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SITE ENVIRONMENTAL REPORT

Idaho National Laboratory

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Hot Rock Penstemon

To Our Readers:

The Idaho National Laboratory (INL) Site Environmental Report for Calendar Year 2023 is an overview of environmental activities conducted on and in the vicinity of the INL Site from January 1 through December 31, 2023. This report includes the following components:

- Effluent monitoring and environmental surveillance of air, water, soil, vegetation, biota, and agricultural products for radioactivity. The results are compared with historical data, background measurements, and applicable standards and requirements to verify that the INL Site does not adversely impact the environment or the health of humans or biota.
- A summary of environmental management systems in place to protect air, water, land, and other natural and cultural resources potentially impacted by INL Site operations.
- Ecological monitoring and other scientific research conducted onsite that may be of interest to the reader.

The report addresses three general levels of reader interest:

- The first level is a brief summary with a take-home conclusion. This is presented in the chapter highlights text box at the beginning of each chapter. There are no tables, figures, or graphs in the highlights. This section is intended to highlight general findings for an audience with a limited scientific background.
- The second level is a more in-depth discussion with figures, summary tables, and summary graphs accompanying the text. The chapters of the annual report represent this level, which requires some familiarity with scientific data and graphs. A person with some scientific background can read and understand this report after reading the section entitled, "Helpful Information."
- The third level includes links to supplemental and technical reports and websites that support the annual report. This level is directed toward scientists who would like to see original data and more in-depth discussions of the methods used and the results.

The links to these reports may be found in the Environmental Publications tab of the webpage at https://inl.gov/aser/.

The INL contractor is responsible for contributing to and producing the annual INL Site Environmental Report.

Other contributors to the INL Site Environmental Report include the ICP contractor, DOE-ID; National Oceanic and Atmospheric Administration, Air Resources Laboratory, Special Operations and Research Division; and the U.S. Geological Survey. Links to their websites are as follows:

- INL (https://www.inl.gov/)
- ICP (https://idaho-environmental.com)
- U.S. Department of Energy–Idaho Operations (https://www.id.energy.gov/)
- Special Operations and Research Division of National Oceanic and Atmospheric Administration's Air Resources Laboratory (https://www.noaa.inl.gov)
- U.S. Geological Survey (https://www.usgs.gov/centers/idaho-water-science-center).

The term INL Site contractors used throughout the report is referring to the INL and ICP contractors.

Horned lark eggs

Executive Summary:

Introduction

The INL Site is a U.S. Department of Energy (DOE) reservation located in the southeastern Idaho desert, approximately 25 miles west of Idaho Falls (Figure ES-1). At 890 square miles (569,135 acres), the INL Site is roughly 85% of the size of Rhode Island. It was established in 1949 as the National Reactor Testing Station, and for many years, it was the site of the largest concentration of nuclear reactors in the world. Fifty-two nuclear reactors were built, including the Experimental Breeder Reactor-I, which, in 1951, produced the first usable amounts of electricity generated by nuclear power. Researchers pioneered many of the world's first nuclear reactor prototypes and advanced safety systems at the INL Site. During the 1970s, the laboratory's mission broadened into other areas such as biotechnology, energy and materials research, and conservation and renewable energy.

Today, INL is a science-based, applied engineering national laboratory dedicated to supporting DOE's nuclear and energy research, science, and national defense missions.

Figure ES-1. Regional location of the INL Site.

INL's mission is to discover, demonstrate, and secure innovative nuclear energy solutions, other clean energy options, and critical infrastructure with a vision to change the world's energy future and secure the nation's critical infrastructure.

To mitigate environmental impacts and clear the way for the facilities required for the new nuclear energy research mission, the ICP has been charged with the environmental cleanup of the legacy wastes generated from World War II-era conventional weapons testing, government-owned reactors, and spent fuel reprocessing. The overarching aim of the project is to reduce risks to workers and production facilities, the public, and the environment and to protect the Snake River Plain Aquifer.

PURPOSE OF THE INL SITE ENVIRONMENTAL REPORT

The INL Site's operations and ongoing cleanup mission involve a commitment to environmental stewardship and full compliance with environmental protection laws. As part of this commitment, the INL Site Environmental Report is prepared annually to inform the public, regulators, stakeholders, and other interested parties of the INL Site's environmental performance during the year. This report is published for the U.S. Department of Energy, Idaho Operations Office (DOE-ID) in compliance with DOE Order 231.1B, "Environment, Safety and Health Reporting." The purpose of the report is to provide the following:

- Present the INL Site, mission, and programs
- Report compliance status with applicable federal, state, and local regulations
- Describe the INL Site environmental programs and activities
- Summarize results of environmental monitoring
- Discuss potential radiation doses to the public residing in the vicinity of the INL Site
- Report on ecological monitoring and research conducted by contractors and affiliated agencies and by independent researchers through the Idaho National Environmental Research Park
- Present property clearance activities
- Describe quality assurance methods used to ensure confidence in monitoring data
- Provide supplemental technical data and reports that support the INL Site Environmental Report (https://inl.gov/environmental-publications).

MAJOR INL SITE PROGRAMS AND FACILITIES

INL is a combination of all operating contractors and DOE-ID, and includes the Idaho Falls campus and the research and industrial complexes termed the "INL Site" that is located 50 miles west of Idaho Falls. For the purpose of this report, INL consists of those facilities operated by Battelle Energy Alliance, LLC (INL contractor), or by the Idaho Environmental Coalition, LLC (Idaho Cleanup Project [ICP] contractor). INL Site contractors are referred to by their noted acronyms and include all facilities under their individual responsibilities.

The INL Site consists of several primary facilities situated on an expanse of otherwise undeveloped terrain. Buildings and structures at the INL Site are clustered within these facilities, which are typically less than a few square miles in size and separated from each other by miles of undeveloped land. In addition, DOE-ID owns or leases laboratories and administrative offices in Idaho Falls, some 25 miles east of the INL Site border. About 30% of employees work in administrative, scientific support, and non-nuclear laboratory programs at offices in Idaho Falls.

The major facilities at the INL Site are the Advanced Test Reactor (ATR) Complex, Central Facilities Area (CFA), Critical Infrastructure Test Range Complex (CITRC), Idaho Nuclear Technology and Engineering Center (INTEC), Materials and Fuels Complex (MFC), Naval Reactors Facility (NRF), Radioactive Waste Management Complex (RWMC), and Test Area North (TAN), which includes the Specific Manufacturing Capability (SMC). The Research and Education Campus (REC) is located in Idaho Falls. The locations of major facilities are shown in Figure 1-6, while their missions are outlined in Table ES-1.

Table ES-1. Major INL Site areas and missions.

MAJOR INL SITE AREA[a]	OPERATED BY	MISSION
Advanced Test Reactor Complex	INL	Research and development of nuclear reactor technologies. Home of the ATR, a DOE Nuclear Science User Facility and the world's most advanced nuclear test reactor. The ATR provides unique irradiation capabilities for nuclear technology research and development.
Central Facilities Area	INL	INL support for the operation of other INL Site facilities and management responsibility for the balance of the INL outside of the facility boundaries.
Critical Infrastructure Test Range Complex	INL	Supports the National and Homeland Security missions of the laboratory, including program and project testing (i.e., critical infrastructure resilience and nonproliferation testing and demonstration).
Idaho Nuclear Technology and Engineering Center	ICP	Dry storage of spent nuclear fuel; management of high-level waste calcine and sodium-bearing liquid waste; and operation of the Idaho Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Disposal Facility, including a landfill, evaporation ponds, and a staging and treatment facility. This is also the location of the Integrated Waste Treatment Unit, a first-of-a-kind, 53,000-square-foot facility that is treating the remaining ~800,000 gallons of liquid radioactive and hazardous waste that has been stored in underground storage tanks.
Materials and Fuels Complex	INL	Research and development of nuclear fuels. Pyro-processing, which uses electricity to separate waste products in the recycling of nuclear fuel, is researched here. Nuclear batteries for use on the nation's space missions are made at MFC.
Radioactive Waste Management Complex	ICP	Environmental remediation and waste treatment, storage, and disposal for wastes generated at the INL Site and other DOE sites. The Advanced Mixed Waste Treatment Project characterizes, treats, and packages transuranic waste for shipment out of Idaho to permanent disposal facilities.
Research and Education Campus	INL	Located in Idaho Falls, the Research and Education Campus is home to DOE's Radiological and Environmental Sciences Laboratory, INL administration, the INL Research Center, the Center for Advanced Energy Studies, and other energy and security research programs. Research is conducted at the INL Research Center in robotics, genetics, biology, chemistry, metallurgy, computational science, and hydropower. The Center for Advanced Energy Studies is a research and education partnership between Boise State University, INL, Idaho State University, and the University of Idaho to conduct energy research and address the looming nuclear energy work-force shortage.
Test Area North/Specific Manufacturing Capability	INL	Several historic nuclear research and development projects were conducted at TAN. Major cleanup and demolition of the facility was completed in 2008, and the current mission is the manufacture of tank armor for the U.S. Army's battle tanks at the Specific Manufacturing Capability for the U.S. Department of Defense.

a. The Naval Reactors Facility (NRF) is also located onsite. It is operated for Naval Reactors by Fluor Marine Propulsion, LLC. The Naval Nuclear Propulsion Program is exempt from DOE requirements and is therefore not addressed in this report.

ENVIRONMENTAL COMPLIANCE (CHAPTER 2)

One measure of the achievement of the environmental programs at the INL Site is compliance with applicable environmental regulations, which have been established to protect human health and the environment. The compliance of INL Site and DOE-ID programs with federal and state environmental protection requirements, such as statutes, acts, agreements, executive orders, and DOE directives are presented in Table 2-1.

ENVIRONMENTAL RESTORATION (CHAPTER 2)

Environmental restoration at the INL Site is conducted under the Federal Facility Agreement and Consent Order (FFA/CO) among DOE, the state of Idaho, and the U.S. Environmental Protection Agency (EPA). The FFA/CO specifies actions that must be completed to safely cleanup sites in compliance with the CERCLA and with the corrective action requirements of the Resource Conservation and Recovery Act. The INL Site is divided into ten Waste Area Groups (WAGs) as a result of the FFA/CO, and each WAG is divided into smaller cleanup areas called operable units. Since the FFA/CO was signed in 1991, the INL Site has cleaned up sites containing asbestos, acids and bases, radionuclides, unexploded ordnance and explosive residues, polychlorinated biphenyls, heavy metals, and other hazardous materials.

Comprehensive remedial investigation/feasibility studies have been conducted at all WAGs and closeout activities have been completed at six WAGs. In 2023, all institutional controls and operational and maintenance requirements were maintained, and active remediation continued on WAGs 1, 3, and 7.

ENVIRONMENTAL PROTECTION PROGRAMS (CHAPTER 2, CHAPTER 3)

Directives, orders, guides, and manuals are DOE's primary means of establishing policies, requirements, responsibilities, and procedures for DOE offices and contractors. Among these are a series of orders directing each DOE site to implement sound stewardship practices that are protective of the public and the environment. These orders require the implementation of an environmental management system (EMS), a Site Sustainability Plan, a radioactive waste management program, and programs addressing radiation protection of the public and the environment. The INL Site contractors have each established and implemented an EMS and have contributed to the INL Site Sustainability Plan, as required by DOE and executive orders. Each EMS integrates environmental protection, environmental compliance, pollution prevention, and waste minimization into work planning and execution throughout all work areas. The INL Site Sustainability Plan contains strategies and activities that will lead to continual greenhouse gas reductions, as well as energy, water, and transportation fuels efficiency at the INL Site. Plan requirements are integrated into each INL Site contractor's Integrated Safety Management System and EMS.

ENVIRONMENTAL MONITORING OF AIR (CHAPTER 4)

Airborne releases of radionuclides from INL Site operations are reported annually in a document prepared in accordance with the 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." An estimated total of 3,341 curies (1.24×10^{14} Bq) of radioactivity, primarily in the form of short-lived noble gas isotopes, were released as airborne effluents in 2023. This represents a significant and expected increase compared to the previous year and was primarily due to the Advanced Test Reactor becoming operational following the completion of the refurbishment of the reactor core. These airborne releases of radionuclides are reported to comply with regulatory requirements and are considered in the design and conduct of INL Site environmental surveillance activities.

The INL Site environmental surveillance monitoring programs, which are conducted by the INL Site contractors, emphasize the measurement of airborne radionuclides because air transport is considered the major potential pathway from INL Site releases to human receptors. During 2023, the INL contractor monitored ambient air at 37 locations (21 onsite, 7 boundary, and 9 offsite). The ICP contractor focused on ambient air surveillance monitoring of waste management facilities, namely INTEC and RWMC.

Air particulate samples were collected weekly by the INL contractor and biweekly by the ICP contractor. These samples were initially analyzed for gross alpha and gross beta activity. The particulate samples were then combined into composite samples and analyzed for gamma-emitting radionuclides and specific alpha- and beta-emitting radionuclides. Air filter composites at MFC collected by the INL contractor were analyzed for chlorine-36 beginning in the second quarter. Charcoal cartridges were also collected weekly by the INL contractor and analyzed for radioiodine.

All radionuclide concentrations in ambient air samples were below DOE radiation protection standards for air. In addition, gross alpha and gross beta concentrations were analyzed statistically, and there were no differences between the samples collected at the onsite, boundary, and offsite locations. All concentrations were within historical measurements made during the past ten years (2013-2022), except for some americium-241 (^{241}Am) and plutonium results collected at RWMC by the INL contractor during the fourth quarter. Plutonium isotopes and ^{241}Am are known to occur in soils at the

Subsurface Disposal Area (SDA). The results observed during the fourth quarter are likely related to work activities being performed at SDA. All concentrations were well below the DOE Derived Concentration Standards for these radionuclides.

The INL contractor collected atmospheric moisture samples at three stations onsite, three stations offsite, and two boundary stations in 2023. Precipitation was collected at one location onsite, two boundary locations, and one offsite location. The samples were all analyzed for tritium. The results were within measurements made historically and below the DOE Derived Concentration Standards. Tritium measured in these samples is most likely the result of natural production in the atmosphere and not the result of INL Site effluent releases.

ENVIRONMENTAL MONITORING OF GROUNDWATER, DRINKING, AND SURFACE WATER (CHAPTER 5, CHAPTER 6)

The INL Site contractors monitor liquid effluents (wastewater), drinking water, groundwater, and storm water runoff at the INL Site, for both radioactive and nonradioactive constituents, and for compliance with applicable laws and regulations, DOE orders, and other requirements. Wastewater is typically discharged from INL Site facilities to infiltration ponds or to evaporation ponds. Wastewater effluent discharges occur at percolation ponds southwest of INTEC, a cold waste pond at the ATR Complex, and an industrial waste pond at MFC. DOE-ID complies with the state of Idaho groundwater quality, wastewater, and reuse rules for these effluents through reuse permits, which provide for monitoring of the wastewater and groundwater in the area. During 2023, liquid effluent and groundwater monitoring were conducted in support of reuse permit requirements. An annual site performance report for each permitted reuse facility was prepared and submitted to the Idaho Department of Environmental Quality. No permit limits were exceeded.

In addition to the monitoring conducted in support of the reuse permits, liquid effluent and groundwater surveillance monitoring was also performed at the ATR Complex Cold Waste Pond, INTEC, and MFC Industrial Waste Pond to comply with environmental protection objectives of DOE orders. The 2023 results were consistent with historical measurements. All radioactive parameters were below applicable health-based levels.

Drinking water parameters are regulated by the state of Idaho under the authority of the Safe Drinking Water Act. The INL Site contractors monitored 11 drinking water systems at the INL Site in 2023. (The NRF contractor monitors an additional drinking water system; those results are reported separately by NRF). The results were below limits for all relevant drinking water standards.

Surface water flows off the Subsurface Disposal Area (SDA) following periods of heavy precipitation or rapid snowmelt. During these times, water may be pumped out of the SDA retention basin into a drainage canal, potentially carrying radionuclides originating from radioactive waste or contaminated surface soil off the SDA. Surface water is collected when it is available. Amounts of ^{241}Am, strontium-90 (^{90}Sr), plutonium-238 (^{238}Pu), and plutonium-239/240 ($^{239/240}$Pu) were detected in 2023 samples collected from the SDA Lift Station. The detected concentrations are well below the standards established by DOE for radiation protection of the public and the environment.

ENVIRONMENTAL MONITORING OF THE EASTERN SNAKE RIVER PLAIN AQUIFER (CHAPTER 6)

The eastern Snake River Plain Aquifer is perhaps the single-most important aquifer in Idaho. Composed of layered basalt lava flows and some sediment, it covers an area of approximately 27,972 km^2 (10,800 square miles). The highly productive aquifer has been declared a sole source aquifer by the EPA due to the nearly complete reliance on the aquifer for drinking water supplies in the area.

The U.S. Geological Survey (USGS) began monitoring the groundwater below the INL Site in 1949. Currently, the USGS performs groundwater monitoring, analyses, and studies of the eastern Snake River Plain Aquifer under and adjacent to the INL Site. These activities use an extensive network of strategically placed monitoring wells on and around the INL Site. In 2023, the USGS continued to monitor localized areas of chemical and radiochemical contamination beneath the INL Site produced by past waste disposal practices, in particular, the direct injection of wastewater into the aquifer at INTEC. Results for monitoring wells sampled within the plumes show nearly all wells had decreasing trends of tritium and ^{90}Sr concentrations over time.

Volatile organic compounds (VOCs) are present in water from the eastern Snake River Plain Aquifer because of historical waste disposal practices at the INL Site. Several purgeable VOCs were detected by USGS in at least one of the 25 groundwater monitoring wells sampled at the INL Site in 2023. Most concentrations of the 61 analyzed compounds were either below the laboratory reporting levels or their respective primary contaminant standards. Trend test results for tetrachloromethane concentrations in water from the RWMC production well show a decreasing trend in that well since 2005. The more recent decreasing trend indicates that remediation efforts designed to reduce VOC movement to the aquifer are having a positive effect. Concentrations of tetrachloromethane from USGS-87 and USGS-120, south of RWMC, have had an increasing trend since 1987; however, concentrations have decreased through time at USGS-88. Trichloroethelene was detected above the maximum contaminant level (MCL) in one well sampled by the USGS at TAN, which was expected as there is a known groundwater plume at this location as well as one perched well.

Groundwater surveillance monitoring continued for the CERCLA WAGs onsite in 2023. At TAN (WAG 1), groundwater monitoring continues to monitor the progress of remediation of the plume of trichloroethylene and to monitor ^{90}Sr and cesium-137 (^{137}Cs). Remedial action consists of three components: in-situ bioremediation, pump and treat, and monitored natural attenuation. Amounts of ^{90}Sr and ^{137}Cs were present in wells in the source area at levels higher than those prior to starting in-situ bioremediation. The elevated concentrations of these radionuclides are due to chemical processes associated with in-situ bioremediation activities. The radionuclide concentrations will continue to be evaluated to determine whether they will meet remedial action objectives by 2095.

Groundwater samples were collected from six aquifer wells in the vicinity of the ATR Complex (WAG 2) during 2023 and were analyzed for ^{90}Sr, cobalt-60 (^{60}Co), tritium, and chromium. Chromium and tritium were the only analytes detected and the concentrations were below the respective drinking water MCL established by the EPA.

Groundwater samples were collected from 17 aquifer monitoring wells at and near INTEC (WAG 3) during 2023 and analyzed for a suite of radionuclides and inorganic constituents. Amounts of ^{90}Sr and technetium-99 (^{99}Tc) exceeded their respective drinking water MCLs in one or more aquifer monitoring wells at or near INTEC, with ^{90}Sr exceeding its MCL by the greatest margin in a well south (downgradient) of the former INTEC injection well. All other well locations showed ^{90}Sr levels similar to or slightly lower than those reported in previous samples.

Monitoring groundwater at CFA (WAG 4) consists of CFA landfill monitoring and monitoring of a nitrate plume south of the CFA. Wells at the landfill were monitored in 2023 for metals (filtered), VOCs, and anions (e.g., nitrate, chloride, fluoride, sulfate). No CFA landfill monitoring samples exceeded a MCL but the iron and lower threshold aluminum secondary maximum contaminant level (SMCL) was exceeded in one well, and two wells exceeded a pH SMCL. Nitrate continued to exceed the EPA MCL in one well in the plume south of the CFA in 2023; however, the data show a downward trend since 2006.

Groundwater samples were collected from monitoring wells near and downgradient of the RWMC (WAG 7) in May 2023, which were analyzed for radionuclides, inorganic constituents, and VOCs. Carbon tetrachloride was detected slightly above the MCL (5 ug/L) in one regular sample from Well M15S. Carbon tetrachloride concentrations in all other well locations were below the MCL and consistent with historical detections.

Groundwater monitoring at MFC as part of WAG 9 CERCLA monitoring was discontinued in 2022 as discussed in Chapter 6. In 2023, groundwater monitoring continued in support of the MFC Industrial Waste Pond Reuse Permit and DOE orders. Three wells were sampled for radionuclides, metals, and other water quality parameters in the spring and fall of 2023. Overall, the results remain below the primary constituent standard/secondary constituent standards and continue to show no evidence of impacts from MFC activities.

Wells along the southern INL Site boundary (as part of WAG 10) are sampled every two years. Groundwater samples were collected in 2023. Seven wells and three intervals from two Westbay® wells were sampled. Groundwater samples from all wells were analyzed for chloride, nitrate/nitrite as nitrogen, gross alpha, and gross beta. Sulfate and volatile organic compounds were collected from a subset of Operable Unit 10-08 monitoring wells. None of the noted analytes exceeded EPA MCLs or SMCLs.

Groundwater is monitored at the Remote-Handled Low-Level Waste Facility for gross alpha, gross beta, carbon-14 (^{14}C), iodine-129 (^{129}I), ^{99}Tc, and tritium. Samples were collected from three monitoring wells in the spring and fall of 2023. The results remain below the primary constituent standard/secondary constituent standard and show no discernible impacts to the aquifer from Remote-Handled Low-Level Waste Facility operations.

Drinking water and surface water samples were sampled downgradient of the INL Site and analyzed for gross alpha and beta activity and tritium. Tritium was detected in two surface water samples and two drinking water samples (one was the control). These results were within historical measurements and well below the EPA MCL of 20,000 pCi/L. Gross alpha and beta results were within historical measurements and below the EPA's screening level. The data appear to show no discernible impacts from activities at the INL Site.

USGS RESEARCH (CHAPTER 6)

The USGS INL Project Office drills and maintains research wells that provide information about subsurface water, rock and sediment, and contaminant movement in the eastern Snake River Plain Aquifer at and near the INL Site. In 2023, the USGS published three research reports, two software releases, and six data releases.

ENVIRONMENTAL SURVEILLANCE MONITORING OF AGRICULTURAL PRODUCTS, WILDLIFE, SOIL, AND DIRECT RADIATION MEASUREMENTS (CHAPTER 7)

To help assess the impact of contaminants released to the environment by operations at the INL Site, agricultural products (e.g., milk, lettuce, alfalfa, grain, potatoes) and wildlife were sampled and analyzed for radionuclides in 2023. The agricultural products were collected onsite, offsite, and at INL Site boundary locations by the INL contractor.

No human-made radionuclides were detected in agricultural products with one exception. Cesium-137 was detected in a milk sample collected in Monteview; however, a review of the result and uncertainty suggest the result was a false positive. Cesium-137 was not detected in any other milk sample collected in 2023. All measurements were consistent with those made historically.

No human-made radionuclides were detected in big game animal samples collected in 2023. Amounts of ^{137}Cs, ^{60}Co, zinc-65 (^{65}Zn), and ^{90}Sr were detected in tissues of waterfowl collected near the ATR Complex ponds, indicating that they accessed the contaminated ponds.

Direct radiation measurements made at onsite, offsite, and boundary locations were consistent with historical and natural background levels.

Soil sampling is conducted on a five-year rotation at the INL Site with the next sampling event scheduled for 2027.

RADIATION DOSE TO THE PUBLIC AND BIOTA FROM INL SITE RELEASES (CHAPTER 8)

Humans, plants, and animals potentially receive radiation doses from various INL Site operations. DOE sets dose limits for the public and biota to ensure that exposure to radiation from site operations is not a health concern. Potential radiological doses to the public from INL Site operations were calculated to determine compliance with pertinent regulations and limits (Table 8-5). The calculated dose to the maximally exposed individual in 2023 from the air pathway was 0.029 mrem (0.29 µSv), which is well below the 10-mrem standard established by the Clean Air Act. The maximally exposed individual is a hypothetical member of the public who could receive the maximum possible dose from INL Site releases as determined by the air dispersion model. This person is assumed to live at a location east of the INL Site's east entrance and south of Highway 20. For comparison, the dose from natural background radiation was estimated in 2023 to be 376 mrem (3.8 mSv) to an individual living on the Snake River Plain.

The maximum potential population dose to the approximately 353,789 people residing within an 80 km (50 mi) radius of any INL Site facility was calculated as 0.031 person-rem (0.00031 person-Sv), below that expected from exposure to background radiation (133,025 person-rem or 1,330 person-Sv).

The maximum potential individual dose from consuming waterfowl contaminated at the INL Site, based on the highest concentrations of radionuclides measured in edible tissue of samples collected near the ATR Complex ponds, was estimated to be 0.026 mrem (0.26 µSv). In 2023, none of the big game samples collected (e.g., four elk, one mule deer) had a detectable concentration of ^{137}Cs or other human-made radionuclides. When the dose estimated for the air pathway was summed with the dose from consuming contaminated waterfowl, assuming that the waterfowl is eaten by the same hypothetical individual, the representative person off the INL Site could potentially receive a total dose of 0.055 mrem (0.55 µSv) in 2023. This is 0.055% of the DOE health-based dose limit of 100 mrem/yr (1 mSv/yr) from all pathways for the INL Site.

Tritium has been previously detected in two USGS monitoring wells located onsite along the southern boundary. A hypothetical individual ingesting the maximum concentration of tritium (3,620 pCi/L) via drinking water from these wells would receive a dose of approximately 0.2 mrem (0.002 mSv) in one year. This is an unrealistic pathway to humans because there are no drinking water wells located along the southern boundary of the INL Site. The maximum contaminant level established by EPA for tritium (20,000 pCi/L) corresponds to a dose of approximately 4 mrem (0.04 mSv [40 µSv/yr]).

A dose to a maximally exposed individual located in Idaho Falls, near the DOE Radiological and Environmental Sciences Laboratory and the INL Research Center, within the REC, was calculated for compliance with the Clean Air Act. For 2023, the dose was conservatively estimated to be 0.005 mrem (0.05 µSv), which is less than 0.1% of the 10-mrem/yr federal standard.

Doses were also evaluated for nonhuman biota at the INL Site using a graded approach. Based on the conservative screening calculations, there is no evidence that INL Site-related radioactivity in soil or water is adversely affecting populations of plants or animals.

NATURAL AND CULTURAL RESOURCES CONSERVATION AND MONITORING (CHAPTER 9)

Natural resources conservation, monitoring, and land stewardship activities onsite are organized in four categories: (1) planning and implementing conservation efforts for high priority natural resources; (2) frequently evaluating the regulatory rankings, distribution, and populations for special status species; (3) ongoing monitoring and research to provide baseline and trend data for specific taxa and broader ecological communities; and (4) conducting land stewardship activities to minimize impacts to natural resources and restore ecological condition, where appropriate.

DOE has developed conservation plans to address species of elevated conservation concern and the valuable ecosystems they inhabit. Conservation plans that are specific to or include the INL Site are the DOE Conservation Action Plan, the Candidate Conservation Agreement for Greater sage-grouse (*Centrocercus urophasianus*), the INL Site Bat Protection Plan, the Sagebrush Steppe Ecosystem Reserve, and the Migratory Bird Conservation Plan and Avian Protection Planning documents. Many of these plans include conservation measures; best management practices; monitoring programs; and annual reports to facilitate, evaluate, and communicate results of conservation efforts for resources with high conservation priority.

To better inform conservation efforts, biologists regularly evaluate the regulatory status of key special status species identified by state or federal agencies. For animals, these include 28 species of birds, 13 species of mammals, one species of reptile, and one species of amphibian. There are also currently 20 special status plant species that have been documented to occur onsite. Many of the plant species are rare and occur very infrequently within their optimal habitats. While several animals and plants listed as threatened or endangered under the Endangered Species Act are present in Idaho, none are known to occur onsite.

Additional ecological monitoring has been conducted for more than 70 years, with some studies dating back to the 1950s. The focus of this work is to better understand the INL Site's ecosystem and biota and to determine the impact on populations of these species from activities conducted at the INL Site. Natural resource monitoring activities include breeding bird surveys, midwinter raptor survey, long-term vegetation transect surveys, and vegetation mapping. Furthermore, the INL Site was designated as a National Environmental Research Park in 1975 and serves as an outdoor laboratory for environmental scientists to study Idaho's native plants and wildlife in an intact and relatively undisturbed ecosystem. Ongoing National Environmental Research Park activities range from characterizing sagebrush steppe ecohydrology to identifying high quality foodscape for sage-grouse.

Land stewardship involves managing ecosystems to increase habitat connectivity and enhance ecosystem services through planning, assessment, restoration and rehabilitation activities, as well as continuing to explore additional nature-based solutions. Areas where DOE-ID is actively employing land stewardship activities include wildland fire protection planning, management, and recovery; restoration and revegetation; weed management; and ecological support for the National Environmental Policy Act.

The INL Cultural Resource Management Office (CRMO) coordinates cultural resource-related activities at the INL Site and implements the INL Cultural Resource Management Plan (DOE-ID 2016) with oversight by DOE-ID's Cultural Resource Coordinator. During 2023, the INL CRMO assisted DOE-ID with continued negotiations and finalization of the Programmatic Agreement (DOE-ID 2023) with the Idaho State Historic Preservation Office, the Advisory Council on Historic Preservation, the Shoshone-Bannock Tribes, and other consulting parties. The Advisory Council on Historic Preservation provided the fully executed Programmatic Agreement to the DOE-ID on May 8, 2023. Cultural resource identification and evaluation studies in fiscal year 2023 included: (1) archaeological field surveys, (2) cultural resource monitoring and site record updates related to INL Site project activities and research, and (3) comprehensive evaluations of built environment resources 45 years of age and older. Additionally, the CRMO supports DOE-ID with their government-to-government consultation and meaningful collaboration with members of the Shoshone-Bannock Tribes to include the Fort Hall Business Council, the Language and Cultural Committee, and the Heritage Tribal Office (known as the HeTO), as well as interested stakeholders. Preservation and stewardship activities in 2023 included: (1) issuance and revisions to seven Management Control Procedures, (2) development of historic context statements (Precontact and Pre-World War II), (3) support to five active research projects, (4) participating in public outreach and education opportunities, (5) archaeological site stabilization and restoration, and (6) improvements to the Archives and Special Collections.

QUALITY ASSURANCE (CHAPTER 10)

Quality assurance and quality control programs are maintained by contractors conducting environmental surveillance monitoring and by laboratories performing environmental analyses to help provide confidence in the data and ensure data completeness. Programs involved in environmental surveillance monitoring developed quality assurance programs and documentation, which follow requirements and criteria established by DOE. Environmental surveillance monitoring programs implemented quality assurance program elements through quality assurance project plans developed for each contractor.

Adherence to procedures and quality assurance project plans was maintained during 2023. Data reported in this document were obtained from several commercial, university, government, and government contractor laboratories. To ensure quality results, these laboratories participated in several laboratory quality check programs. Quality issues that arose with laboratories used by INL Site contractors during 2023 were addressed with the laboratories and have been resolved.

Sagebrush steppe with wildflowers

Helpful Information:

What is Radiation?

Much of the Annual Site Environmental Report deals with radioactivity levels measured in environmental media such as air, water, soil, and plants. The following information is intended for individuals with little or no familiarity with radiological data or radiation dose. It presents terminology and concepts used in the Annual Site Environmental Report to aid the reader.

Matter is composed of atoms. Some atoms are energetically unstable and change to become more stable. During this transformation, unstable or radioactive atoms give off energy called radiation in the form of particles or electromagnetic waves. Generally, we refer to the various radioactive atoms as radionuclides. The radiation released by radionuclides has enough energy to eject electrons from other atoms it encounters. The resulting charged atoms or molecules are called ions, and the energetic radiation that produced the ions is called ionizing radiation. Ionizing radiation is referred to simply as radiation throughout this report. The most common types of radiation are alpha particles, beta particles, X-rays, and gamma-rays. X-rays and gamma-rays, just like visible light and radio waves, are packets of electromagnetic radiation. Collectively, packets of electromagnetic radiation are called photons. One may, for instance, speak of X-ray photons or gamma-ray photons.

Alpha Particles. An alpha particle is a helium nucleus without orbital electrons. It is composed of two protons and two neutrons and has a positive charge of two. Because alpha particles are relatively heavy and have a double charge, they cause intense tracks of ionization but have little penetrating ability, as observed in Figure HI-1. Alpha particles can be stopped by thin layers of materials, such as a sheet of paper or a piece of aluminum foil. Examples of alpha-emitting radionuclides include radioactive atoms of radon, uranium, plutonium, and americium.

Beta Particles. Beta particles are electrons that are ejected from unstable atoms during the transformation or decay process. Beta particles penetrate more than alpha particles but are less penetrating than X-rays or gamma-rays of equivalent energies. A piece of wood or a thin block of plastic can stop beta particles, as can be seen in Figure HI-1. The ability of beta particles to penetrate matter increases with energy. Examples of beta-emitting radionuclides include tritium (^{3}H) and radioactive strontium.

X-Rays and Gamma-Rays. X-rays and gamma-rays are photons with very short wave-lengths compared to other electromagnetic waves such as visible light, heat rays, and radio waves. Gamma-rays and X-rays have identical properties, behavior, and effects but differ in their origin. Gamma-rays originate from an atomic nucleus, and X-rays originate from interactions with the electrons orbiting around atoms. All photons travel at the speed of light. Their energies, however, vary over a large range. The penetration of X-ray or gamma-ray photons depend on the energy of the photons, as well as the thickness, density, and composition of the shielding material. Concrete is a common material used to shield people from gamma-rays and X-rays, as shown in Figure HI-1.

Examples of gamma-emitting radionuclides include radioactive atoms of iodine and cesium. X-rays may be produced by medical X-ray machines in a doctor's office.

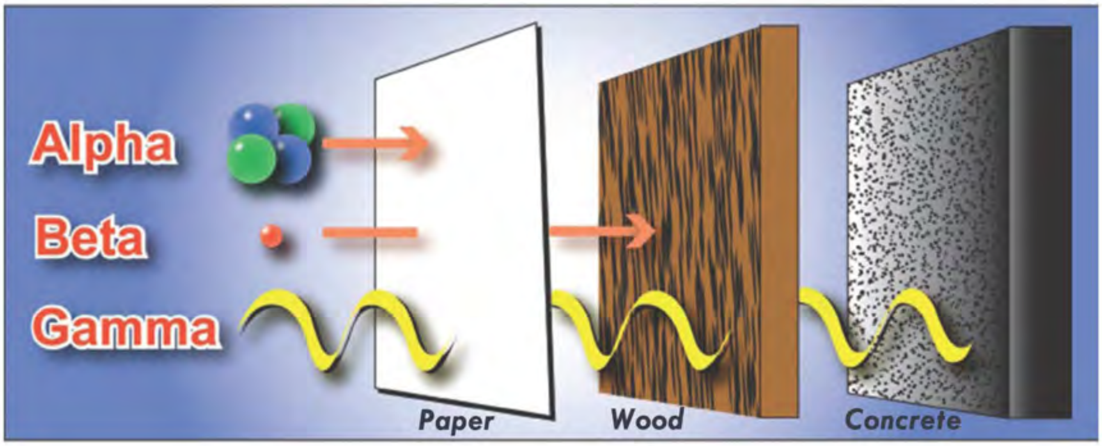

Figure HI-1. Comparison of penetrating ability of alpha, beta, and gamma radiation.

How are Radionuclides Designated?

Radionuclides are frequently expressed with a one or two letter abbreviation for the element and a superscript to the left of the symbol that identifies the atomic weight of the isotope. The atomic weight is the number of protons and neutrons in the nucleus of the atom. Most radionuclide symbols used in this report are shown in Table HI-1. This table also shows the half-life of each radionuclide. Half-life refers to the time in which one-half of the atoms of a radioactive sample transforms or decays in the quest to achieve a more energetically stable nucleus. Most radionuclides do not decay directly to a stable element, but rather undergo a series of decays until a stable element is reached. This series of decays is called a decay chain.

How are Radioactivity and Radionuclides Detected?

Environmental samples of air, water, soil, and plants are collected in the field and then prepared and analyzed for radioactivity in a laboratory. A prepared sample is placed in a radiation-counting system with a detector that converts the ionization produced by the radiation into electrical signals or pulses. The number of electrical pulses recorded over a unit of time is called a count rate. The count rate is proportional to the amount of radioactivity in the sample.

Air and water samples are often analyzed to determine the total amount of alpha-emitting and beta-emitting radioactivity present. This is referred to as a gross measurement because the radiation from all alpha-emitting and beta-emitting radionuclides in the sample is quantified. Such sample analyses measure both human-generated and naturally occurring radioactive material. Gross alpha and beta analyses are generally considered screening measurements since specific radionuclides are not identified. The amount of gross alpha-emitting and beta-emitting radioactivity in air samples is frequently measured to screen for the potential presence of man-made radionuclides. If the results are higher than normal, sources other than background radionuclides may be suspected, and other laboratory techniques may be used to identify the specific radionuclides in the sample. Gross alpha and beta activity also can be examined over time and between locations to detect trends.

The low penetration ability of alpha-emitting particles makes detection by any instrument difficult. Identifying specific alpha-emitting radionuclides typically involves chemical separations in the laboratory to purify the sample prior to analysis with an alpha detection instrument. Radiochemical analysis is very time-consuming and expensive.

Beta particles are easily detected by several types of instruments, including the common Geiger-Mueller counter. However, detection of specific beta-emitting radionuclides, such as ^{3}H and ^{90}Sr, requires chemical separation first.

Table HI-1. Radionuclides and their half-lives.

SYMBOL	RADIONUCLIDE	HALF-LIFE[a,b]	SYMBOL	RADIONUCLIDE	HALF-LIFE[a,b]
^{241}Am	Americium-241	432.2 yr	^{54}Mn	Manganese-54	312.12 d
^{243}Am	Americium-243	7,370 yr	^{59}Ni	Nickel-59	1.01 × 10^5 yr
^{125}Sb	Antimony-125	2.75856 yr	^{63}Ni	Nickel-63	100.1 yr
^{41}Ar	Argon-41	109.61 min	^{238}Pu	Plutonium-238	87.7 yr
^{137m}Ba	Barium-137m	2.552 min	^{239}Pu	Plutonium-239	2.411 × 10^4 yr
^{140}Ba	Barium-140	12.752 d	^{240}Pu	Plutonium-240	6,564 yr
^{7}Be	Beryllium-7	53.22 d	^{241}Pu	Plutonium-241	14.35 yr
^{14}C	Carbon-14	5,700 yr	^{242}Pu	Plutonium-242	3.75 × 10^5 yr
^{141}Ce	Cerium-141	32.508 d	^{40}K	Potassium-40	1.251 × 10^9 yr
^{144}Ce	Cerium-144	284.91 d	^{226}Ra	Radium-226	1,600 yr
^{134}Cs	Cesium-134	2.0648 yr	^{228}Ra	Radium-228	5.75 yr
^{137}Cs	Cesium-137	30.1671 yr	^{220}Rn	Radon-220	55.6 s
^{36}Cl	Chlorine-36	3.01 x 10^5 yr	^{222}Rn	Radon-222	3.8235 d
^{51}Cr	Chromium-51	27.7025 d	^{103}Ru	Ruthenium-103	39.26 d
^{60}Co	Cobalt-60	5.2713 yr	^{106}Ru	Ruthenium-106	373.59 d
^{152}Eu	Europium-152	13.537 yr	^{90}Sr	Strontium-90	28.79 yr
^{154}Eu	Europium-154	8.593 yr	^{99}Tc	Technetium-99	2.111 × 10^5 yr
^{3}H	Tritium	12.32 yr	^{232}Th	Thorium-232	1.405 × 10^{10} yr
^{129}I	Iodine-129	1.57 × 10^7 yr	^{233}U	Uranium-233	1.592 × 10^5 yr
^{131}I	Iodine-131	8.0207 d	^{234}U	Uranium-234	2.455 × 10^5 yr
^{55}Fe	Iron-55	2.737 yr	^{235}U	Uranium-235	7.04 × 10^8 yr
^{59}Fe	Iron-59	44.495 d	^{238}U	Uranium-238	4.468 × 10^9 yr
^{85}Kr	Krypton-85	10.756 yr	^{90}Y	Yttrium-90	64.1 hr
^{87}Kr	Krypton-87	76.3 min	^{65}Zn	Zinc-65	244.06 d
^{88}Kr	Krypton-88	2.84 hr	^{95}Zr	Zirconium-95	64.032 d
^{212}Pb	Lead-212	10.64 hr			

a. From ICRP Publication 107 (ICRP 2008).
b. d = days; hr = hours; min = minutes; s = seconds; yr = years.

The high-energy photons from gamma-emitting radionuclides are relatively easy to detect. Because the photons from each gamma-emitting radionuclide have a characteristic energy, gamma emitters can be simply identified in the laboratory with only minimal sample preparation prior to analysis. Gamma-emitting radionuclides, such as ^{137}Cs, can even be measured in soil by field detectors called in situ detectors.

Gamma radiation originating from naturally occurring radionuclides in soil and rocks on the earth's surface is a primary contributor to the background external radiation exposure measured in the air. Cosmic radiation from outer space is another contributor to the external radiation background. External radiation is easily measured with devices known as environmental dosimeters.

How are Results Reported?

Scientific Notation. Concentrations of radionuclides detected in the environment are typically quite small. Scientific notation is used to express numbers that are very small or very large. A very small number may be expressed with a negative exponent, for example, 1.3×10^{-6} (or 1.3E-06). To convert this number to its decimal form, the decimal point is moved left by the number of places equal to the exponent (in this case, six). The number 1.3×10^{-6} may also be expressed as 0.0000013. When considering large numbers with a positive exponent, such as 1.0×10^{6}, the decimal point is moved to the right by the number of places equal to the exponent. In this case, 1.0×10^{6} represents one million and may also be written as 1,000,000.

Unit Prefixes. Units for very small and very large numbers are often expressed with a prefix. One common example is the prefix kilo (abbreviated k), which means 1,000 of a given unit. One kilometer, therefore, equals 1,000 meters. Table HI-2 defines the values of commonly used prefixes.

Table HI-2. Multiples of units.

MULTIPLE	DECIMAL EQUIVALENT	PREFIX	SYMBOL
10^{6}	1,000,000	mega-	M
10^{3}	1,000	kilo-	k
10^{2}	100	hecto-	h
10	10	deka-	da
10^{-1}	0.1	deci-	d
10^{-2}	0.01	centi-	c
10^{-3}	0.001	milli-	m
10^{-6}	0.000001	micro-	µ
10^{-9}	0.000000001	nano-	n
10^{-12}	0.000000000001	pico-	p
10^{-15}	0.000000000000001	femto-	f
10^{-18}	0.000000000000000001	atto-	a

Units of Radioactivity. The basic unit of radioactivity used in this report is the curie (abbreviated Ci), which is based on the disintegration rate occurring in 1 gram of the radionuclide radium-226 (^{226}Ra) that is 37 billion (3.7×10^{10}) disintegrations per second (becquerels). For any other radionuclide, 1 Ci is the amount of the radionuclide that produces this same decay rate.

Units of Exposure and Dose (Table HI-3). Exposure, or the amount of ionization produced by gamma or X-ray radiation in the air, is measured in terms of the roentgen (R). Dose is a general term to express how much radiation energy is deposited into something. The energy deposited can be expressed in terms of absorbed, equivalent, and effective dose. The term rad, which is short for radiation absorbed dose, is a measure of the energy absorbed in an organ or tissue. The equivalent dose, which considers the effect of different types of radiation on tissues and is therefore the potential for biological effects, is expressed as the R equivalent man or rem. Radiation exposures to the human body, whether from external or internal sources, can involve all or a portion of the body. To enable radiation protection specialists to express partial-body exposures (and the accompanying doses) to portions of the body in terms of an equal dose to the whole body, the concept of effective dose was developed.

Table HI-3. Names and symbols for units of radioactivity and radiological dose used in this report.

SYMBOL	NAME
Bq	Becquerel
Ci	Curie (37,000,000,000 Bq)
mCi	Millicurie (1 × 10^{-3} Ci)
µCi	Microcurie (1 × 10^{-6} Ci)
mrad	Millirad (1 × 10^{-3} rad)
mrem	Millirem (1 × 10^{-3} rem)
R	Roentgen
mR	Milliroentgen (1 × 10^{-3} R)
µR	Microroentgen (1 × 10^{-6} R)
Sv	Sievert (100 rem)
mSv	Millisievert (100 mrem)
µSv	Microsievert (0.1 mrem)

The Système International (SI) is the official system of measurement used internationally to express units of radioactivity and radiation dose. The basic SI unit of radioactivity is the Becquerel (Bq), which is equivalent to one nuclear disintegration per second. The number of curies must be multiplied by 3.7 × 10^{10} to obtain the equivalent number of becquerels. The concept of dose may also be expressed using the SI units, Gray (Gy) for absorbed dose (1 Gy = 100 rad) and sievert (Sv) for effective dose (1 Sv = 100 rem).

Concentrations of Radioactivity in Environmental Sample Media. Table HI-4 shows the units used to identify the concentration of radioactivity in various sample media. There is always uncertainty associated with the measurement of radioactivity in environmental samples. This is mainly because radioactive decay events are inherently random. Thus, when a radioactive sample is counted again and again for the same length of time, the results will differ slightly, but most of the results will be close to the true value of the activity of the radioactive material in the sample. Statistical methods are used to estimate the true value of a single measurement and the associated uncertainty of the measurement. The uncertainty of a measurement is reported by following the result with an uncertainty value that is preceded by the plus or minus symbol, ± (e.g., 10 ± 2 pCi/L). The uncertainty is often referred to as sigma (or σ). For concentrations of greater than or equal to three times the uncertainty, there is 99% probability that the radionuclide was detected in a sample. For example, if a radionuclide is reported for a sample at a concentration of 10 ± 2 pCi/L, then the radionuclide is considered to be detected in that sample because 10 is greater than 3 × 2, or 6. On the other hand, if the reported concentration of a radionuclide (e.g., 10 ± 6 pCi/L) is smaller than three times its associated uncertainty, then the sample probably does not contain that radionuclide (i.e., 10 is less than 3 × 6, or 18). Such low concentrations are considered to be undetected by the method or instrumentation used.

Table HI-4. Units of radioactivity.

MEDIA	UNIT
Air	Microcuries per milliliter (µCi/mL)
Liquid, such as water and milk	Picocuries per liter (pCi/L)
Soil and agricultural products	Picocuries per kilogram (pCi/kg) dry weight
Annual human radiation exposure, measured by environmental dosimeters	Milliroentgens (mR) or millirem (mrem), after being multiplied by an appropriate dose equivalent conversion factor

Mean, Median, Maximum, and Minimum Values. Descriptive statistics are often used to express the patterns and distribution of a group of results. The most common descriptive statistics used in this report are the mean, median, minimum, and maximum values. Mean and median values measure the central tendency of the data. The mean is calculated by adding up all the values in a set of data and then dividing that sum by the number of values in the dataset. The median is the middle value in a group of measurements. When the data are arranged from largest (maximum) to smallest (minimum), the result in the exact center of an odd number of results is the median. If there is an even number of results, the median is the average of the two central values. The maximum and minimum results represent the range of the measurements.

Statistical analysis of many of the air data reported in this annual report indicate that the median is a more appropriate representation of the central tendency of those results. For this reason, some of the figures present the median value of a data group. For example, Figure HI-2 is a box plot showing the minimum, maximum, and median of a set of air measurements.

How are Data Represented Graphically?

Charts and graphs often are used to compare data and to visualize patterns, such as trends over time. Four kinds of graphics are used in this report to represent data: pie charts, column graphs, line plots, and contour lines.

A ***pie chart*** is used in this report to illustrate fractions of a whole. For example, Figure HI-3 shows the approximate contribution to dose that a typical person might receive while living in southeast Idaho. The percentages are derived from the table in the lower left-hand corner of the figure. The medical, consumer, and occupational/industrial portions are from the National Council on Radiation Protection and Measurements Report No. 160 (NCRP 2009). The contribution from background radiation (e.g., natural radiation, mostly radon) is estimated in Table 7-7 of this report.

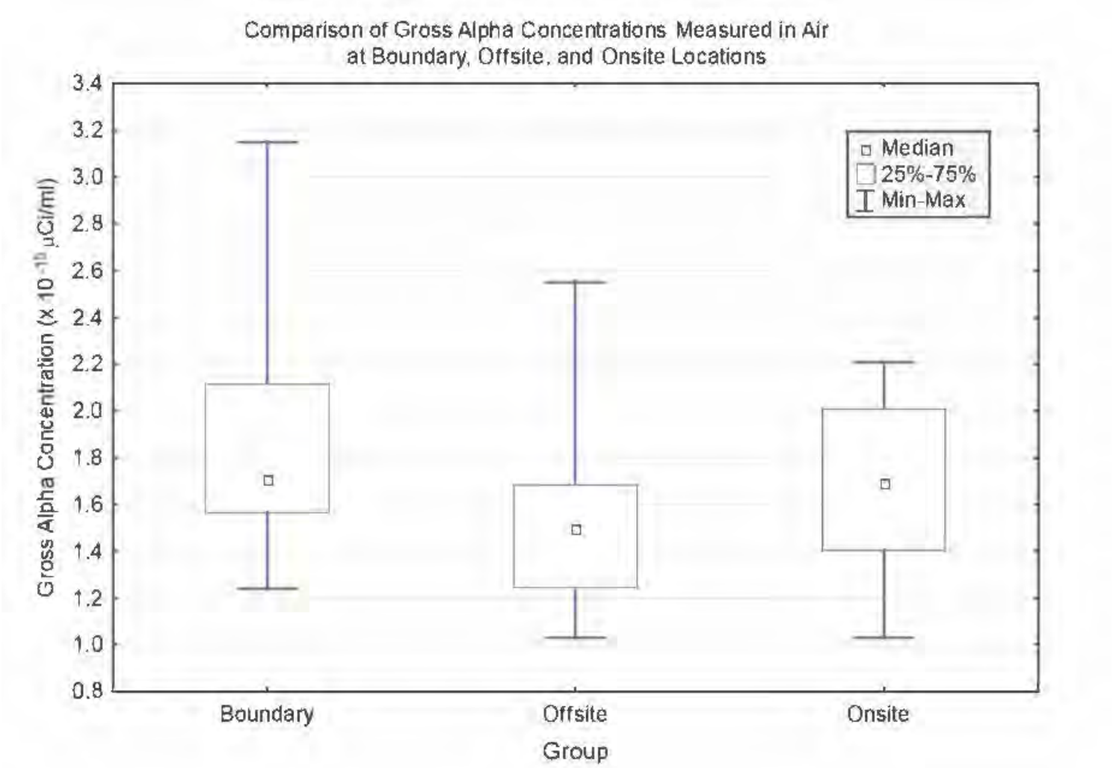

Figure HI-2. A graphical representation of minimum, median, and maximum results with a box plot. *The 25th and 75th percentiles are the values such that 75% of the measurements in the dataset are greater than the 25th percentile, and 75% of the measurements are less than the 75th percentile.*

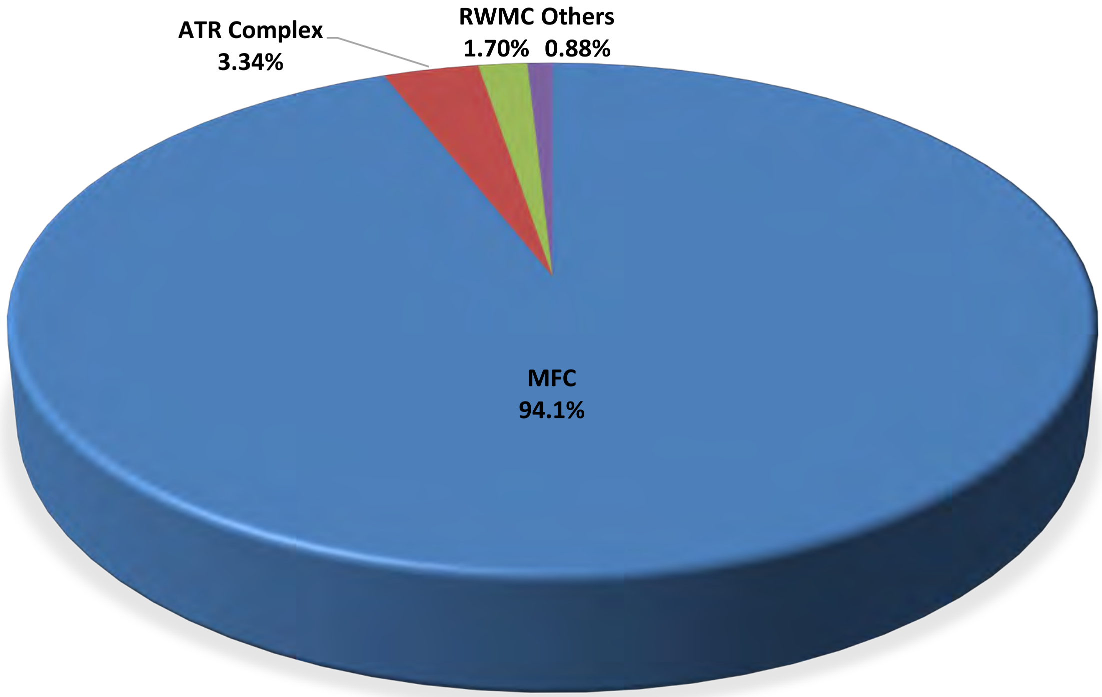

Figure HI-3. Data presented using a pie chart.

A ***column or bar chart*** can show data changes over a period of time or illustrate comparisons among items. Figure HI-4 illustrates the maximum dose (mrem) calculated for the maximally exposed individual from 2014 through 2023. The maximally exposed individual is a hypothetical member of the public who is exposed to radionuclides from airborne releases through various environmental pathways and the media through which the radionuclides are transported (i.e., air, water, and food). The chart shows the general trend of the dose over time.

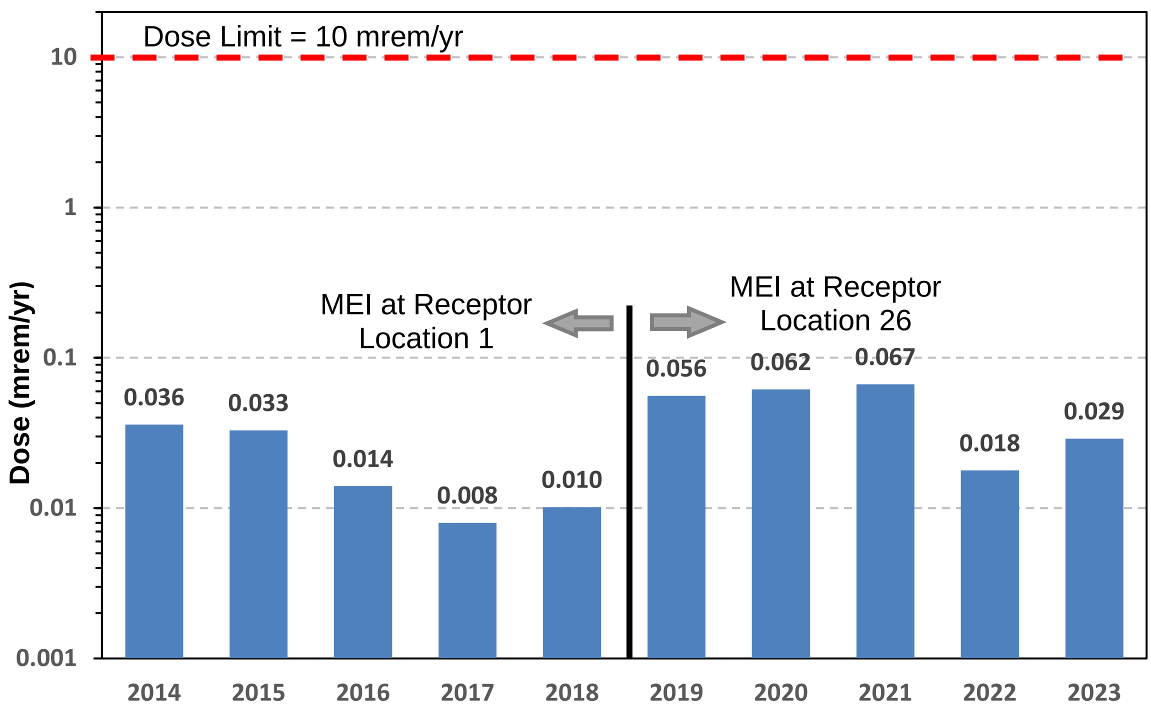

Figure HI-4. Data plotted using a column chart.

A ***plot chart*** can be useful to visualize differences in results over time. Figure HI-5 shows the ^{90}Sr measurements in three wells collected by USGS for 21 years (2003–2023). The results are plotted by year.

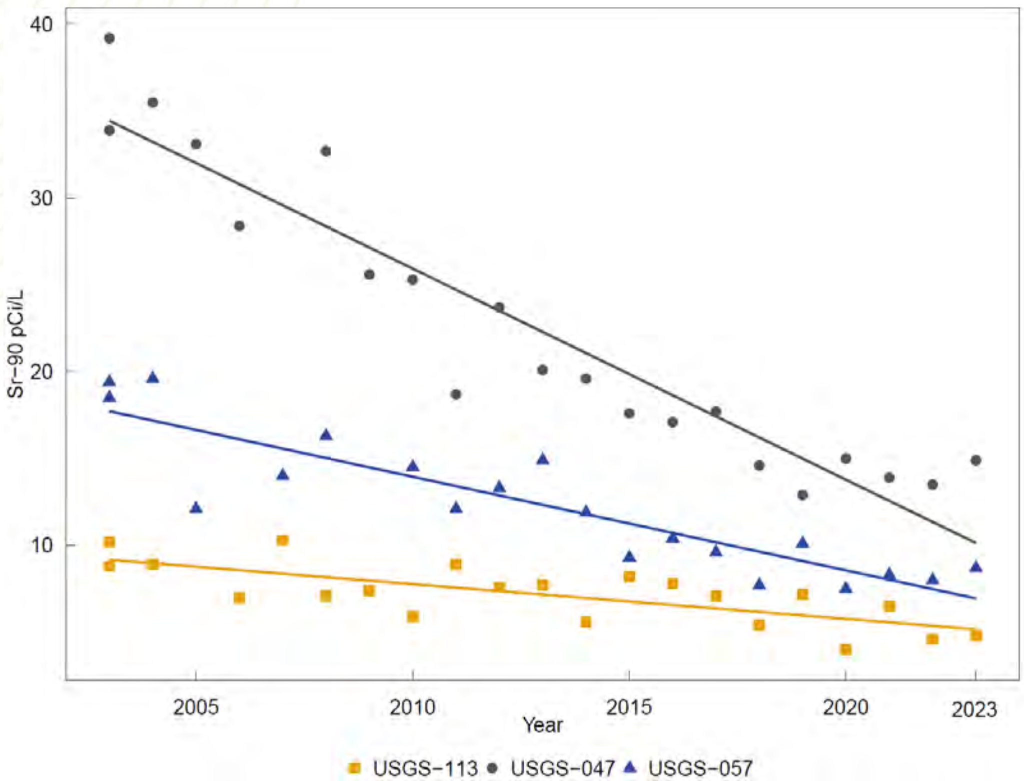

Figure HI-5. Data plotted using a linear plot.

Contour lines are sometimes drawn on a map to discern patterns over a geographical area. For example, Figure HI-6 shows the distribution of ^{90}Sr in groundwater around INTEC. Each contour line, or isopleth, represents a specific concentration of the radionuclide in groundwater. It was estimated from measurements of samples collected from wells around INTEC. Each contour line separates areas that have concentrations above the contour line value from those that have concentrations below that value. The figure shows the highest concentration gradient near INTEC and the lowest farther away. It reflects the movement of the radionuclide in groundwater from INTEC where it was injected into the aquifer in the past.

How Are Results Interpreted?

To better understand data, results are compared in one or more ways, including the following:

- Comparison of results collected at different locations. For example, measurements made at onsite locations are compared with those made at locations near the boundary of the onsite and offsite to find differences that may indicate an impact (Figure HI-2).
- Trends over time or space. Data collected during the year can be compared with data collected at the same location or locations during previous years to see if concentrations are increasing, decreasing, or remaining the same with time. See, for example, Figure HI-4, which shows a general decrease in dose from 2014 to 2018, followed by a slight increase in 2019. Figure HI-6 illustrates a clear spatial pattern of radionuclide concentrations in groundwater decreasing with distance from the source.
- Comparison with background measurements. Humans are now, and always have been, continuously exposed to ionizing radiation from natural background sources. Background sources include natural radiation and radioactivity, as well as radionuclides from human activities. These sources are discussed in the following section.

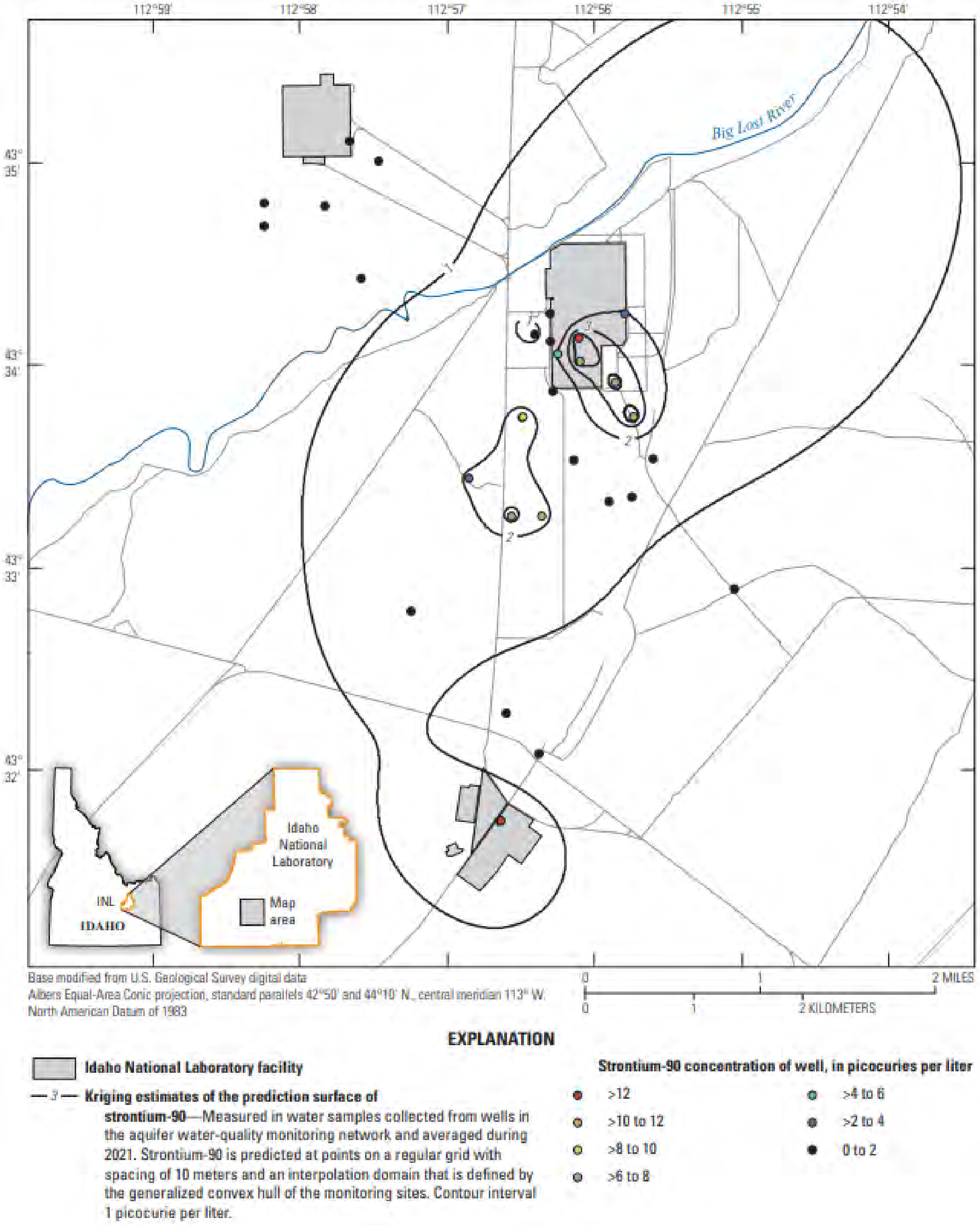

***Figure HI-6. Data plotted using contour lines.** Each contour line drawn on this map connects points of equal ^{90}Sr concentration in water samples collected at the same depth from wells onsite.*

What Is Background Radiation?

Radioactivity from natural and fallout sources is detectable as background in all environmental media. Natural sources of radiation include: (1) radiation of extraterrestrial origin (called cosmic rays), (2) radionuclides produced in the atmosphere by cosmic ray interaction with matter (called cosmogenic radionuclides), and (3) radionuclides present at the time of the formation of the earth (called primordial radionuclides). Radiation that has resulted from the activities of modern man is primarily fallout from past atmospheric testing of nuclear weapons. One of the challenges to environmental monitoring on and around the INL Site is to distinguish between what may have been released from the INL Site and what is already present in background from natural and fallout sources. These sources are discussed in more detail below.

Natural radiation and radioactivity in the environment, which is natural background, represent a major source of human radiation exposure (NCRP 1987, 2009). For this reason, natural radiation frequently is used as a standard of comparison for exposure to various human-generated sources of ionizing radiation. An individual living in southeast Idaho was estimated, in 2023, to receive an average dose of about 376 mrem/yr (3.7 mSv/yr) from natural background sources of radiation on earth, as observed in Figure HI-7. These sources include cosmic radiation and naturally occurring radionuclides.

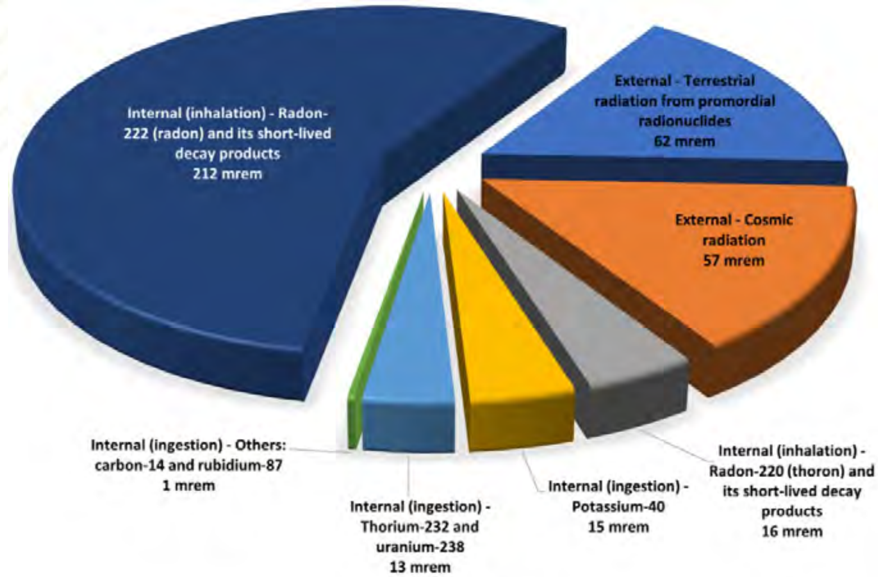

Figure HI-7. Calculated doses (mrem per year) from natural background sources for an average individual living in southeast Idaho (2023).

Cosmic radiation is radiation that constantly bathes the earth in extraterrestrial sources. The atmosphere around the earth absorbs some of the cosmic radiation, so doses are lowest at sea level and increase sharply with altitude. Cosmic radiation is estimated using data in NCRP (2009) to produce a dose of about 62 mrem/yr (0.62 mSv/yr) to a typical individual living in southeast Idaho (Figure HI-7). Cosmic radiation also produces cosmogenic radionuclides, which are found naturally in all environmental media and are discussed in more detail below.

Naturally occurring radionuclides are of two general kinds: cosmogenic and primordial. Cosmogenic radionuclides are produced by the interaction of cosmic radiation within the atmosphere or in the earth. Cosmic rays have high enough energies to blast apart atoms in the earth's atmosphere. The result is the continuous production of radionuclides, such as ^{3}H, beryllium-7 (^{7}Be), sodium-22 (^{22}Na), and ^{14}C. Cosmogenic radionuclides, particularly ^{3}H and ^{14}C, have been measured in humans, animals, plants, soil, polar ice, surface rocks, sediments, the ocean floor, and the atmosphere. Concentrations are generally higher at mid-latitudes than at low- or high-latitudes. Cosmogenic radionuclides contribute only about 1 mrem/yr to the total average dose, mostly from ^{14}C, that might be received by an adult living in the U.S. (NCRP 2009). Tritium and ^{7}Be are routinely detected in environmental samples collected by environmental monitoring programs on and around the INL Site, as observed in Figure HI-5, but these contribute little to the dose that might be received from natural background sources.

Primordial radionuclides are those that were present when the earth was formed. The primordial radionuclides detected today are billions of years old. The radiation dose to a person from primordial radionuclides comes from internally deposited radioactivity, inhaled radioactivity, and external radioactivity in soils and building materials. Three of the primordial radionuclides—potassium-40 (^{40}K), uranium-238 (^{238}U), and thorium-232 (^{232}Th)—are responsible for most of the dose received by people from natural background radioactivity. They have been detected in environmental samples collected on and around the INL Site (Table HI-5). The external dose to an adult living in southeast Idaho from terrestrial natural background radiation exposure (73 mrem/yr or 0.73 mSv/yr) has been estimated using concentrations of ^{40}K, ^{238}U, and ^{232}Th measured in soil samples collected from areas surrounding the INL Site from 1976 through 1993. This number varies slightly from year to year based on the amount of snow cover. Amounts of ^{238}U and ^{232}Th are also estimated to contribute 13 mrem/yr (0.13 mSv/yr) to an average adult through ingestion (NCRP 2009).

Table HI-5. Naturally occurring radionuclides that have been detected in environmental media collected on and around the INL Site.

RADIONUCLIDE	HALF-LIFE	HOW PRODUCED?	DETECTED OR MEASURED IN:
Beryllium-7 (^{7}Be)	53.22 days	Cosmic rays	Rain, air
Potassium-40 (^{40}K)	1.2516×10^{9} yr	Primordial	Water, air, soil, plants, animals
Radium-226 (^{226}Ra)	1,600 yr	^{238}U progeny	Water
Thorium-232 (^{232}Th)	1.405×10^{10} yr	Primordial	Soil
Tritium (^{3}H)	12.32 yr	Cosmic rays	Water, rain, air moisture
Uranium-234 (^{234}U)	2.455×10^{5} yr	^{238}U progeny	Water, air, soil
Uranium-238 (^{238}U)	4.468×10^{9} yr	Primordial	Water, air, soil

Potassium-40 is abundant and measured in living and nonliving matter. It is found in human tissue and is a significant source of internal dose to the human body (approximately 15 mrem/yr [0.15 mSv/yr] according to NCRP [2009]). Rubidium-87 (^{87}Rb), another primordial radionuclide, contributes a small amount (< 1 mrem/yr) to the internal dose received by people but is not typically measured in onsite samples.

Uranium-238 and ^{232}Th initiate a decay chain of radionuclides. A radioactive decay chain starts with one type of radioactive atom called the parent that decays and changes into another type of radioactive atom called a progeny radionuclide. This system repeats, involving several different radionuclides. The parent radionuclide of the uranium decay chain is ^{238}U. The most familiar element in the uranium series is radon, specifically radon-222 (^{222}Rn). This is a gas that can accumulate in buildings. Radon and its progeny are responsible for most of the inhalation dose (e.g., an average of 200 mrem/yr [2.0 mSv/yr] nationwide) produced by naturally occurring radionuclides, as shown in Figure HI-7.

The parent radionuclide of the thorium series is ^{232}Th. Another isotope of radon, called thoron, occurs in the thorium decay chain of radioactive atoms. Amounts of ^{238}U, ^{232}Th, and their progeny are often detected in environmental samples (Table HI-5).

Global Fallout. The U.S., the Union of Soviet Socialist Republics, and China tested nuclear weapons in the Earth's atmosphere in the 1950s and 1960s. This testing resulted in the release of radionuclides into the upper atmosphere, and such a release is referred to as fallout from weapons testing. Concerns over worldwide fallout rates eventually led to the Partial Test Ban Treaty in 1963, which limited signatories to underground testing. Not all countries stopped atmospheric testing with the treaty. France continued atmospheric testing until 1974, and China continued until 1980. Additional fallout, but to a substantially smaller extent, was produced by the Chernobyl and Fukushima nuclear accidents in 1986 and 2011, respectively.

Most of the radionuclides associated with nuclear weapons testing and the Chernobyl and Fukushima accidents have decayed and are no longer detected in environmental samples. Radionuclides that are currently detected in the environment and typically associated with global fallout include ^{90}Sr and ^{137}Cs. Strontium-90, a beta-emitter with a 29-year half-life, is important because it is chemically similar to calcium and tends to accumulate in bone tissues. Cesium-137, which has a 30-year half-life, is chemically similar to potassium and accumulates rather uniformly in muscle tissue throughout the body.

The deposition of these radionuclides on the earth's surface varies by latitude, with most occurring in the northern hemisphere at approximately 40 degrees. Variation within latitudinal belts is a function primarily of precipitation, topography, and wind patterns. The dose produced by global fallout from nuclear weapons testing has decreased steadily since 1970. The annual dose rate from fallout was estimated in 1987 to be less than 1 mrem (0.01 mSv) (NCRP 1987). It has been nearly 34 years since that estimate, so the current dose is assumed to be even lower.

What are the Risks of Exposure to Low Levels of Radiation?

Radiation protection standards for the public have been established by state and federal agencies based mainly on recommendations of the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The International Commission on Radiological Protection is an association of scientists from many countries, including the U.S. The National Council on Radiation Protection and Measurements is a nonprofit corporation chartered by Congress. Through radiation protection standards, exposure of members of the general public to radiation is controlled so that risks are small enough to be considered insignificant compared to the risks undertaken during other activities deemed normal and acceptable in modern life.

A large amount of data exists concerning the effects of acute delivery (all at once) of high doses of radiation, especially in the range of 50–400 rem (0.5 to 4.0 Sv). Most of this information was gathered from the Japanese atomic bombing survivors and patients who were treated with substantial doses of X-rays. Conversely, information is limited, and therefore, it is difficult to estimate risks associated with low-level exposure. Risk can be defined in general as the probability (chance) of injury, illness, or death resulting from some activity. Low-dose effects are those that might be caused by doses of less than 20 rem (0.2 Sv), whether delivered acutely or spread out over a period as long as a year (Taylor 1996). Most of the radiation exposures that humans receive are very close to background levels. Moreover, many sources emit radiation that is well below natural background levels. This makes it extremely difficult to isolate its effects. For this reason, government agencies make the conservative (cautious) assumption that any increase in radiation exposure is accompanied by an increased risk of health effects. Cancer is considered by most scientists to be the primary health effect from long-term exposure to low levels of radiation while each radionuclide represents a somewhat different health risk. A 2011 report by the EPA estimated a 5.8×10^{-2} Gy^{-1} cancer mortality risk coefficient for uniform whole-body exposure throughout life at a constant dose rate. Given a 1 gray (100 rad) ionizing radiation lifetime exposure, this corresponds to 580 deaths, above normal cancer mortality rates, within an exposure group of 10,000 people. For low-linear energy transfer radiation (i.e., beta and gamma radiation) the dose equivalent in Sv (100 rem) is numerically equal to the absorbed dose in Gy (100 rad). Therefore, if each person in a group of 10,000 people is exposed to 1 rem (0.01 Sv) of ionizing radiation in small doses over a lifetime, we would expect around six people to die of cancer than would otherwise. For perspective, most people living on the eastern Snake River Plain receive approximately 376 mrem (3.8 mSv) every year from natural background sources of radiation.

DOE limits the dose to a member of the public from all sources and pathways to 100 mrem (1 mSv) and the dose from the air pathway to 10 mrem (0.1 mSv) (DOE O 458.1). The doses estimated to maximally exposed individuals from INL Site releases are typically well below 1 mrem per year.

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Acronyms:

AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AIP	Agreement-in-Principle
ALLWDF	active low-level waste disposal facility
ARIR	Administrative Record Information Repository
ARP	Accelerated Retrieval Project
ATR	Advanced Test Reactor
BBS	breeding bird survey
BCG	Biota Concentration Guide
BEA	Battelle Energy Alliance, LLC
BIL	Bipartisan Infrastructure Law
BLM	Bureau of Land Management
BMP	best management practices
BORAX	Boiling Water Reactor Experiment
BRR	Biological Resource Review
C&D	construction and demolition
CAA	Clean Air Act
CAP	criteria air pollutant
CAP88-PC	Clean Air Act Assessment Package-1988 computer model, PC
CARP	Climate Adaptation and Resilience Plan
CCA	Candidate Conservation Agreement
CEJST	Climate and Economic Justice Screening Tool
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
CITRC	Critical Infrastructure Test Range Complex
CRAC	computer room air conditioning
CRDB	Cultural Resources Database
CRMO	Cultural Resource Management Office
CRR	Cultural Resource Review
CTF	Contained Test Facility
CWA	Clean Water Act
CWP	Cold Waste Pond
D&D	decontamination and decommissioning
DCS	Derived Concentration Standard
DEQ	Department of Environmental Quality (state of Idaho)
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOECAP	U.S. Department of Energy Consolidated Audit Program
DOECAP-AP	U.S. Department of Energy Consolidated Audit Program-Accreditation Program
DOE-ID	U.S. Department of Energy, Idaho Operations Office
DOME	Demonstration of Microreactor Experiments
DOSEMM	dose multi-media
DQO	data quality objective
EA	Environmental Assessment
EAD	Environmental Assessment Determination
EBR-I	Experimental Breeder Reactor No. 1
EBR-II	Experimental Breeder Reactor No. 2
EC	Environmental Checklist
ECP	Environmental Compliance Permit
EFS	Experimental Field Station
EIS	Environmental Impact Statement
EJ	environmental justice
EJP	Environmental Justice Program
EMS	Environmental Management System
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPEAT	Electronic Product Environmental Assessment Tool
ERP	Environmental Review Process
ESA	Endangered Species Act
EV	electric vehicle
FEC	facility emission cap
FFA/CO	Federal Facility Agreement and Consent Order
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRM	form
FSV	Fort St. Vrain

FY	fiscal year
GHG	greenhouse gas
GIS	geographic information system
GPRS	Global Positioning Radiometric Scanner
HALEU	high-assay low-enriched uranium
HeTO	Heritage Tribal Office
HFC	hydrofluorocarbons
HFEF	Hot Fuel Examination Facility
HLW	high-level waste
HVAC	heating, ventilation, and air conditioning
HYSPLIT	Hybrid Single-particle Lagrangian Integrated Trajectory
ICDF	Idaho CERCLA Disposal Facility
ICP	Idaho Cleanup Project
ICPP	Idaho Chemical Processing Plant
IDAPA	Idaho Administrative Procedures Act
IDFG	Idaho Department of Fish and Game
IEC	Idaho Environmental Coalition, LLC
INEEL	Idaho National Engineering and Environmental Laboratory
INL	Idaho National Laboratory
INL Site Contractors	INL contractor and ICP contractor
INTEC	Idaho Nuclear Technology and Engineering Center (formerly Idaho Chemical Processing Plant)
IPDES	Idaho Pollutant Discharge Elimination System
IRC	INL Research Center
ISA	Idaho Settlement Agreement
ISB	in-situ bioremediation
ISU-EAL	Idaho State University-Environmental Assessment Laboratory
IWCS	Industrial Wastewater Collection System
IWP	Industrial Waste Pond
IWTU	Integrated Waste Treatment Unit
LAN	local area network
LED	light-emitting diode
LLW	low-level waste
LOFT	Loss-of-Fluid Test
LTS	Long-Term Stewardship
LTV	long-term vegetation
MAPEP	Mixed Analyte Performance Evaluation Program
MBTA	Migratory Bird Treaty Act
MCL	maximum contaminant level
MCLG	maximum contaminant level goals
MCP	management control procedure
MCRE	Molten Chloride Reactor Experiment
MEI	maximally exposed individual
MFC	Materials and Fuels Complex
MOU	memorandum of understanding
NA	not applicable
NAIP	National Agricultural Imagery Program
NAREL	National Analytical Radiation Environmental Laboratory
NASA	National Aeronautics and Space Administration
NCRP	National Council on Radiation Protection and Measurements
ND	not detected
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NHS	National and Homeland Security
NM	not measured
NOAA	National Oceanic and Atmospheric Administration
NON/CO	Notice of Noncompliance/Consent Order
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
NRF	Naval Reactors Facility
NRG	Natural Resources Group
NRHP	National Register of Historic Places
NRIC	National Reactor Innovation Center
NRTS	National Reactor Testing Station
NS	no sample
NSUF	National Scientific User Facility
O&M	Operations and Maintenance
OSLD	optically stimulated luminescence dosimeter
OU	Operable Unit
PA	Programmatic Agreement
PCB	polychlorinated biphenyls
PCC	Precontact Context
PCS	primary constituent standard
PE	performance evaluation
PFAS	perfluoroalkyl substances
PFBS	perfluorobutanesulfonic acid
PFHxS	perfluorohexanesulfonic acid
PFOA	perfluorooctanoic acid

PFOS	perfluorooctanesulfonic acid
PL	primary line
PT	performance testing
PTC	permit to construct
PWS	public water system
QA	quality assurance
QC	quality control
RBDA	risk-based disposal approval
RCL	Radioanalytical Chemistry Laboratory
RCRA	Resource Conservation and Recovery Act
REC	Research and Education Campus
RESL	Radiological and Environmental Sciences Laboratory
RHLLW	Remote-Handled Low-level Waste Disposal Facility
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RWMC	Radioactive Waste Management Complex
SARA	Superfund Amendments and Reauthorization Act
SBL	Southwestern Branch Line
SCS	Secondary Constituent Standard
SDA	Subsurface Disposal Area
SDWA	Safe Drinking Water Act
SGCA	Sage-grouse Conservation Area
SGCN	Species of Greatest Conservation Need
SGIN	Species of Greatest Information Need
SHPO	State Historic Preservation Office
SMC	Specific Manufacturing Capability
SMCL	secondary maximum contaminant level
SME	subject matter expert
SNF	spent nuclear fuel
SSER	Sagebrush Steppe Ecosystem Reserve
STEAM	science, technology, engineering, arts, and mathematics
STEM	science, technology, engineering, and mathematics
STP	Sewage Treatment Plant
TAN	Test Area North
TCE	trichloroethylene
TFF	Tank Farm Facility
TMI	Three Mile Island
TRA	Test Reactor Area
TREAT	Transient Reactor Experiment and Test Facility
TRISO	tri-isotropic
TRU	transuranic
TSCA	Toxic Substances Control Act
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTL	upper tolerance limit
VOC	volatile organic compound
WAG	waste area group
WFMC	Wildland Fire Management Committee
WIPP	Waste Isolation Pilot Plan
XRF	x-ray fluorescence spectroscopy
YOY	year-over-year
ZEV	zero-emission vehicle

Sagebrush Rockcress


Units:

Bq	becquerel
C	Celsius
cfm	cubic feet per minute
CFU	colony forming unit
Ci	curie
cm	centimeter
cps	counts per second
d	day
F	Fahrenheit
ft	feet
g	gram
gal	gallon
Gy	gray
ha	hectare
keV	kilo-electron-volts
kg	kilograms (10^3) gram
km	kilometer (10^3) meter
L	liter
lb	pound
m	meter
μCi	microcurie (10^{-6}) curies
μg	microgram (10^{-6}) grams
μR	microroentgen (10^{-6}) roentgen
μS	microsiemen (10^{-6}) siemen
μSv	microsievert (10^{-6}) sievert
Ma	million years
mCi	millicurie (10^{-3}) curies
MeV	mega electron volt
mg	milligram (10^{-3}) grams
MG	million gallons
mGy	milligray (10^{-3}) gray
Ml	million liters
mi	mile
min	minute
mL	milliliter (10^{-3}) liter
mR	milliroentgen (10^{-3}) roentgen
mrad	milliard (10^{-3}) rad
mSv	millisievert (10^{-3}) sievert
oz	ounce
pCi	picocurie (10^{-12} curies)
R	roentgen
rad	radiation absorbed dose
rem	roentgen equivalent man
Sv	sievert
yd	yard
yr	year

Stacked rock feature found on the INL Site.

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