratio of Estimated Annual Concentration to DCS
Silver-110m	2.00E-05	4.83E-13	1.10E-02	4.39E-11
Cerium-114	1.70E-03	4.10E-11	5.50E-03	7.46E-09
Cobalt-60	2.00E-05	4.83E-13	7.20E-03	6.70E-11
Cesium-134	9.37E-01	2.26E-08	2.10E-03	1.08E-05
Cesium-137	9.40E-02	2.27E-09	3.00E-03	7.56E-07
Europium-154	1.50E-04	3.62E-12	1.50E-02	2.41E-10
Niobium-95	5.00E-05	1.21E-12	5.30E-02	2.28E-11
Scandium-46	1.11E+02	2.68E-06	2.10E-02	1.28E-04
Thorium-232	1.33E-01	3.21E-09	1.40E-04	2.29E-05
Uranium-234	4.31E+00	1.08E-07	6.80E-04	1.53E-04
Uranium-235	2.09E-01	5.03E-09	7.20E-04	6.99E-06
Uranium-238	1.23E+00	2.96E-08	7.50E-04	3.95E-05
Zinc-65	4.70E-02	1.13E-09	8.30E-03	1.36E-07
Sum	—	–	—	3.62E-04

A-1.3 Direct Radiation

Dosimeters are deployed at the IRC Complex to verify there is no measurable dose from gamma sources (primarily sealed sources) in IF-603 and IF-638. Neutron dosimetry (see section A-2) is also deployed at IF-638 at location O-39 because the building houses a ^{241}AmBe sealed neutron source (Figure A-4). Sealed sources are located in the BCTC building (IF-670). Four locations, plus one duplicate location, are monitored by OSL and neutron badges (Figure A-4).

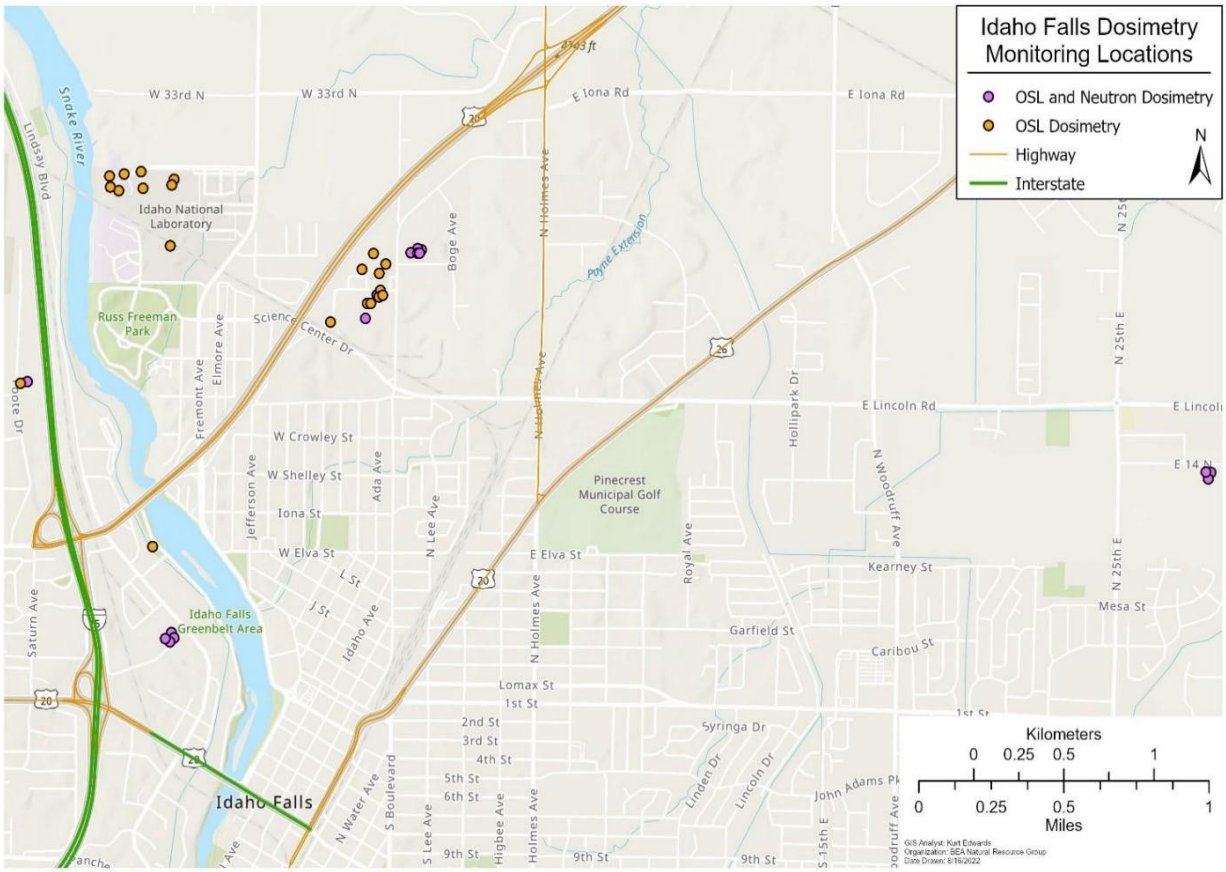

Figure A-4. Dosimetry locations in Idaho Falls include IRC Complex buildings IF-603, IF-627, IF-638, IF-670, and IF-689. Other areas include IF-616 Willow Creek Building, IF-652A Lindsay Building,IF-665 Center for Advanced Studies, IF-675 PINS Laboratory, and IF-688 Energy Innovation Laboratory. Additional locations on Foote Drive and the Idaho Falls Greenbelt are part of the INL Site monitoring network.

A-2. PINS LABORATORY

The PINS Laboratory (IF-675) utilizes 14 MeV Deuterium-Tritium (D-T) neutron generators, 2.5 MeV Deuterium-Deuterium (D-D) neutron generators, and Cf-252 neutron sources. The PINS facility was designed to ensure that no member of the general public would receive an effective dose equivalent (EDE) exposure exceeding 10 mrem in a year (Chichester et al. 2009). To verify that the measured neutron dose at the PINS fence line does not exceed the design dose, direct measurements were collected at the fence line when the largest neutron generator was operational. The measured doses were less than the modeled values.

Neutron dosimetry at the PINS facility (IF-675) began in November 2011 using a neutron area block dosimeter on the eastern facility fence. This dosimeter was in place until November 2012. Unfortunately, the corresponding control dosimeter was not maintained for the same period of time, precluding a usable measurement. In 2013, dosimetry was switched to Landauer Neutrak (CR-39) fast/intermediate/thermal neutron dosimeters. The selected Neutrak dosimeter has a dose-measurement range that begins at 10 mrem. These Neutrak dosimeters were placed at three locations around the IF-675 facility fence and at the Idaho Falls O-10 background location (Figure A-4). The Cf-252 neutron source has a significant gamma source term due to the presence of fission products; gamma radiation may also be generated by neutron interactions. Therefore, optically stimulated luminescence dosimeters (OSLDs) are deployed alongside the neutron dosimeters.

Although the initial rounds of neutron dosimeter measurements suffered from ultraviolet (UV) damage and did not provide usable measurements, this problem appears to have been resolved by sheathing the Neutrak dosimeters in aluminum foil and UV-resistant cloth. Subsequent measurements have been below the detection limit of 10 mrem. Because of the potential for weather-related damage to the dosimeters over extended periods of time, the dosimeters will be collected every six months or more frequently if necessary.

Appendix B

Current Radiological Air Emissions on Idaho National Laboratory Site

The Idaho National Laboratory (INL) Site consists of eight major facilities:

1. (Figure B-1): Advanced Test Reactor (ATR) Complex.
2. Central Facilities Area (CFA).
3. Materials and Fuels Complex (MFC).
4. Critical Infrastructure Test Range Complex (CITRC), which includes the Power Burst Facility (PBF).
5. Test Area North (TAN), which includes the Specific Manufacturing Capability (SMC).
6. Idaho Nuclear Technology and Engineering Center (INTEC).
7. Radioactive Waste Management Complex (RWMC).
8. Naval Reactors Facility (NRF), which is owned by the Naval Reactors–Idaho Branch Office. The Naval Nuclear Propulsion Program is exempt from United States (U.S.) Department of Energy (DOE) requirements and maintains a separate environmental monitoring program; therefore, NRF is not included in this report.

INL Site facility operations produce airborne effluents that can contain radiological constituents.

Airborne effluent can be released from individual point sources, such as laboratory ventilation systems or stacks, or diffuse sources such as re-suspension of contaminated soil. Some INL Site sources require continuous monitoring for compliance (e.g., continuous stack monitors). Every year, an estimate of the annual radionuclide emissions at the INL Site is prepared in accordance with the Code of Federal Regulations (CFR), Title 40, "Protection of the Environment," Part 61, "National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities" or NESHAP (e.g., DOE-ID 2022). The report includes estimation of the effective dose equivalent (EDE) to a maximally exposed individual (MEI) member of the public and comparison to the 10 mrem/year standard. The EDE is estimated using numerous conservative assumptions, such as: (1) the source is active for 100 years to allow accumulation of radionuclides in the environment; and (2) a rural scenario that allows for uptake/contamination of plants and animals that make up a portion of the diet (EPA 2020). The dose estimates consider immersion dose from direct exposure to airborne radionuclides, internal dose from inhalation of airborne radionuclides, internal dose from ingestion of radionuclides in plants and animals, and external dose from direct exposure to radionuclides deposited on soil. Further discussion regarding the methodology employed to calculate EDE to the MEI and other dose modelling processes can be found in INL/RPT-22-6745, "Idaho National Laboratory CY-2021 National Emissions Standards for Hazardous Air Pollutants Analysis, Methodology, and Results for Radionuclides" (Overin and Sondrup 2022).

In 2019, the estimated EDE from INL Site activities to an MEI located at NESHAP Receptor 54 (south of MFC) was 0.0561 mrem/year, or 0.56% of the standard. The estimated EDE for 2020 and 2021 was 0.0617 mrem/year and 0.0667 mrem/year, respectively (DOE-ID 2020; DOE-ID 2022). Emissions for 2019 to 2021 are included to demonstrate that the primary sources of air emissions and the principal radionuclides are relatively static. New projects or programs that would result in a significant change to the sources, types, or quantities of radionuclides released would require further evaluation using the process outlined in Section 1.

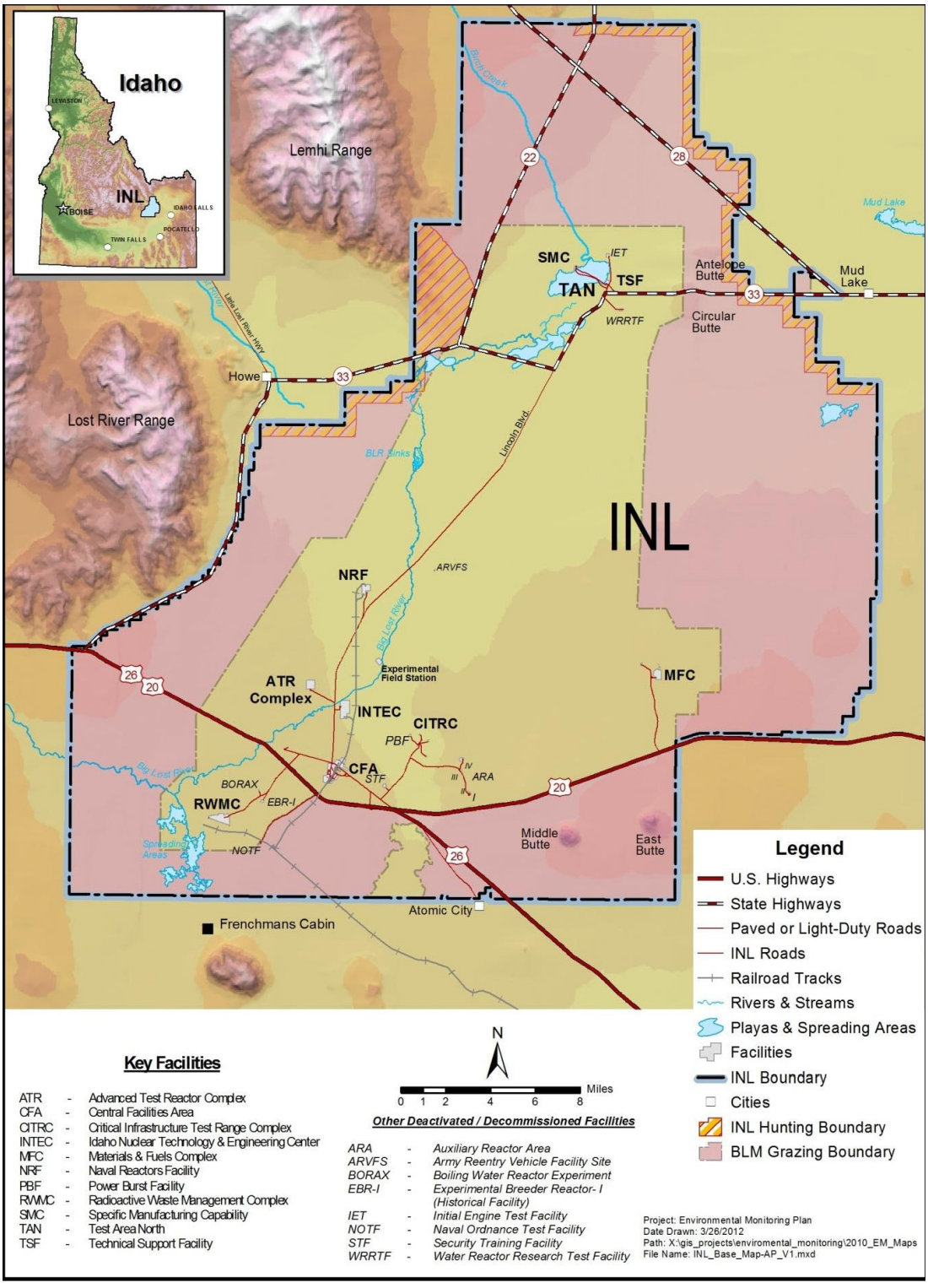

Figure B-1. Major facilities at the INL Site.

B-1. ADVANCED TEST REACTOR COMPLEX

The ATR Complex (formerly known as the Reactor Technology Complex [RTC] and Test Reactor Area [TRA]) was established in the early 1950s for studying the effects of radiation on materials, fuels, and equipment. Three major reactors have been built at the ATR Complex, including the Materials Test Reactor (MTR), the Engineering Test Reactor (ETR), and the ATR. The MTR and ETR have undergone decontamination and decommissioning (D&D); the ATR is currently the only operating nuclear reactor at the ATR Complex. The ATR tests materials for the nation's next generation of nuclear power plants. ATR is also used to manufacture a significant portion of the nation's medical nuclear isotopes.

Radiological air emissions from the ATR Complex are primarily associated with operation of the ATR. These emissions include noble gases, iodines, and other mixed fission and activation products. Other radiological air emissions are associated with sample analysis, site remediation, research and development (R&D) activities, and decommissioning and demolition activities. Air emissions at the ATR Complex were primarily from the ATR Main Stack and TRA evaporation pond (Table B-1, Figure B-2).

Table B-1. Primary sources of radionuclide emissions at ATR Complex (2019–2021) (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

Facility	Contribution to Estimate Dose to the MEI (%)		
	2019	2020	2021
TRA-715, Warm Waste Evaporation Pond	1.71	2.00	1.11
TRA-770-001, ATR Main Stack	<1	<1	<1
TRA-678-001, Radiation Measurements Laboratory fume hoods vent	<1	<1	<1
TRA-670, ATR Canal	<1	<1	<1
TRA-710-001, Materials Test Reactor (MTR) stack	<1	<1	None
TRA-1627-001, Radioanalytical Chemistry Laboratory	<1	<1	<1
TRA-670-086, Lab fume hood exhaust	<1	<1	<1
TRA-670-074, ATR Chemistry Lab fume hoods exhaust	<1	<1	<1
TRA-670-098, Lab fume hood exhaust	<1	<1	<1
TRA-666, Laboratory	None	None	<1

Table B-2 summarizes the 2019 to 2021 annual radiological air emissions at the ATR Complex that were >1 Ci or contributed at least 1% of the total estimated dose to the MEI.

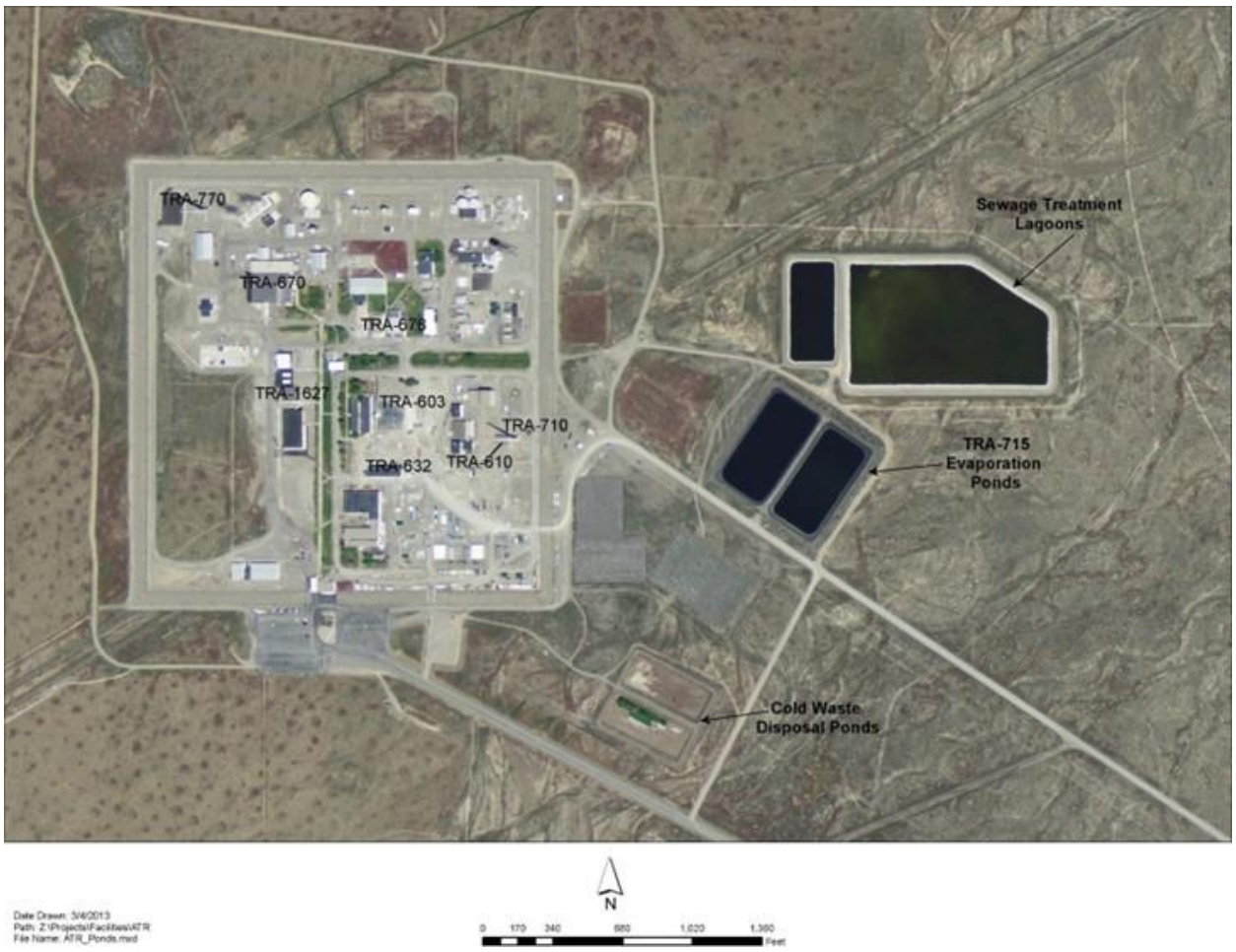

Figure B-2. Major facilities at the ATR Complex.

Table B-2. Estimated radiological air emissions at the ATR Complex that were >1 Ci or contributed at least 1% of total dose to MEI (2019-2021) (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

	Estimated Annual Emissions (Ci)			Contribution to Total Dose at MEI (%)		
Radionuclide	2019	2020	2021	2019	2020	2021
Argon-41	803.00	790.62	347.34	<1	<1	<1
Hydrogen-3	389.49	386.08	454.80	<1	<1	<1
Xenon-138	29.70	26.80	11.31	<1	<1	<1
Xenon-135	14.80	20.77	6.18	<1	<1	<1
Krypton-87	8.19	8.46	3.11	<1	<1	<1
Xenon-135m	3.87	7.33	2.94	<1	<1	<1
Krypton-85m	3.15	7.18	1.15	<1	<1	<1
Krypton-88	1.82	31.60	0.01	<1	<1	<1
Xenon-133	0.42	27.48	0.00	<1	<1	<1
Krypton-89	0.00	0.00	0.00	<1	<1	<1

Radionuclide	Estimated Annual Emissions (Ci)			Contribution to Total Dose at MEI (%)		
	2019	2020	2021	2019	2020	2021
Xenon-137	0.00	0.00	0.00	<1	<1	<1
Bromine-82	0.00	0.00	0.00	<1	<1	<1
Rrubidium-90	0.00	0.00	0.00	<1	<1	<1
Krypton-85	0.00	0.00	0.00	<1	<1	<1
Total	1,254	1306	827	1.10	1.09	0.57

B-2. CENTRAL FACILITIES AREA

The first buildings at CFA were constructed in the 1940s and 1950s to house the U.S. Navy's gunnery range personnel. The facilities have been modified over the years to fit the changing needs of the laboratory and now house centralized support services for contractors and DOE. Today, CFA houses technical and support services, including administrative offices, monitoring and calibration laboratories, fire protection, medical services, warehouses, vehicle and equipment pools, and bus operations.

Minor emissions occur from CFA facilities where work with small quantities of radioactive materials is routinely conducted, such as the CFA Laboratory Complex (CFA-625; Figure B-3). Prior to June 2011, the preparation of low-level radiological performance-testing samples at the U.S. Department of Energy–Idaho Operations Office (DOE-ID) Radiological and Environmental Sciences Laboratory (RESL).

(CFA-690) contributed to the estimated emissions from CFA. The primary radionuclide estimated to be released to the air at CFA is tritium from the use of contaminated groundwater, primarily due to evaporation from sewage treatment lagoons, which contain relatively low concentrations of tritium and iodine-129 because the groundwater at CFA is contaminated from historical discharges at INTEC (see Section 3.2).

During 2019 to 2021, air emissions at CFA were primarily from activities at the facilities listed below (DOE ID 2019; DOE ID 2020; DOE ID 2021):

- CFA-625, CFA Laboratory Complex
- CFA-1618, Health Physics Instrument Laboratory (HPIL)
- Tritium emissions from pumped aquifer water.

None of the facilities at CFA contributed at least 1% of the total estimated dose to the MEI.

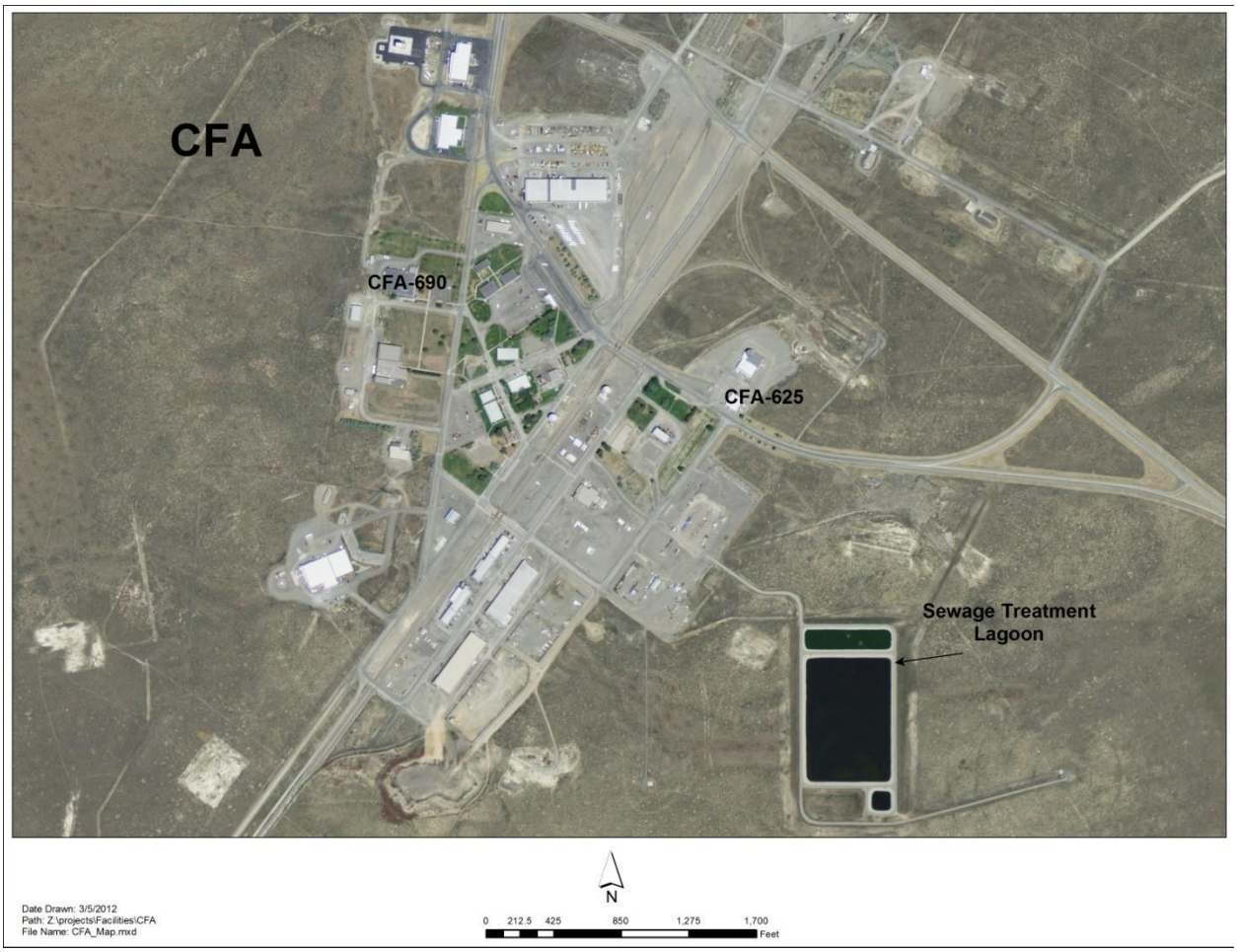

Figure B-3. Location of selected facilities at CFA.

The estimated release of tritium in 2019 through 2021 was less than 0.65 Ci; no other annual releases during 2019 to 2021 were >1 Ci (DOE ID 2020; DOE ID 2021; DOE ID 2022).

B-3. IDAHO NUCLEAR TECHNOLOGY AND ENGINEERING CENTER

INTEC was established in the 1950s to recover usable uranium from spent nuclear fuel (SNF) generated in government reactors and to store SNF. Radiological air emissions from INTEC sources are primarily associated with liquid-waste operations, including effluents from the Tank Farm Facility, Process Equipment Waste Evaporator, and Liquid Effluent Treatment and Disposal, which are exhausted through the Main Stack. These radioactive emissions include particulates and gaseous radionuclides.

Additional radioactive emissions are associated with D&D activities, wet-to-dry SNF transfers, environmental remediation, remote-handled transuranic waste management, radiological and hazardous-waste storage facilities, and contaminated-equipment maintenance (Table B-3, Figure B-4). In the near future, the Integrated Waste Treatment Unit (IWTU) will become operational to process the remaining sodium-bearing liquid waste at INTEC.

The Idaho CERCLA Disposal Facility is located on the southwest corner of INTEC. Radiological emissions from this facility are estimated from waste disposal in the landfill, evaporation pond operations, and waste treatment operations.

Table B-3. Primary sources of radionuclide emissions at INTEC: 2019-2021 (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

Facility	Contribution to Estimate Dose to the MEI (%)		
	2019	2020	2021
CPP-603, Irradiated Fuels Storage Facility	<1	<1	<1
CPP-659, New Waste Calcine Facility	<1	<1	<1
CPP-663, Maintenance Building Hot Shop	<1	<1	None
CPP-684, Remote Analytical Laboratory	<1	<1	<1
CPP-708, Main Stack	<1	<1	<1
CPP-767, FAST Stack	<1	<1	None
CPP-1608, Manipulator Repair Cell	<1	<1	<1
CPP-1774, TMI-2 Independent Spent Fuel Storage Installation	14.96	26.74	31.76
CPP-2707, Dry Cask Storage Pad	<1	<1	<1
Idaho CERCLA Disposal Facility (ICDF)	1.59	<1	<1

Table B-4 summarizes the 2019 to 2021 radiological air emissions at INTEC that were >1 Ci or contributed at least 1% of the total estimated dose to the MEI.

Table B-4. Estimated radiological air emissions at INTEC that were >1 Ci or contributed at least 1% of total dose to MEI (2019-2021) (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

	Estimated Annual Air Emissions (Ci)			Contribution to Total Dose at MEI (%)		
Radionuclide	2019	2020	2021	2019	2020	2021
Krypton-85	1.08	1.08	1.08	<1	<1	<1
Total	1.08	1.08	1.08	<1	<1	<1

Figure B-4. Selected facilities at INTEC.

B-4. MATERIALS AND FUELS COMPLEX

MFC, originally called Argonne National Laboratory-West, was established in the 1950s to research and develop nuclear reactors and fuel. Four reactors have been constructed at MFC: (1) Transient Reactor Test Facility; (2) Experimental Breeder Reactor II (EBR-II); (3) Zero Power Physics Reactor (ZPPR); and (4) Neutron Radiography Reactor (NRAD). Only one of these reactors, NRAD, is currently operating. Today, MFC is the prime testing center in the U.S. for demonstration and proof-of-concept of nuclear energy technologies. R&D activities at MFC are focused on areas of national concern, including energy, nuclear safety, SNF treatment, nuclear material disposal, nonproliferation, D&D technologies, projects to support space exploration, and homeland security.

Radiological air emissions are primarily associated with spent-fuel treatment at the Fuel Conditioning Facility (FCF) and waste characterization at the Hot Fuel Examination Facility (HFEF). Both of these facilities are equipped with continuous emission monitoring (CEM) systems. On a monthly basis, the effluent streams from FCF, HFEF, and other non-CEM radiological facilities are sampled and analyzed for particulate radionuclides. The FCF and HFEF are also sampled monthly for gaseous radionuclides.

Gaseous and particulate radionuclides may also be released from other MFC facilities during laboratory research activities, sample analysis, waste handling and storage, and maintenance operations. Both measured and estimated emissions from MFC sources are consolidated for NESHAP reporting on an annual basis. Radionuclides contributing to dose and associated emissions are shown in Table B-5.

During 2019 to 2021, air emissions at MFC were primarily from activities at the facilities listed below (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022; see Figure B-5):

- MFC-704-008, Fuel Manufacturing Facility stack
- MFC-720-007, Transient Reactor Test Facility reactor cooling air exhaust
- MFC-752-004, Laboratory and Office Building (L&O) main stack
- MFC-752-005, L&O nondestructive assay stack
- MFC-764-001, Main Stack (FCF exhaust)
- MFC-768-105, Decontamination shower suspect waste tank vent
- MFC-768-108, Health Physics Area fume hood
- MFC-774-026, Electron Microscopy Laboratory (EML) exhaust
- MFC-774-027, EML exhaust
- MFC-774-028, EML exhaust
- MFC-774-029, EML exhaust
- MFC-777-002, Zero Power Physics Reactor
- MFC-784, Advanced Fuels Facility
- MFC-785-018, Hot Fuel Examination Facility stack
- MFC-787-001, Fuel Assembly and Storage Building
- MFC-792A-001, Space and Security Power Systems Facility
- MFC-793-001, Sodium Components Maintenance Shop (SCMS) stack
- MFC-794-002, Experimental Fuels Facility-West exhaust
- MFC-794-006, Experimental Fuels Facility-East exhaust

- MFC-1702, Radiochemistry Laboratory
- MFC-1729, Irradiated Materials Characterization Laboratory
- MFC-798-017.

Table B-5. Estimated radiological air emissions at MFC that were >1 Ci or contributed at least 1% of total dose to MEI (2019-2021) (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

Radionuclide	Estimated Annual Emissions (Ci)			Contribution to Total Dose at MEI (%)		
	2019	2020	2021	2019	2020	2021
Cesium-137	>1	>1	>1	55.87	55.00	54.56
Uranium-238	>1	>1	>1	20.02	15.72	16.32
Uranium-234	>1	>1	>1	7.66	7.96	8.31
Chlorine-36	>1	>1	>1	6.28	5.82	6.03
Zinc-65	>1	>1	>1	3.42	6.32	6.98
Argon-41	81.40	90.30	80.90	>1	>1	>1
Krypton-89	34.50	38.20	34.20	>1	>1	>1
Krypton-90	26.30	29.20	0.00	>1	>1	>1
Xenon-138	16.30	18.10	16.20	>1	>1	>1
Xenon-137	15.30	17.00	15.20	>1	>1	>1
Krypton-87	10.50	11.70	10.50	>1	>1	>1
Krypton-85m	10.10	11.20	9.99	>1	>1	>1
Xenon-139	9.58	10.60	>1	>1	>1	>1
Krypton-88	9.58	10.60	9.51	>1	>1	>1
Krypton-91	4.64	5.15	>1	>1	>1	>1
Rb-90	3.26	3.61	5.36	>1	>1	>1
Xenon-140	3.26	3.61	>1	>1	>1	>1
Rubidium-91	2.97	3.29	>1	>1	>1	>1
Xenon-135	2.63	2.92	2.62	>1	>1	>1
Cesium-140	1.29	1.43	>1	>1	>1	>1
Iodine-131	>1	1.75	>1	>1	3.41	>1
Uranium-235	>1	>1	>1	>1	>1	3.61

Figure B-5. Selected facilities at MFC.

B-5. RADIOACTIVE WASTE MANAGEMENT COMPLEX

RWMC, located in the southwestern corner of the INL Site, is a controlled-access area with a primary mission to dispose of INL Site-generated low-level radioactive waste and to temporarily store contact-handled and remote-handled transuranic waste that will be shipped to other designated facilities for disposal. The Accelerated Retrieval Project (ARP), regulated under CERCLA, is removing targeted waste from the Subsurface Disposal Area (SDA), disposing of transuranic waste at an off-Site facility, and remediating and closing the SDA. To fulfill these missions, RWMC maintains facilities and processes in separate areas for administrative and operations support, and waste storage and disposal.

Administrative and Operations Area buildings are used for security and access control, personnel offices, lunchrooms, change and shower rooms, equipment and materials storage, craft and maintenance shops, and radiological control.

Current operations at RWMC include the Advanced Mixed Waste Treatment Project (AMWTP), which comprises the retrieval of mixed transuranic waste from temporary storage, characterizing the waste, treating the waste to meet disposal criteria, and packaging the waste for shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. Radiological air emissions from AMWTP may result from the retrieval, characterization, and treatment of transuranic waste, low-level mixed waste (LLMW), and alpha-contaminated low-level mixed waste (alpha LLMW).

From 2019 to 2021, the primary sources at RWMC that contributed to the dose to the MEI were activities at the Drum Treatment Facility and tritium emissions from beryllium blocks buried in the SDA (Table B-6; Figure B-6).

Table B-6. Primary sources of radionuclide emissions at RWMC (2019-2021) (DOE-ID 2019; DOE-ID 2020; DOE-ID 2021).

Facility	Contribution to Estimate Dose to the MEI (%)		
	2019	2020	2021
WMF-601, Health Physics Laboratory	<1	<1	<1
WMF-1612, ARP-II	<1	<1	<1
WMF-1614, ARP-III	<1	<1	<1
WMF-1615, ARP-IV	<1	<1	<1
WMF-1617, ARP-V/Sludge Repackaging Project	<1	<1	<1
WMF-1619, ARP-VII	<1	<1	<1
WMF-1621, ARP-VIII	<1	<1	<1
WMF-1622, ARP-IX	<1	<1	<1
Tritium emissions from beryllium blocks buried in the SDA	<1	<1	<1
CERCLA remediation activities	<1	<1	<1
Waste Management Facility (WMF)-615-001, Drum Vent Facility	<1	<1	<1
WMF-634, Characterization Facility	<1	<1	<1
WMF-636, Transuranic Storage Area	<1	<1	<1
WMF-676, Advanced Mixed Waste Treatment Facility	<1	<1	<1

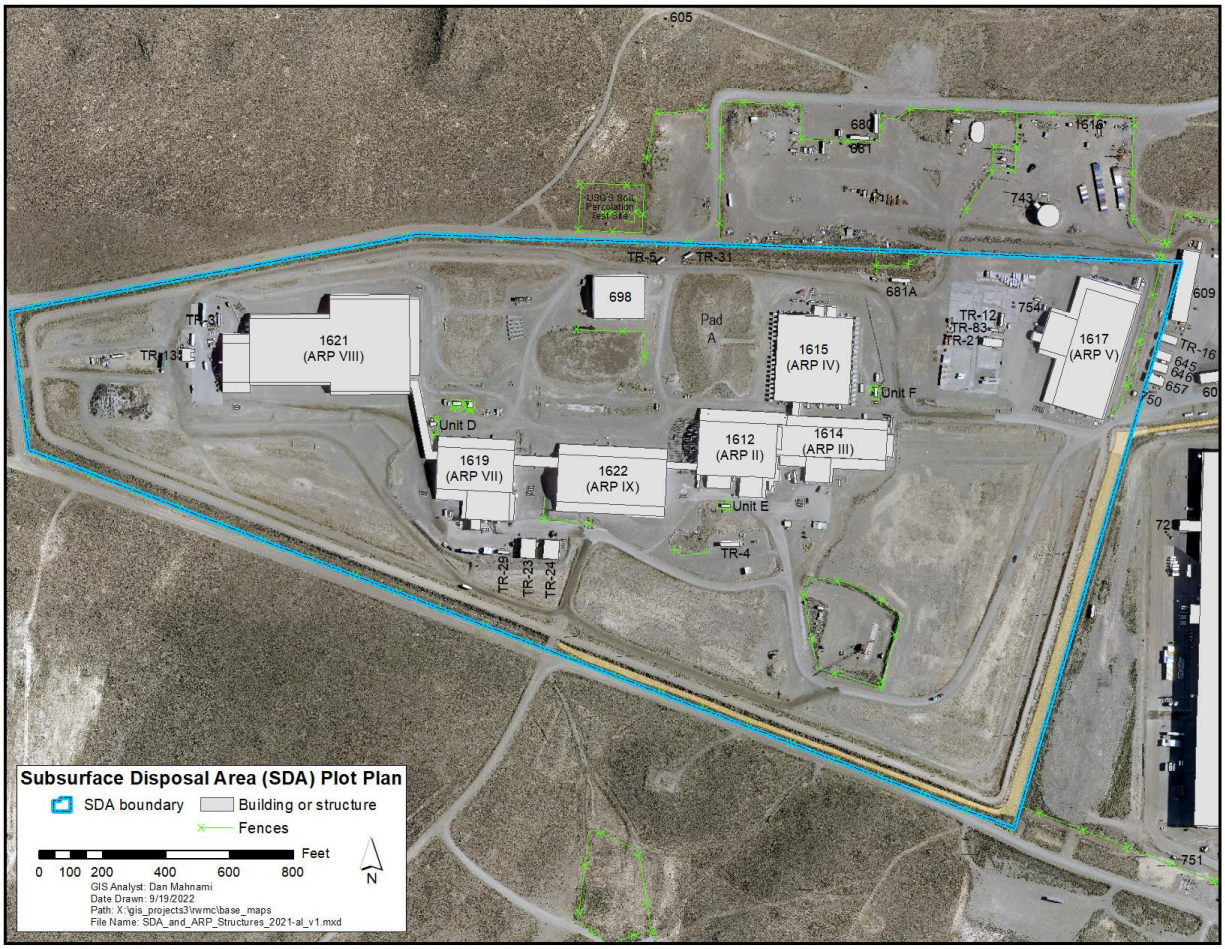

Figure B-6. Selected facilities at RWMC.

Table B-7 summarizes the radiological air emissions at RWMC that were >1 Ci or contributed at least 1% of the total estimated dose to the MEI.

Table B-7. Estimated radiological air emissions at RWMC >1 Ci or contributed at least 1% of total dose to maximally-exposed individual (2019-2021) (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022).

	Estimated Annual Air Emissions %			Contribution to Total Dose at MEI (Ci)		
Radionuclide	2019	2021	2022	2019	2020	2021
Tritium	59.3	51.4	48.1	<1	<1	<1
Total	59.3	51.4	48.1	<1	<1	<1

B-6. TEST AREA NORTH

TAN is the northernmost developed area within the INL Site. It was originally established to support the Aircraft Nuclear Propulsion Program, which operated from 1951 to 1961. Since 1961, TAN buildings have been adapted for use by various other programs, including current operations at SMC. The TAN/SMC Project is a manufacturing operation that produces an armor package for the U.S. Army. The TAN/SMC Project was assigned to the laboratory in 1983. Operations at TAN/SMC include material development, fabrication, and assembly work to produce armor packages. The operation uses standard metal-working equipment in fabrication and assembly. Other activities include developing tools and fixtures and preparing and testing metallurgical specimens. Radiological air emissions from TAN/SMC are associated with the processing of depleted uranium. Potential emissions are uranium isotopes and associated radioactive progeny.

From 2019 to 2021, air emissions at TAN were primarily from activities at the facilities listed below (DOE-ID 2020; DOE-ID 2021; DOE-ID 2022) (see Figure B-7). A total of 8.5 Ci (primarily bromine-42) was estimated to have been released to the air at TAN/SMC in 2019. Releases from 2020 and 2021 were dominated by bromine-42 as well, with an estimated 4.06 and 10.61 Ci released, respectively.

Bromine-42 accounts for 97% of these emissions. The annual releases from TAN/SMC account for less than 0.6% of the total dose to the MEI:

- TAN-629-013, manufacturing process, Line 2A
- TAN-679-022, -023, -024 manufacturing process, north process
- TAN-679-025, -026, -027 manufacturing process, south process
- TAN-681-018, Process Reclamation Facility
- TAN-681-020, Process Reclamation Facility
- TAN-681-016, Process Reclamation Facility
- North Radiological Response Test Range (RRTR).Figure B-7. Selected facilities at TAN/SMC.

B-7. SUMMARY

The primary contributors to the modeled dose to the MEI for 2019 to 2021 are estimated emissions of:

- Cesium-137 and uranium from the MFC Radiochemistry Laboratory
- Uranium-234 and uranium-238 from the MFC Advanced Fuels Facility
- Zinc-65 and chlorine-36 from the MFC EML exhaust.

REFERENCES

"National Primary Drinking Water Regulations." 40 CFR 141, Code of Federal Regulations National Archives. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-141.

"Re-application for the Industrial Wastewater Acceptance Permit." Letter from J. Stenzel to D. Smith, March 21, 2008. CCN 213080, Idaho National Laboratory Research Center, Idaho National Laboratory, Idaho Falls, ID.

AEC. 1960. "Environmental Monitoring Data for the National Reactor Testing Station October through December 1960." U.S. Atomic Energy Commission, Washington, D.C.

AEC. 1964. "Environmental Monitoring Report, No. 14, First and Second Quarter." U.S. Atomic Energy Commission, Washington, D.C.

AEC. 1966a. "Environmental Monitoring Report No. 19, Third and Fourth Quarter and Annual Summary." AEC. 1966b. "Environmental Monitoring Report, No. 18, First and Second Quarter." U.S. Atomic Energy Commission, Washington D.C.

AEC. 1968a. "Environmental Monitoring Report, No. 23, July–December and Annual Summary." U.S. Atomic Energy Commission, Washington D.C.

AEC. 1968b. "Annual Report of the Health Services Laboratory." IDO-12071, U.S. Atomic Energy Commission, Idaho Operations Office (AEC), Health Services Laboratory, Idaho Falls, ID.

AEC. 1969. "Annual Report of the Health Services Laboratory." IDO-12071, U.S. Atomic Energy Commission, Idaho Operations Office (AEC), Health Services Laboratory, Idaho Falls, ID.

AEC. 1971. "Annual Report of the Health Services Laboratory." IDO-12075, U.S. Atomic Energy Commission, Idaho Operations Office (AEC), Health Services Laboratory, Idaho Falls, ID.

AEC.1961. "Environmental Monitoring Report No. 9, Fourth Quarter of 1961 and Annual Summary." U.S. Atomic Energy Commission, Washington, D.C.

ANL. 2007. "Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas." Argonne National Laboratory, Environmental Sciences Division, U.S. Department of Energy–Richland Operations Office, U.S. Department of Energy–Chicago Operations Office, Leland, IL. https://remm.hhs.gov/ANL_ContaminantFactSheets_All_070418.pdf.

ANL-W. 1996. "WAG 9—Site Code: ANL-04—ANL Sewage Lagoons." Addendum to Previously Signed Waste Area Group 9, May 23, 1996, Argonne National Laboratory–West, Scoville, ID, USA. https://inldigitallibrary.inl.gov/PRR/83433.pdf.

ANL-W. 1998. "Final Record of Decision for Argonne National Laboratory-West." W7500-000-ES-04, Argonne National Laboratory–West, Scoville, ID. https://idaho-environmental.com/arir/search/details?id=uUG5LtODGSSrKKcjuiM18g==&r=7hzUehj5n2Q4elgPBwB5Ew==.

ANSI/ASQC. 1994. "Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs." ANSI/ASQC E4-1994, American National Standards Institute/American Society for Quality Control, New York, NY. https://webstore.ansi.org/standards/asq/ansiasqce41994.

Ansley, S., T. Brock, D. Walker, M. Abbott, and A. Rood. 1997. "Idaho National Engineering and Environmental Laboratory Management Standard for Disposal of Wastewater." INEL-96/0277, Idaho National Environmental Laboratory, Idaho Falls, ID.

Apostoaei, A. I., W. E. Reed. 2005. "Exposure Scenarios for Use in Estimating Radiation Doses to the Public from Historical Atmospheric Releases of Radionuclides at INEL Final Report." Centers for Disease Control and Prevention, Atlanta, GA. https://www.cdc.gov/nceh/radiation/ineel/task3-scenarios.pdf.

Arthur, W. J. 1982. "Radionuclide Concentrations in Vegetation at a Solid Radioactive Waste-Disposal Area in Southeastern Idaho." *Journal of Environmental Quality* 11(3): 394–399. https://doi.org/10.2134/jeq1982.00472425001100030015x.

Arthur, W. J., III, and O. D. Markham. 1983. "Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho." *Journal of Environmental Quality* 12(1): 117–212. https://doi.org/10.2134/jeq1983.00472425001200010021x.

Arthur, W. J., III, O. D. Markham, C. R. Groves, B. L. Keller, and D. K. Halford, 1986. "Radiation dose to small mammals inhabiting a solid radioactive waste area." *Journal of Applied Ecology* 23(1): 13–26. https://doi.org/10.2307/2403077.

ASME. 2008. "Quality Assurance Requirements for Nuclear Facility Applications." ASME NQA-1-2008, American Society of Mechanical Engineers, New York, NY.

Baes, C. F., III, R. D. Sharp, A. L. Sjoreen, and R. W. Shor. 1984. "A Review and Analysis of Parameters for Assessing Transport of Environmental Released Radionuclides through Agriculture." ORNL-5786, Oak Ridge National Laboratory, Oak Ridge, TN. https://doi.org/10.2172/6355677.

Barg, D. C. 1997. "Lagoon Sample Radioanalysis—DCB-39-97." Interdepartmental Communication to H. D. Jackson, Lockheed Idaho Technologies Company, Idaho Falls, ID.

Bartholomay, R. C., B. J. Tucker, L. C. Davis, and M. R. Green. 2000. "Hydrologic Conditions and Distribution of Selected Constituents in Water: Snake River Plain Aquifer and Idaho National Plain Aquifer, Idaho National Laboratory, Idaho, 1996 through 1998." DOE/ID-22167. U.S. Geological Survey Water- Resources Investigations Report 2000-4192, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID. https://doi.org/10.3133/wri004192.

Bartholomay, R. C., N. V. Maimer, G. W. Rattray, and J. C. Fisher. 2020. "An Update of Hydrologic Conditions and Distribution of Selected Constituents in Water, Eastern Snake River Plain Aquifer, and Perched Groundwater Zones, Idaho National Laboratory, Idaho, Emphasis 2016-18." DOE-ID-22251 U.S. Geological Survey Scientific Investigations Report 2019-5149. U.S. Geological Survey in cooperation with the U.S. Department of Energy Idaho Operations Office. https://doi.org/10.3133/sir20195149.

Boothe, G. F., G. R. Priddy, R. H. Ruben, and D. McBaugh. 2008. "Determining the Optimum Sample Volume for Environmental Airborne Radioactivity Monitoring." *Health Physics* 94(2): S21–S26. https://doi.org/10.1097/01.hp.0000290607.56397.47.

Bowman, A. L., W. F. Downs, K. S. Moor, and B. F. Russell. 1984. "INEL Environmental Characterization Report." Vol. II, EGG-NPR-6688, September 1984, EG&G Idaho, Inc., Idaho Falls, ID.

Braun, D. R. 1992. "ANL-W 779 Pond Seepage Test." EGG-FE-10499, EG&G Idaho, Inc., Idaho Falls, ID. https://digital.library.unt.edu/ark:/67531/metadc1281385/m2/1/high_res_d/10115817.pdf.

Bryan, M. F. 1991. "Perimeter Monitoring Airborne Radionuclide Particulates at EG&G Waste Management Facilities at the Idaho National Engineering Laboratory." ED-SRE-002.

Butler Engineering. 1993. "SMC Sanitary Waste Upgrade Design." Project No. EIR 12141, Butler Engineering, Idaho Falls, ID.

CFR. 1975.CFR. 1976. "Other Safe Drinking Water Act Regulations." 40 CFR 143, Code of Federal Regulations National Archives. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-143.

CFR. 1979. "National Primary Drinking Water Regulations Implementation." 40 CFR 142, Code of Federal Regulations National Archives.https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-142?toc=1

CFR. 2023a. "National Emission Standards for Hazardous Air Pollutants." 40 CFR 61, Code of Federal Regulations National Archives. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-61?toc=1.

CFR. 2023b. "Subpart H, National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." 40 CFR 61, Code of Federal Regulations National Archives. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-61/subpart-H.

CFR. 2023c. "Emission Monitoring and Test Procedures." 40 CFR 61.93(g), Code of Federal Regulations National Archives. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-61/subpart-H

Chichester, D. L., E. H. Seabury, J. M. Zabriskie, J. Wharton, and A.J. Caffrey. 2009. "Dose profile modeling of Idaho National Laboratory's active neutron interrogation laboratory." *Applied Radiation and Isotopes* 67(6)" 1013–1022. https://doi.org/10.1016/j.apradiso.2009.01.002.

City of Idaho Falls. 2007. "City of Idaho Falls Industrial Wastewater Acceptance Permit IF-8733-54171-1 and Transmittal Letter to D. Wagoner from D. Smith." City of Idaho Falls Sewer Department, February 5, 2007. CCN 208766, City of Idaho Falls, Idaho Falls, ID.

City of Idaho Falls. 2013. "City of Idaho Falls Industrial Wastewater Acceptance Permit IF-8733-54171-1." CCN 230277, City of Idaho Falls, Idaho Falls, ID.

City of Idaho Falls. 2018. "City of Idaho Falls Industrial Wastewater Acceptance Permit, Permit No. IF-8733-54171-1."

Clawson, K. L., G. E. Start, and N. R. Ricks. 1989. "Climatography of the Idaho National Engineering Laboratory." U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Washington D.C. https://www.osti.gov/biblio/5195033.

Comer, M. J. 2000. "Elk Population Characteristics and Habitat Use in Southeastern Idaho." M.S. Thesis, University of Idaho, Moscow, ID.

Cosgrove, D. M., G. S. Johnson, S. Laney, and J. Lindgren. 1999. "Description of the IDWR/UI Snake River Plain Aquifer Model (SRPAM)." Idaho Water Resources Research Institute, University of Idaho, Moscow, ID. https://idwr.idaho.gov/wp-content/uploads/sites/2/legal/american-falls/AF-199904-Mod-Desc-14.pdf.

Davis, L. C., 2010. "An Update of Hydrologic Conditions and Distribution of Selected Constituents in Water, Snake River Plain Aquifer, and Perched Groundwater Zones, Idaho National Laboratory, Idaho, Emphasis 2006-08." U.S. Geological Survey Water-Resources Scientific Investigations Report. DOE-ID-2212, U.S. Geological Survey in cooperation with the U.S. Department of Energy Idaho Operations Office, Idaho Falls, ID. https://doi.org/10.3133/sir20105197.

Davis, L. C., R. C. Bartholomay, and G. W. Rattray. 2013. "An Update of Hydrologic Conditions and Distribution of Selected Constituents in Water, Snake River Plain Aquifer, and Perched Groundwater Zones, Idaho National Laboratory, Idaho, Emphasis 2009-2011." U.S. Geological Survey Water-Resources Scientific Investigations Report. DOE/ID-22226, U.S. Geological Survey in cooperation with the U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://doi.org/10.3133/sir20135214.

Davis, L. C., R. C. Bartholomay, J. C. Fisher, and N. V. Maimer. 2015. "Water-quality Characteristics and Trends for Selected Wells Possibly Influenced by Wastewater Disposal at the Idaho National Laboratory, Idaho, Emphasis 1981–2012." DOE/ID-22233. U.S. Geological Survey Scientific Investigations Report 2015-5003, U.S. Geological Survey in cooperation with the U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://pubs.usgs.gov/sir/2015/5003/.

Denham, D. H. 1979. "Environmental Radiological Surveillance in Perspective: the Relative Importance of Environmental Media As a Function of Effluent Pathway and Radionuclides." *Health Physics*, Vol. 36(3): 273–281. https://journals.lww.com/health-physics/Abstract/1979/03000/Environmental_Radiological_Surveillance_in.5.aspx.

DEQ. 2002. "Air Quality Permit to Construct for the Idaho National Engineering and Environmental Laboratory—TRA Evaporation Pond." No. 023-00001, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2008. "Reactor Technology Complex (RTC) Cold Waste Pond Wastewater Reuse Permit No. LA-000161-01." Letter to W. Hamel. CCN 212842, February 26, 2008, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2010a. "LA-000141-03 INL CFA Sewage Treatment Facility, Final Wastewater Reuse Permit." Letter to R. Furstenau and D. Coburn, March 17, 2010, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2010b. "LA-000160-01 INL Materials and Fuels Complex Cold Waste Pond, Issuance of Final Wastewater Reuse Permit." Letter to W. Hamel and D. Coburn, April 14, 2010. CCN 220726, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2012a. "Municipal and Industrial Wastewater Reuse Permit, LA-000130-05, Idaho Nuclear Technology and Engineering Center (INTEC) Facility's New Percolation Ponds." Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2012b. "WRU-I-0160-01 INL MFC Industrial Waste Pond, Permit Modification 1 (formerly LA-000160-01)." Letter to W. Hamel and C. Melbihess, June 21, 2012. CCN 227704, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2012c. "RE: INL Materials and Fuels Complex Lagoon Seepage Test Results Approval. DEQ No. 10-04-12." Letter to Jo Anna Stenzel, October 3, 2012. Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2014. "RE: I-161-02 INL ATR Cold Waste Ponds, Final Permit." Letter to Robert Boston, November 20, 2014. CCN 234522, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2015. "RE: Comments on the operable Unit 9-04 Operations and Maintenance Report for Fiscal Years 2008-2014, DOE-ID-11525, Draft Rev. B." Letter to N. Badrov, May 14, 2015. EDMS Document # 5073982, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2016. "RE: I-160-02 INL MFC Industrial Waste Pond, Draft Reuse Permit for review." Letter to R. Boston and T. Miller, December 2, 2016. CCN 239483, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2017a. "Idaho National Laboratory (INL) Materials and Fuels Complex (MFC) Industrial Waste Ditch and Pond, Reuse Permit I-160-02." Letter to T. Miller, January 26, 2017. CCN 239767, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2017b. "LA-000141-03 Idaho National Laboratory (INL) Central Facilities Area (CFA) Sewage Treatment Plant (STP), Permit termination and approval of final closure report." Letter to T. Miller, December 15, 2017. CCN 241829, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2019a. "Industrial Reuse Permit Renewal Application for the Advanced Test Reactor Complex Cold Waste Ponds." INL/EXT-19-53571, May 2019, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2019b. "Reuse Permit No. I-161-03 (Currently I-161-02), INL ATR Cold Waste Ponds – Draft Reuse Permit for Review." including DEQ Staff Analysis, CCN 245446, September 2019, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2019c. "Idaho National Laboratory (INL) Advanced Test Reactor (ATR) Complex Cold Waste Ponds – Reuse Permit I-161-03." PER-132, Idaho Department of Environmental Quality, October 2019, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2019d. "Biosolids Management and Closure Plan for the Idaho National Laboratory (INL) Materials and Fuels Complex (MFC) ANL-04 Sewage Lagoons, Approved, CCN 244907." Letter to Tim Miller, June 6, 2019. Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2020a. "RE: Facility ID No. 023-00001, U.S. Department of Energy – Idaho Operations Office Permit to Construct Termination." Letter from Dan Pitman to W. E. Miller, May 29, 2020. PTC No. 023-00001, CCN 247204. Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2020b. "RE: I-160-02 Request for Deferral of INL-ATR Sewage Treatment Lagoons Seepage Test to Spring 2021 Approval." Letter from G. Eager to C. Morgan, September 14, 2020. Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2020c. "Idaho National Laboratory (INL) Materials and Fuels Complex (MFC) Industrial Waste Pond (IWP), Reuse Permit No. I-160-02, Modification 3." Letter to W. Miller, September 15, 2020. CCN 247864, Idaho Department of Environmental Quality, Boise, ID.

DEQ. 2022a. "Rules for the Control of Air Pollution in Idaho." 58.01.01, Idaho Department of Environmental Quality, Boise, ID. https://adminrules.idaho.gov/rules/current/58/580101.pdf.

DEQ. 2022b. "Ground Water Quality Rule." IDAPA 58.01.11, Idaho Department of Environmental Quality, Boise, ID. https://adminrules.idaho.gov/rules/current/58/580111.pdf.

DEQ. 2022c. "Wastewater Rules." IDAPA 58.01.16, Idaho Department of Environmental Quality, Boise, ID. https://adminrules.idaho.gov/rules/current/58/580116.pdf.

DEQ. 2022d. "Recycled Water Rules." IDAPA 58.01.17, Idaho Department of Environmental Quality, Boise, ID. https://adminrules.idaho.gov/rules/current/58/580117.pdf.

DOE. 1991. "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance." DOE/EH-0173T, Assistant Secretary for Environment, Safety, and Health, Washington D.C. https://doi.org/10.2172/5771704.

DOE. 1997. "Environmental Measurements Laboratory, Procedures Manual, 28th Edition." HASL-300, Environmental Measurements Laboratory, U.S. Department of Energy, Washington D.C. https://www.wipp.energy.gov/namp/emllegacy/procman.htm.

DOE. 1999a. "Quality Assurance." DOE O 414.1A, U.S. Department of Energy, Washington D.C. https://www.directives.doe.gov/directives-documents/400-series/0414.1-BOrder-a.

DOE. 1999b. "Radioactive Waste Management." DOE Order 435.1 Chg 1 (PgChg), U.S. Department of Energy, Washington D.C. https://www.directives.doe.gov/directives-documents/400-series/0435.1-BOrder-chg1-PgChg.

DOE. 2001. "Radioactive Waste Management Manual." DOE M 435.1-1 Chg 3, U.S. Department of Energy, Washington D.C. https://www.directives.doe.gov/directives-documents/400-series/0435.1-DManual-1-chg3-ltdchg-1.

DOE. 2002. “A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota.” DOE-STD-1153-2002, U.S. Department of Energy, Washington, D.C. https://www.standards.doe.gov/standards-documents/1100/1153-AStd-2002.

DOE. 2005. “Draft Guidance for Release of Game Animals for Human Consumption.” DOE G441.1-xy, April 2005, U.S. Department of Energy, Washington D.C.

DOE. 2011a. “Derived Concentration Technical Standard.” DOE-STD-1196-2011, U.S. Department of Energy, Washington D.C. https://www.standards.doe.gov/standards-documents/1100/1196-astd-2011/@@images/file.

DOE. 2011b. “Radiation Protection of the Public and the Environment.” DOE O 458.1, U.S. Department of Energy, Washington D.C. https://www.directives.doe.gov/directives-documents/400-series/0458.1-BOrder.

DOE. 2013. “Radiation Protection of the Public and the Environment.” DOE O 458.1 Chg 3 (Admin Chg), U.S. Department of Energy, Washington D.C. https://www.directives.doe.gov/directives-documents/400-series/0458.1-BOrder-chg3-admchg.

DOE. 2014. “Accident Investigation Report Phase 1: Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014.” U.S. Department of Energy, Washington, D.C. https://www.energy.gov/sites/default/files/2016/06/f33/WIPP-Radiological-Release-Event-Phase-1-04-22-2014.pdf.

DOE. 2015. “Environmental Radiological Effluent Monitoring and Environmental Surveillance.” DOE-HDBK-1216-2015, U.S. Department of Energy, Washington D.C. https://www.standards.doe.gov/standards-documents/1200/1216-hdbk-2015-cn1-2022-reaff-2022/@@images/file

DOE, 2019, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, DOE-STD-1153-2019, U.S. Department of Energy, Washington D.C., USA.

DOE. 2020. “Quality Assurance.” DOE O 414.1D Chg 2, U.S. Department of Energy, Washington D.C. https://www.directives.doe.gov/related-items/doe_o_414.1d_chg2_chg_chart.

DOE/ID-12082(21). U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASERdocuments2021.html#:~:text=The%20Idaho%20National%20Laboratory%20Site,1%20through%20December%2031%2C%202021.

DOE-HS. 2010. “Independent Oversight of Environmental Monitoring at the Idaho National Laboratory Site.” U.S. Department of Energy Office of Independent Oversight and Office of Health, Safety and Security, Washington, D.C. https://www.energy.gov/sites/default/files/hss/Enforcement%20and%20Oversight/Oversight/docs/reports/eshevals/2010/2010_INL_Environmental_Monitoring_final_May2010.pdf.

DOE-HSS. 2010. “Independent Oversight of Environmental Monitoring at the Idaho National Laboratory Site.” U.S. Department of Energy–Office of Independent Oversight, Office of Health, Safety and Security, Washington, D.C. https://www.energy.gov/sites/default/files/hss/Enforcement%20and%20Oversight/Oversight/docs/reports/eshevals/2010/2010_INL_Environmental_Monitoring_final_May2010.pdf.

DOE-ID. 1981. “1980 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site.” IDO-12082(80), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 1991a. “Idaho National Engineering Laboratory Historical Dose Evaluation.” DOE/ID-12119, DOE-ID. 1991b. “Idaho National Engineering Laboratory Historical Dose Evaluation.” DOE/ID-12119, (2): Appendices, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://inis.iaea.org/collection/NCLCollectionStore/_Public/23/021/23021743.pdf.

DOE-ID. 1995. “Long-Term Land Use Future Scenarios for the Idaho National Engineering Laboratory.” DOE/ID-10440, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://www.osti.gov/servlets/purl/416909.

DOE-ID. 1997. “Final Record of Decision: Test Reactor Area, Operable Unit 2-13.” DOE-ID-10586, Idaho National Engineering and Environmental Laboratory, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://semspub.epa.gov/work/10/100002770.pdf.

DOE-ID. 1998a. “Field Sampling Plan for Confirmation Sampling and Field Screening of Selected Sites at Waste Area Group 2, Operable Unit 2-13.” DOE/ID-10657, Rev. 0, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 1998b. “Proposed Plan for Waste Area Group 9 (Argonne National Laboratory-West) at the Idaho National Engineering and Environmental Laboratory.” 10441, Rev. 0, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://www.energy.gov/em/icpcab/articles/select-alternative-5-achieving-remedial-objectives-wag-9.

DOE-ID. 2000. “Remedial Action Report for the Test Reactor Operable Unit 2-13.” DOE/ID-10720, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2002. “Idaho National Laboratory Site Environmental Report, Calendar Year 1999.” DOE/ID-12082(99), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASER/1999ASER.pdf

DOE-ID. 2006. “INL Sitewide Institutional Controls Annual Report—FY 2006.” DOE/ID-11289, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2007. “Five-Year Review of CERCLA Response Actions at the Idaho National Laboratory.” DOE/NE-ID-11201, Rev. 3, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://semspub.epa.gov/work/10/500010407.pdf.

DOE-ID. 2008. “Record of Decision for Radioactive Waste Management Complex Operable Unit 7-13/14.” DOE/ID-11359, Rev. 0, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://semspub.epa.gov/work/10/100053899.pdf.

DOE-ID. 2009. “Operable Unit 10-08 Record of Decision for Site-Wide Groundwater, Miscellaneous Sites, and Future Sites.” DOE-ID-11385, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2011. “Idaho National Laboratory Site Environmental Report Calendar Year 2010.” DOE-ID-12082(10), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASER/2010ASER.pdf.

DOE-ID. 2012. “Idaho National Laboratory Site Environmental Report, Calendar Year 2011.” DOE/ID-12082(11), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASER/2011ASER.pdf.

DOE-ID. 2013. “Idaho National Laboratory Site Environmental Report, Calendar Year 2012.” DOE/ID-12082(12), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2014a. “National Emission Standards for Hazardous Air Pollutants—Calendar Year 2013 INL Report for Radionuclides.” DOE/ID-11441, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://doi.org/10.2172/1149028.

DOE-ID. 2014b. “Technical Basis for Environmental Monitoring and Surveillance at the Idaho National Laboratory Site.” DOE/ID-11485, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://inldigitallibrary.inl.gov/PRR/164104.pdf.

DOE-ID. 2014c. “Idaho National Laboratory Site Environmental Report, Calendar Year 2013.” DOE/ID-12082(13), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASER/2013ASER.pdf.

DOE-ID. 2015. “Operable Unit 9-04 Operations and Maintenance Report for Fiscal Years 2008-2014.” DOE/ID 11529, Rev. 0, June 2015, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2020. “National Emission Standards for Hazardous Air Pollutants—Calendar Year 2019 INL Report for Radionuclides.” DOE/ID-11441 (2020). https://inldigitallibrary.inl.gov/PRR/DOE-ID-11441-2020.pdf.

DOE-ID. 2021a. “Idaho National Laboratory Site Environmental Monitoring Plan.” DOE/ID-11088 Rev. 5, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://doi.org/10.2172/1873101.

DOE-ID. 2021b. “Idaho National Laboratory Groundwater Monitoring and Contingency Plan Update.” DOE-ID-11034, Rev. 4. July 2021, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2021c. “Idaho National Laboratory Annual Site Environmental Report.” DOE/ID-12082(21), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASER/2021/2021%20ASER_Final.pdf.

DOE-ID. 2021d. “Five-Year Review of CERCLA Response Actions at the Idaho National Laboratory Site – Fiscal Years 2015-2019.” DOE-ID/12034, Rev. 0, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2021e. “National Emissions Standards for Hazardous Air Pollutants—-Calendar Year 2021.” DOE/ID-11441(21), June 2021, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

DOE-ID. 2021f. “Statistical Methods Used in the Idaho National Laboratory Annual Site Environmental Report: A Supplement to the INL Site Environmental Report for 2021.” U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASER/ASERDocuments/Statistical%20Methods%20used%20in%20the%20Idaho%20National%20Laboratory%20Annual%20Site%20Environmental%20Report.pdf.

DOE-ID. 2022a. “2021 Idaho National Laboratory Annual Site Environmental Report.” DOE-ID. 2022b. “Sampling Atmospheric Tritium.” LI-351, U.S. Department of Energy– Idaho Operations Office, Idaho Falls, ID. Unpublished.

DOE-ID. 2022c. “National Emission Standards for Hazardous Air Pollutants – CY 2021 INL Report for Radionuclides.” DOE/ID-11441, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://idahoeser.inl.gov/Surveillance/ASER/ASERDocuments/DOEID-11441%20(2019)%20-%20INL%20National%20Emission%20Standards%20for%20Hazardous%20Air%20Pollutants%20INL%20Final.pdf.

DOE-ID. 2023. “ICDF Complex Waste Acceptance Criteria.” DOE/ID-10881, Rev. 16, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

Edwards, M. J. 2011. "Transmittal of Data Documentation for the NRF Recapitalization EIS." Interoffice Memorandum, Battelle Energy Alliance, LLC, to T. L. Carlson, January 11, 2011. EG&G Idaho, Inc. 1986. "Development of Criteria for Release of Idaho National Engineering Laboratory Sites Following Decontamination and Decommissioning." EGG-2400, Rev. 0, Idaho National Engineering Laboratory, Idaho Falls, ID.

EG&G Idaho, Inc. 1988. "RCRA Facility Investigation Work Plan, Vol. 1." EGG-WM-8219, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID.

Einerson, J. J. 1996. "Implementation of the Risk-based Approach to Liquid Effluent Monitoring at the INEL." INEL-96/254, Idaho National Engineering Laboratory, Idaho Falls, ID.

EPA QAMS-005-80. "Interim Guidelines and Specifications for Quality Assurance Project Plans, U.S. Environmental Protection Agency." Washington D.C. https://www.epa.gov/sites/default/files/2016-06/documents/r5-final_0.pdf.

EPA. 1987. "Radiochemistry Procedures Manual." EPA-520/5-84-006, U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1993. "External Exposure to Radionuclides in Air, Water, and Soil." EPA-402-R-93-081, Federal Guidance Report No. 12. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, D.C. https://www.nrc.gov/docs/ML1015/ML101590169.pdf.

EPA. 1998. "Guidelines for Ecological Risk Assessment." EPA/630/R-95/002F, U.S. Environmental Protection Agency, Washington, D.C. https://www.epa.gov/sites/default/files/2014-11/documents/eco_risk_assessment1998.pdf.

EPA. 2000." EPA Radionuclides Notice of Data Availability Technical Support Document." EPA. 2001. "EPA Requirements for Quality Assurance Project Plans." EPA/240/B-01/003, QA/R-5, Quality Assurance Division, Office of Research and Development and U.S. Environmental Protection Agency, Washington, D.C. https://www.epa.gov/sites/default/files/2016-06/documents/r5-final_0.pdf.

EPA. 2005. "Uniform Federal Policy for Quality Assurance Project Plans—Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs—Part 1: UFP-QAPP Manual." EPA-505-B-04-900A, Intergovernmental Data Quality Task Force, U.S. Environmental Protection Agency, Washington D.C. https://www.epa.gov/fedfac/uniform-federal-policy-quality-assurance-project-plans-evaluating-assessing-and-documenting.

EPA. 2006. "Guidance on Systematic Planning Using the Data Quality Objectives Process." EPA QA/G-4, EPA. 2020a. "Clean Air Act Assessment Package-1988, PC Version (CAP88-PC), Version 4.1.1." U.S. Environmental Protection Agency, Washington, D.C. Accessed 05/30/2023. https://www.epa.gov/radiation/cap88-pc.

EPA. 2020b. "CAP88-PC Version 4.1 User Guide." https://www.epa.gov/sites/default/files/2019-11/documents/cap88-pc_4.1_user_guide.pdf. Accessed May 31, 2023.

FDA. 2004. "Compliance Policy Guide: Guidance Levels for Radionuclides in Domestic and Imported Foods." FDA/ORA CPG 7119.14, U.S. Food and Drug Administration, Washington, D.C. https://www.fda.gov/media/72014/download.

Gallegos, G. 1995. "Surveillance monitoring of soils for radioactivity: Lawrence Livermore National Laboratory 1976 to 1992." *Health Physics* 69(4): 487–493. https://journals.lww.com/health-physics/Abstract/1995/10000/Surveillance_Monitoring_of_Soils_for.6.aspx.

Gill, J. W. 2013. "MFC Sewage Lagoon Wastewater." Email message to D. B. Frederick, September 16, 2013, CCN 234650, Idaho National Laboratory, Idaho Falls, ID.

Hain, K. E. 2005. "Request Waste Area Group (WAG) 9, Release Site ANL-04, Sewage Lagoon be placed in Operable Unit (OU) 10-08 for Administrative Control (FMDP-FFA/CO-05-123)." Letter to N. Ceto (EPA) and D. Koch (DEQ), March 7, 2005, Idaho National Laboratory, Idaho Falls, ID.

Halford, D. K., and O. D. Markham. 1978. "Radiation Dosimetry of Small Mammals Inhabiting a Liquid Radioactive Waste Disposal Area." *Ecology* 59(5): 1047–1054. https://doi.org/10.2307/1938557.

Halford, D. K., and O. D. Markham. 1984. "Iodine-129 concentrations in muscle from waterfowl using a liquid radioactive waste pond." *Health Physics* 46: 1259–1263.

Halford, D. K., J. B. Millard, and O. D. Markham. 1981. "Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man." *Health Physics* 40(2): 173–181. https://doi.org/10.1097/00004032-198102000-00002.

Halford, D. K., O. D. Markham, and G. C. White. 1983. "Biological elimination rates of radioisotopes by mallards contaminated at a liquid radioactive waste disposal area." *Health Physics* 45: 745–756. https://doi.org/10.1097/00004032-198309000-00016.

Halford, D. K., O. D. Markham, and R. L. Dickson. 1982. "Radiation Doses to Waterfowl Using a Liquid Radioactive Waste Disposal Area." *Journal of Wildlife Management* 46: 905–914. https://doi.org/10.2307/3808223.

Hardy, E. P. and P. W. Krey. 1971. "Determining the Accumulated Deposit of Radionuclides by Soil Sampling and Analysis." in Proceedings of Environmental Plutonium Symposium, LA-4756. August 4–5, 1971, 37–42. Los Alamos Scientific Laboratory, Los Alamos, NM. https://www.osti.gov/servlets/purl/4704329.

Harris, K. L. and R. C. Starr. 2009. "2009 Seepage Rate Test Results for the Wastewater Lagoons at the Idaho National Laboratory Specific Manufacturing Capability Facility." Forsgren Assoc. Inc., and Northwind, Inc., NWI-10121-001, August 2009, Northwind, Inc., Idaho Falls, ID.

Henricksen, M. 2009. "No IWA for RESL Building." City of Idaho Falls, 2009, email to M. Lewis, Battelle Energy Alliance, LLC, November 18, 2009, CCN 219327, Idaho National Laboratory, Idaho Falls, ID.

Henricksen, M., 2009. "No IWA for RESL Building." City of Idaho Falls, email to M. Lewis, Battelle Energy Alliance, November 18, 2009. LLC, CCN 219327.

Hoff, D. L., R. G. Mitchell, R. Moore, and L. Bingham. 1992. "The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1991." DOE/ID-12082(91), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://www.osti.gov/biblio/10104465.

Hoff, D. L., R. G. Mitchell, R. Moore, and L. Bingham. 1993. "The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1991." DOE/ID-12082(92), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

Hoff, D. L., R. G. Mitchell, R. Moore, and R. M. Shaw. 1991. "The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1990." DOE-ID-12082(90), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID.

Hoskinson, R. L. and J. R. Tester. 1980. "Migration behavior of pronghorn in southeastern Idaho." *Journal of Wildlife Management* 44: 132–144. https://doi.org/10.2307/3808359.

ICP. 2010. "INTEC Service Waste System." SDD-129, Rev. 2, February 4, 2010, Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2013a. "INTEC Service Waste System." SDD-129, Rev. 4, November 26, 2013. Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2013b. “Management of Sewage Lagoon Levels at the Radioactive Waste Management Complex.” EDF-10498, Rev. 0, Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2015. “Submittal of the Lagoon Seepage testing Report for the Idaho Nuclear Technology and Engineering Center Sewage Treatment Plant Lagoons.” Letter to T. A. Rackow, CCN 318031. Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2016a. “Management Plan and Implementation of Best Available Technology per DOE Order 5400.5 for Disposal of Wastewater.” PLN-932, Rev. 5, Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2016b. “Recycled Water Reuse Permit Renewal Application for the Idaho Nuclear Technology and Engineering Center New Percolation Ponds.” RPT-1510, Rev. 0, Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2017. “INL Site-wide Institutional Controls, and Operations and Maintenance Annual Report – FY 2015.” RPT-1503, Rev. 0, Idaho Cleanup Project, January 2017, Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2018. “Reporting Requirements of the Liquid Effluent Monitoring and Wastewater Land Application Permit Groundwater Monitoring Programs.” MCP-9235, Rev. 15, May 2, 2018, Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2020. “Environmental Surveillance Program Plan.” PLN-720, Rev. 16. September 24, 2020.

ICP. 2021. “Submittal of the Lagoon Seepage Testing Report for Radioactive Waste Management Complex Wastewater Lagoons 1 and 2.” Letter to G. Eager, August 30, 2021. CCN 327368, Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2022. “INL Site-wide Institutional-Controls and Operations-and-Maintenance Annual Report – FY 2021.” RPT-2003 Rev.0. Idaho Cleanup Project, Idaho Falls, ID.

ICP. 2022. “Submittal of the Lagoon Seepage Testing Report for Radioactive Waste Management Complex Wastewater Storage Lagoons 3 and 4.”Letter to C. Feisthamel, September 6, 2022. CCN 329608, Idaho Cleanup Project, Idaho Falls, ID.

IDAPA. 2022. “Idaho Rules for Public Drinking Water Systems.” IDAPA 58.01.08, Idaho Administrative Procedures Act, Idaho Administrative Rules. Idaho Department of Environmental Quality, Boise, ID. https://adminrules.idaho.gov/rules/current/58/580108.pdf.

INEEL. 2004. “Sample Analysis of Wastewater Samples from the Service Waste System and other Nonhazardous and Nonradioactive Wastewater Systems at INTEC, Idaho National Engineering and Environmental Laboratory.” EDF-4545, Rev. 1, December 21, 2004, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID.

INEL. 1991. “Environmental Assessment for the Continued Operation of the Specific Manufacturing Capability Project.” DOE-0526, August 1, 1991, Idaho National Engineering Laboratory, Idaho Falls, ID.

INL. 2005. “Battelle Energy Alliance Industrial Wastewater Acceptance Permits Renewal Applications.” Letter from F. Williams to D. Smith, April 19, 2005. CCN 200772, Idaho National Laboratory, Idaho Falls, ID.

INL. 2006a. “Revised Wastewater Land Application for the Reactor Technology Complex Cold Waste Ponds.” INEEL/EXT-04-02556, Idaho National Laboratory, Idaho Falls, ID.

INL. 2006b. “Battelle Energy Alliance Statement of Work for Analytical Services.” SOW-8500, Rev. 4, Idaho National Laboratory, Idaho Falls, ID.

INL. 2006c. “Central Facilities Area Sewage Treatment Lagoons Seepage Rate Test Report.” INL/EXT-06-11520, Idaho National Laboratory, Idaho Falls, ID.

INL. 2006d. “Management Plan and Implementation of Best Available Technology per DOE Order 5400.5 for Disposal of Wastewater.” PLN-8104, Idaho National Laboratory, Idaho Falls, ID.

INL. 2007. “RTC Ponds Wastewater Acceptance Criteria.” SP-10.6.5.10, Idaho National Laboratory, Idaho Falls, ID.

INL. 2008. INL. 2009a. “Hazard Categorization Document for the CFA-625 Laboratory.” ECAR-521, Idaho National Laboratory, Idaho Falls, ID.

INL. 2009b. “Request for City of Idaho Falls Personnel to Perform the Semiannual Sampling at the Idaho National Laboratory Research Center per the City of Idaho Falls Industrial Wastewater Acceptance Permit (IF-8733-54171-1).” Letter from J. Stenzel to D. Smith, April 20, 2009. CCN 216838.

INL. 2010a. “2009 Wastewater Land Application Site Performance Report for the Idaho National Laboratory Site’s Central Facilities Area Sewage Treatment Plant.” INL/EXT-10-17549, February 2010, Idaho National Laboratory, Idaho Falls, ID.

INL. 2010b. “INL Research Complex (IRC) Accidental Spill Prevention Plan, Rev. 0.” PLN-3530, Idaho National Laboratory, Idaho Falls, ID.

INL. 2010c. “Technical Basis Document for Internal Dosimetry—Chapter 3—Overview of INL Radiological Operations.” TEV-232, Idaho National Laboratory, Idaho Falls, ID.

INL. 2010d. “Advanced Test Reactor Complex Sewage Treatment Lagoons Seepage Rate Test Report.” INL/EXT-10-20337, Idaho National Laboratory, Idaho Falls, ID.

INL. 2011. “Operation and Maintenance Manual for the Central Facilities Area Sewage Treatment Plant.” INL/EXT-10-20704, February 2011, Idaho National Laboratory, Idaho Falls, ID.

INL. 2012a. “2011 Annual Industrial Wastewater Reuse Report for the Idaho National Laboratory Site’s Advanced Test Reactor Complex Cold Waste Pond.” INL/EXT-12-24337, Idaho National Laboratory, Idaho Falls, ID. https://doi.org/10.2172/1035891.

INL. 2012b. “Industrial Wastewater Reuse Permit Renewal Application for the Advanced Test Reactor Complex Cold Waste Pond.” INL/MIS-12-25959, Idaho National Laboratory, Idaho Falls, ID.

INL. 2012c. “2011 Annual Wastewater Reuse Report for the Idaho National Laboratory Site’s Central Facilities Area Sewage Treatment Plant.” INL/EXT-11-24269, Idaho National Laboratory, Idaho Falls, ID. https://doi.org/10.2172/1035907.

INL. 2012d. “2011 Annual Industrial Wastewater Reuse Report for the Idaho National Laboratory Site’s Materials and Fuels Complex Industrial Waste Ditch and Industrial Waste Pond.”

INL. 2014a. “Transmittal of the Seepage Test Report for the Central Facilities Area Sewage Treatment Plant Lagoons.” Letter to T. Rackow, October 16, 2014. CCN 234223, Idaho National Laboratory, Idaho Falls, ID.

INL. 2014b. “Transmittal of Idaho National Laboratory Recycled Water Reuse Permit Renewal Application for the Materials and Fuels Complex Industrial Waste Ditch and Industrial Waste Pond and Application Forms.” Letter to E. Neher, October 28, 2014. CCN 234270, Idaho National Laboratory, Idaho Falls, ID.

INL. 2015. “Idaho National Laboratory Central Facilities Area Sewage Treatment Plant Closure Plan for Lagoon #3 and Wastewater Land Application Area.” Letter to T. Rackow, February 23, 2015. CCN 235243, Idaho National Laboratory, Idaho Falls, ID.

INL. 2016a. "Central Facilities Area Sewage Treatment Plant Revised Closure Plan for Lagoon 3 and the Land Application Area, and request for Termination of Wastewater Reuse Permit LA-000141-03." Letter to T. Rackow, May 6, 2016. CCN 238192, Idaho National Laboratory, Idaho Falls, ID.

INL. 2016b. "Environmental Support and Services Monitoring Services Surveillance Plan." PLN-8550, Rev. 2, Idaho National Laboratory, Idaho Falls, ID. Unpublished.

INL. 2017a. "Closure Report for the Central Facilities Area Sewage Treatment Plant Lagoon 3 and the Land Application Area." Letter to T. Rackow, November 8, 2017. CCN 241558, Idaho National Laboratory, Idaho Falls, ID.

INL. 2017b. "Gross Alpha and Beta Decision Levels for the Environmental Air Monitoring Program for the Idaho National Laboratory." INL/EXT-17-42255, Rev. 0, Idaho National Laboratory, Idaho Falls, ID. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_2280.pdf.

INL. 2017c. "Historical Data Analysis Supporting the Data Quality Objectives for the INL Site Environmental Soil Monitoring Program." INL/INT-15-37431, Idaho National Laboratory, Idaho Falls, ID. https://doi.org/10.2172/1769951.

INL. 2018a "Management Plan for Disposal of Wastewater to the Ground Surface." PLN-8104, Rev. 3, Idaho National Laboratory, Idaho Falls, ID.

INL. 2018b. "Transmittal of the Lagoon Seepage Testing Report for the Specific Manufacturing Capability Facility." Letter to T. Rackow, November 15, 2018. CCN 243717, Idaho National Laboratory, Idaho Falls, ID.

INL. 2018c. "INL Research Complex (IRC) Accidental Spill Prevention Plan." PLN-3530, Rev. 3.

INL. 2018d. "Idaho National Laboratory Research Center Renewal Application for the Industrial Wastewater Acceptance Permit Number IF-8733-54171-1." INL/EXT-18-44401. Idaho National Laboratory, Idaho Falls, ID. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_4392.pdf.

INL. 2019a. "Transmittal of the Biosolids Management and Closure Plan for the Materials and Fuels Complex ANL-04 Sewage Lagoons." Letter to T. Rackow, May 2, 2019. CCN 244645, Idaho National Laboratory, Idaho Falls, ID.

INL. 2019b. "Biosolids Management and Closure Plan for the Materials and Fuels Complex ANL-04 Sewage Lagoons." INL/EXT-19-53679, Idaho National Laboratory, Idaho Falls, ID.

INL. 2019c. "Transmittal of the Industrial Reuse Permit Renewal Application for the Advanced Test Reactor Complex Cold Waste Ponds and Idaho Department of Environmental Quality Recycled Water Reuse Permit Application Forms." Letter to G. Eager, May 15, 2019. CCN 244643, Idaho National Laboratory, Idaho Falls, ID.

INL. 2019d. "Materials and Fuels Complex ANL-04 Sewage Lagoon Biosolids Management and Closure Report." Letter to T. Rackow, December 10, 2019. CCN 246067, Idaho National Laboratory, Idaho Falls, ID.

INL. 2020a. "Rescission of Permit to Construct for the ATR Complex Evaporation Pond." Letter to D. Pampaian, February 21, 2020. CCN 246359, Idaho National Laboratory, Idaho Falls, ID.

INL. 2020b. "Operation and Maintenance Manual for the Materials and Fuels Complex Evaporative Sewage Lagoons System." INL/EXT-13-28749, Rev. 1. Idaho National Laboratory, Idaho Falls, ID. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_57203.pdf.

INL. 2020c. "Idaho National Laboratory Drinking Water Monitoring Plan." PLN-8530, Rev. 12, Idaho National Laboratory, Idaho Falls, ID. Unpublished.

INL. 2021a. “2020 Annual Reuse Report for the Idaho National Laboratory Site’s Advanced Test Reactor Complex Cold Waste Pond.” INL/EXT-20-60643, Idaho National Laboratory, Idaho Falls, ID.

INL. 2021b. “Submittal of Lagoon Seepage Testing Report for ATR Complex at the Idaho National Laboratory.” Letter to G. Eager, November 23, 2021. CCN 250513, Idaho National Laboratory, Idaho Falls, ID.

INL. 2022a. “2021 Annual Industrial Wastewater Reuse Report for the Idaho National Laboratory Site’s Materials and Fuels Complex Industrial Waste Pond.” INL/EXT-21-65036, Idaho National Laboratory, Idaho Falls, ID.

INL. 2022b. “Submittal of the Seepage Test Report for MFC Sewage Lagoons #1, #2, #3 – DEQ Project #22-03-12.” Letter to C. Feisthamel, September 21, 2022. CCN 252283, Idaho National Laboratory, Idaho Falls, ID.

INL. 2022c. “Data Quality Objectives Summary Report Supporting Radiological Air Surveillance Monitoring for the INL Site.” INL/MIS-15-34927, Rev. 1, Idaho National Laboratory, Idaho Falls, ID.

INL. 2022e. “Data Quality Objectives Supporting the Environmental Direct Radiation Monitoring Program for the INL Site.” INL/EXT-15-34803, Revision 2, Idaho National Laboratory, Idaho Falls, ID.

INL. 2022f. “Data Quality Objectives Supporting the Environmental Soil Monitoring Program for the INL Site.” Idaho National Laboratory, INL/EXT-15-34909, Idaho Falls, ID.

INL. 2022g. “Data Quality Objectives Summary Report Supporting Agricultural Products Monitoring.” INL/MIS-22-68866, Rev. 0, Idaho National Laboratory, Idaho Falls, ID. Unpublished.

INL. 2022h. “Data Quality Objectives Summary Report Supporting Big Game Animal (Pronghorn, Elk, and Mule Deer) Monitoring on the INL Site.” INL/MIS-22-68711, Rev. 0, Idaho National Laboratory, Idaho Falls, ID.

INL. 2022i. “Data Quality Objectives Summary Report Supporting Waterfowl Monitoring.” INL/MIS-22-68700, Rev. 0, Idaho National Laboratory, Idaho Falls, ID.

INL. 2022j. “Waterfowl Sampling.” LI-1128, Battelle Energy Alliance, Idaho Falls, ID.

INL/EXT-12-24452, Idaho National Laboratory, Idaho Falls, ID. https://inldigitallibrary.inl.gov/sites/sti/sti/5250286.pdf.

ISO. 1975. “General Principles for Sampling Airborne Radioactive Materials.” ISO 2889:1975, International Organization for Standardization, Geneva, Switzerland. https://www.iso.org/standard/7913.html.

ISO. 2000. “Quality Management Systems.” ISO-9000, 2000. https://www.iso.org/iso-9001-quality-management.html

ISU. 2011. “Idaho State University Environmental Assessment Laboratory Monthly Data Report.” December 2011, Pocatello, ID.

Jackson, H. D. 1994a. “SMC effluent sampling—HDJ-33-94.” Interdepartmental communication to distribution, November 10, 1994. Lockheed Idaho Technologies Company, Idaho Falls, ID.

Jackson, H. D. 1994b. “SMC septage disposal—HDJ-32-94.” Interdepartmental communication to distribution. November 9, 1994. Lockheed Idaho Technologies Company, Idaho Falls, ID.

Jessmore, P. J., L. A. Lopez, and T. J. Haney, 1994. “Compilation and Evaluation of INEL Radiological and Environmental Sciences Laboratory Surface Soil Sample Data for Use in Operable Unit 10-06 Baseline Risk Assessment.” EGG-ER-11227, Idaho National Laboratory, Idaho Falls, ID.

Kirchner, D. R. 2009. "Closure Report for ESP-032-09 SMC/TAN Pond Sampling-Baseline Study." Interoffice memorandum to M. L. Marlor, December 2, 2009, Idaho Cleanup Project, Idaho Falls, ID.

Kirchner, G. 1994. "Transport of cesium and iodine via the grass-cow-milk pathway after the Chernobyl accident." *Health Physics* 66(6): 653–665. https://doi.org/10.1097/00004032-199406000-00005.

Knobel, L. L., R. C. Bartholomay, and J. P. Rousseau, 2005. "Historical Development of the U.S. Geological Survey Hydrologic Monitoring and Investigative Programs at the Idaho National Engineering and Environmental Laboratory, Idaho, 1949 to 2001." DOE/ID-22195, U.S. Geological Survey in cooperation with the U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://doi.org/10.3133/ofr20051223.

Lee, S. D., M. J. Rohe, A. S. Rood, and I. E. Stepan. 1997. "Comprehensive Remedial Investigation/ Feasibility Study for the Argonne National Laboratory-West Operable Unit 9-04 at the Idaho National Engineering and Environmental Laboratory." W7500-0000-ES-02, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID.

Lewis, M. G. 2012. "November 19 Meeting with City of Idaho Falls Personnel Concerning the Energy Systems Laboratory." Email to Vanica Dugger and others, November 26, 2012. CCN 229080.

Lewis, M. G. 2013a. "Conference Call with Mike Henricksen from the City of Idaho Falls Sewer Department Concerning ESL and REL; CCN 231263." Email to Vanica Dugger and others, August 27, 2013.

Lewis, M. G. 2013b. "City of Idaho Falls Determination the Research and Education Laboratory Does Not Require an Industrial Wastewater Acceptance Permit." Email to Deborah Layton, December 10, 2013. CCN 232014.

Long, R. A. 2013. "Linking Climatic Variability to Behavior and Fitness of Herbivores: A Bioenergetic Approach." Ph.D. Dissertation, Idaho State University, Pocatello, ID. https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.highlight/abstract_id/9350.

Maheras, S. J., and D. J. Thorne, 1993. "New Production Reactor Exposure Pathways at the Idaho National Engineering Laboratory." EGG-NPR-8957, Idaho National Engineering Laboratory, Idaho Falls, ID.

Maimer, N. V., and R. C. Bartholomay. 2019. "Iodine-129 in the Eastern Snake River Plain Aquifer at and Near the Idaho National Laboratory, Idaho, Emphasis 2017-2018." Scientific Investigations Report 2019-5133, DOE/ID-22250. U.S. Geological Survey in cooperation with the U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://pubs.usgs.gov/sir/2019/5133/sir20195133.pdf.

Markham, O. D. and D. K. Halford. 1985. "Effects of decreased effluents from nuclear fuel reprocessing on Cs-137 concentrations in wildlife." *Northwest Science* 59(3): 180–184.

Markham, O. D., D. K. Halford, and R. E. Autenrieth. 1980. "Strontium-90 concentrations in Pronghorn Antelope bones near a nuclear fuel reprocessing plant." *Health Physics* 38: 811–816. https://doi.org/10.1097/00004032-198005000-00008.

Markham, O. D., D. K. Halford, D. E. Bihl, and R. E. Autenrieth. 1980. "I-131 concentrations in air, milk, and antelope thyroids in southeastern Idaho." *Health Physics* 38: 321–326. https://journals.lww.com/health-physics/Abstract/1980/03000/131I_Concentrations_in_Air,_Milk_and_Antelope.6.aspx.

Markham, O. D., D. K. Halford, R. E. Autenrieth, and R. L. Dickson. 1982. "Radionuclides in Pronghorn resulting from nuclear fuel reprocessing and worldwide fallout." *Journal of Wildlife Management* 46(1): 30–42. https://doi.org/10.2307/3808405.

Markham, O. D., D. K. Halford, S. K. Rope, and G. B. Kuzo. 1988. "Plutonium, Am, Cm and Sr in Ducks Maintained on Radioactive Leaching Ponds in Southeast Idaho." *Health Physics* 55(3): 517–524. https://doi.org/10.1097/00004032-198809000-00002.

Markham, O. D., K. W. Puphal, and T. D. Filer. 1978. "Plutonium and Americium Contamination near a Transuranic Storage Area in Southeastern Idaho." *Journal of Environmental Quality* 7(3): 422–428. https://doi.org/10.2134/jeq1978.00472425000700030026x.

Martin, C., D. Halford, and R. Marty. 2004. "Preliminary Sediment Sampling at the Big Lost River Sinks: Results and Recommendations." Stoller-ESER-59, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID, USA. https://idahoeser.inl.gov/Vegetation/PDF/BLRSFINAL.pdf.

Mitchell, R. G. 1994. "The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1993." DOE-ID-12082(93), U.S. Department of Energy–Idaho Operations Office, Idaho Falls. https://inis.iaea.org/collection/NCLCollectionStore/_Public/26/032/26032739.pdf.

Mitchell, R. G., D. Peterson, and D. L. Hoff. 1995. "The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1994." DOE-ID-12082(94), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://inis.iaea.org/collection/NCLCollectionStore/_Public/27/014/27014050.pdf

Mitchell, R. G., D. Peterson, and D. L. Hoff. 1996. "The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1995." DOE-ID-12082(95), U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://inis.iaea.org/collection/NCLCollectionStore/_Public/30/022/30022670.pdf.

Mohler, H. J., et al. 2004. "Application of NCRP air screening factors for evaluating both routine and episodic radionuclide releases to the atmosphere." *Health Physics* 86(2): 135–144. https://doi.org/10.1097/00004032-200402000-00003.

Morris, R. C. 1993. "The Implications of a Lined Waste Pond for Waterfowl Contamination." Kathren, R. L., D. H. Denham, and K. Salmon (eds.). In proceedings of the 26th Midyear Topical Meeting of the Health Physics Society: 147–155. Richland, WA.

Morris, R. C. 2000. "Radioecology of Iodine-129 in the Sagebrush-Steppe Ecosystem: Annual Technical Report to DOE-ID." ESRF-037, Environmental Science & Research Foundation, Inc., Idaho Falls, ID, USA.

Morris, R. C. 2003. "RE: Iodine-129." E-mail from R. C. Morris to D. Halford, August 22, 2003.

Morris, R. C., and C. Soto. Unpublished. "Areal Distribution and Environmental Inventory of 129I on the Idaho National Engineering and Environmental Laboratory."

MWH. 2002. "A Review of the ESER Program Using Value-of-Information Analysis – Final." Montgomery Watson Harza, Broomfield, CO.

NCRP. 1996. "Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground.", NRCP Report No. 123, National Council on Radiation Protection and Measurements, Bethesda, MD. https://www.osti.gov/biblio/207043.

NCRP. 1999. "Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies." NCRP Report No. 129, National Council on Radiation Protection and Measurements, Bethesda, MD. https://www.osti.gov/biblio/351235.

NCRP. 2010. "Design of Effective Radiological Effluent Monitoring and Environmental Surveillance Programs." National Council on Radiation Protection and Measurements Report No. 169: 321. Bethesda, MD. https://ncrponline.org/publications/reports/ncrp-report-169/.

Neher, E. 2014. "INL INTEC Reuse Permit LA-000130-05 Minor Modification." Letter to David P. Hutchison, August 8, 2014. CCN 316762, Idaho Department of Environmental Quality and CH2M-WG Idaho, LLC, Boise, ID.

No MJE011111, BEA, Idaho Falls, ID.

Noakes, J. E., F. Schonhofer, and H. A. Polach. 1993. "Liquid Scintillation Spectrometry 1992." *Radiocarbon* 37(1): 343–348.

Overin, K. B., and A. J. Sondrup. 2022. "Idaho National Laboratory CY 2021 National Emission Standards for Hazardous Air Pollutants Analysis, Methodology and Results for Radionuclides." INL/RPT-22-67457, Idaho National Laboratory, Idaho Falls, ID. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_61604.pdf.

Peek, J. M. and M. J. Comer. 2000. "Elk Habitat Use on the INEEL." ESRF-037, Environmental Science and Research Foundation Inc., Annual Technical Report to DOE-ID: Calendar Year 1999.

Portage. 2005. "Data Quality Assessment Report for the Post-Remedial Action Confirmation Sampling of the ANL-W CERCLA Sites, 04-015, Rev. 1." Portage Environmental, Inc., Idaho Falls, ID.

Rasch, D. N. 2006. "Information on the Relationship of the Reactor Technology Complex Warm Waste Facility to the Atomic Energy Act." U. S. Department of Energy Idaho Operations Office to B. Burnell, Idaho Department of Environmental Quality, Idaho Falls, ID.

Reynolds, T. D. 1984. "Daily summer movements, activity patterns, and home range of Pronghorn." *Northwest Science* 58(4): 300–311.

Reynolds, T. D., J. W. Connelly, D. K. Halford, and W. J. Arthur. 1986. "Vertebrate fauna of the Idaho National Environmental Research Park." *Great Basin Naturalist* 46(3): 513–527. https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=3414&context=gbn.

Rood, A. S., and A. J. Sondrup. 2014. "Development and Demonstration of a Methodology to Quantitatively Assess the INL Site Ambient Air Monitoring Network." INL/EXT-14-33194, Idaho National Laboratory, Idaho Falls, ID. http://dx.doi.org/10.13140/RG.2.1.4713.3522.

Rood, A.S. and A.J. Sondrup. 2015. "Application of Frequency of Detection Methods in Design and Optimization of the INL Site Ambient Air Monitoring Network." INL/EXT-15-36544, Idaho National Laboratory, Idaho Falls, ID. https://inldigitallibrary.inl.gov/sites/sti/sti/6760052.pdf.

Schulz, R. K. 1965. "Soil chemistry of radionuclides." *Health Physics* 11(12). https://doi.org/10.1097/00004032-196512000-00008.

Singlevich, W., J. W. Healy, J. J. Paas, and Z. E. Carey. 1951. "Natural Radioactive Materials at the Arco Reactor Test Site." HW-21221, INEL, Idaho Falls, ID.

Smith, D. 2009. "Permits not required for minor facilities in Idaho Falls occupied by Idaho National Laboratories (INL)." Letter from City of Idaho Falls Sewer Department to T. Miller, Battelle Energy Alliance, LLC, November 2, 2009. CCN 219204, INL, Idaho Falls, ID.

Stroube, W. B., Jr.; and C. F. Jelinek. 1985. "Survey of radionuclides in foods: 1978–1982." *Health Physics* 49: 731–735. https://doi.org/10.1097/00004032-198511000-00006.

U.S. Atomic Energy Commission, Washington, D.C.

U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID. https://inis.iaea.org/collection/NCLCollectionStore/_Public/23/021/23021742.pdf.

U.S. Environmental Protection Agency, Office of Environmental Information, Washington, D.C., EPA/240/B-06/001. https://www.epa.gov/quality/guidance-systematic-planning-using-data-quality-objectives-process-epa-qag-4.

U.S. Environmental Protection Agency, Office of Groundwater and Drinking Water, Washington, D.C. March 2000. https://www.epa.gov/sites/default/files/2015-09/documents/2009_04_16_radionuclides_regulation_radionuclides_rulemaking_techsupportdoc.pdf.

U.S.C. 1974. "Safe Drinking Water Act." 42 U.S.C. § 300f et seq., U.S. Environmental Protection Agency. https://uscode.house.gov/view.xhtml?req=granuleid%3AUSC-prelim-title42-chapter6A-subchapter12&saved=%7CZ3JhbnVsZWlkOlVTQy1wcmVsaW0tdGl0bGU0Mi1zZWN0aW9uMzAwZg%3D%3D%7C%7C%7C0%7Cfalse%7Cprelim&edition=prelim

USDA. 2017. "Census of Agriculture – 2017 Census Volume 1, Chapter 2: County Level Data." U.S. Department of Agriculture, Washington D.C. https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_US_State_Level/.

Waite, D. A. 1973. "An Analytical Technique for Distributing Air Sampling Locations Around Nuclear Facilities." BNWL-SA-4534, Pacific Northwest National Laboratory, Richland, WA. https://www.osti.gov/servlets/purl/4472567.

Wang, Y. Y., B. M. Biwer, and C. Yu. 1993. "A Compilation of Radionuclide Transfer Factors for the Plane, Meat, Milk, and Aquatic Food Pathways and the Suggested Default Values for the RESRAD Code." ANL/EAIS/TM-103, Argonne National Laboratory, Argonne, IL. https://resrad.evs.anl.gov/docs/Radionuclide_Transfer_factors.pdf.

Warren, R. W. 1999. "Uptake of Contaminants by Vegetation and Burrowing Activity on a Decommissioned Radioactive Waste Pond Complex." Environmental Science and Research Foundation, Inc., Annual Technical Report to DOE-ID: Calendar Year 1998, ESRF-033.

Warren, R. W., S. J. Majors, and R. C. Morris. 2001. "Waterfowl Uptake of Radionuclides from the TRA Evaporation Ponds and Potential Dose to Humans Consuming Them." Stoller-ESER-01-40, S.M, U.S. Department of Energy–Idaho Operations Office, Idaho Falls, ID, USA. https://idahoeser.inl.gov/PDF/TRADuckReport.pdf.Whiting, J., 2010, "Big Game Surveys on the INL during Winter and Summer 2010." Letter to Idaho Department of Fish and Game, November 8, 2010, SM-4101-11-5003.

Witbeck, L. C. 1988. "ANL-W Environmental Sampling and Analysis Information." Letter from Argonne National Laboratory-West to C.E. Clark, February 1, 1988, U.S. Department of Energy Environmental Protection Office, Argonne National Laboratory–West, Scoville, ID.