









Calendar Year 2012

Idaho National Laboratory Site

Site Environmental Report

Environmental Surveillance, Education, and Research Program

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IDAHO NATIONAL LABORATORY

SITE ENVIRONMENTAL REPORT

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U.S. Department of Energy, Idaho Operations Office

September 2013

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To Our Readers

The Idaho National Laboratory Site Environmental Report for Calendar Year 2012 is an overview of environmental management activities conducted on and in the vicinity of the Idaho National Laboratory (INL) Site from January 1 through December 31, 2012. This report includes:

- 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/or applicable standards and requirements in order 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 impacted by INL Site operations.
- Ecological and other scientific research conducted on the INL Site which may be of interest to the reader.

The report addresses three general levels of reader interest:

- The first 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. A lay person with little knowledge of science may comfortably read the Chapter Highlights.
- 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 results. The links to these reports may be found on this page or in the CD provided with the hard copy of this report.

In addition to the Environmental Surveillance, Education, and Research Program, which is managed by Gonzales-Stoller Surveillance, LLC, the contributors to the annual report include Battelle Energy Alliance (BEA), CH2M-WG Idaho (CWI), Department of Energy, Idaho Operations Office (DOE-ID), National Oceanic and Atmospheric Administration (NOAA), and U.S. Geological Survey (USGS). Links to their websites may be found on this page or in the CD provided with the hard copy of this report.

- Idaho National Laboratory (https://inlportal.inl.gov/portal/server.pt/community/home/255)
- Idaho Cleanup Project (https://idahocleanupproject.com/)
- Department of Energy, Idaho Operations Office (http://www.id.doe.gov/)
- Field Research Division of NOAA’s Air Resources Laboratory (http://www.noaa.inel.gov/)
- U.S. Geological Survey (http://id.water.usgs.gov/)

Woven throughout this report are historic and current photographs of late 19th and early 20th century INL Site artifacts, archaeological sites, structures, and objects. The photographs were taken by the INL Cultural Resource Management Office staff, former and present, unless otherwise noted. The report header is a 1993 photograph of a wagon train reenactment crossing Goodale's Cutoff near the INL Site's southern border. The California-Oregon Trails Association organized the event to mark the 150th anniversary of the opening of the Oregon Trail.

Big Lost River Diversion Dam

Executive Summary

Introduction

In operation since 1949, the Idaho National Laboratory (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 percent the size of Rhode Island. It was established in 1949 as the National Reactor Testing Station, and for many years was the site of the largest concentration of nuclear reactors in the world. Fifty-two nuclear reactors were built, including the Experimental Breeder Reactor Number 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 the INL is a science-based, applied engineering national laboratory dedicated to supporting the DOE's missions in nuclear and energy research, science, and national defense. The INL mission is to ensure the nation's energy security with safe, competitive, and sustainable energy systems and unique national and homeland security capabilities.

Figure ES-1. Regional location of the Idaho National Laboratory Site.

In order to clear the way for the facilities required for the new nuclear energy research mission, the Idaho Cleanup Project (ICP) has been charged with the environmental cleanup of the legacy wastes generated from World War II-era conventional weapons testing, government-owned reactors, spent fuel reprocessing, and nuclear and alternative energy research. The overarching aim of the project is to reduce risks to workers, the public, and the environment and to protect the Snake River Plain aquifer. A great deal of this cleanup has occurred since 2005. Significantly, the ICP Decontamination and Decommissioning Project was officially closed out in 2012 with the safe decontamination and decommissioning of 223 buildings and structures for a total footprint reduction of over 1.6 million square feet.

Purpose of the INL Site Environmental Report

The INL Site's operations, as well as the ongoing cleanup, necessarily 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." Its purpose is to:

- Present the INL Site, mission, and programs
- Report compliance status with all 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 at the Idaho National Environmental Research Park
- Describe quality assurance methods used to ensure confidence in monitoring data.

Major INL Site Programs and Facilities

There are three primary programs at the INL Site: the INL, the ICP, and the Advanced Mixed Waste Treatment Project (AMWTP). DOE is committed to safely retrieve, characterize, treat, and package transuranic waste for shipment out of Idaho to permanent disposal at the Waste Isolation Pilot Plant in New Mexico. Characterized waste containers that need further treatment before they can be shipped are sent to the AMWTP Treatment Facility where the waste can be size-reduced, sorted, and repackaged.

The prime contractors at the INL Site are: Battelle Energy Alliance, the management and operations contractor for the INL; CH2M-WG Idaho, LLC, which manages ongoing cleanup operations under the ICP; and Idaho Treatment Group, LLC, which operates AMWTP.

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 the city of Idaho Falls, some 25 miles east of the INL Site border. About 30 percent of employees work in administrative, scientific support, and non-nuclear laboratory programs and have offices in Idaho Falls.

The Advanced Test Reactor

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 (Figure ES-2). The Research and Education Campus is located in Idaho Falls. The major facilities and their missions are outlined in Table ES-1.

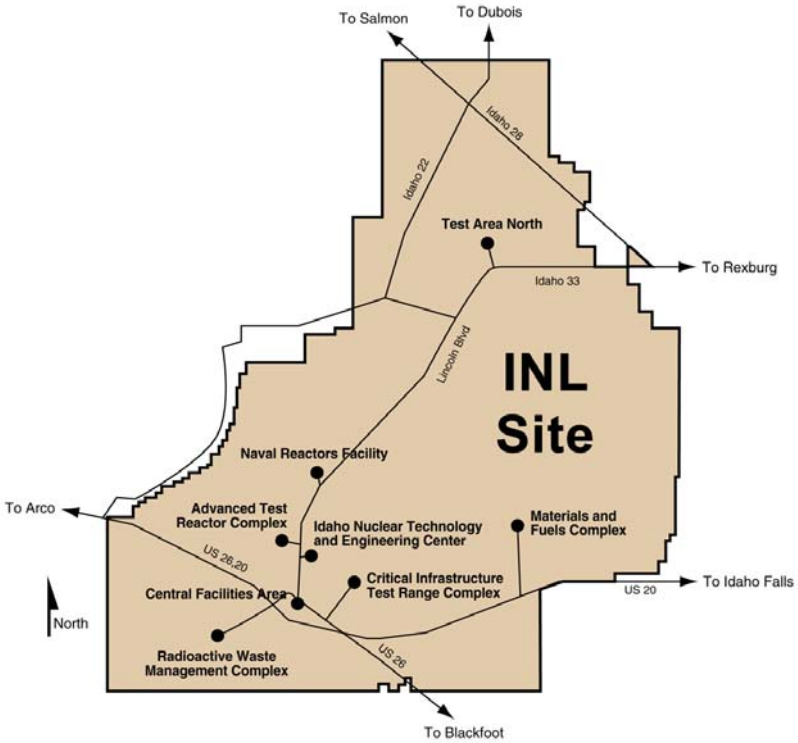


Figure ES-2. Idaho National Laboratory Site Facilities.

Table ES-1. Major INL Site Areas and Missions.

Major INL Site Area[1]	Operated By	Mission
Advanced Test Reactor (ATR) Complex	INL	Research and development of nuclear reactor technologies. Home of the ATR, a DOE National Scientific User Facility and the world's most advanced nuclear test reactor.
Central Facilities Area (CFA)	INL	Support for the operation of other INL Site facilities.
Critical Infrastructure Test Range Complex (CITRC)	INL	Supports 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 (INTEC)	ICP	Dry and wet 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 Disposal Facility including a landfill, evaporation ponds, and a staging and treatment facility.
Materials and Fuels Complex (MFC)	INL	Focuses on research and development of nuclear fuels. Pyroprocessing, which uses electricity to separate waste products in the recycling of nuclear fuel, is also researched here. Nuclear batteries for use on the nation's space missions are made at MFC.
Radioactive Waste Management Complex (RWMC)	ICP	Environmental remediation; and waste treatment, storage, and disposal for wastes generated at the INL Site and other DOE sites. Advanced Mixed Waste Treatment Project (AMWTP), operated by Idaho Treatment Group, LLC, and co-located with RWMC, characterizes, treats, and packages transuranic waste for shipment out of Idaho to permanent disposal facilities.
Research and Education Campus (REC)	INL	Located in Idaho Falls, is home to INL administration, the INL Research Center (IRC), the Center for Advanced Energy Studies (CAES), and other energy and security research programs. Research is conducted at IRC in robotics, genetics, biology, chemistry, metallurgy, computational science, and hydropower. CAES is a research and education partnership between Boise State University, INL, Idaho State University, and University of Idaho to conduct energy research and address the looming nuclear energy work-force shortage.
Test Area North (TAN)/Specific Manufacturing Capability (SMC)	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 manufacture of tank armor for the U.S. Army's battle tanks at the SMC for the U.S. Department of Defense.

1 The Naval Reactors Facility (NRF) is also located on the INL Site. It is operated for Naval Reactors by Bechtel Marine Propulsion Corporation. The Naval Nuclear Propulsion Program is exempt from DOE requirements and is therefore not addressed in this report.

Environmental Protection Programs

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, radioactive waste management, and radiation protection of the public and biota.

The Center for Advanced Energy Studies

Battelle Energy Alliance, CH2M-WG Idaho, LLC, and Idaho Treatment Group have each established and implemented an EMS and contribute 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 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. In 2012, the INL Site as a whole achieved reductions in energy, water, and fossil fuel usage, decreased greenhouse gas emissions, and increased alternative fuels usage.

An essential element for the successful implementation of the INL Site EMSs is the Pollution Prevention Program, which incorporates national and DOE requirements to reduce, reuse, and recycle wastes and pollutants as an integral part of the site's operating philosophy.

INL Site radioactive waste management involves four types of radioactive wastes: low-level, mixed (hazardous and radioactive), transuranic, and high-level radioactive wastes. Significant accomplishments during 2012 include the shipment of treated transuranic waste to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, for disposal. The mixed low-level waste and low-level waste were sent to Nevada Test Site or to commercial facilities.

The INL Site met all DOE public and biota dose limits for radiation protection in 2012.

Environmental Restoration

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 U.S. Environmental Protection Agency (EPA). The Consent Order governs the INL Site's environmental remediation. It specifies actions that must be complete to safely clean up past release sites at the INL Site

in compliance with the CERCLA. 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 within each WAG called operable units. Since the FFA/CO was signed in 1991, the INL Site has cleaned up release 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 implemented at five WAGs. In 2012, all institutional controls and operational and maintenance requirements were maintained and active remediation continued on WAGs 1, 3, 7, and 6/10.

Radiation Dose to the Public and Biota from INL Site Releases

Humans, plants, and animals potentially receive radiation doses from various INL Site operations. The DOE sets dose limits for the public and biota to ensure that exposure to radiation from site operations are 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 ES-2). The calculated dose to the maximally exposed individual in 2012 was 0.036 mrem (.00036 mSv), 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. This person was assumed to live just south of the INL boundary. For comparison, the dose from natural background radiation was estimated in 2012 to be 390 mrem (3.9 mSv).

Table ES-2. Contribution to Estimated Dose to a Maximally Exposed Individual by Pathway (2012).

Pathway	Dose to Maximally Exposed Individual (mrem)	Dose to Maximally Exposed Individual (mSv)	Percent of DOE 100-mrem/yr Dose Limit[a]	Estimated Population Dose (person-rem)	Estimated Population Dose (person-Sv)	Population within 80 km	Estimated Background Radiation Population Dose (person-rem)[b]
Air	0.036	0.00036	0.036	0.2	0.002	309,730	120,795
Waterfowl ingestion	0.009	0.00009	NA[c]	NA	NA	NA	NA
Big game animals	NC[d]	NC[d]	NA	NA	NA	NA	NA
Total pathways	0.045	0.00045	0.045	NA	NA	NA	NA

a. The EPA regulatory standard for the air pathway is 10 mrem/yr effective dose. The DOE limit for all pathways is 100 mrem/yr total effective dose.

b. The individual dose from background was estimated to be 390 mrem (3.9 mSv) in 2012 (Table 7-4).

c. NA = Not applicable

d. NC = Not calculated. No human-made radionuclides were detected in the samples analyzed this year.

The maximum potential population dose to the approximately 309,730 people residing within an 80-km (50-mi) radius of any INL Site facility was calculated as 0.2 person-rem (0.002 person-Sv), below that expected from exposure to background radiation (120,795 person-rem or 1,208 person-Sv).

The maximum potential individual dose from consuming waterfowl at the INL Site, based on the highest concentrations of radionuclides measured in samples of these animals, was estimated to be 0.009 mrem (0.00009 mSv). There were no gamma-emitting radionuclides detected in big game animals collected in 2012 and, therefore, no dose was estimated for this pathway. When the dose from waterfowl ingestion was summed with the dose estimated for the air pathway, the maximally exposed individual could potentially receive a total dose of 0.045 mrem (0.00045 mSv) in 2012. This is 0.045 percent 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 U.S. Geological Survey (USGS) monitoring wells located along the southern INL Site boundary. A hypothetical individual drinking water from these wells would receive a dose of less than 0.2 mrem (0.002 mSv) in one year. This is an unrealistic pathway to humans as there are no drinking water wells located along the southern boundary of the INL Site. The maximum contaminant level established by EPA for tritium corresponds to a dose of approximately 4 mrem (0.04 mSv).

Doses were also evaluated using a graded approach for nonhuman biota at the INL Site. Maximum concentrations of radionuclides measured in waterfowl tissue were used to estimate doses to those wildlife accessing ATR Complex ponds. Ducks were estimated to receive less than the standard of 1 rad/d (1 mGy/d) established by DOE for aquatic biota. Based on the calculations, there is no evidence that INL Site-related radioactivity in soil or water is harming populations of plants or animals.

Environmental Compliance

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. Overall, the INL Site met all federal, state, and local regulatory commitments in 2012. There were no reportable environmental occurrences or unplanned releases in 2012.

Environmental Monitoring of Air

Airborne releases from INL Site operations are reported annually in a document prepared in accordance with the Code of Federal Regulations, Title 40, “Protection of the Environment,” Part 61, “National Emission Standards for Hazardous Air Pollutants,” Subpart H, “National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities.” An estimated total of 2,930 curies of radioactivity, primarily in the form of short-lived noble gas isotopes, were released as airborne effluents in 2012. The highest releases were from INTEC (47 percent of total), the ATR Complex (41 percent of total) and RWMC (12 percent of total.)

The INL Site environmental surveillance programs, conducted by the INL, ICP, and the Environmental Surveillance, Education and Research (ESER) contractors, emphasize measurement of airborne radionuclides because air transport is considered the major potential pathway from INL Site releases to human receptors. During 2012, the INL contractor monitored ambient air outside 17 INL Site facilities and at four locations off the INL Site. The ICP contractor focused on ambient air monitoring of waste management facilities, namely INTEC and the RWMC. The ESER contractor sampled ambient air at three locations on the INL Site, at seven locations bounding the INL Site, and at six locations distant from the INL Site.

Air Sample Collection

Air particulate samples were collected weekly by the ESER and INL contractors and bimonthly by the ICP contractor. These samples were then analyzed for gross alpha and gross beta activity. Charcoal cartridges were also collected weekly or bimonthly and analyzed for radioiodine. The particulate samples were combined into monthly, quarterly, or semiannual composite samples by the ICP, ESER, and INL contractors, respectively, and were analyzed for gamma-emitting radionuclides, such as cesium-137. Particulate filters were also composited quarterly by the ICP and ESER contractors and analyzed for specific alpha- and beta-emitting radionuclides, specifically strontium-90, plutonium-238, plutonium-239/240, and americium-241.

All radionuclide concentrations in ambient air samples were below DOE radiation protection standards for air and were within historical measurements. In addition, gross alpha and gross beta concentrations were analyzed statistically, and there were no differences between samples collected on the INL Site, at the INL Site boundary, and off the INL Site. Trends in the data appear to be seasonal in nature and do not demonstrate any INL Site influence. This indicates that INL Site airborne effluents were not measureable in environmental air samples.

The INL and ESER contractors also collected atmospheric moisture samples at three stations on and five stations off the INL Site. In addition, the ESER contractor sampled precipitation at two stations on the INL Site and one location off the INL Site. These samples were all analyzed for tritium. The results were within measurements made historically and by the EPA and were below DOE 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 for Compliance Purposes

The INL and ICP contractors monitor liquid effluents, drinking water, groundwater, and storm water runoff at the INL Site, primarily for nonradioactive constituents, to comply with applicable laws and regulations, DOE orders, and other requirements.

Wastewater is typically discharged from INL Site facilities to the ground surface. Wastewater discharges occur at percolation ponds southwest of INTEC, a cold waste pond at the ATR Complex, and a sewage treatment facility at CFA. These effluents are regulated by the state of Idaho groundwater quality and wastewater rules through wastewater reuse permits, which require monitoring of the wastewater and, in some instances, groundwater in the area. During 2012, liquid effluent and groundwater monitoring were conducted in support of wastewater reuse permit requirements. An annual report for each permitted facility was prepared and submitted to the Idaho Department of Environmental Quality. No permit limits were exceeded.

Additional liquid effluent monitoring was performed at ATR Complex, CFA, INTEC, and MFC to comply with environmental protection objectives of DOE orders. Most results were within historical measurements. All radioactive parameters were below health-based contaminant levels.

Drinking water parameters are regulated by the state of Idaho under authority of the Safe Drinking Water Act. Drinking water was sampled in nine drinking water systems at the INL Site in 2012. Results were below limits for all relevant drinking water standards. The CFA distribution system serves 600 workers daily and is downgradient from an historic groundwater plume of radionuclides resulting from wastewater injection by INTEC and the ATR Complex directly into the aquifer. Because of this, a dose was calculated to a worker who might obtain all their drinking water from the CFA drinking water system during 2012. The dose, 0.21 mrem (0.0021 mSv), is below the EPA standard of 4 mrem/yr (0.04 mSv/yr) for public drinking water systems.

Surface water flows off the 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. Americium-241, plutonium-238, plutonium-239/240, and strontium-90 were detected within historical levels. The detected concentrations are well below standards established by DOE for radiation protection of the public and the environment.

Environmental Monitoring of the Eastern Snake River Plain Aquifer

The eastern Snake River Plain aquifer beneath the eastern Snake River Plain is perhaps the single-most important aquifer in Idaho. Composed of layered basalt lava flows and some sediment, it covers an area of approximately 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 USGS began to monitor 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 utilize an extensive network of strategically placed monitoring wells on and around the INL. In 2012, 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 and the ATR Complex. Results for monitoring wells sampled within the plumes show decreasing concentrations of tritium and strontium-90 over time.

Several purgeable organic compounds were detected by USGS in the 28 wells monitored at the INL Site. The concentration of tetrachloromethane (carbon tetrachloride) was above the EPA maximum contaminant level in one production well at the RWMC during 2012. Concentrations of most other organic compounds and trace elements detected were below their respective primary contaminant standards.

Groundwater surveillance monitoring continued for the CERCLA WAGs on the INL Site in 2012. At TAN (WAG 1), results of groundwater monitoring indicated that in situ bioremediation of the plume of trichloroethene has been effective. Data from groundwater in the vicinity of the ATR Complex (WAG 2) show declining concentrations of chromium, strontium-90, and tritium. Groundwater samples collected from aquifer and perched water monitoring wells at and near INTEC (WAG 3) had three constituents which exceeded drinking water maximum contaminant levels: strontium-90, technetium-99 and nitrate. The source of strontium-90 is past disposal of service waste to the injection well at INTEC. Technicium-99 is from past releases from the INTEC Tank Farm. The presence of elevated nitrate is attributed to past Tank Farm releases and has remained relatively constant over the past few years at INTEC. Strontium-90, technicium-99, and nitrate show stable or declining trends. Monitoring of groundwater for the CFA landfills (WAG 4) consists of sampling wells for metals, volatile organic compounds, and anions. Five organic compounds were detected in groundwater downgradient of the CFA, at levels well below the established EPA maximum concentrations levels. Nitrate exceeded its maximum contaminant level in 2012, but the concentration was within historic levels. None of the organic compounds exceeded any EPA maximum contaminant level. At the RWMC (WAG 7), carbon tetratchloride slightly exceeded its maximum contaminant level in one aquifer well north of the facility in 2012. Wells at the MFC (WAG 9) are sampled for radionuclides, metals, total organic carbon, total organic halogens, and other water quality parameters. Overall, the results show no evidence of impacts from MFC activities.

Groundwater Sample Collection

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 only one sample collected in the spring, but in about half of the samples collected in the fall of 2012. The results were well within historical

measurements and below the EPA maximum contaminant level. Gross alpha and beta results were within historical measurements. The Big Lost River was also sampled, and none of the detected constituents exceeded maximum contaminant limits and were below measurements made in 2011.

Monitoring of Agricultural Products, Wildlife, and Direct Radiation Measurements

To help assess the impact of contaminants released to the environment by operations at the INL Site, agricultural products (milk, lettuce, wheat, and potatoes) and wildlife were sampled and analyzed for radionuclides in 2012. The agricultural products were collected on, around and distant from the INL Site by the ESER contractor. Wildlife sampling included collection of ducks from wastewater ponds in the vicinity of the ATR Complex and the MFC, as well as big game animals killed by vehicles on roads within the INL Site. In addition, direct radiation was measured on and off the INL Site in 2012.

Some human-made radionuclides were detected in agricultural product and waterfowl samples. However, measurements were consistent with those made historically. No human-made radionuclides were detected in the big game animals sampled in 2012. Direct radiation measurements made at offsite, boundary, and onsite locations were consistent with historical and/or natural background levels.

Monitoring of Wildlife Populations

Field data are routinely collected on several key groups of wildlife at the INL Site for information that can be used to prepare National Environmental Policy Act documents and to enable DOE to make informed decisions for planning projects and compliance with environmental policies and executive orders related to protection of wildlife. Surveys are routinely conducted on bird, big game, and bat populations on the INL Site. Monitoring in 2012 included the midwinter eagle survey, sage-grouse lek surveys, and a breeding bird survey. During 2012 permanent bat monitoring stations were established at the INL Site.

Environmental Research at the Idaho National Environmental Research Park at the INL Site

In 1975, the mostly pristine land within the INL Site's borders became DOE's second National Environmental Research Park. All lands within the Park serve as an ecological field laboratory where scientists from government agencies, universities, and private foundations may set up long-term research. This research has covered a broad range of topics and issues from studies on the basic ecology of native sagebrush steppe organisms to the

Idaho National Environmental Research Park

potential natural pathways of radiological materials through the environment, and even to highly applied research on the design of landfill covers that prevent water from reaching buried waste. The research topics have included native plants and wildlife as well as attempts to understand and control non-native, invasive species. The Park also provides interpretation of research results to land and facility managers to support the National Environmental Policy Act process natural resources management, radionuclide pathway analysis, and ecological risk assessment.

The Idaho National Environmental Research Park maintains several regionally and nationally important long-term ecological data sets. It is home to one of the largest data sets on sagebrush steppe vegetation anywhere. In 1950, 100 vegetation plots were established on the INL Site and were originally designed to look for the potential effects of nuclear energy research on native vegetation. Since then the plots have been surveyed about every 5 to 7 years.

In 2012, six major ecological research projects took place on the Idaho National Environmental Research Park. The researchers were from Idaho State University, Boise State University; Montana State University; Texas A&M; Washington State University; Environmental Surveillance, Education, and Research Program; Wildlife Conservation Society; and U.S. Department of Agriculture.

USGS Research

The USGS INL Project Office drills and maintains research wells which 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 2012, the USGS published six research reports.

Quality Assurance

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

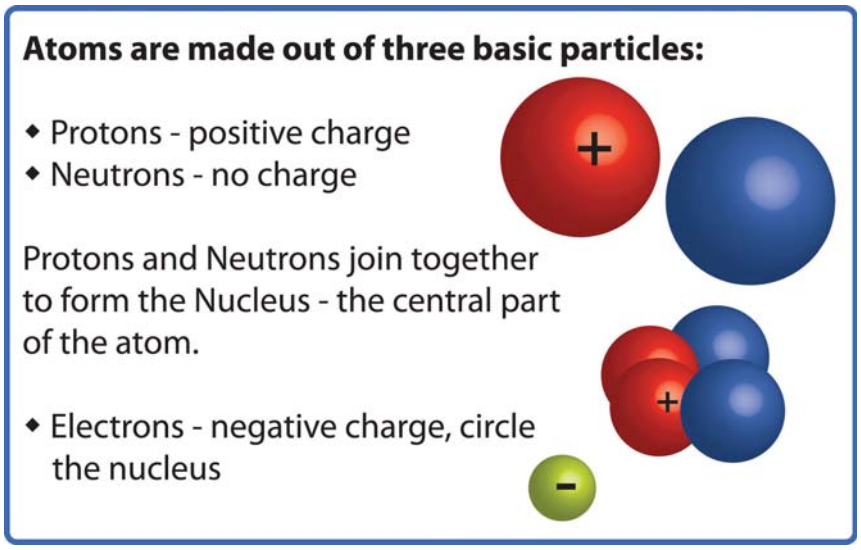
Adherence to procedures and quality assurance project plans was maintained during 2012. Data reported in this document were obtained from several commercial, university, government, and government contractor laboratories. To assure quality results, these laboratories participated in a number of laboratory quality check programs. Quality issues that arose with laboratories used by the INL, ICP and ESER contractors during 2012 were addressed with the laboratories and have been or are being resolved.

Helpful Information

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.

What is Radiation?

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 ejected electrons and associated positively charged atoms are called "ions," and the energetic radiation that produced the ions is called "ionizing" radiation. Ionizing radiation is referred to simply as "radiation" in the rest of 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 radiowaves, 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 plus two. Because alpha particles are relatively heavy and have a double charge, they cause intense tracks of ionization, but have little penetrating ability (Figure HI-1). Alpha particles can be stopped by thin layers of materials, such as a sheet of paper or piece of aluminum foil. Alpha particles can be detected in samples containing 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 (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.

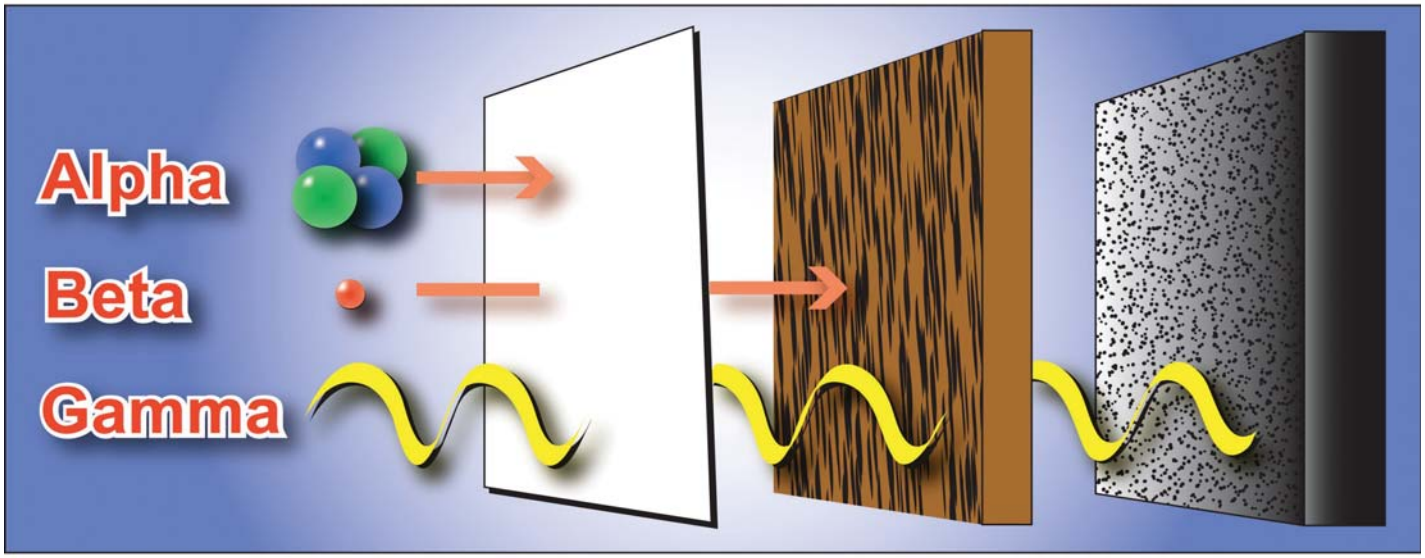


Figure HI-1. Comparison of Penetrating Ability of Alpha, Beta, and Gamma Radiation.

X-Rays and Gamma-Rays. X-rays and gamma-rays are photons that have very short wavelengths 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 only 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 depends 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 (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.

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. The 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.

Table HI-1. Radionuclides and Their Half-lives.

Symbol	Radionuclide	Half-life[a,b]	Symbol	Radionuclide	Half-life
^{241}Am	Americium-241	432.2 yr	^{54}Mn	Manganese-54	312.5 d
^{243}Am	Americium-243	7,380 yr	^{59}Ni	Nickel-59	7.5×10^{4} yr
^{125}Sb	Antimony-125	2.77 yr	^{63}Ni	Nickel-63	96 yr
^{41}Ar	Argon-41	1.827 hr	^{238}Pu	Plutonium-238	87.74 yr
^{137m}Ba	Barium-137m	2.552 min	^{239}Pu	Plutonium-239	2.4065×10^{4} yr
^{140}Ba	Barium-140	12.74 d	^{240}Pu	Plutonium-240	6.537×10^{3} yr
^{7}Be	Beryllium-7	53.3 d	^{241}Pu	Plutonium-241	14.4 yr
^{14}C	Carbon-14	5,730 yr	^{242}Pu	Plutonium-242	3.763×10^{5} yr
^{141}Ce	Cerium-141	32.5 d	^{40}K	Potassium-40	1.28×10^{9} yr
^{144}Ce	Cerium-144	284.3 d	^{226}Ra	Radium-226	1.62×10^{3} yr
^{134}Cs	Cesium-134	2.062 yr	^{228}Ra	Radium-228	5.75 yr
^{137}Cs	Cesium-137	30.0 yr	^{220}Rn	Radon-220	55.6 s
^{51}Cr	Chromium-51	27.704 d	^{222}Rn	Radon-222	3.8235 d
^{60}Co	Cobalt-60	5.271 yr	^{103}Ru	Ruthenium-103	39.28 d
^{152}Eu	Europium-152	13.33 yr	^{106}Ru	Ruthenium-106	368.2 d
^{154}Eu	Europium-154	8.8 yr	^{90}Sr	Strontium-90	29.12 yr
^{3}H	Tritium	12.35 yr	^{99}Tc	Technetium-99	2.13×10^{5} yr
^{129}I	Iodine-129	1.57×10^{7} yr	^{232}Th	Thorium-232	1.405×10^{10} yr
^{131}I	Iodine-131	8.04 d	^{233}U	Uranium-233	1.585×10^{5} yr
^{55}Fe	Iron-55	2.7 yr	^{234}U	Uranium-234	2.445×10^{5} yr
^{59}Fe	Iron-59	44.529 d	^{235}U	Uranium-235	7.038×10^{8} yr
^{85}Kr	Krypton-85	10.72 yr	^{238}U	Uranium-238	4.468×10^{9} yr
^{87}Kr	Krypton-87	1.27 hr	^{90}Y	Yttrium-90	64.0 hr
^{88}Kr	Krypton-88	2.84 hr	^{65}Zn	Zinc-65	243.9 d
^{212}Pb	Lead-212	10.64 hr	^{95}Zr	Zirconium-95	63.98 d

a. From EPA (1999).

b. d = days; hr = hours; min = minutes; s = seconds; yr = years.

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 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 and beta-emitting radioactivity in air samples is frequently measured to screen for the 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 (G-M) counter. However, detection of specific beta-emitting radionuclides, such as ^{3}H and strontium-90 (^{90}Sr), requires chemical separation first.

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 cesium-137 (^{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 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}. To convert this number to its decimal form, the decimal point is moved left by the number of

places equal to the exponent (six, in this case). 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.

Units of Radioactivity. The basic unit of radioactivity used in this report is the curie (abbreviated Ci). The curie is based on the disintegration rate occurring in 1 gram of the radionuclide radium-226 (^{226}Ra), which 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 air, is measured in terms of the roentgen (R). Dose is a general

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

Table HI-3. Names and Symbols for Units of Radioactivity, Exposure, 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
Gy	Gray (100 rad)
mGy	Milligray (100 mrad)
Sv	Sievert (100 rem)
mSv	Millisievert (100 mrem)

term to express how much radiation energy is deposited in something. The energy deposited can be expressed in terms of absorped, equivalent, and/or 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 takes into account the effect of different types of radiation on tissues and therefore the potential for biological effects, is expressed as the roentgen 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.

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 and sievert (Sv) for effective dose, where 1 Sv equals 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

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 gram (pCi/g) 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

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 which is preceded by the plus or minus symbol, ± (e.g., 10 ± 2 pCi/L). For concentrations of greater than or equal to three times the uncertainty, there is 95 percent 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, that 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 and/or instrumentation used.

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 data set. 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 the 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 illustrates the minimum, maximum, and median of a set of air measurements. The vertical lines drawn above and below the median represent the range of values between the minimum and maximum results.

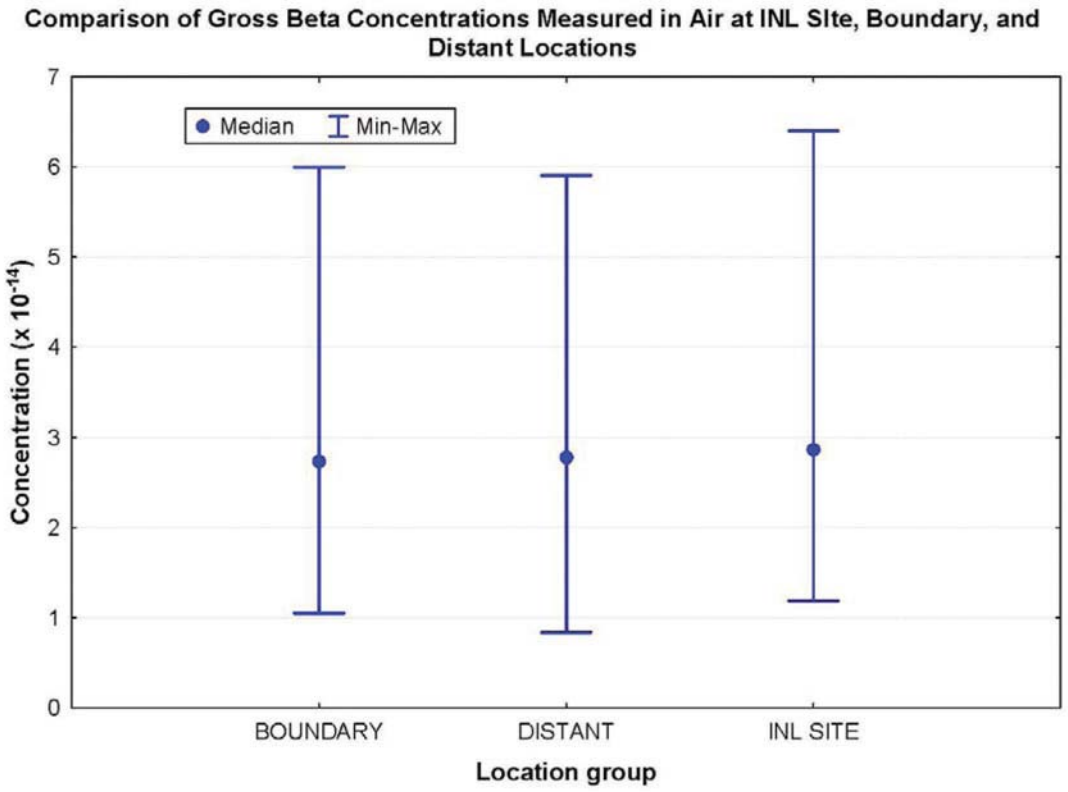


Figure HI-2. A Graphical Representation of Minimum, Median, and Maximum Results.

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 upper right-hand corner of the figure. The medical, consumer, and occupational/industrial portions are from National Council on Radiation Protection and Measurements Report No. 160 (NCRP 2009). The contribution from background (natural radiation, mostly radon) is estimated in Table 7-5 of this report.

A **column or bar chart** can show data changes over a period of time or illustrate comparisons among items. Figure HI-4 illustrates the contribution of radionuclides released into air from INL Site operations from 1975 through 1984 to the dose (mrem) calculated for the maximally exposed individual. The maximally exposed individual is a hypothetical member of

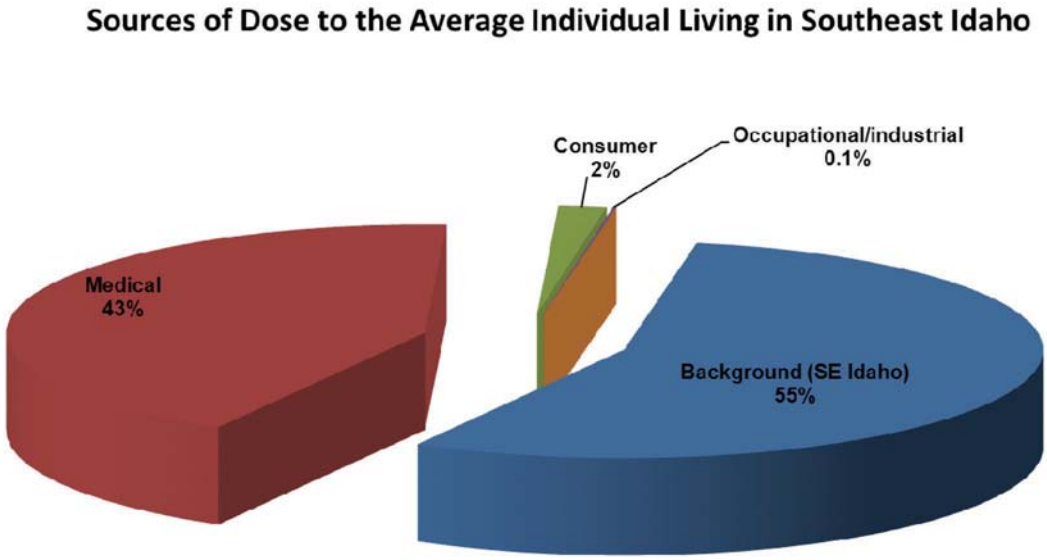


Figure HI-3. Data Presented Using a Pie Chart.

the public who is exposed to radionuclides from airborne releases through various environmental pathways and the media through which the radionculides are transported (i.e., air, water, and food). One column (red) represents the annual dose from krypton-88 (^{88}Kr) released. The second column (green) plots the annual dose from all radionuclides released into the air. The chart shows the general decreasing trend of the dose as well as the relative contribution to dose from the ^{88}Kr. The relative contribution to the total dose from ^{88}Kr varies over time. For example, it represents approximately one-third of the total dose in 1975 and a little over one-half of the dose in 1976.

A **plot** can be useful to visualize differences in results over time. Figure HI-5 shows the median, minimum, and maximum results of gross beta measurements in all air filters collected by the Environmental Surveillance, Education, and Research contractor for the previous ten years (2002 through 2011). The results are plotted by the week of the year. Thus, the median for each week represents the midpoint of measurements made at all locations during the ten-year period for that week. The plot shows that the results can vary greatly, particularly during the winter.

Contour lines are sometimes drawn on a map to discern patterns over a geographical area. For example, Figure HI-6 shows the distribution of ^{3}H in groundwater around the Idaho Nuclear Technology and Engineering Center (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

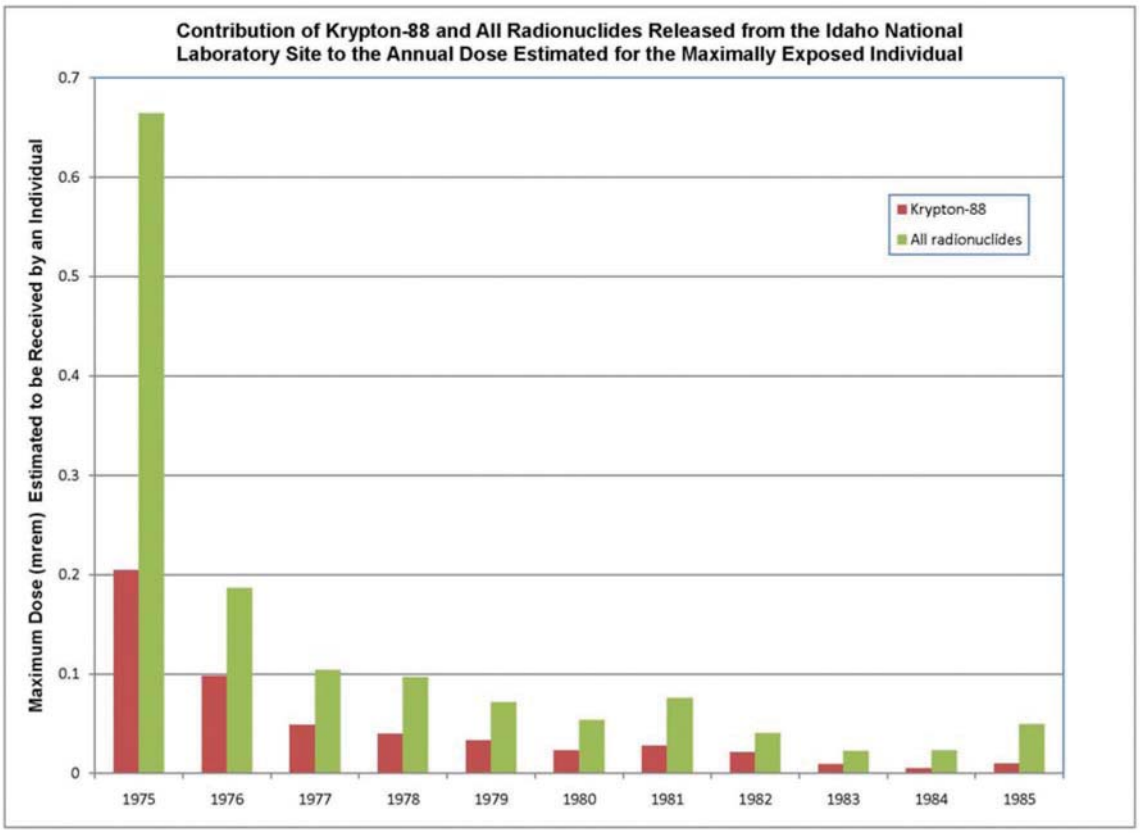


Figure HI-4. Data Plotted Using a Column Chart.

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:

- Comparison of results collected at different locations. For example, measurements made at INL Site locations are compared with those made at locations near the boundary of the INL Site and distant from the INL Site 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,

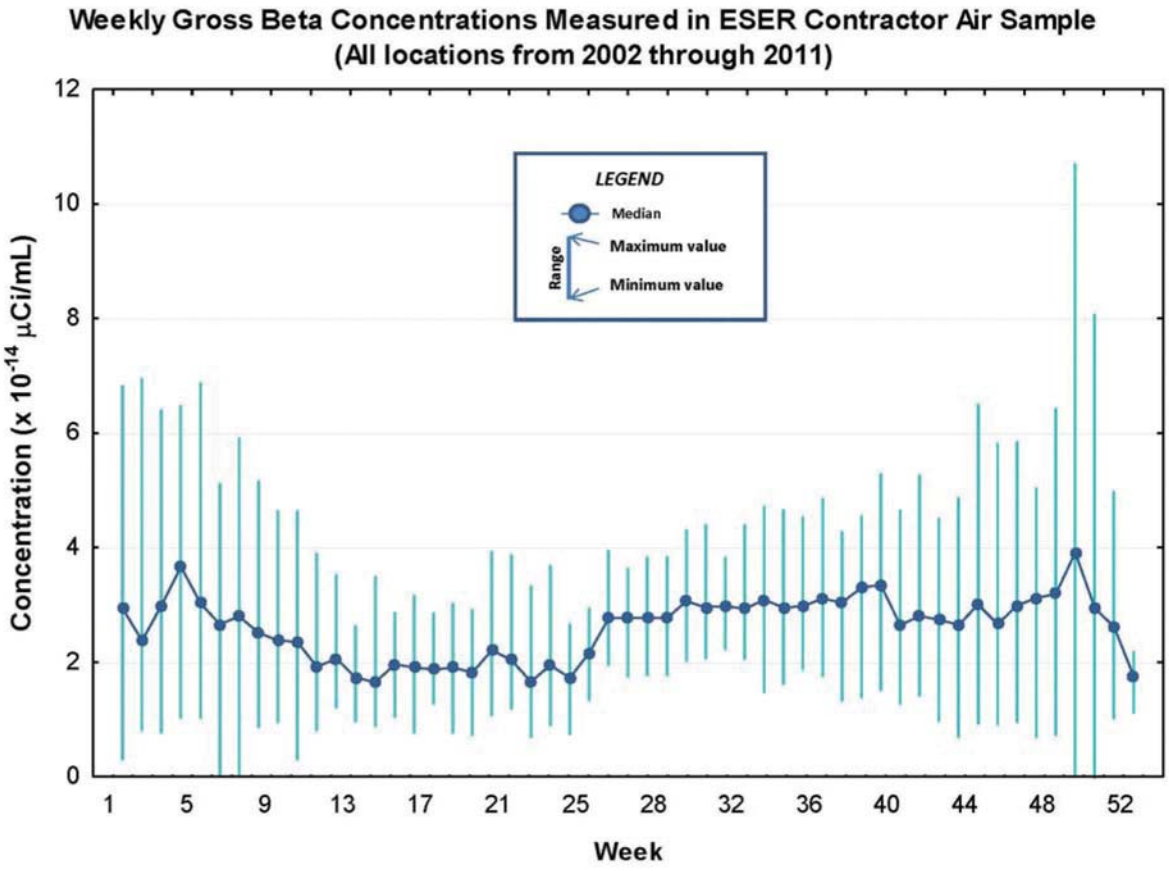


Figure HI-5. Data Plotted Using a Linear Plot.

which shows a general decrease in dose over time. 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.

What is Background Radiation?

Radioactivity from natural and fallout sources is detectable as “background” in all environmental media. Natural sources of radiation include: radiation of extraterrestrial origin (called cosmic rays), radionuclides produced in the atmosphere by cosmic ray interaction with matter (called cosmogenic radionuclides), and radionuclides present at the time of the formation of the earth (called primordial radionuclides). Radiation that has resulted from the activities of

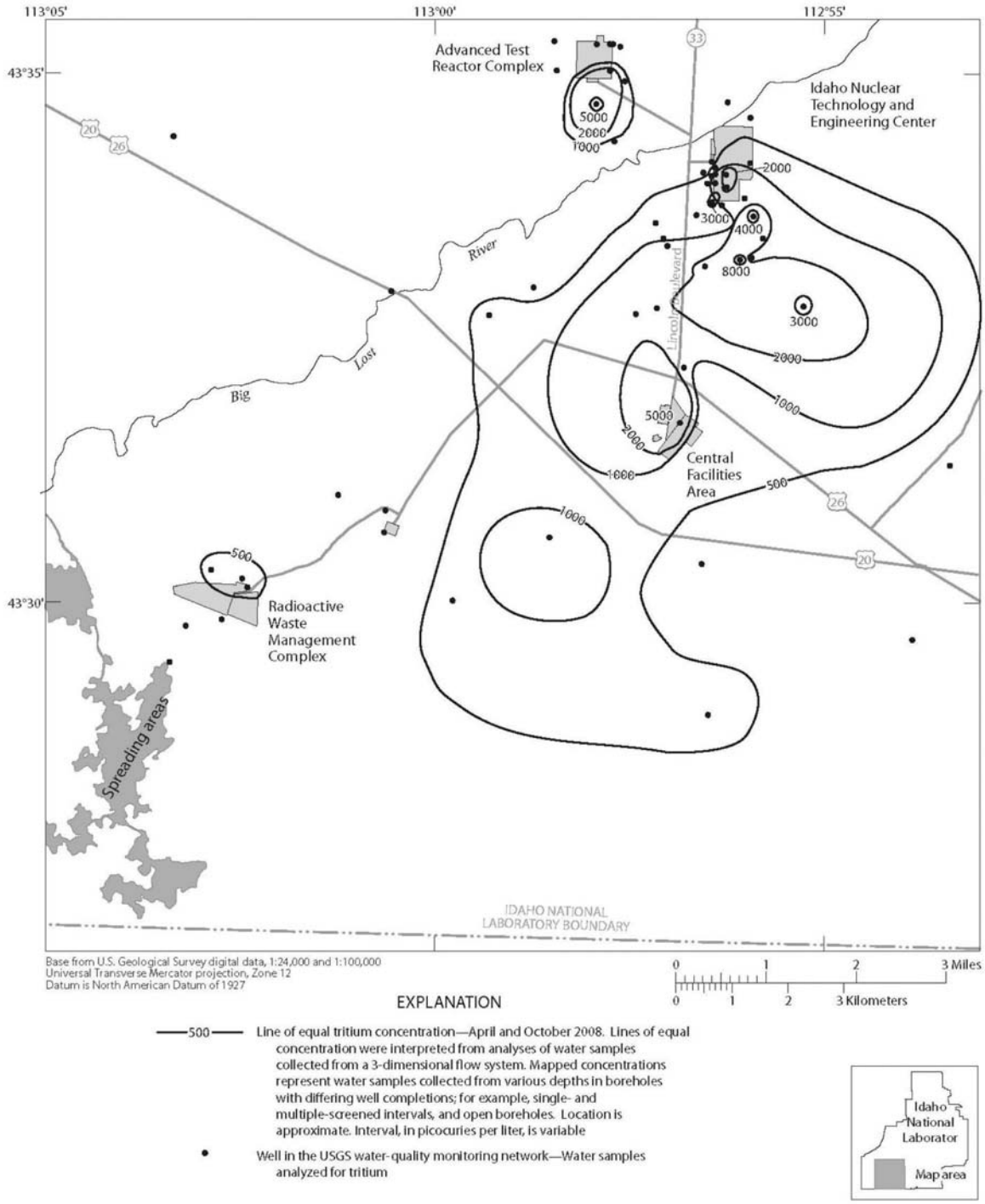


Figure HI-6. Data Plotted Using Contour Lines. Each contour line drawn on this map connects points of equal tritium concentration in water samples collected at the same depth from wells on the INL Site.

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 Sources. Natural radiation and radioactivity in the environment, that is natural background, represent a major source of human radiation exposure (NCRP 1987, NCRP 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 2012 to receive an average dose of about 390 mrem/yr (3.9 mSv/yr) from natural background sources of radiation on earth (Figure HI-7). These sources include cosmic radiation and naturally occurring radionuclides.

Cosmic radiation is radiation that constantly bathes the earth from extraterrestrial sources. The atmosphere around the earth absorbs some of the cosmic radiation, so doses are lowest at

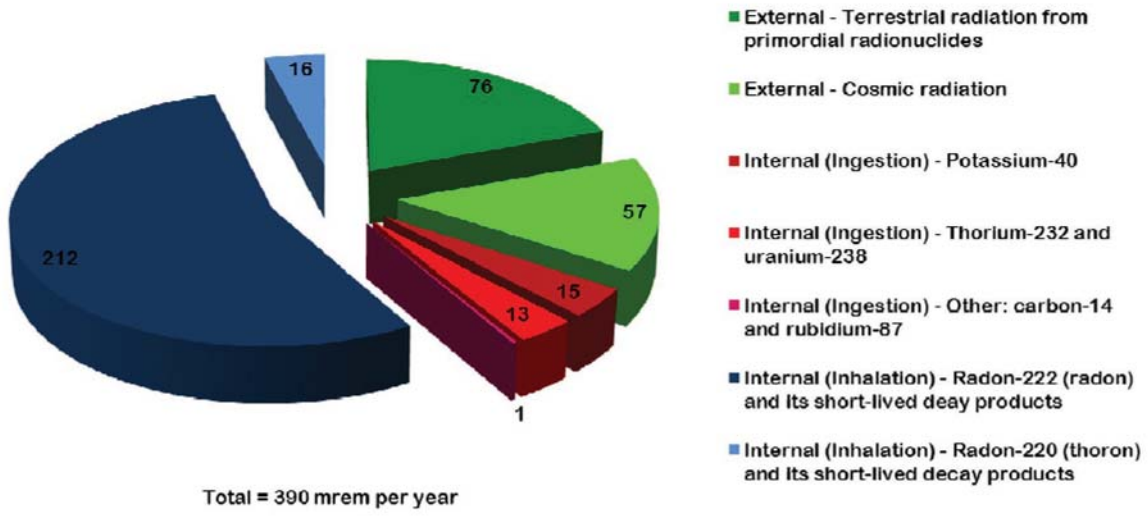


Figure HI-7. Calculated Doses (mrem per year) from Natural Background Sources for an Average Individual Living in Southeast Idaho (2012).

sea level and increases sharply with altitude. Cosmic radiation is estimated, using data in NCRP (2009), to produce a dose of about 57 mrem/yr (0.57 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 carbon-14 (^{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 United States (NCRP 2009). Tritium and ^{7}Be are routinely detected in environmental samples collected by environmental monitoring programs on and around the INL Site (Table HI-5), but contribute little to the dose which 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 (76 mrem/yr or 0.76 mSv/yr) has been estimated using concentrations of ^{40}K, ^{238}U, and ^{232}Th

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)	2.7×10^{6} yr	Cosmic rays	Rain, air
Tritium (^{3}H)	12.3 yr	Cosmic rays	Water, rain, air moisture
Potassium-40 (^{40}K)	1.26×10^{9} yr	Primordial	Water, air, soil, plants, animals
Thorium-232 (^{232}Th)	1.4×10^{10} yr	Primordial	Soil
Uranium-238 (^{238}U)	4.5×10^{9} yr	Primordial	Water, air, soil
Uranium-234(^{234}U)	2.5×10^{5} yr	^{238}U progeny	Water, air, soil
Radium-226 (^{226}Ra)	1,620 yr	^{238}U progeny	Water

measured in soil samples collected from areas surrounding the INL Site from 1976 through 1993. Uranium-238 and ^{232}Th are also estimated to contribute 13 mrem/yr (0.13 mSv/yr) to an average adult through ingestion (NCRP 2009).

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 INL Site samples.

Uranium-238 and ^{232}Th each 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 (an average of 200 mrem/yr [2.0 mSv/yr] nationwide) produced by naturally occurring radionuclides (Figure HI-7). The parent radionuclide of the thorium series is ^{232}Th. Another isotope of radon (^{220}Rn), called thoron, occurs in the thorium decay chain of radioactive atoms. Uranium-238, ^{232}Th, and their progeny often are detected in environmental samples (Table HI-5).

Global Fallout. The United States, the USSR, and China tested nuclear weapons in the atmosphere in the 1950s and 1960s, which resulted in the release of radionuclides into the upper atmosphere. This 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 though. France continued atmospheric testing until 1974, and China until 1980. Additional fallout, but to a substantially smaller extent, was produced by the Chernobyl nuclear accident in 1986.

Most of the radionuclides associated with nuclear weapons testing and the Chernobyl accident 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 lodge 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^{o}. 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 over 30 years since that estimate, so the current dose is 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 (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). The ICRP is an association of scientists from many countries, including the United States. The NCRP 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.

Risk can be defined in general as the probability (chance) of injury, illness, or death resulting from some activity. There are a large amount of data showing the effects of receiving high doses of radiation, especially in the range of 50 to 400 rem (0.5 to 4.0 Sv), delivered acutely (all at once.) These are largely data resulting from studies of the survivors of the Japanese atomic bombing and of some relatively large groups of patients who were treated with substantial doses of X-rays.

It is difficult to estimate risks from low levels of radiation. 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.

Each radionuclide represents a somewhat different health risk. However, health physicists (radiation protection professionals) currently estimate that overall, 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 five or six more people to die of cancer than would otherwise (EPA 2013). In this group of 10,000 people, about 2,000 would be expected to die of cancer from all non-radiation causes. A lifetime exposure to 1 rem (0.01 Sv) of radiation would increase that number to about 2,005 or 2,006. For perspective, most people living on the eastern Snake River Plain receive over one-third of a rem (390 mrem or 3.9 mSv) every year from natural background sources of radiation.

Health physicists generally agree on limiting a person's exposure beyond background radiation to about 100 mrem/yr (1 mSv) from all sources (EPA 2010). Exceptions are occupational, medical, or accidental exposures. 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 only to 10 mrem (0.1 mSv) (DOE Order 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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INL Site From the Top of Big Southern Butte

Acronyms

AIP	Agreement in Principle
AMWTP	Advanced Mixed Waste Treatment Project
ANOVA	Analysis of Variance
ANSI	American National Standards Institute
ARA	Auxiliary Reactor Area
ARP	Accelerated Retrieval Project
ASME	American Society of Mechanical Engineers
ATR	Advanced Test Reactor
BEA	Battelle Energy Alliance
BBS	Breeding Bird Survey
BLS	Below Land Surface
CAA	Clean Air Act
CAP88-PC	Clean Air Act Assessment Package, 1988 Personal Computer
CCA	Candidate Conservation Agreement
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
CITRC	Critical Infrastructure Test Range Complex
CRM	Cultural Resource Management
CWA	Clean Water Act
CWI	CH2M-WG Idaho, LLC
CWP	Cold Waste Pond
CY	Calendar Year
DCS	Derived Concentration Standard
D&D	Decontamination and Decommissioning
DEQ	Department of Environmental Quality (state of Idaho)
DOE	U.S. Department of Energy
DOECAP	DOE Consolidated Audit Program
DOE-ID	U.S. Department of Energy, Idaho Operations Office
EA	Environmental Assessment
EAL	Environmental Assessment Laboratory
EBR	Experimental Breeder Reactor
EFS	Experimental Field Station
EIC	Electret Ionization Chamber
EIS	Environmental Impact Statement
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESA	Endangered Species Act
ESER	Environmental Surveillance, Education, and Research
FFA/CO	Federal Facility Agreement and Consent Order

FR	Federal Register
FY	Fiscal Year
GCP	General Permit for Storm Water Discharges from Construction Sites
GHG	Greenhouse Gas
GP	Guiding Principles
GPS	Global Positioning System
GSS	Gonzales-Stoller Surveillance, LLC
ICDF	Idaho CERCLA Disposal Facility
ICP	Idaho Cleanup Project
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units
IDAPA	Idaho Administrative Procedures Act
IDFG	Idaho Department of Fish and Game
IEC	International Electrotechnical Commission
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center (formerly Idaho Chemical Processing Plant)
IOP	INL Oversight Program (state of Idaho DEQ)
ISB	In Situ Bioremediation
ISO	International Organization for Standardization
ISU	Idaho State University
ISU-EAL	Idaho State University-Environmental Assessment Laboratory
IWTU	Integrated Waste Treatment Unit
LEED	Leadership in Energy and Environmental Design
LSD	Least Significant Difference
LTV	Long-Term Vegetation
MAPEP	Mixed Analyte Performance Evaluation Program
MCL	Maximum Contaminant Level
MD	Mean Difference
MDIFF	Mesoscale Diffusion Model
MFC	Materials and Fuels Complex
NA	Not Applicable
NAD	Normalized Absolute Difference
NAPL	Non-aqueous Phase Liquid
NCRP	National Council on Radiation Protection and Measurements
ND	Not Detected
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NIS	Non-indigenous Plant Species
NIST	National Institute of Standards and Technology
NOAA ARL-FRD	National Oceanic and Atmospheric Administration Air Resources Laboratory - Field Research Division
NPDES	National Pollutant Discharge Elimination System

NRF	Naval Reactors Facility
OMB	Office of Management and Budget
OSLD	Optically Stimulated Luminescence Dosimeters
PCB	Polychlorinated Biphenyls
PLN	Plan
PT	Proficiency Testing
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RESL	Radiological and Environmental Sciences Laboratory
RPD	Relative Percent Difference
RPS	Rare Plant Species
ROD	Record of Decision
RSD	Relative Standard Deviation
RWMC	Radioactive Waste Management Complex
SCS	Secondary Constituent Standards
SDA	Subsurface Disposal Area
SHPO	State Historic Preservation Office
SI	Système International
SMC	Specific Manufacturing Capability
SNF	Spent Nuclear Fuel
TAN	Test Area North
TCE	Trichloroethylene
TIC	Time Integrated Concentration
TLD	Thermoluminescent Dosimeter
TOC	Total Organic Carbon
TSF	Technical Support Facility
TRU	Transuranic (waste)
TSCA	Toxic Substances Control Act
USGS	U.S. Geological Survey
VOC	Volatile Organic Compounds
WAG	Waste Area Group
WNS	White-nose Syndrome

Units

Bq	becquerel
C	Celsius
Ci	curie
cm	centimeter
cps	counts per second
d	Day
F	Fahrenheit
ft	feet
g	gram
gal	gallon
ha	hectare
keV	kilo-electron-volts
kg	kilogram
km	kilometer
L	liter
lb	pound
m	meter
µCi	microcurie (10^{-6} curies)
µg	microgram
µm	micrometerse
µR	microentgen
µS	microsiemens
µSv	microsieverts
Ma	million years
mCi	millicurie
MeV	mega electron volt
mg	milligram
MG	million gallons
mGy	milligrey
mi	mile
min	minute
mL	milliliter
mR	milliroentgen
mrad	millirad
mrem	millirem
mSv	millisievert
oz	ounce
pCi	picocurie (10^{-12} curies)
R	roentgen
rad	radiation absorbed dose
rem	roentgen equivalent man
Sv	sievert
yd	yard
yr	year

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1. Introduction

1. INTRODUCTION

This annual report is prepared in compliance with the following U.S. Department of Energy (DOE) orders:

- DOE Order 231.1B, “Environment, Safety and Health Reporting”
- DOE Order 436.1, “Departmental Sustainability”
- DOE Order 458.1, “Radiation Protection of the Public and the Environment.”

The purpose of the report, as outlined in DOE Order 231.1B, is to present summary environmental data to:

- Characterize site environmental performance
- Summarize environmental occurrences and responses during the calendar year
- Confirm compliance with environmental standards and requirements
- Highlight significant facility programs and efforts.

This report is the principal document that demonstrates compliance with DOE Order 458.1 requirements and, therefore, describes the Idaho National Laboratory (INL) Site’s impact to the public and the environment with emphasis on radioactive contaminants.

1.1 Site Location

The INL Site encompasses about 2,305 square kilometers (km^2) (890 square miles [mi^2]) of the upper Snake River Plain in southeastern Idaho (Figure 1-1). Over 50 percent of the INL Site is located in Butte County and the rest is distributed across Bingham, Bonneville, Clark, and Jefferson counties. The INL Site extends 63 km (39 mi) from north to south, and is approximately 61 km (38 mi) at its broadest east-west portion. By highway, the southeast boundary is approximately 40 km (25 mi) west of Idaho Falls. Other towns surrounding the INL Site include Arco, Atomic City, Blackfoot, Rigby, Rexburg, Mud Lake, and Howe. Pocatello is almost 85 km (53 mi) to the southeast.

Federal lands surround much of the INL Site, including Bureau of Land Management lands and Craters of the Moon National Monument to the southwest, Challis National Forest to the west, and Targhee National Forest to the north. Mud Lake Wildlife Management Area, Camas National Wildlife Refuge, and Market Lake Wildlife Management Area are within 80 km (50 mi) of the INL Site. The Fort Hall Indian Reservation is located approximately 60 km (37 mi) to the southeast.

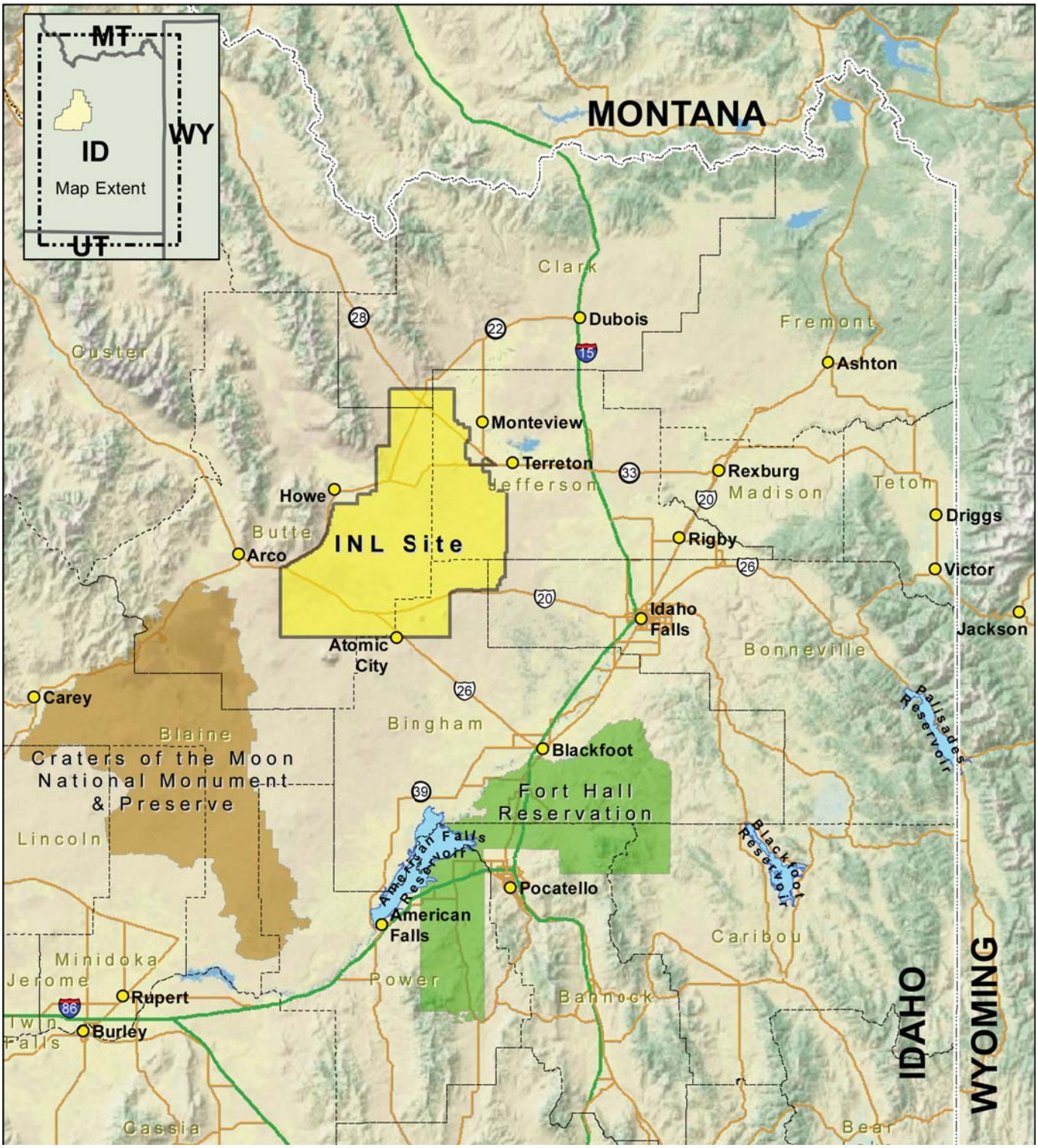

Figure 1-1. Location of the Idaho National Laboratory Site.

1.2 Environmental Setting

The INL Site is located in a large, relatively undisturbed expanse of sagebrush steppe. Approximately 94 percent of the land on the INL Site is open and undeveloped. The INL Site has an average elevation of 1,500 m (4,900 ft) above sea level and is bordered on the north and west by mountain ranges and on the south by volcanic buttes and open plain. Lands immediately adjacent to the INL Site are open sagebrush steppe, foothills, or agricultural fields. Agriculture is concentrated in areas northeast of the INL Site.

About 60 percent of the INL Site is open to livestock grazing. Controlled hunting is permitted on INL Site land but is restricted to a very small portion of the northern half of the Site.

The climate of the high desert environment of the INL Site is characterized by sparse precipitation (about 21.6 cm/yr [8.5 in./yr]), warm summers (average daily temperature of 18.2°C [64.8°F]), and cold winters (average daily temperature of -6.2°C [20.8°F]), with all averages based on 1950-2012 observations. The altitude, intermountain setting, and latitude of the INL Site combine to produce a semiarid climate. Prevailing weather patterns are from the southwest, moving up the Snake River Plain (DOE-ID 1989). Air masses, which gather moisture over the Pacific Ocean, traverse several hundred miles of mountainous terrain before reaching southeastern Idaho. Frequently, the result is dry air and little cloud cover. Solar heating can be intense, with extreme day-to-night temperature fluctuations.

Basalt flows cover most of the plain, producing rolling topography. Vegetation is visually dominated by big sagebrush (*Artemisia tridentata*). Beneath these shrubs are grasses and wild flowers adapted to the harsh climate. A total of 409 plant species have been recorded on the INL Site (Anderson et al. 1996).

Vertebrate animals found on the INL Site include small burrowing mammals, snakes, birds, and several game species. Published species records include six fishes, one amphibian, nine reptiles, 164 birds, and 39 mammals (Reynolds et al. 1986).

The Big Lost River on the INL Site flows northeast, ending in a playa area, called the Big Lost River Sinks, on the northwestern portion of the INL Site. Here, the river evaporates or infiltrates into the subsurface, with no surface water moving off the INL Site.

The fractured volcanic rocks under the INL Site form a portion of the eastern Snake River Plain aquifer (Figure 1-2), which stretches 320 km (199 mi) from Island Park to King Hill, and stores one of the most bountiful supplies of groundwater in the nation. An estimated 247 to 370 billion m^3 (200 to 300 million acre-ft) of water is stored in the aquifer's upper portions. The aquifer is primarily recharged from the Henry's Fork and the South Fork of the Snake River, and to a lesser extent by the Big Lost River, Little Lost River, Birch Creek, and irrigation. Beneath the INL Site, the aquifer moves laterally southwest at a rate of 1.5 to 6 m/day (5 to 20 ft/day) (Lindholm 1996). The eastern Snake River Plain aquifer emerges in springs along the Snake River between Milner and Bliss, Idaho. Crop irrigation is the primary use of both surface water and groundwater on the Snake River Plain.

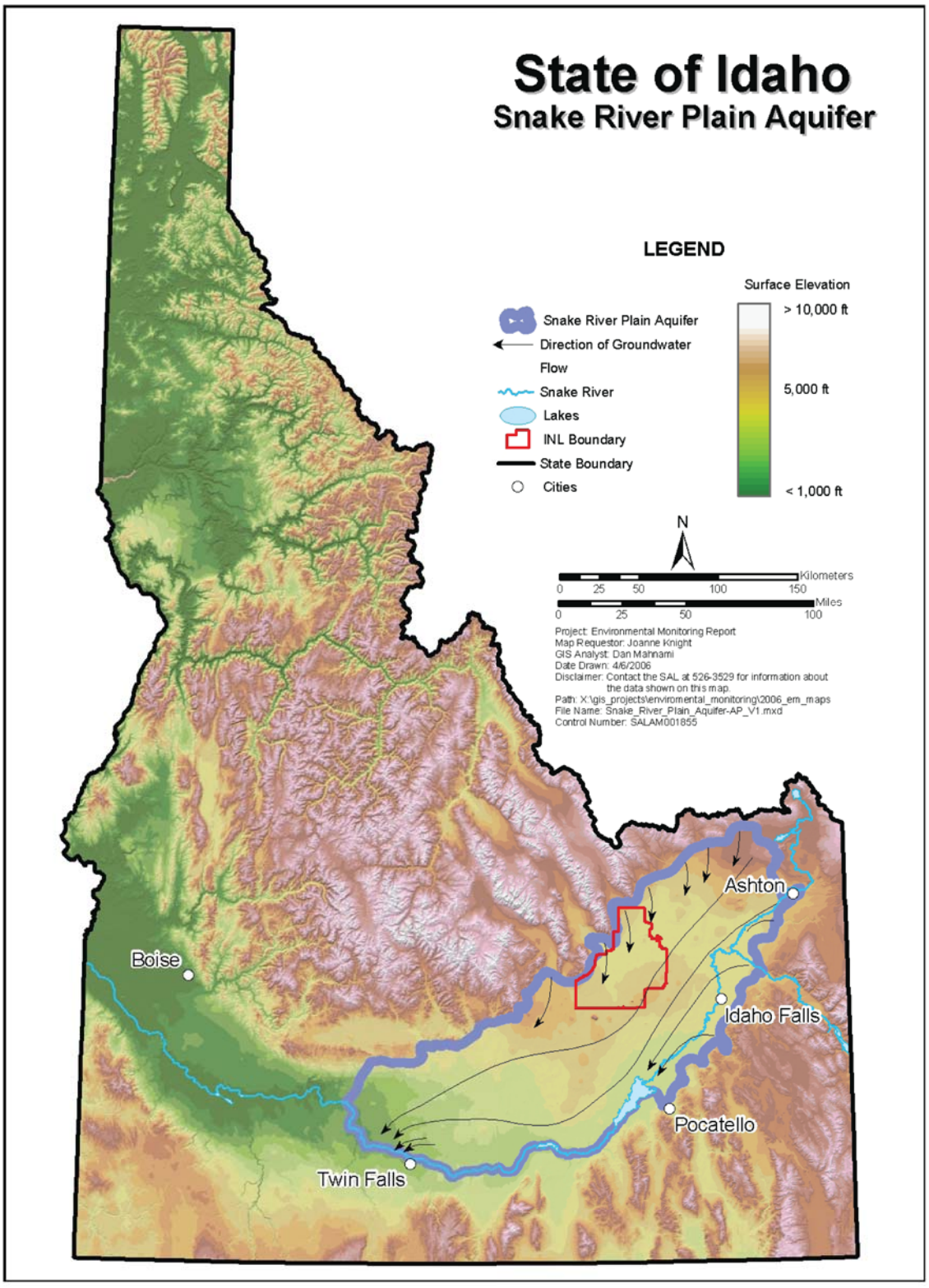

Figure 1-2. Idaho National Laboratory Site in Relation to the Eastern Snake River Plain Aquifer.

1.3 Idaho National Laboratory Site Primary Program Missions and Facilities

The INL Site mission is to operate a multi-program national research and development laboratory and to complete environmental cleanup activities stemming from past operations. The U.S. Department of Energy, Idaho Operations Office (DOE-ID) receives implementing direction and guidance primarily from two DOE Headquarters offices, the Office of Nuclear Energy and the Office of Environmental Management. The Office of Nuclear Energy is the Lead Program Secretarial Office for all DOE-ID-managed operations on the INL Site. The Office of Environmental Management provides direction and guidance to DOE-ID for environmental cleanup on the INL Site and functions in the capacity of Cognizant Secretarial Office. Naval Reactors operations on the INL Site report to the Pittsburgh Naval Reactors Office and fall outside the purview of DOE-ID and are not included in this report.

1.3.1 Idaho National Laboratory

The INL mission is to ensure the nation's energy security with safe, competitive, and sustainable energy systems and unique national and homeland security capabilities. Its vision is to be the pre-eminent nuclear energy laboratory, with synergistic, world-class, multi-program capabilities and partnerships. To fulfill its assigned duties during the next decade, INL will work to transform itself into a laboratory leader in nuclear energy and homeland security research, development, and demonstration. Highlighting this transformation will be the development of nuclear energy and national and homeland security leadership highlighted by achievements such as demonstration of Generation IV reactor technologies, creation of national user facilities based on the Advanced Test Reactor and the Critical Infrastructure Test Range, piloting of advanced fuel cycle technology, the rise to prominence of the Center for Advanced Energy Studies, and recognition as a regional clean energy resource and world leader in safe operations. Battelle Energy Alliance, LLC (BEA) is responsible for management and operation of the INL.

1.3.2 Idaho Cleanup Project

The Idaho Cleanup Project (ICP) involves the safe environmental cleanup of the INL Site, which was contaminated with waste generated during World War II-era conventional weapons testing, government-owned research and defense reactor operations, laboratory research, fuel reprocessing, and defense missions at other DOE sites. The project is led by CH2M-WG Idaho, LLC (CWI) and funded through the DOE Office of Environmental Management. The project focuses on meeting Idaho Settlement Agreement (DOE 1995) and environmental cleanup milestones while reducing risks to workers. Protection of the Snake River Plain aquifer, the sole drinking water source for more than 300,000 residents of eastern Idaho, was the principal concern addressed in the Settlement Agreement.

The ICP involves treating a million gallons of sodium-bearing waste, removing targeted transuranic waste from the Subsurface Disposal Area (SDA), placing spent nuclear fuel in dry storage, selecting a treatment for high-level waste calcine, and demolishing more than 200 structures, including reactors, spent nuclear fuel storage basins, and laboratories used for radioactive experiments.

1.3.3 Advanced Mixed Waste Treatment Project

The Advanced Mixed Waste Treatment Project (AMWTP) prepares and ships contact-handled transuranic waste out of Idaho. AMWTP is managed and operated by Idaho Treatment Group, LLC. Operations at AMWTP retrieve, characterize, treat, and package transuranic waste currently stored at the INL Site. The project's schedule is aligned with court-mandated milestones in the 1995 Settlement Agreement (DOE 1995) among the state of Idaho, U.S. Navy, and DOE to remove waste from Idaho. The majority of waste AMWTP processes resulted from the manufacture of nuclear weapons components at DOE's Rocky Flats Plant in Colorado. This waste was shipped to Idaho in the 1970s and early 1980s for storage and contains industrial debris, such as rags, work clothing, machine parts, and tools, as well as soil and sludge, and is contaminated with transuranic radioactive elements (primarily plutonium). Most of the waste is "mixed waste" that is contaminated with radioactive and nonradioactive hazardous chemicals, such as oil and solvents. Since 1999, more than 49,371 m^3 (64,575 yd^3) of transuranic waste has been shipped off the INL Site.

1.3.4 Primary Idaho National Laboratory Site Facilities

Most INL Site buildings and structures are located within developed areas that are typically less than a few square miles and separated from each other by miles of undeveloped land. DOE controls all land within the INL Site (Figure 1-3).

In addition to the INL Site, DOE owns or leases laboratories and administrative offices in the city of Idaho Falls, 40 km (25 mi) east of the INL Site.

Central Facilities Area – The Central Facilities Area (CFA) is the main service and support center for INL Site's desert facilities. Activities at CFA support transportation, maintenance, medical, construction, radiological monitoring, security, fire protection, warehouses, and calibration activities. It is operated by the INL contractor.

Critical Infrastructure Test Range Complex – The Critical Infrastructure Test Range Complex (CITRC) encompasses a collection of specialized test beds and training complexes that create a centralized location where government agencies, utility companies, and military customers can work together to find solutions for many of the nation's most pressing security issues. CITRC provides open landscape, technical employees, and specialized facilities for performing work in three main areas – physical security, contraband detection, and infrastructure testing. It is operated by the INL contractor.

Idaho Nuclear Technology and Engineering Center – The Idaho Chemical Processing Plant was established in the 1950s to recover usable uranium from spent nuclear fuel used in DOE and Department of Defense reactors. Over the years, the facility recovered more than $1 billion worth of highly enriched uranium that was returned to the government fuel cycle. In addition, an innovative high-level liquid waste treatment process known as calcining was developed at the plant. Calcining reduced the volume of liquid radioactive waste generated during reprocessing and placed it in a more stable granular solid form. In the 1980s, the facility underwent a modernization, and safer, cleaner, and more efficient structures replaced most major facilities. Reprocessing of Spent Nuclear Fuel was discontinued in 1992. In 1998, the plant was renamed the Idaho Nuclear Technology and Engineering Center (INTEC). Current

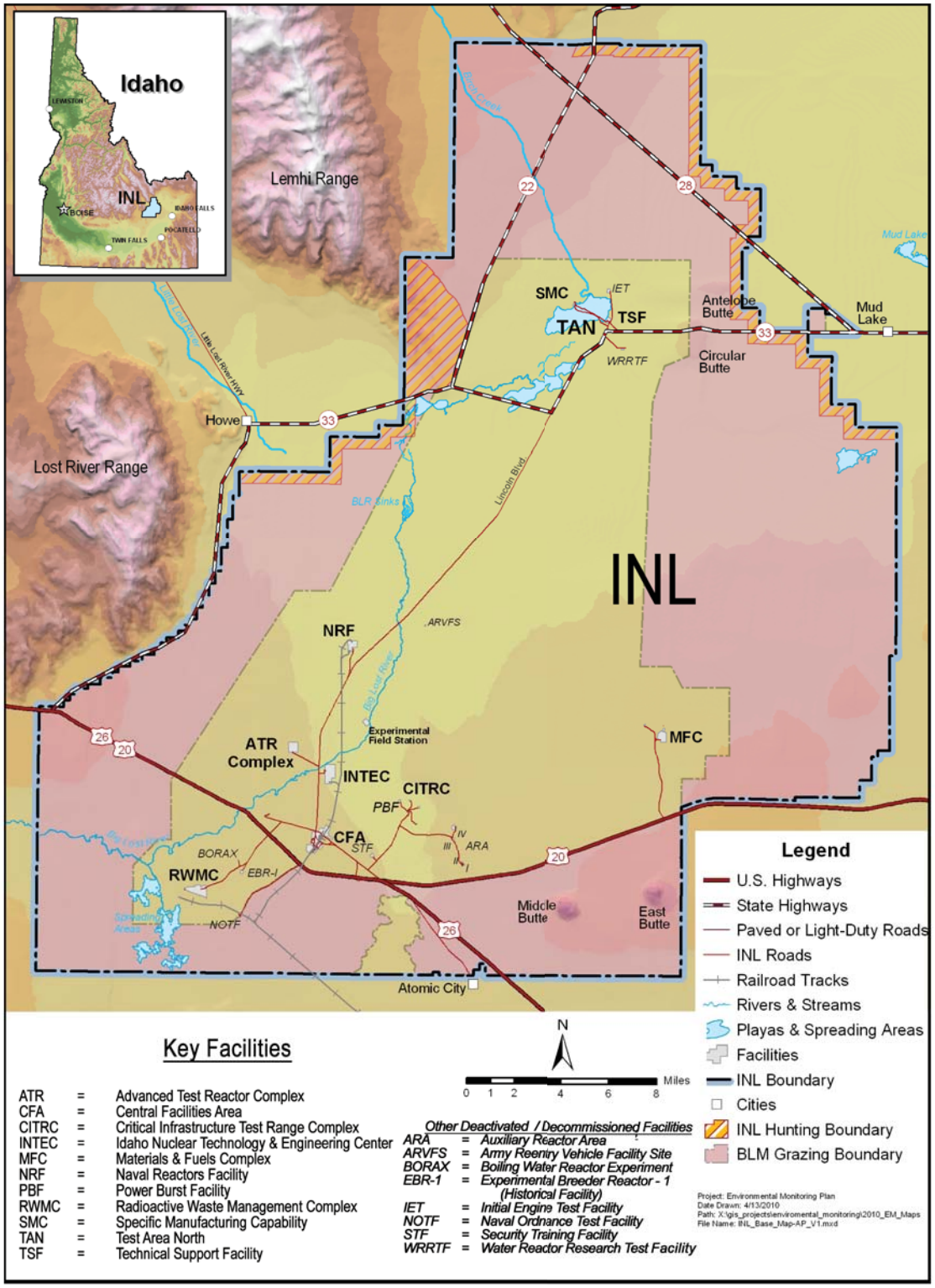

Figure 1-3. Location of the Idaho National Laboratory Site, Showing Facilities.

operations include management of sodium-bearing waste, special nuclear material disposition, spent nuclear fuel storage, environmental remediation, and demolition of excess facilities. INTEC is operated by the ICP contractor.

Materials and Fuels Complex – The Materials and Fuels Complex (MFC) is a prime testing center for advanced technologies associated with nuclear power systems. This complex is the nexus of research and development for new reactor fuels and related materials. As such, it will contribute increasingly efficient reactor fuels and the important work of nonproliferation – harnessing more energy with less risk. Facilities at MFC also support manufacturing and assembling components for use in space applications. It is operated by the INL contractor.

Naval Reactors Facility – The Naval Reactors Facility (NRF) is operated by Bechtel Marine Propulsion Corporation.

As established in Executive Order 12344 (1982), the Naval Nuclear Propulsion Program is exempt from the requirements of DOE Orders 436.1, 458.1, and 414.1C. Therefore, NRF is excluded from this report. The director, Naval Nuclear Propulsion Program, establishes reporting requirements and methods implemented within the program, including those necessary to comply with appropriate environmental laws. The NRF's program is documented in the NRF Environmental Monitoring Report (BMPC 2013).

Radioactive Waste Management Complex – Since the 1950s, DOE has used the Radioactive Waste Management Complex (RWMC) to manage, store, and dispose of waste contaminated with radioactive elements generated in national defense and research programs. RWMC manages solid transuranic and low-level radioactive waste. RWMC provides treatment, temporary storage and transportation of transuranic waste destined for the Waste Isolation Pilot Plant. Management of stored wastes at RWMC is the responsibility of the AMWTP contractor.

The Subsurface Disposal Area (SDA) is a 39-hectare (96-acre) radioactive waste landfill that was used for more than 50 years. Approximately 14 of the 39 hectares (35 of 96 acres) contain waste, including radioactive elements, organic solvents, acids, nitrates, and metals from historical operations such as reactor research at INL and weapons production at other DOE facilities. A Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Record of Decision (OU-7-13/14) was signed in 2008 (DOE-ID 2008) that includes exhumation and off-site disposition of targeted waste. Through December 2012, 3.11 of the required 5.69 acres (1.20 of 2.30 hectares) have been exhumed and 5,684 m^3 (7,434 yd^3) of waste have been shipped out of Idaho. Cleanup of RWMC is managed by the ICP contractor.

Advanced Test Reactor Complex – The Advanced Test Reactor (ATR) Complex was established in the early 1950s and has been the site for operation of three major test reactors – the Materials Test Reactor (1952 – 1970), the Engineering Test Reactor (1957 – 1982), and the Advanced Test Reactor (1967 – present). The current primary mission at the ATR Complex is operation of the Advanced Test Reactor, the world's premier test reactor used to study the effects of radiation on materials. This reactor also produces rare and valuable medical and industrial isotopes. The ATR Complex also features the Advanced Test Reactor – Critical Facility, Test Train Assembly Facility, Radiation Measurements Laboratory, Radiochemistry Laboratory, and the Safety and Tritium Applied Research Facility – a national fusion safety user facility. The

ATR Complex will design, test, and prove the new technologies of the nuclear renaissance. It is operated by the INL contractor. The ATR is a national scientific user facility.

Research and Education Campus – The Research and Education Campus, operated by the INL contractor, is the collective name for INL's administrative, technical support, and computer facilities in Idaho Falls, and the in-town laboratories where researchers work on a wide variety of advanced scientific research and development projects. As the name implies, the Research and Education Campus uses both basic science research and engineering to apply new knowledge to products and processes that improve quality of life. This reflects the emphasis INL is placing on strengthening its science base and increasing the commercial success of its products and processes. The Center for Advanced Energy Studies, designed to promote education and world-class research and development, is also located at the Research and Education Campus. New laboratory facilities are under development, and other facilities proposed over the next 10 years include a national security building, a visitor's center, visitor housing, and a parking structure close to current campus buildings. Facilities already in place and those planned for the future are integral for transforming INL into a renowned research laboratory.

Test Area North – Test Area North (TAN) was established in the 1950s to support the government's Aircraft Nuclear Propulsion program with the goal to build and fly a nuclear-powered airplane. When President Kennedy cancelled the nuclear propulsion program in 1961, TAN began to host a variety of other activities. The Loss-of-Fluid Test (LOFT) reactor became part of the new mission. The LOFT reactor, constructed between 1965 and 1975, was a scaled-down version of a commercial pressurized water reactor. Its design allowed engineers, scientists, and operators to create or re-create loss-of-fluid accidents (reactor fuel meltdowns) under very controlled conditions. The LOFT dome provided containment for a relatively small, mobile test reactor that was moved in and out of the facility on a railroad car. The Nuclear Regulatory Commission incorporated data received from these accident tests into commercial reactor operating codes. Before closure, the LOFT facility conducted 38 experiments, including several small loss-of-coolant experiments designed to simulate the type of accident that occurred at Three Mile Island (TMI) in Pennsylvania. In October 2006, the LOFT reactor and facilities were decontaminated, decommissioned, and demolished.

Additionally, TAN housed the TMI Unit 2 Core Offsite Examination Program that obtained and studied technical data necessary for understanding the events leading to the TMI-2 reactor accident. Shipment of TMI-2 core samples to the INL Site began in 1985, and the program ended in 1990. INL scientists used the core samples to develop a database that predicts how nuclear fuel will behave when a reactor core degrades.

In July 2008, the TAN Cleanup Project was completed. The TAN Cleanup Project demolished 44 excess facilities and the TAN Hot Shop and LOFT reactor. Environmental monitoring continues at TAN.

The Specific Manufacturing Capability Project is located at TAN. This project is operated for the Department of Defense by the INL contractor and manufactures protective armor for the Army M1-A1 and M1-A2 Abrams tanks.

1.4 History of the INL Site

The geologic events that have shaped the modern Snake River Plain took place during the last 2 million years (Ma) (Lindholm 1996; ESRF 1996). The plain, which arcs across southern Idaho to Yellowstone National Park, marks the passage of the earth's crust over a plume of melted mantle material.

The volcanic history of the Yellowstone-Snake River Plain volcanic field is based on the time-progressive volcanic origin of the region characterized by several large calderas in the eastern Snake River Plain, with dimensions similar to those of Yellowstone's three giant Pleistocene calderas. These volcanic centers are located within the topographic depression that encompasses the Snake River drainage. Over the last 16 Ma, there was a series of giant, caldera-forming eruptions, with the most recent at Yellowstone National Park 630,000 years ago. The youngest silicic volcanic centers correspond to the Yellowstone volcanic field that are less than 2.0 Ma old and are followed by a sequence of silicic centers at about 6 Ma ago, southwest of Yellowstone. A third group of centers, approximately 10 Ma, is centered near Pocatello, Idaho. The oldest mapped silicic rocks of the Snake River Plain are approximately 16 Ma, are distributed across a 150-km-wide (93-mi-wide) zone in southwestern Idaho and northern Nevada, and are the suspected origin of the Yellowstone-Snake River Plain (Smith and Siegel 2000).

Humans first appeared on the upper Snake River Plain approximately 11,000 years ago. Tools recovered from this period indicate the earliest human inhabitants were hunters of large game. The ancestors of the present-day Shoshone and Bannock people came north from the Great Basin around 4,500 years ago (ESRF 1996).

People of European descent began exploring the Snake River Plain between 1810 and 1840; these explorers were trappers and fur traders seeking new supplies of beaver pelts. Between 1840 (by which time the fur trade was essentially over) and 1857, an estimated 240,000 immigrants passed through southern Idaho on the Oregon Trail. By 1868, treaties had been signed forcing the native populations onto the reservation at Fort Hall. During the 1870s, miners entered the surrounding mountain ranges, followed by ranchers grazing cattle and sheep in the valleys.

A railroad was opened between Blackfoot and Arco, Idaho, in 1901. By this time, a series of acts (the Homestead Act of 1862, the Desert Claim Act of 1877, the Carey Act of 1894, and the Reclamation Act of 1902) provided sufficient incentive for homesteaders to attempt building diversionary canals to claim the desert. Most of these canal efforts failed because of the extreme porosity of the gravelly soils and underlying basalts.

During World War II, large guns from U.S. Navy warships were retooled at the U.S. Naval Ordnance Plant in Pocatello, Idaho. These guns needed to be tested, and the nearby uninhabited plain was put to use as a gunnery range, then known as the Naval Proving Ground. The U.S. Army Air Corps also trained bomber crews out of the Pocatello Airbase and used the area as a bombing range.

After the war ended, the nation turned to peaceful uses of atomic power. DOE's predecessor, the U.S. Atomic Energy Commission, needed an isolated location with ample groundwater supply on which to build and test nuclear power reactors. The relatively isolated Snake River Plain was

chosen as the best location. Thus, the Naval Proving Ground became the National Reactor Testing Station in 1949.

In 1951, Experimental Breeder Reactor I became the first reactor to produce useful electricity. In 1955, the Boiling-Water Reactor Experiments (BORAX)-III reactor provided electricity to Arco, Idaho – the first time a nuclear reactor powered an entire community in the U.S. The laboratory also developed prototype nuclear propulsion plants for Navy submarines and aircraft carriers. Over time, the Site evolved into an assembly of 52 reactors, associated research centers, and waste handling areas.

The National Reactor Testing Station was renamed the Idaho National Engineering Laboratory in 1974 and Idaho National Engineering and Environmental Laboratory in 1997 to reflect the Site's leadership role in environmental management. The U.S. Atomic Energy Commission was renamed the U.S. Energy Research and Development Administration in 1975 and reorganized to the present-day DOE in 1977.

With renewed interest in nuclear power, DOE announced in 2003 that Argonne National Laboratory-West and the Idaho National Engineering and Environmental Laboratory would be the lead laboratories for development of the next generation of power reactors, and on February 1, 2005, the Idaho National Engineering and Environmental Laboratory and Argonne National Laboratory-West became the Idaho National Laboratory.

1.5 Populations Near the INL Site

The population of the region within 80 km (50 mi) of the INL Site is estimated, based on the 2010 census and projected growth, to be 311,334. Over half of this population (168,454) resides in the census divisions of Idaho Falls (97,061) and northern Pocatello (71,393). Another 25,730 live in the Rexburg census division. Approximately 16,869 reside in the Rigby census division and 14,848 in the Blackfoot census division. The remaining population resides in small towns and rural communities.

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2012

2. Environmental Compliance Summary

1920s Homestead along the Big Lost River

Chapter 2 Highlights

Operations at the Idaho National Laboratory (INL) Site are subject to numerous federal and state environmental statutes, executive orders, and Department of Energy (DOE) orders. As a requirement of many of these regulations, the status of compliance with the regulations and releases of non-permitted hazardous materials to the environment must be documented. Overall, the INL Site met all its regulatory commitments in 2012, and programs are in place to address areas for continued improvement.

The *National Emission Standards for Hazardous Air Pollutants-Calendar Year 2012 INL Report* for Radionuclides report was submitted to U.S. Environmental Protection Agency, DOE Headquarters, and state of Idaho officials in June 2013, in compliance with the Clean Air Act. All Emergency Planning and Community Right-to-Know Act and Resource Conservation and Recovery Act reports were submitted as scheduled. There were no reportable environmental releases or environmental occurrences at the INL Site in 2012.

With respect to the National Environmental Policy Act, the DOE Idaho Operations Office (DOE-ID) did not prepare any environmental assessments (EAs) or environmental impact statements in 2012.

The U.S. Fish and Wildlife Service determined in 2010 that the Greater Sage-Grouse warranted protection of the Endangered Species Act but was not listed at that time because of the need to attend to higher priority species first. However, in a 2011 U.S. district court lawsuit settlement, the USFWS agreed to make a final listing decision on all candidate species by 2016.

The *2012 Site Sustainability Plan with the Annual Report* was completed in compliance with the new Department of Energy Order 436.1, “Departmental Sustainability.” The document provides plans for providing continual energy efficiency, greenhouse gas reductions, environmental improvements, and transportation fuels efficiency at the INL Site.

The *2012 Idaho Hazardous Waste Generator Annual Report* was submitted to the state of Idaho, which is authorized by Environmental Protection Agency (EPA) to regulate hazardous waste under the Resource Conservation and Recovery Act. The state of Idaho approved closure plans for one facility at the Materials and Fuels Complex in 2012. The State also conducted three annual hazardous waste compliance inspections of the INL Site and identified some alleged violations during one of these inspections. Corrective actions were taken to remedy the alleged violations and no penalties were assessed by the State.

In 2012, 23 INL Site projects were reviewed for potential impacts to cultural resources. About 197 acres were intensively examined during project surveys, 14 new archaeological resources were identified and recommended for avoidance or other protective measures, and six prehistoric sites were subject to test excavations. To date, approximately ten percent of the INL Site has been surveyed for archeological resources.

There are 40 active permits for air emissions, groundwater, wastewater, and hazardous waste compliance that have been granted to the INL Site from the city of Idaho Falls, state of Idaho, Environmental Protection Agency, and the Corps of Engineers.

2. ENVIRONMENTAL COMPLIANCE SUMMARY

This chapter reports the compliance status of the Idaho National Laboratory (INL) Site with environmental protection requirements. Operations at the INL Site are subject to numerous federal and state environmental protection requirements, such as statutes, acts, agreements, executive orders, and Department of Energy (DOE) orders. These are listed in Appendix A. The programs in place to comply with environmental protection requirements are discussed in Chapter 3.

2.1 Air Quality and Radiation Protection

2.1.1 Clean Air Act

The Clean Air Act (CAA) is the basis for national air pollution control. Congress passed the original CAA in 1963, which resulted in non-mandatory air pollution standards and studies of air pollution, primarily from automobiles. Amendments to the CAA are passed periodically, with significant amendments enacted in 1970, 1977 and 1990. These amendments contained key pieces of legislation that are considered basic elements of the CAA, which are listed below:

- **National Ambient Air Quality Standards** – The National Ambient Air Quality Standards establish permissible exposure levels for six pollutants (criteria air pollutants) identified as primary contributors to health-related deaths and illnesses. The six pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulates, and sulfur oxides.
- **State Implementation Plans** – A state may assume responsibility for the CAA by developing an Environmental Protection Agency (EPA)-approved state implementation plan. A state implementation plan contains the laws and regulations a state will use to administer and enforce the provisions of the CAA. The state of Idaho has been delegated authority for the CAA through an approved state implementation plan.
- **New Source Performance Standards** – The New Source Performance Standards Program is a permitting performance standard for specific industry source categories. The standard targets sources that contribute significantly to air pollution and ensures the sources pay to meet ambient air quality standards. The criteria air pollutants are the focus of the New Source Performance Standards Program.

- **Prevention of Significant Deterioration** – The Prevention of Significant Deterioration (PSD) program applies to new major sources or major modifications at existing sources for pollutants where the area the source is located is in attainment or unclassifiable with the National Ambient Air Quality Standards. An attainment area is one that meets the national primary or secondary ambient air quality standards. An unclassifiable area is one that cannot be classified on the basis of available information as meeting or not meeting the national primary or secondary ambient air quality standards.
- **National Emissions Standards for Hazardous Air Pollutants (NESHAPs)** – The NESHAPs Program regulates emissions of hazardous air pollutants from a published list of industrial sources. The source categories must meet control technology requirements for these hazardous air pollutants. The state of Idaho has added to the federal NESHAPs list of hazardous air pollutants with the State List of Toxic Air Pollutants.

  The state of Idaho has not been delegated authority for one key subpart of the NESHAPs Program. Specifically, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities" (40 Code of Federal Regulations [CFR] 61, Subpart H) is regulated by EPA. Subpart H applies to facilities owned or operated by DOE, including the INL Site. The Department of Energy, Idaho Operations Office (DOE-ID) submits an annual NESHAPs Subpart H report to EPA and the Idaho Department of Environmental Quality. The latest report is *National Emmission Standards for Hazardous Air Pollutants – Calendar Year 2012 INL Report for Radionuclides* (DOE-ID 2013a). Subpart H requires the use of an EPA-approved computer model to calculate the hypothetical maximum individual effective dose equivalent to a member of the public resulting from INL Site airborne radionuclide emissions. The calculations for this code are discussed further in Chapter 8, "Dose to the Public and Biota."
- **Stratospheric Ozone Protection Program** – The Stratospheric Ozone Protection Program limits emissions of chlorofluorocarbons, halons, and other halogenic chemicals that contribute to the destruction of stratospheric ozone.
- **Operating Permit Program** – The Operating Permit Program provides for states to issue federally enforceable operating permits to applicable stationary sources. The permits aid in clarifying operating and control requirements for stationary sources.

The Idaho Air Quality Program is primarily administered through a permitting process that sets conditions under which facilities that generate air pollutants may operate. Potential sources of air pollutants are evaluated against regulatory criteria to determine if the source is exempt from permitting. If the source is not exempted, the type of permit required depends on the type of emission or emitting source or both. Two primary types of air permits have been issued to the INL Site (Table 2-1):

- **Permit to Construct** – An air quality permit to construct is required of new or modified stationary sources, such as buildings, structures, or equipment that may emit pollutants into the air. State of Idaho air regulations and guidelines are used to apply for all permits to construct.

Table 2-1. Environmental Permits for the INL Site (2012).

Permit Type	Active Permits
Air Emissions:	
Permit to Construct	14
Title V Operating Permit	1
Groundwater:	
Injection Well	10
Well construction	1
Surface Water:	
Wastewater Reuse Permits	4
Industrial Wastewater Acceptance	1
Resource Conservation and Recovery Act:	
Part A	2
Part B	7[a]

a. A Part B permit is a single permit comprised of several volumes.

- **Title V Operating Permit** – A Title V operating permit, also known as a Tier I operating permit, is required for major sources. Major sources emit, or have the potential to emit, 10 tons or more of one hazardous air pollutant or 25 or more tons per year of any combination of hazardous air pollutants. EPA promulgated regulations in July 1992 that established the Tier I requirements for state programs. Through the state implementation plan, Idaho has approved one Tier I operating permit for the INL Site.
- **Enforcement Provisions** – Enforcement provisions establish maximum fines and penalties for CAA violations.

2.1.2 DOE Order 458.1, Radiation Protection of the Public and the Environment

DOE Order 458.1, "Radiation Protection of the Public and the Environment," 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, as amended. The objectives of this Order are:

- To conduct DOE radiological activities so that exposure to members of the public is maintained within the dose limits established in this Order
- To control the radiological clearance of DOE real and personal property

- To ensure that potential radiation exposures to members of the public are as low as reasonably achievable
- To ensure that DOE sites have the capabilities, consistent with the types of radiological activities conducted, to monitor routine and non-routine radiological releases and to assess the radiation dose to members of the public
- To provide protection of the environment from the effects of radiation and radioactive material.

DOE Order 458.1 was issued in February 2011, and replaced DOE Order 5400.5 by the same title. The Order sets the public dose limit at a total effective dose not to exceed 100 mrem/yr (1 mSv/yr) above background radiation levels. Chapter 8 presents dose calculations for INL Site releases for 2012.

DOE Standard DOE-STD-1196-2011, Derived Concentration Technical Standard, was issued in April 2011, and defines the quantities used in the design and conduct of radiological environmental protection programs at DOE facilities and sites. These quantities, derived concentration standards (DCSs), represent the concentration of a given radionuclide in either water or air that results in a member of the public receiving 100 mrem (1 mSv) effective dose following continuous exposure for one year via each of the following pathways: ingestion of water, submersion in air, and inhalation. They replace the Derived Concentration Guides (DCGs), which were previously published by DOE in 1993 in DOE Order 5400.5 and represented the best available information on doses at that time. Since that publication, the radiation protection framework on which DCSs are based has evolved with more sophisticated biokinetic and dosimetric information provided by the International Commission on Radiological Protection (ICRP), thus enabling consideration of age and gender. The purpose of DOE-STD-1196-2011 is to establish DCS values reflecting the current state of knowledge and practice in radiation protection. These DCSs are based on age-specific effective dose coefficients, revised gender-specific physiological parameters for the Reference Man (ICRP 2002), and the latest information on the energies and intensities of radiation emitted by radionuclides (ICRP 2008). Previous versions of the Annual Site Environmental Report used DCGs, as defined in DOE Order 5400.5, to evaluate environmental monitoring results for the INL Site. With the issuance of DOE Order 458.1 and DOE-STD-1196-2011, this report will now evaluate environmental monitoring results according to the corresponding DCSs.

In addition to discharges to the environment, the release of property containing residual radioactive material is a potential contributor to the dose received by the public. DOE Order 458.1 specifies limits for unrestricted release of property to the public. All INL Site contractors use a graded approach for release of material and equipment for unrestricted public use. Material has been categorized so that in some cases an administrative release can be accomplished without a radiological survey. Such material originates from non-radiological areas and includes the following:

- personal items or materials
- documents, mail, diskettes, compact disks, and other office media

- paper, cardboard, plastic products, aluminum beverage cans, toner cartridges, and other items released for recycling
- office trash
- non-radiological area housekeeping materials and associated waste
- break-room, cafeteria, and medical wastes
- medical and bioassay samples
- other items with an approved release plan.

Items originating from non-radiological areas within the Site's controlled areas not in the listed categories are surveyed prior to release to the public, or a process knowledge evaluation is conducted to verify that material has not been exposed to radioactive material or beams of radiation capable of creating radioactive material. In some cases both a radiological survey and a process knowledge evaluation are performed (e.g., a radiological survey is conducted on the outside of the item, and a process knowledge form is signed by the custodian for inaccessible surfaces).

When the process knowledge approach is employed, the item's custodian is required to sign a statement that specifies the history of the material and confirms that no radioactive material has passed through or contacted the item. Items advertised for public sale via an auction are also surveyed by the contractor prior to shipment to the INL Property/excess warehouse where the materials are again resurveyed on a random basis by INL personnel prior to release, giving further assurance that material and equipment are not being released with inadvertent contamination.

All contractors complete material surveys prior to release and transport to the state-permitted landfill at Central Facilities Area. The only exception is for items that could be internally contaminated; these items are submitted to Waste Generator Services for disposal using one of the Offsite Treatment, Storage, and Disposal facilities that can accept low level contamination. All INL Site contractors continue to follow the requirements of the scrap metal suspension. No scrap metal directly released from radiological areas is being recycled.

2.2 Environmental Protection and Remediation

2.2.1 Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) provides the process to assess and remediate areas contaminated by the release of chemically hazardous or radioactive substances or both. Nuclear research and other operations at the INL Site left behind contaminants that pose a potential risk to human health and the environment. The INL Site was placed on the National Priorities List under CERCLA on November 29, 1989. DOE-ID, the state of Idaho, and EPA Region 10 signed the Federal Facility Agreement and Consent Order in December 1991 (DOE 1991). The Idaho Cleanup Project (ICP) contractor, in accordance with the Federal Facility Agreement and Consent Order, is conducting environmental restoration activities at the INL Site. Specific environmental restoration activities are discussed in Chapter 3.

2.2.2 DOE Order 436.1, Departmental Sustainability

The purpose of DOE Order 436.1, "Departmental Sustainability," is to provide requirements and responsibilities for managing sustainability within DOE to:

- Ensure the Department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges, and advances sustainable, efficient and reliable energy for the future
- Institute wholesale cultural change to factor sustainability and greenhouse gas reductions into all DOE corporate management decisions
- Ensure DOE achieves the sustainability goals established in its Strategic Sustainability Performance Plan pursuant to applicable laws, regulations and Executive Orders, related performance scorecards, and sustainability initiatives.

These programs are summarized in this chapter and elsewhere in this report. DOE Order 436.1 was issued in May 2011, and replaces most of the requirements of DOE Order 450.1A "Environmental Program Protection," and DOE Order 430.2B, "Departmental Energy, Renewable Energy and Transportation Management."

2.2.3 Emergency Planning and Community Right-to-Know Act

The Emergency Planning and Community Right-to-Know Act (EPCRA) is Title III of the 1986 Superfund Amendments and Reauthorization Act to CERCLA. EPCRA is intended to help local emergency response agencies better prepare for potential chemical emergencies and to inform the public of the presence of toxic chemicals in their communities. The INL Site's compliance with key EPCRA provisions is summarized in the following subsections and in Table 2-2.

Table 2-2. INL Site EPCRA Reporting Status (2012).

EPCRA Section	Description of Reporting	2012 Status
Section 304	Extremely Hazardous Substance release notification	Not Required
Section 311-312	Material Safety Data Sheet/Chemical Inventory	Required
Section 313	Toxic Chemical Release Inventory Reporting	Required

Section 304 – Section 304 requires owners and operators of facilities where hazardous chemicals are produced, used, or stored to report releases of CERCLA hazardous substances or extremely hazardous substances that exceed reportable quantity limits to state and local authorities (i.e., state emergency response commissions and local emergency planning committees). There were no CERCLA-reportable chemicals released at the INL Site during 2012.

Sections 311 and 312 – Sections 311 and 312 require facilities manufacturing, processing, or storing designated hazardous chemicals to make material safety data sheets describing the properties and health effects of these chemicals available to state and local officials and local fire departments. Facilities also are required to report, to state and local officials and local fire departments, inventories of all chemicals that have material safety data sheets. The INL Site satisfies the requirements of Section 311 by submitting quarterly reports to state and local officials and fire departments, identifying chemicals that exceed regulatory thresholds. In compliance with Section 312, the annual Emergency and Hazardous Chemical Inventory (Tier II) Report was provided to local emergency planning committees, the State emergency response commission, and local fire departments by the regulatory due date of March 1. This report includes the types, quantities, and locations of hazardous chemicals and extremely hazardous substances stored at INL Site facilities that exceed regulatory thresholds.

Section 313 – Section 313 requires facilities to submit a Toxic Chemical Release Inventory Form annually for each of the more than 600 Toxic Release Inventory chemicals that are manufactured, processed, or otherwise used above applicable threshold quantities. Releases under EPCRA 313 reporting include transfers to waste treatment and disposal facilities off the INL Site, air emissions, recycling, and other activities. The INL Site submitted Toxic Chemical Release Inventory Forms for ethylbenzene, lead, naphthalene, and nickel, to EPA and the state of Idaho by the regulatory due date of July 1.

Reportable Environmental Releases – There were no reportable environmental releases at the INL Site during calendar year 2012.

2.2.4 National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires federal agencies to consider and analyze potential environmental impacts of proposed actions and explore appropriate alternatives to mitigate those impacts, including a “no action” alternative. Agencies are required to inform the public of the proposed actions, impacts, and alternatives and consider public feedback in selecting an alternative. DOE implements NEPA according to procedures in the CFR (40 CFR 1500; 10 CFR 1021) and assigns authorities and responsibilities according to DOE Order 451.1B, “National Environmental Policy Act Compliance Program.” Processes specific to DOE-ID are set forth in its Idaho Operations Office Management System. DOE-ID issued the Annual NEPA Planning Summary on January 30, 2012. The summary is a requirement of DOE Order 451.1B, and is prepared to inform the public and other DOE elements of:

- The status of ongoing NEPA compliance activities
- Environmental assessments expected to be prepared in the next 12 months
- Environmental impact statements expected to be prepared in the next 24 months
- The planned cost and schedule for completion of each NEPA review identified.

DOE-ID did not prepare any environmental assessments or environmental impact statements in 2012. Ongoing NEPA Reviews of INL Site Projects are discussed in the "Fiscal Year 2012 National Environmental Policy Act Planning Summary" (OS-ETSD-12-011).

2.2.5 Endangered Species Act

The Endangered Species Act:

- Provides a means whereby the ecosystems upon which endangered and threatened species depend may be conserved
- Provides a program for the conservation of such endangered and threatened species and their habitat
- Takes such steps as may be appropriate to achieve the purposes of the international treaties and conventions on threatened and endangered species.

The Act requires that all federal departments and agencies shall seek to conserve endangered and threatened species and shall use their authorities to further the purposes of this Act.

Personnel in the Environmental Surveillance, Education, and Research Program conduct ecological research, field surveys, and NEPA evaluations regarding ecological resources on the INL Site. Particular emphasis is given to threatened and endangered species and species of special concern identified by the U.S. Fish and Wildlife Service (USFWS) and Idaho Department of Fish and Game.

There are several species categorized under the Endangered Species Act (ESA) which occur or may occur on the INL Site. Table 2-3 presents a list of those species and the likelihood of their occurrence on the INL Site. Several species have been removed from the list based on the limited likelihood they would occur on the INL Site. The wolverine (*Gulo gulo luscus*) has been added to the list.

Table 2-3. Species Designated Under the ESA and Occur or May Occur on the INL Site.

Species	Designation	Presence on INL Site
Greater sage-grouse (*Centrocercus urophasianus*)	Candidate	Large populations present on INL Site.
Yellow-billed cuckoo (*Coccyzus americanus*)	Candidate	Documented occasionally on south border of INL Site.
Wolverine (*Gulo gulo luscus)*	Candidate	Not documented but may pass through the INL Site.

In March 2010, the USFWS classified the Greater sage-grouse (*Centrocercus urophasianus*) as a candidate for listing under the ESA of 1973. This means that although the species warrants protection under the ESA, it is currently precluded from being listed due to higher agency priorities. However, in a recent (2011) U.S. district court lawsuit settlement, the USFWS agreed to make a final listing decision on all candidate species by 2016. A resulting agency work plan commits the USFWS to make a determination by 2015 to either list sage-grouse as threatened or endangered, or to remove it from the candidate list.

Recently, white-nose syndrome (WNS) has been identified as a major threat to many bats that hibernate in caves. This disease is caused by a cold-adapted fungus (*Geomyces destructans*) and has killed at least 5.5 to 6.7 million bats in seven species. WNS has been labeled by some as the greatest wildlife crisis of the past century, and many species of bats could be at risk of significant declines or extinction due to this disease. At least two species of bats that occupy the INL Site could be affected by WNS if this disease arrives in Idaho – the little brown myotis (*Myotis lucifugus*) and the big brown bat (*Eptesicus fuscus*). In 2010, the little brown myotis was petitioned for emergency listing under the Endangered Species Act, and the USFWS is collecting information on both species to determine if, in addition to existing threats, this disease may be increasing the extinction risk of these bats. Currently, biologists from the Environmental Surveillance, Education, and Research Program have initiated a monitoring program using acoustical detectors set at hibernacula and important habitat features (caves and facility ponds) used by these mammals on the INL Site. The results of our monitoring program will provide critical information regarding bat ecology on the INL Site.

2.2.6 Migratory Bird Treaty Act

The Migratory Bird Treaty Act prohibits taking any migratory bird, or any part, nest, or egg of any such bird without authorization from the U.S. Department of the Interior. Permits may be issued for scientific collecting, banding and marking, falconry, raptor propagation, depredation, import, export, taxidermy, waterfowl sale and disposal, and special purposes. The ICP contractor received a Special Purpose Permit for limited take, movement, and management of migratory birds and their in-use nests related to conducting cleanup operations. The permit is only applied in very limited and extreme situations where no other recourse other than relocation of nest and young is possible. ICP did not have to use their permit during 2012.

No incidences of unintentional take occurred on the INL Site during 2012.

2.2.7 Executive Order 11988 – Floodplain Management

Executive Order 11988 requires each federal agency to issue or amend existing regulations and procedures to ensure that the potential effects of any action it may take in a floodplain are evaluated and that its planning programs and budget requests consider flood hazards and floodplain management. It is the intent of Executive Order 11988 that federal agencies implement floodplain requirements through existing procedures, such as those established to implement NEPA. 10 CFR 1022 contains DOE policy and floodplain environmental review and assessment requirements through the applicable NEPA procedures. In those instances where impacts of actions in floodplains are not significant enough to require the preparation of an Environmental Impact Statement (EIS) under NEPA, alternative floodplain evaluation requirements are established through the INL Site Environmental Checklist process.

For the Big Lost River, DOE-ID has accepted the *Big Lost River Flood Hazard Study, Idaho National Laboratory, Idaho* (Bureau of Reclamation 2005). This flood hazard report is based on geomorphological models and has undergone peer review. On January 12, 2006, DOE-ID directed the ICP contractor to use this floodplain determination for any activities that require the characterization of flows and hazards associated with the Big Lost River. All activities on the INL Site requiring characterization of flows and hazards are expected to use this report.

For facilities at Test Area North, the 100-year floodplain has been delineated in a U.S. Geological Survey report (USGS 1997).

2.2.8 Executive Order 11990 – Protection of Wetlands

Executive Order 11990 requires each federal agency to issue or amend existing regulations and procedures to ensure wetlands are protected in decision-making. It is the intent of this Executive Order that federal agencies implement wetland requirements through existing procedures, such as those established to implement NEPA. The 10 CFR 1022 statute contains DOE policy and wetland environmental review and assessment requirements through the applicable NEPA procedures. In those instances where impacts of actions in wetlands are not significant enough to require the preparation of an EIS under NEPA, alternative wetland evaluation requirements are established through the INL Site Environmental Checklist process. Activities in wetlands considered waters of the United States or adjacent to waters of the United States also may be subject to the jurisdiction of Sections 404 and 402 of the Clean Water Act.

The only area of the INL Site identified as potentially jurisdictional wetlands is the Big Lost River Sinks. The USFWS National Wetlands Inventory map is used to identify potential jurisdictional wetlands and non-regulated sites with ecological, environmental, and future development significance. In 2012, no actions took place or impacted potentially jurisdictional wetlands on the INL Site. Cattle grazing is conducted in the area of the Big Lost River Sinks under Bureau of Land Management permits obtained by private parties.

2.2.9 Executive Order 13514 – Federal Leadership in Environmental, Energy, and Economic Performance

Executive Order 13514, “Federal Leadership in Environmental, Energy, and Economic Performance,” was signed by President Obama on October 5, 2009. This Executive Order expands on the energy reduction and environmental performance requirements for federal agencies identified in Executive Order 13423, “Strengthening Federal Environmental, Energy, and Transportation Management.”

The goal of Executive Order 13514 is “to establish an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal agencies.” Towards meeting that goal, federal agencies are required to meet a series of deadlines critical to achieving the greenhouse gas (GHG) reduction goals of the Executive Order.

- On November 5, 2009, each agency submitted the name of their Senior Sustainability Officer to the Council on Environmental Quality (CEQ) Chair and Office of Management and Budget (OMB) Director

- On January 4, 2010, a percentage reduction target for agency-wide reductions of Scope 1 and 2 GHG emissions, in absolute terms, by fiscal year 2020, relative to a fiscal year 2008 baseline of the agency's Scope 1 and 2 GHG, was due to the CEQ Chair and OMB Director
- On June 2, 2010, Scope 3 targets and the Strategic Sustainability Performance Plan were submitted to the CEQ Chair and the OMB Director
- On January 31, 2011, the comprehensive GHG inventory was due from each of the agencies to the CEQ Chair and OMB Director.

In addition to guidance, recommendations, and plans that are due by specific dates, Executive Order 13514 specifies numerical and non-numerical targets for agencies to reach in areas such as sustainable buildings, water efficiency, electronic products, and transportation management. Beyond targets, Executive Order 13514 requires agencies to follow specific management strategies to improve sustainability. These targets and management strategies are listed in Table 2-4.

On May 22, 2011, DOE issued DOE Order 436.1 "Departmental Sustainability". The order defines requirements and responsibilities for managing sustainability at DOE to ensure that the Department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges, and advances sustainable, efficient and reliable energy for the future; institutes wholesale cultural change to factor sustainability and GHG reductions into all DOE corporate management decisions; and ensures that DOE achieves the sustainability goals established in its Strategic Sustainability Performance Plan. This order combined, added to and cancels DOE Order 450.1A Environmental Protection Program and DOE Order 430.2B Departmental Energy, Renewable Energy, and Economic Performance.

DOE-ID submitted the *2012 INL Site Sustainability Plan with the Annual Report t*o DOE Headquarters in January 2012 (DOE-ID 11383) (DOE-ID 2012a). This plan contains strategies and activities for 2012 that are leading to continual energy efficiency, greenhouse gas reductions, environmental improvements, and transportation fuels efficiency to facilitate the INL Site in meeting the goals and requirements of Executive Order 13514, and DOE Order 436.1 before the end of fiscal year 2020.

The INL Site as a whole spent over $12.6 M in 2012 for facility and equipment energy. Of this total $11.9 M was spent for building energy, $1.06 M was spent for process energy, and $696 K was spent on equipment fuel. The managed area consumes over 858.2 billion Btu of energy and 859 million gallons of water annually. Energy consumption at the INL Site for 2012 on a Btu/ft2 basis has been reduced by 13.8 percent when compared to the base year of 2003.

Transportation fuel use across the INL Site totaled over 1,001,042 gallons of various types of fuels for 2012. The fleet is composed of light-duty vehicles fueled by gasoline and E-85. Heavy-duty vehicles include over-the-road-buses fueled by diesel and bio-diesel, and a complex assortment of trucks and equipment. Table 2-5 lists energy and water use reduction goals for the INL Site. A more detailed discussion of environmental management systems, waste minimization, and pollution prevention programs is provided in Chapter 3.

Table 2-4. Executive Order 13514 Targets and Management Strategies for Federal Agencies (2012).

Numerical Targets
• Reduce petroleum consumption by 2 percent per year through FY[a] 2020 • Reduce by 2 percent annually: – Potable water intensity by FY 2020 (26 percent total reduction). – Industrial, landscaping, and agricultural water intensity by FY 2020 (20 percent total reduction) • Achieve 50 percent or higher diversion rate: – Non-hazardous solid waste by FY 2015. – Construction and demolition materials and debris by FY 2015. • Ensure at least 15 percent of existing buildings and leases meet the Guiding Principles by FY 2015, with continued progress towards 100 percent. • Ensure 95 percent of all new contracts, including non-exempt contract modifications, require products and services that are energy-efficient, water-efficient, biobased, environmentally preferable, non-ozone depleting, contain recycled-content, non-toxic or less-toxic alternatives. • Reduce Scope 1 & 2 GHG 28 percent by 2020 • Produce at least 7.5 percent of sites energy from onsite renewable sources. • Reduce building energy intensity by 3 percent annually or 30 percent by 2015.
Non-Numerical Targets
• Increase renewable energy and renewable energy generation on agency property. • Pursue opportunities with vendors and contractors to reduce GHG[a] emissions (i.e., transportation options and supply chain activities). • Reduce building energy intensity. • Ensure all new Federal buildings that enter the planning process in 2020 and thereafter are designed to achieve zero-net-energy standards by 2030. • Use low GHG emitting vehicles, including AFVs[a], and optimize the number of vehicles in agency fleets. • Implement water management strategies including water-efficient and low-flow fixtures. • Implement source reduction to minimize waste and pollutant generation. • Decrease use of chemicals directly associated with GHG emissions. • Participate in transportation planning and recognize existing infrastructure in regions/communities. • Ensure procurement preference for EPEAT[a]-registered electronic products.
Specific Management Strategies to Improve Sustainability
• Develop and implement innovative, agency-specific policies and practices to reduce scope 3 GHG emissions in agency operations. • Manage existing buildings to reduce energy, water, and materials consumption. • Implement and achieve objectives in EPA's Stormwater Management Guidance. • Reduce paper use and acquire paper containing at least 30 percent postconsumer fiber. • Minimize the acquisition, use, and disposal of toxic and hazardous materials. • Employ environmentally sound practices for the disposition of all agency excess or surplus electronic products. • Procure Energy Star and FEMP[a]-designated electronic equipment. • Continue implementation of existing EMS programs.

a. FY = fiscal year; GHG = greenhouse gas; AFV = alternative fuel vehicle; EPEAT = Electronic Product Environmental Assessment Tool; FEMP = Federal Energy Management Program.

Table 2-5. Estimated Future Energy and Water Use Reduction for the INL Site (2012).

Performance Area	Baseline[a]	2015 Goal
Total Building Energy Use	981,300 MBtu	702,280 MBtu
Total Building Water Use	1,010.0 Mgal	810.1 Mgal

a. 2003 is the baseline year for Energy Use and 2007 is the baseline year for Water Use.

2.3 Waste Management

2.3.1 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) established regulatory standards for generation, transportation, storage, treatment, and disposal of hazardous waste. The Idaho Department of Environmental Quality (DEQ) is authorized by EPA to regulate hazardous waste and the hazardous components of mixed waste at the INL Site. Mixed waste contains both radioactive and hazardous materials. The Atomic Energy Act, as administered through DOE orders, regulates radioactive wastes and the radioactive part of mixed wastes. A RCRA hazardous waste permit application contains two parts – Part A and Part B. Part A of the RCRA hazardous waste permit application consists of EPA Form 8700-23, along with maps, drawings, and photographs, as required by 40 CFR 270.13. Part B of the RCRA hazardous waste permit application contains detailed, site-specific information as described in applicable sections of 40 CFR 270.14 through 270.27. The INL Site currently has two RCRA Part A permit volumes and seven Part B permit volumes (Parts A and B are considered a single RCRA permit and are comprised of several volumes).

RCRA Reports – As required by the state of Idaho, the INL Site submitted the 2012 Idaho Hazardous Waste Generator Annual Report in January 2013. The report contains information on waste generation, treatment, recycling, and disposal activities at INL Site facilities.

RCRA Closure Plan – The state of Idaho approved closure plans for the following facilities in 2012:

- Materials and Fuels Complex, Sodium Processing Facility and Secondary Sodium Piping Closure.

RCRA Inspection – On January 31 – February 2 and February 29, 2012, DEQ conducted an annual RCRA inspection of the INL Site. No enforcement actions were initiated against INL Site contractors, as a result of the inspection.

On April 23 – 25, 2012, DEQ conducted an annual RCRA inspection of the INL Site. No enforcement actions were initiated against INL contractors as a result of the inspection.

On February 27 – 29, 2012, DEQ conducted an annual RCRA inspection of the INL Site. On May 9, 2012, DEQ sent a RCRA/Hazardous Waste Management Act Compliance Warning Letter to DOE and an INL Site contractor stating that alleged violations were identified during the inspection. A response to the Warning Letter was provided to DEQ detailing corrective actions taken to remedy the apparent violations. No penalty was assessed by the DEQ.

2.3.2 Federal Facility Compliance Act

The Federal Facility Compliance Act requires the preparation of site treatment plans for the treatment of mixed wastes stored or generated at DOE facilities. Mixed waste contains both hazardous and radioactive components. The INL Site Proposed Site Treatment Plan was submitted to the state of Idaho and EPA on March 31, 1995. This plan outlined DOE-ID's proposed treatment strategy for INL Site mixed-waste streams, called the "backlog," and provided a preliminary analysis of potential offsite mixed low-level waste treatment capabilities. The Federal Facility Compliance Act Consent Order and Site Treatment Plan was finalized and signed by the state of Idaho on November 1, 1995 (DEQ 1995). A status of Site Treatment Plan milestones for 2012 is provided in Chapter 3.

2.3.3 Toxic Substances Control Act

The Toxic Substances Control Act (TSCA), which is administered by EPA, requires regulation of production, use, or disposal of chemicals. TSCA supplements sections of the Clean Air Act, the Clean Water Act, and the Occupational Safety and Health Act. Because the INL Site does not produce chemicals, compliance with TSCA is primarily directed toward use and management of certain chemicals, particularly polychlorinated biphenyls (PCBs). PCB-containing light ballasts are being removed at buildings undergoing demolition. The ballasts are disposed off the INL Site in a TSCA-approved disposal facility.

2.3.4 DOE Order 435.1, Radioactive Waste Management

DOE Order 435.1, "Radioactive Waste Management," was issued to ensure that all DOE radioactive waste is managed in a manner that protects the environment and worker and public safety and health. This Order, effective July 1, 1999, includes the requirements that DOE facilities and operations must meet in managing radioactive waste. Change 1 was added to the Order in August 2001. INL Site activities related to this Order are discussed in Chapters 3 and 6.

2.3.5 1995 Settlement Agreement

On October 16, 1995, DOE, the U.S. Navy, and the state of Idaho entered into an agreement that guides management of spent nuclear fuel and radioactive waste at the INL Site. The agreement (DOE 1995) limits shipments of DOE and Naval spent nuclear fuel into the state and sets milestones for shipments of spent nuclear fuel and radioactive waste out of the state. DOE must have all Idaho spent nuclear fuel in dry storage by 2023 and all spent nuclear fuel out of Idaho by 2035.

The INL Site continues to ship transuranic waste to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, in compliance with the Settlement Agreement requirement to ship a running average of no fewer than 2,000 m^3 (2,616 yd^3) of transuranic waste per year out of Idaho. The running average over the past three years is 4,216 m^3 (5,514 yd^3). In calendar year 2012,

2,536 m^3 (3,317 yd^3) of transuranic waste was shipped out of Idaho. This amount included 6 m^3 (7.8 yd^3) of remote-handled transuranic waste. In addition, 1,430 m^3 (1,870 yd^3) of mixed low-level waste historically managed as transuranic was shipped.

In 2012, 289 m^3 (378 yd^3) of buried transuranic waste was shipped.

The INL Site received two truck cask shipments containing 0.0215 metric tons heavy metal of spent nuclear fuel. Specifically, the spent nuclear fuel was received from Mexico's National Nuclear Research Institute and Austria's Vienna University of Technology.

2.4 Water Quality and Protection

2.4.1 Clean Water Act

The Clean Water Act (CWA), passed in 1972, established goals to control pollutants discharged to U.S. surface waters. Among the main elements of the CWA are effluent limitations for specific industry categories set by EPA and water quality standards set by states. The CWA also provided for the National Pollutant Discharge Elimination System (NPDES) permit program, requiring permits for discharges into regulated surface waters.

The INL Site complies with two CWA permits through the implementation of procedures, policies, and best management practices. The first permit covers discharges from Idaho Falls facilities to the city of Idaho Falls publicly-owned treatment works. The second permit, NPDES General Permit for Storm Water Discharges from Construction Activities, provides protective requirements for construction activities located within the INL Site storm water corridor (63 FR 31). These permits are discussed further in the following sections.

National Pollutant Discharge Elimination System Permits – The city of Idaho Falls is authorized by the NPDES permit program to set pretreatment standards for nondomestic discharges to publicly-owned treatment works. This program is set out in the Municipal Code of the city of Idaho Falls regulations in Chapter 1, Section 8. The INL Research Center is the only facility that is required to have an Industrial Wastewater Acceptance Permit. The Industrial Wastewater Acceptance Permit contains special conditions and compliance schedules, prohibited discharge standards, reporting requirements, monitoring requirements, and effluent concentration limits for specific parameters. All discharges from Idaho Falls facilities in 2012 were within compliance levels established in the acceptance permit.

Storm Water Discharge Permits for Construction Activity – INL Site contractors obtain coverage under the general permit for individual construction projects. Storm water pollution prevention plans are completed for individual construction projects. Only construction projects that are determined to have a reasonable potential to discharge pollutants to regulated surface water are required to have a storm water pollution prevention plan and general permit inspections of construction sites are performed in accordance with permit requirements. Coverage for the INL Site under the General Permit for Storm Water Discharges from Construction Sites (CGP) was issued in June 1993. The coverage under the general permit was renewed twice. In 2012, the criteria regarding erosion and sedimentation was achieved at the permitted INL sites, therefore Notice of Terminations from the CGP requirements were submitted to the EPA and approved. Any new construction projects within the INL Site storm water corridor will require a new CGP.

2.4.2 Safe Drinking Water Act

The Safe Drinking Water Act establishes primary standards for water delivered by systems supplying drinking water to 15 or more connections or 25 individuals for at least 60 days per year. The INL Site drinking water supplies meet these criteria for public water systems and are classified as either nontransient noncommunity or transient noncommunity systems.

The INL Site has 12 active public water systems, one of which serves the Naval Reactors Facility. All INL Site facilities sample drinking water as required by the state of Idaho and EPA. Chapter 5 contains details on drinking water monitoring.

2.4.3 State of Idaho Wastewater Reuse Permits

Wastewater consists of spent or used water from a home, community, farm, or industry that contains dissolved or suspended matter. To protect public health and prevent pollution of surface and ground waters, state of Idaho regulations require anyone wishing to land-apply or otherwise use wastewater to obtain a Wastewater Reuse Permit according to Idaho Administrative Procedures Act (IDAPA) 58.01.17 (“Recycled Water Rules”) and (IDAPA) 58.01.16 (“Wastewater Rules”). DEQ is responsible to issue Wastewater Reuse Permits. Two types of Wastewater Reuse Permits are issued – industrial and municipal. Industrial Wastewater Reuse Permits regulate reuse of wastewater from such operations as food processing facilities. Municipal Wastewater Reuse Permits regulate reuse of wastewater that contains treated sewage. All Wastewater Reuse Permits specify both standard and site-specific conditions. Land application of wastewater is one method of reusing treated wastewater. It is a natural way of recycling by which wastewater is applied to land and is absorbed by vegetation or infiltrated into the soil column. Reuse is the broader topic of which land application is but one method. Other methods of reuse include irrigation, commercial toilet flushing, dust control, and fire suppression.

Applications for Wastewater Reuse Permits have been submitted to DEQ for all existing INL Site land application facilities. DEQ has issued permits for:

- Central Facilities Area Sewage Treatment Plant
- Advanced Test Reactor Complex Cold Waste Ponds
- Idaho Nuclear Technology and Engineering Center New Percolation Ponds
- Materials and Fuels Complex Industrial Waste Ditch and Industrial Waste Pond.

2.4.4 IDAPA 58.01.02, Water Quality Standard

In August 2007, analysis of groundwater samples from the ICPP-2018 monitoring well at INTEC detected petroleum products. An investigation of the source of the petroleum products determined it likely to be weathered diesel No. 2, the source of which was most likely the CPP-701A Diesel Tank that had leaked in 2005 and had been repaired. On April 1, 2008, DEQ gave DOE and the ICP contractor an Administrative Order to assess the extent of the contamination and to develop corrective actions if necessary. On December 9, 2008, ICP submitted a Schedule and Criteria document to outline the investigation and a subsequent groundwater monitoring plan with proposed corrective actions in March 2009. The plan identifies activities for removal of petroleum product and the sampling and analysis of groundwater for benzene toluene, ethylbenzene, xylenes (BTEX) compounds, and polynuclear aromatic hydrocarbons to fulfill

the requirements of the Administrative Order and IDAPA 58.01.02.852. The monitoring and free product recovery activities required by the Corrective Action/ Monitoring Plan for the petroleum release associated with Well ICPP-2018 (ICP 2012) continued through 2012. Monitoring activities included measuring water levels in selected perched water and aquifer wells, checking for the presence of non-aqueous phase liquid (NAPL) in these wells, measuring product quantities removed, and collecting and analyzing groundwater samples.

Measurable thicknesses of petroleum product (NAPL) were observed and recovered from Well ICPP-2018 at times throughout 2012. The insertion of absorbent socks into Well ICPP-2018 has been effective in removing petroleum product. During 2012, approximately 12.4 L of petroleum product was recovered from Well ICPP-2018. During the July 2012, sampling event, approximately 4 ft of free product was measured in the well. Between July and August 2012, the thickness of product in the well decreased to approximately 1 ft. through a combination of using an absorbent sock and well purging.

No benzene toluene, ethylbenzene, xylenes constituents were detected at the applicable detection levels in monitoring well ICPP-2018. Because monitoring well CPP-33-4-1 was determined to be essentially dry on July 25, 2012, no perched water samples were collected from this well. Four polynuclear aromatic hydrocarbons compounds (fluorine, pyrene, chrysene, and benzo[b]fluoranthene) were positively detected in ICPP-2018 (ICP 2012).

2.5 Cultural Resources Protection

Cultural resources at the INL Site are numerous and include prehistoric archaeological resources representing more than 13,000 years of human occupation, historic resources representing the period from 1805 to the late 1920s, important historic World War II, post-war, and nuclear facilities like Experimental Breeder Reactor I, which was the first reactor in the world to produce usable electrical power and is recognized as a National Historic Landmark, and places and resources of importance to the Shoshone-Bannock Tribes.

Preservation of cultural resources on lands managed by DOE is mandated by a number of federal laws and their implementing regulations, primary among them are: the National Historic Preservation Act (NHPA) of 1966, the National Environmental Policy Act of 1969, and the Archaeological Resource Protection Act of 1979. Many of the cultural resources located at the INL Site are historic properties, potentially eligible for nomination to the National Register of Historic Places. The NHPA includes specific guidelines (Section 106) for a legal process used to assess the potential impacts of federal undertakings and determine if adverse effects to these properties will occur. Communication and formal consultation, when required, between DOE-ID and the Idaho State Historic Preservation Office and interested parties such as the Shoshone-Bannock Tribes are used to develop reasonable means of avoiding or mitigating adverse effects when they are anticipated. The NHPA also outlines requirements for developing a broad understanding of all cultural resources to provide a basis for decisions regarding management and mitigation (Section 110).

The INL Cultural Resource Management Plan (DOE-ID 2013b) was written specifically for INL Site resources. The Plan provides a tailored approach to comply with NHPA and other federal laws and state laws and regulations and to implement DOE cultural resource policies and

goals while meeting the unique needs of the INL. The Plan is reviewed annually and updated, as needed and is legitimized through a signed Programmatic Agreement between DOE-ID, the Advisory Council on Historic Preservation, and the Idaho State Historic Preservation Office, dated July 2004, *Concerning Management of Cultural Resources on the INL Site* (DOE-ID 2004).

2.5.1 Compliance with Cultural Resource Management Requirements

The INL is an active facility where thousands of work orders for projects ranging from lawn care to new facility construction are processed each year. Several laws, guidelines, Executive Orders, and other requirements guide the management of cultural resources on federal lands, including those that are under the jurisdiction of DOE-ID. The comprehensive *INL Cultural Resource Management Plan* (DOE-ID 2013b) contains a complete list of cultural resource management requirements and tailors these requirements to meet the unique needs of the INL. A tailored approach for assessing and, when necessary, mitigating adverse impacts to cultural resources as a consequence of all activities large or small. Under INL procedures, a cultural resource review is prompted whenever ground disturbance or major structural or landscape modifications are proposed. In 2012, 23 INL projects were reviewed for potential impacts to cultural resources. Table 2-6 provides a summary of the cultural resource activities performed. In the majority of projects reviews, archival records of previous cultural resource investigations demonstrated that no sensitive cultural resources would be affected by the activities proposed.

In five instances, field studies were completed to identify and evaluate archaeological sites. Approximately 197 acres were intensively examined during these project surveys, 14 new archaeological resources were identified and recommended for avoidance or other protective measures, and six prehistoric sites were subject to test excavations. Cumulatively, the total number of acres surveyed for archaeological resources on the INL Site increased to 55,627 with the addition of these surveys (approximately 10 percent of the 890 square mile laboratory) and the total number of known archaeological resources identified rose to 2,741.

In addition to project reviews involving archaeological resources, nine reviews were conducted for projects that had the potential to impact INL historic architectural properties. Activities associated with eight of the projects were determined to be exempt from cultural resource review and one proposed project involved resources that had been determined ineligible for listing on the National Register of Historic Places. No adverse effects to historic architectural properties or any other cultural resources were proposed in 2012, so no Memoranda of Agreement were negotiated with the Idaho SHPO or other stakeholders and no mitigation (i.e., Historic American Engineering Record documentation, large format photographs, archaeological data recovery activities) was necessary.

The results of project-specific cultural resource reviews are documented in a number of ways per the guidelines of the *INL Cultural Resource Management Plan*. Recommendations tailored to specific projects and any cultural resources that may require consideration are delivered in official e-mail notes that become part of the project's National Environmental Policy Act-driven Environmental Checklist and permanent record. For larger projects, technical reports are often prepared to synthesize cultural resource information and recommendations. In 2012, two such reports were completed:

Table 2-6. Cultural Resource Reviews Performed at the INL Site (2012).

Project #	Project Name	INL CRM Activities	Acres Surveyed	Cultural Resources Identified
BEA-12-01:	Homeland Security Electrical Grid projects	Environmental Checklist review and limited field survey	1	None
BEA-12-02:	Remote Handled Low Level Waste Facility Future Expansion Area and Utility Tie-in	Archive search, archaeological survey, and reporting	60	2 isolates
BEA-12-03:	New USGS Well No. 138	Environmental Checklist review and limited field survey	1	1 site
BEA-12-04:	NRF Infrastructure Recapitalization	Archaeological survey, site monitoring, archaeological test excavations, and reporting	135	9 isolates 2 sites 7 sites tested
BEA-12-05:	NRF Parking Improvements	Archaeological test excavation	None	1 site tested
BEA-12-06:	Texas A & M Archaeological Field School	Permit oversight, archaeological research-oriented excavation, and reporting	None	1 site excavated
BEA-12-07:	Texas A & M Perishable Artifact Analysis	Permit oversight, artifact analysis, and reporting	None	1 site analyzed
BEA-12-08:	INL Cave Inventory	Archaeological monitoring of known resource locations	None	None
BEA-12-09:	DoD Training at CITRC	Environmental Checklist review	None	None
BEA-12-10:	Quaking Aspen Grazing Allotment Permit Renewal	Coordination with Bureau of Land Management	None	None
BEA-12-11:	Small CWI projects	Environmental Checklist reviews	292 acres	7 isolates 1 site
BEA-12-12:	National Security Test Range Sign Realignment	Environmental Checklist review and recommendations for future work	None	None
BEA-12-13:	CWI Ordnance Surveys	Environmental Checklist review	None	None
BEA-12-14:	Railroad Maintenance	Environmental Checklist review	None	None
Architectural BEA-12-01:	MFC ZPPR Glovebox Installation	Eligible; exempt activity	NA	NA
Architectural	INTEC Routine Maintenance	Exempt activity	NA	NA

Table 2-6. Cultural Resource Reviews Performed at the INL Site (2012). (cont.)

Project #	Project Name	INL CRM Activities	Acres Surveyed	Cultural Resources Identified
BEA-12-02:				
Architectural BEA-12-03:	TRA-609 Drain Line Mod/Valve Replacement	Eligible; exempt activity	NA	NA
Architectural BEA-12-04:	CF-688 Standby Generator and Switch Replacement	Ineligible	NA	NA
Architectural BEA-12-05:	INL Routine Maintenance	Eligible; exempt activity	NA	NA
Architectural BEA-12-06:	TRA-670 Monorail Installation	Eligible; exempt activity	NA	NA
Architectural BEA-12-07:	TRA-653 HVAC Mods	Eligible; exempt activity	NA	NA
Architectural BEA-12-08:	TRA-670 Backup Power Lighting Installation	Eligible; exempt activity	NA	NA
Architectural BEA-12-09:	CF-614 and CF-1605 Vacated	Ineligible	NA	NA

- "Archaeological Test Excavations at the Naval Reactors Facility on the Idaho National Laboratory Preliminary Results" (INL/LTD-11-24007, December 2011), and
- "Archaeological Investigations for Parking Improvements at the Naval Reactors Facility on the Idaho National Laboratory" (INL/LTD-12-26298, June 2012).

Information gathered during INL cultural resource investigations is carefully managed as a valuable archive of INL cultural resources and a record of decision-making related to cultural resource compliance. These hard copy and electronic data provide the foundation for archaeological predictive modeling efforts that facilitate land use planning in both the long- and short-term and serve important roles in local and regional archaeological research. Important documents related to the historical development of the INL Site, the ground-breaking scientific research conducted throughout INL history, and inventories to identify historic properties associated with these activities are also preserved.

INL cultural resources investigations in 2012 also were conducted to further DOE-ID obligations under Section 110 of the National Historic Preservation Act to develop a broad understanding of all INL Site archaeological resources, not only those located in active project areas. For a third year, the INL Cultural Resources Management program collaborated with researchers from the Center for the Study of the First Americans at Texas A & M University to pursue ongoing scholarly research on long-term human occupation of the INL Site region. In

2012, the INL Cultural Resource Management (CRM) Office hosted an archaeological field school from Texas A & M to teach field methods and continue excavations at an important prehistoric campsite (10-BT-676) located on the banks of the Big Lost River. Deeply stratified cultural deposits at this site extend more than two meters below surface and hold promise for providing information to contribute to a clearer understanding of regional cultural chronology and human adaptations. Analysis of the artifacts and other samples recovered from excavations at this site are ongoing into 2013.

No archaeological materials were unexpectedly discovered at the INL Site in 2012. Under INL-wide Stop Work Authorities, INL employees are authorized to stop work at all DOE-ID, contractor, and/or subcontractor operations if they believe the work poses an imminent danger to human health and safety, or the environment, including irreplaceable cultural resources. Procedures are in place to make immediate notifications to appropriate parties (INL CRM, DOE-ID, Shoshone-Bannock Tribes, State of Idaho, local law enforcement) in the event of any discoveries of this nature. Additionally, areas that have previously revealed unanticipated discoveries of sensitive cultural materials are routinely monitored for new finds.

2.5.2 Cultural Resources Monitoring

The INL CRM Office conducts yearly cultural resource monitoring that includes many sensitive archaeological, historic architectural, and tribal resources. The results of fiscal year (FY) 2012 INL cultural resource monitoring are documented in a technical report, INL Cultural Resource Monitoring Report for FY 2012 (DOE-ID 2012b). During the reporting year, 29 archaeological localities and 11 historic architectural properties were revisited and monitored including:

- Two locations with Native American human remains, one of which is a cave,
- Seven additional caves, one of which is listed on the National Register,
- Fifteen prehistoric archaeological sites,
- Four historic archaeological sites (two homesteads and two stage stations),
- One historic trail,
- Experimental Breeder Reactor I (EBR-601) and associated guardhouse (EBR-602), and
- Central Facilities Area World War II Signature Properties (CF-606, CF-607, CF-613, CF-632, CF-633, CF-637, CF-638, CF-642, and CF-651).

In 2012, one new impact was noted. A historic trail, T-16, was impacted by the 2012 Midway Fire suppression activities. The T-16 trail connects several historic archaeological sites, including the Wakefield Homestead, to one another and other locations on the landscape, such as the ca. 1910 town of Cerro Grande. In 2012, monitoring revealed that portions of the original T-16 trail had been widened to create a fire containment line (Figure 2-1). This impact does not affect the trail's eligibility to the National Register of Historic Places but has the potential to change the historic trail to a 4-lane road. Monitoring and possible corrective actions will continue in 2012. Investigations are also ongoing for the unauthorized visitation and artifact collection discovered and reported at three archaeological sites in 2010 and 2011. A final report is expected from DOE-ID Security and the U.S. Fish and Wildlife Service agents in 2013.

Figure 2-1. The Truck is Parked on the Original T-16 Trail and the Containment Line is to its Right.

The results of monitoring conducted at the Central Facilities Area World War II historic properties have been reported previously. The results include impacts associated with vacancy and a lack of basic maintenance on CF-606, CF-607, CF-613, CF-632, and CF-633. The structures are slated for removal and in 2013, the INL CRM staff will continue to work with DOE-ID, Battelle Energy Alliance facility managers, the DOE-Headquarters Federal Preservation Officer, Idaho State Historic Preservation Officer, and Advisory Council on Historic Preservation to determine their final disposition (DOE-ID 2012b).

2.5.3 Stakeholder, Tribal, Public, and Professional Outreach

Outreach and education are important elements in the INL CRM program and efforts are routinely oriented toward the general public, INL employees, important stakeholders such as the Idaho State Historic Preservation Office and Shoshone-Bannock Tribes, and cultural resource professionals. Tools that facilitate communication include activity reports, presentations, newspaper articles and interviews, periodic tours, monthly meetings with Tribal representatives, and various INL-specific internal and external media outlets. Educational exhibits at the Experimental Breeder Reactor I Visitor's Center (a National Historic Landmark) and the Big Lost River Rest Area on U.S. Highway 20/26 are also important public outreach tools. Several legal drivers mandate these efforts, including a new 2012 Memorandum of Understanding between the DOE, the Departments of Defense, Interior, and Agriculture, and the national Advisory Council on Historic Preservation to improve the protection of Indian sacred sites along with tribal access to those sites through enhanced interdepartmental coordination and collaboration.

The INL Site is located on the aboriginal territory of the Shoshone and Bannock people. The Shoshone-Bannock Tribes have a government-to-government relationship with DOE-ID that is strengthened and maintained through an Agreement-in-Principle (AIP) (revised and signed in December 2012) between the Tribes and the DOE-ID (DOE-ID 2012c). The AIP defines working relationships between the Shoshone-Bannock Tribes and DOE-ID and fosters a mutual understanding and commitment to addressing a variety of tribal concerns regarding protection of health, safety, and environment, including cultural resources of importance to the Tribes. To aid with implementing cultural resource aspects of the AIP, a Cultural Resources Working Group comprised of representatives from the Shoshone-Bannock's Heritage Tribal Office, DOE-ID, and the INL CRMO was established in 1993. It was the first of its kind within the DOE complex and its regular Cultural Resources Working Group meetings enable issues and opportunities to be addressed in an environment of mutual respect and learning. Tribal input is sought for new and ongoing projects and a standing invitation is extended to comment on, visit, observe, and/or assist in INL CRM Office field activities (Figure 2-2). The holistic view of cultural resources and cooperative spirit encouraged in this group foster an atmosphere of mutual respect that is conducive to open communication and effective consideration of tribal views in decisions regarding INL cultural resources and overall land management.

2.5.4 Cultural Resource Monitoring

More detail on monitoring activities is captured in an annual monitoring report. The report is due each year at the end of October and is available through the DOE-ID Cultural Resource Management Coordinator or the INL Cultural Resources Management Office.

2.6 Summary of Environmental Permits

Table 2-1 summarizes active permits for the INL Site through year-end 2012 that were issued for sitewide or individual facility operations or both that have been referenced in previous sections of this chapter.

Figure 2-2. LaRae Bill, Shoshone-Bannock Heritage Tribal Office, and Julie Braun Williams, INL CRMO, measure test unit.

REFERENCES

10 CFR 1021, 2012, "National Environmental Policy Act Implementing Procedures," *Code of Federal Regulations*, Office of the Federal Register.

10 CFR 1022, 2012, "Compliance with Floodplain and Wetland Environmental Review Requirements," *Code of Federal Regulations*, Office of the Federal Register.

40 CFR 61, Subpart H, 2012, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities," *Code of Federal Regulations*, Office of the Federal Register.

40 CFR 1500, 2012, "National Environmental Policy Act (NEPA), Purpose, Policy, and Mandate," *Code of Federal Regulations*, Office of the Federal Register.

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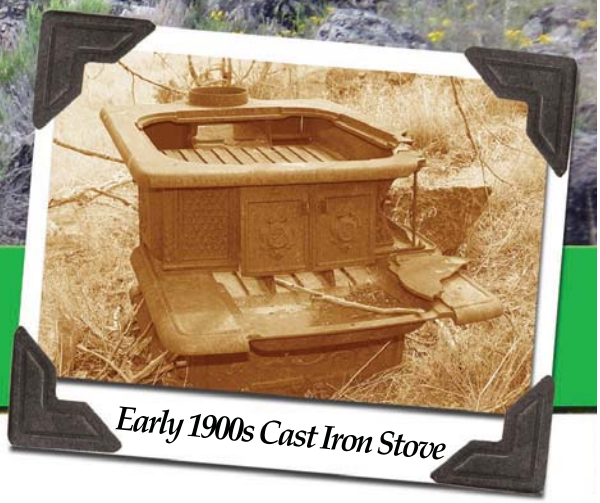
2012

3. Environmental Program Information



Early 1900s Cast Iron Stove

Chapter 3 Highlights

Environmental monitoring programs at the Idaho National Laboratory (INL) Site involve sampling environmental media, including ambient air; drinking water, surface water, and groundwater; soils; vegetation; agricultural products and wildlife; and measuring direct radiation. More than 6,100 samples were collected and analyzed in 2012 for a wide array of constituents, including pH, inorganics, volatile organics, gases, gross alpha and beta activity, and specific radionuclides, such as tritium, strontium, americium, and plutonium isotopes.

The Department of Energy Headquarters Office of Independent Oversight within the Office of Health, Safety, and Security conducted an independent assessment of the INL Site environmental monitoring programs in 2010, at the request of the Department of Energy Idaho Operations Office. Most of the recommendations of the assessment team for individual programs were implemented in 2011 and 2012. INL Site contractors also continued to develop the technical basis for the sitewide environmental monitoring program.

Significant progress continues on INL Site cleanup activities. Among the 2012 accomplishments are:

- 2,536 m^3 (3,317 yd^3) of treated transuranic waste was sent from the Advanced Mixed Waste Treatment Project to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, for disposal
- 1,430 m^3 (1,870 yd^3) of mixed low-level waste, historically managed as stored transuranic waste, was also shipped off the INL Site from the Advanced Mixed Waste Treatment Project
- More than 203 m^3 (266 yd^3) of mixed low-level waste and 1,741 m^3 (2,277 yd^3) of low-level waste were shipped off the INL Site from the Radioactive Waste Management Complex (RWMC) for treatment or disposal or both. Approximately 26.62 m^3 (35 yd^3) of newly generated, low-level waste was disposed of at the RWMC.

Contractors in charge of nuclear energy and cleanup operations at the INL Site had environmental management systems in place that were compliant with Department of Energy Order 436.1 (“Departmental Sustainability”) requirements. The INL Site energy usage was reduced by 13.8 percent in FY-2012 from the FY-2003 baseline. Water usage was reduced by 18.3 percent in FY-2012 from the FY-2007 baseline. In 2012, greenhouse gas emissions produced at the INL Site were reduced by 20.3 percent from the 2008 baseline. In 2012, the Pollution Prevention Program successfully accomplished the goals of the INL Site Pollution

Prevention Plan through projects such as the Federal Electronics Challenge, Earth Day, and the INL's recycling initiative.

The Idaho Cleanup Project Decontamination and Decommissioning project was officially closed out in September 2012. The project safely decontaminated and decommissioned 223 buildings and structures for a total footprint reduction of over 1.6 million square feet. The project demolished three nuclear reactors, two hot cell facilities, the largest hot shop in the world, a spent fuel reprocessing complex, large laboratory buildings, and numerous warehouses and storage buildings.

3. ENVIRONMENTAL PROGRAM INFORMATION

This chapter highlights the Idaho National Laboratory (INL) Site environmental programs that help maintain compliance with major acts, agreements, and orders. Much of the regulatory compliance activity is performed through the various environmental monitoring programs (Section 3.1), environmental restoration (Section 3.2), waste management and disposition (Section 3.3), and the Environmental Management System (EMS) (Section 3.4). Section 3.5 summarizes other significant INL Site environmental programs and activities.

3.1 Environmental Monitoring Programs

Facility effluents and environmental media are monitored for radioactive and nonradioactive constituents to ensure INL Site operations protect human health and the environment and comply with applicable environmental protection laws, regulations, and permits. INL Site environmental monitoring consists of effluent monitoring and environmental surveillance, which are defined as follows:

- Effluent monitoring is the collection and analysis of samples or measurements of liquid and gaseous effluents for the purpose of:
  - Characterizing and quantifying contaminants
  - Assessing radiation exposure of members of the public
  - Providing means to control effluents at or near the point of discharge
  - Demonstrating compliance with applicable standards and permit requirements.
- Environmental surveillance is the measurement of contaminants in the environment to assess any potential incremental effects that INL Site operations may have on human health and the environment. Routine surveillance of all exposure pathways (Figure 3-1) is performed on specific environmental media (air, water, agricultural products, animal tissue, soil, and direct radiation).

At the INL Site, several organizations conduct environmental monitoring:

- The INL contractor (Battelle Energy Alliance, LLC [BEA]) and the Idaho Cleanup Project (ICP) contractor (CH2M-WG Idaho, LLC [CWI]) perform monitoring activities on the INL Site.

- The Environmental Surveillance, Education, and Research (ESER) contractor, Gonzales-Stoller Surveillance, LLC (GSS), performs monitoring activities off the INL Site.
- Two federal agencies also perform monitoring activities on and around the INL Site under interagency agreements with the Department of Energy, Idaho Operations Office (DOE-ID). The National Oceanic and Atmospheric Administration conducts meteorological monitoring and research, and the U.S. Geological Survey (USGS) conducts groundwater monitoring and research.

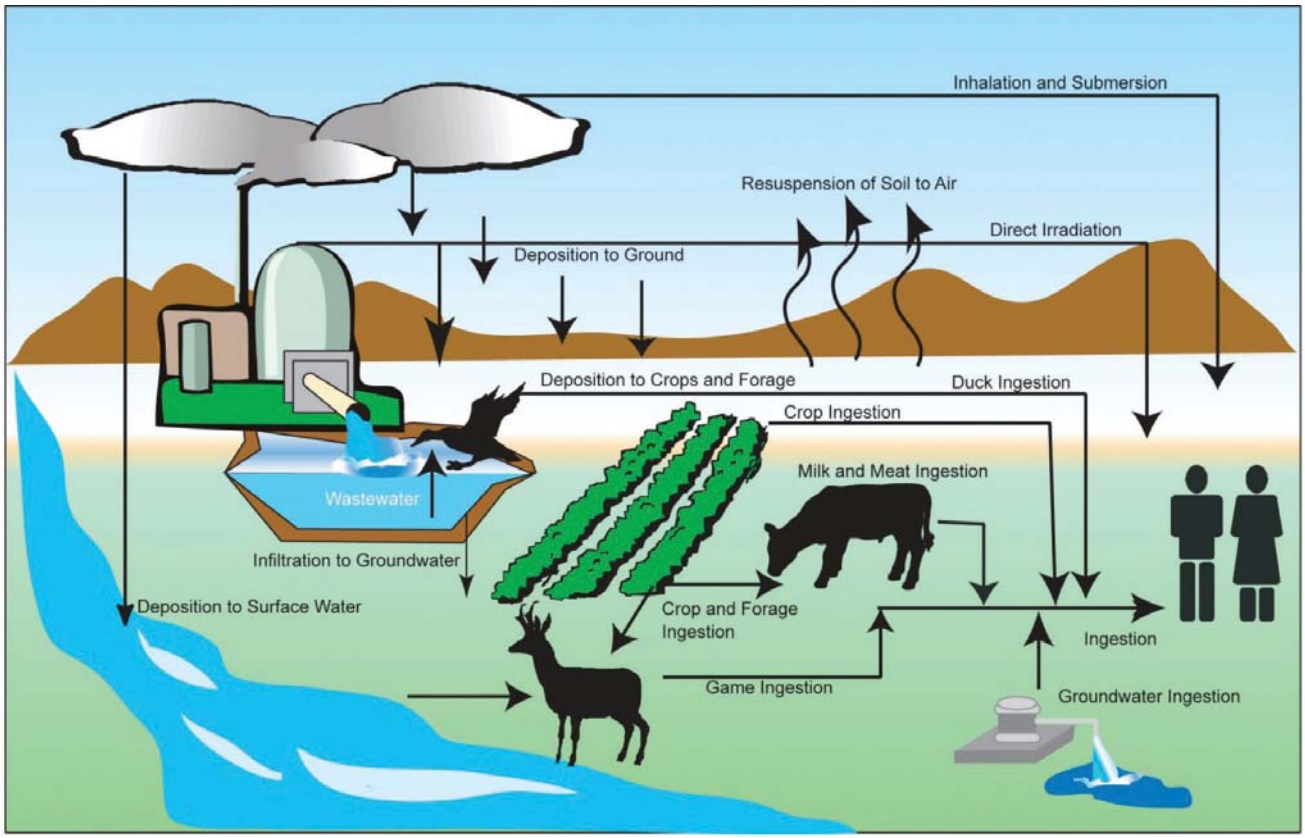


Figure 3-1. Potential Exposure Pathways to Humans from the Idaho National Laboratory Site.

Tables 3-1 through 3-6 present a summary of the environmental surveillance programs conducted by the ESER, INL, and ICP contractors and the USGS in 2012. In addition to the monitoring constituents listed in Table 3-6, the USGS collected samples twice a year from two wells in cooperation with the Naval Reactors Facility (NRF), one time last year from 13 wells in cooperation with NRF, and collected an expanded list of constituents from 11 multi-depth sampling wells. This expanded constituent list changes from year to year in response to USGS program remedial investigation/feasibility study requirements. The constituents collected during 2012 for the multi-depth wells were major anions and cations, trace elements, nutrients, selected radionuclides including iodine-129, and selected stable isotopes. These data are available from the USGS by request. For a more detailed description of INL Site monitoring activities, see the Idaho National Laboratory Site Environmental Monitoring Plan (DOE-ID 2012a).

Results of the environmental monitoring programs for 2012 are presented in Chapter 4 (air), Chapter 5 (compliance monitoring for liquid effluents, groundwater, drinking water, and surface water), Chapter 6 (eastern Snake River Plain aquifer), and Chapter 7 (agricultural, wildlife, soil, and direct radiation). Chapter 8 discusses radiological doses to humans and biota. Chapter 9 summarizes wildlife population monitoring at the INL Site, and Chapter 10 presents abstracts of ecological and USGS research studies conducted at the INL Site. Quality assurance activities of the various organizations conducting environmental monitoring are described in Chapter 11. A summary of historical environmental monitoring activities, meteorological monitoring, and statistical methods used in this report are provided as supplemental reports.

3.1.1 Sitewide Monitoring Committees

Sitewide monitoring committees include the INL Monitoring and Surveillance Committee and the INL Water Committee. The INL Monitoring and Surveillance Committee was formed in March 1997 and meets every other month or as needed to coordinate activities among groups involved in environmental monitoring on and off the INL Site. This standing committee includes representatives of DOE-ID, INL Site contractors, the ESER contractor, Shoshone-Bannock Tribes, the state of Idaho INL Oversight Program, the National Oceanic and Atmospheric Administration, NRF, and USGS. The INL Monitoring and Surveillance Committee has served as a valuable forum to review monitoring, analytical, and quality assurance methodologies; to coordinate efforts; and to avoid unnecessary duplication.

The INL Water Committee was established in 1994 to coordinate drinking-water-related activities across the INL Site and to provide a forum for exchanging information related to drinking water systems. In 2007, the INL Water Committee expanded to include all site-wide water programs: drinking water, wastewater, storm water, and groundwater. The committee includes monitoring personnel, operators, scientists, engineers, management, data entry, and validation representatives of the DOE-ID, INL Site contractors, USGS and NRF, and serves as a forum for coordinating water-related activities across the INL and exchanging technical information, expertise, regulatory issues, data, and training.

The INL Water Committee interacts on occasion with other committees that focus on water-related topics or programs, such as the INL Monitoring and Surveillance Committee.

Table 3-1. Environmental Surveillance, Education, and Research Program Summary (2012).

Medium Sampled	Type of Analysis	Locations and Frequency		Minimum Detectable Concentration
		Onsite	Offsite	
Air (low volume)	Gross alpha	3 weekly[a]	15 weekly[a]	1 x 10^{-15} µCi/mL
	Gross beta	3 weekly	15 weekly	1 x 10^{-14} µCi/mL
	Specific gamma	3 quarterly	15 quarterly	3 x 10^{-16} µCi/mL
	Plutonium-238	2 quarterly	5-6 quarterly	2 x 10^{-18} µCi/mL
	Plutonium-239/240	2 quarterly	5-6 quarterly	2 x 10^{-18} µCi/mL
	Americium-241	2 quarterly	5-6 quarterly	2 x 10^{-18} µCi/mL
	Strontium-90	2 quarterly	5-6 quarterly	6 x 10^{-17} µCi/mL
	Iodine-131	3 weekly	15 weekly	2 x 10^{-15} µCi/mL
	Total particulates	3 quarterly	15 quarterly	10 µg/m^3
	Gross beta	None	1, twice per week	1 x 10^{-15} µCi/mL
Air (high volume)[b]	Gamma scan	None	If gross β > 1 pCi/m^3	1 x 10^{-14} µCi/mL
	Isotopic U and Pu	None	1 annually	2 x 10^{-18} µCi/mL
Air (atmospheric moisture)	Tritium	None	4 locations, 3 to 6 per quarter	2 x 10^{-13} µCi/mL (air)
Air (precipitation)	Tritium	1 weekly/ 1 monthly[c]	1 monthly	100 pCi/L
Animal tissue (big game and waterfowl)[d]	Specific gamma	Varies annually	Varies annually	5 pCi/g
	Iodine-131	Varies annually	Varies annually	3 pCi/g
Alfalfa	Specific gamma	None	1 annually	0.1 pCi/g
Agricultural products (milk)	Cesium-137	None	1 weekly	1 pCi/L
	Iodine-131	None	1 weekly/9 monthly	3 pCi/L
	Strontium-90	None	9 semiannually	5 pCi/L
	Tritium	None	9 semiannually	150 pCi/L
Agricultural products (potatoes)	Specific gamma	None	8 –10 annually	0.1 pCi/g
	Strontium-90	None	8 –10 annually	0.2 pCi/g
Agricultural products (grain)	Specific gamma	None	10 –12 annually	0.1 pCi/g
	Strontium-90	None	10 –12 annually	0.2 pCi/g
Agricultural products (lettuce)	Specific gamma	1 annually	7 – 9 annually	0.1 pCi/g
	Strontium-90	1 annually	7 – 9 annually	0.2 pCi/g
Drinking Water[e]	Gross alpha	None	9-10 semiannually	3 pCi/L
	Gross beta	None	9-10 semiannually	2 pCi/L
	Tritium	None	9-10 semiannually	150 pCi/L
Surface Water[f]	Gross alpha	6 annually	4 semiannually	3 pCi/L
	Gross beta	6 annually	4 annually	2 pCi/L
	Tritium	6 annually	4 annually	150 pCi/L
Soil	Specific gamma	None	14 biennially[g]	0.001 pCi/g
	Plutonium-238	None	14 biennially	0.005 pCi/g
	Plutonium-239/240	None	14 biennially	0.1 pCi/g

Table 3-1. Environmental Surveillance, Education, and Research Program Summary (2012). (cont.)

Medium Sampled	Type of Analysis	Locations and Frequency		Minimum Detectable Concentration
		Onsite	Offsite	
	Americium-241	None	14 biennially	0.005 pCi/g
	Strontium-90	None	13 biennially	0.05 pCi/g
Direct radiation exposure (thermoluminescent dosimeters and optically stimulated luminescence dosimeters)	Ionizing radiation	None	17 semiannually	5 mR

a. Onsite includes three locations and a duplicate sampler at one location; off INL Site includes 13 locations and a duplicate sampler at one location.
b. Filters are collected by Environmental Surveillance, Education, and Research personnel for the Environmental Protection Agency (EPA) RadNet program and sent to the EPA for analysis. Data are reported by the Environmental Protection Agency's RadNet at http://www.epa.gov/narel/radnet/.
c. A portion of the monthly sample collected at Idaho Falls is sent to the Environmental Protection Agency for analysis, and data are reported by RadNet.
d. Only big game animals (pronghorn, elk or mule deer) that are victims of road kills or natural causes are sampled on the INL Site. No big game animal controls are collected. Waterfowl are usually collected on ponds within the Advanced Test Reactor Complex, Materials and Fuels Complex, and control areas.
e. Samples are co-located with the State of Idaho Department of Environmental Quality (DEQ) INL Oversight Program at Shoshone and Minidoka water supplies. An upgradient sample is collected at Mud Lake Well #2. The number of samples includes a duplicate sample.
f. Onsite locations are the Big Lost River (if running) at the public rest stop on highway 20/26, at two locations along Lincoln Boulevard, at EFS, and at the Big Lost River Sinks. A duplicate sample is also collected on the Big Lost River. Offsite samples are co-located with the DEQ INL Oversight Program at Alpheus Spring, Clear Springs, and at a fish hatchery at Hagerman. A duplicate sample is also collected at one location.
g. A duplicate sample is also collected at one location.

Table 3-2. Idaho National Laboratory Contractor Air and Environmental Radiation Surveillance Summary (2012).

Medium Sampled	Type of Analysis	Locations and Frequency		Detectable Concentration
		Onsite[a]	Offsite[a]	
Air (low volume)	Gross alpha	19 weekly	4 weekly	1×10^{-15} µCi/mL
	Gross beta	19 weekly	4 weekly	5×10^{-15} µCi/mL
	Specific gamma	19 semiannually	4 semiannually	Varies by analyte[b]
	Iodine-131	19 weekly	4 weekly	2×10^{-15} µCi/mL
Air (atmospheric moisture)	Tritium	2 to 4 per quarter	2 to 4 per quarter	1×10^{-11} µCi/mL (water)
Soil	In situ gamma	Varies annually	None	Varies by analyte
Direct radiation exposure (thermoluminescent dosimeters and optically stimulated luminescence dosimeters)	Ionizing radiation	54 semiannually	13 semiannually	5 mR
Direct radiation exposure (mobile radiation surveys)	Gamma radiation	Facilities and INL Site roads[b]	Not collected	Not applicable

a. Low volume air sampling locations onsite include ARA, ATR Complex, CFA, EBR-I, Gate 4, INTEC, NRF, PBF, RWMC, SMC, TAN, MFC, EFS, Highway 26 Rest Area, Van Buren and two duplicate locations. Locations offsite include Blackfoot, Craters of the Moon, Idaho Falls and Rexburg. A blank also is analyzed. (ARA = Auxiliary Reactor Area; ATR = Advanced Test Reactor; CFA = Central Facilities Area; EBR-I = Experimental Breeder Reactor – No. 1; INTEC = Idaho Nuclear Technology and Engineering Center; NRF = Naval Reactors Facility; PBF = Power Burst Facility; RWMC = Radioactive Waste Management Complex; SMC = Specific Manufacturing Capability; TAN = Test Area North; MFC = Materials and Fuel Complex; EFS = Experimental Field Station).

b. The perimeter at each INL Site facility and an area outside the northeast corner of INTEC are surveyed each year. All INL Site roadways over which waste is transported are surveyed annually.

Table 3-3. Idaho National Laboratory Contractor Drinking Water Program Summary (2012).

Type of Analysis	Frequency (onsite)	Maximum Contaminant Level
Gross alpha	9 semiannually	15 pCi/L
Gross beta	9 semiannually	4 mrem/yr
Tritium	11 annually, 9 semiannually	20,000 pCi/L
Iodine-129	2 semiannually	1 pCi/L
Parameters required by the state of Idaho under authority of the Safe Drinking Water Act	9 triennally	Varies
Nitrate	9 annually	10 mg/L (as nitrogen)
Microbes	13 quarterly 12 monthly 1 monthly during summer	If <40 samples/ month, no more than one positive for total coliform
Volatile organic compounds	2 annually	Varies

Table 3-4. Idaho Cleanup Project Contractor Environmental Surveillance Program Air, Surface Water, Vegetation, and Radiation Survey Summary (2012).

Medium Sampled	Type of Analysis	Location and Frequency		Minimum Detectable Concentration[c]
		RWMC[a]	INTEC[b]	
Air (low volume)	Gross alpha	8 bimonthly	1 bimonthly	7×10^{-13} µCi/mL
	Gross beta	8 bimonthly	1 bimonthly	2×10^{-12} µCi/mL
	Specific gamma	8 monthly	1 monthly	Varies by analyte
	Specific alpha	8 quarterly	1 quarterly	8×10^{-18} µCi/mL
	Strontium-90	8 quarterly	1 quarterly	1×10^{-16} µCi/mL
Surface water runoff	Specific gamma	1 quarterly	None	Varies by analyte
	Plutonium isotopes	1 quarterly	None	0.02 pCi/L
	Uranium-233/234	1 quarterly	None	0.06 pCi/L
	Uranium-235	1 quarterly	None	0.04 pCi/L
	Uranium-238	1 quarterly	None	0.04 pCi/L
	Americium-241	1 quarterly	None	0.02 pCi/L
	Strontium-90	1 quarterly	None	0.3 pCi/L
Vegetation	Specific gamma	4 annually[d]	None	Varies by analyte
	Plutonium isotopes	4 annually[d]	None	0.0006 pCi/g
	Uranium-233/234	4 annually[d]	None	0.002 pCi/g
	Uranium-235	4 annually[d]	None	0.001 pCi/g
	Uranium-238	4 annually[d]	None	0.001 pCi/g
	Americium-241	4 annually[d]	None	0.0006 pCi/g
	Strontium-90	4 annually[d]	None	0.012 pCi/g
Mobile radiation surveys	Gamma radiation	1 annually	None	Not applicable

a. RWMC = Radioactive Waste Management Complex.
b. INTEC = Idaho Nuclear Technology and Engineering Center.
c. Detection limits vary with each laboratory analysis, but approximate values are provided.
d. Russian thistle was not available for sampling in 2012.

Table 3-5. Idaho Cleanup Project Contractor Drinking Water Program Summary (2012).

Type of Analysis	Location and Frequency		MCL[c], Action Level
	RWMC[a]	INTEC[b]	
Microbiological Contaminants	2 monthly	3 monthly	<40 samples/month, no more than one positive for total coliform
Nitrate (as nitrogen)	1 annually	1 annually	10 mg/L
Gross alpha	1 semiannually	1 semiannually	15 pCi/L
Gross beta	1 semiannually	1 semiannually	4 mrem/yr
Strontium-90	1 annually	1 annually	8 pCi/L
Tritium	1 annually	1 annually	20,000 pCi/L
Volatile Organic Chemicals	2 quarterly	NA	Varies

a. RWMC = Radioactive Waste Management Complex.
b. INTEC = Idaho Nuclear Technology and Engineering Center.
c. MCL = maximum contaminant level.
d. Each volatile organic chemical sample is analyzed for 21 volatile organic chemicals.

Table 3-6. U.S. Geological Survey Monitoring Program Summary (2012).

Constituent	Groundwater		Surface Water		Minimum Detectable Concentration or activity
	Number of Sites[a]	Number of Samples	Number of Sites	Number of Samples	
Gross alpha	49	53	4	4	1.5 pCi/L
Gross beta	49	53	4	4	3.4 pCi/L
Tritium	141	142	7	7	200 pCi/L
Gamma-ray spectroscopy	90	94	4	4	—[b]
Strontium-90	92	91	—[c]	—	2 pCi/L
Americium-241	25	25	—[c]	—	0.03 pCi/L
Plutonium isotopes	25	25	—[c]	—	0.02 pCi/L
Iodine-129	20	20	—[c]	—	<1aCi/L
Specific conductance	141	142	7	7	Not applicable
Sodium ion	136	137	—[c]	—	0.1 mg/L
Chloride ion	141	142	7	7	0.1 mg/L
Nitrates (as nitrogen)	112	114	—[c]	—	0.05 mg/L
Fluoride	8	8	—[c]	—	0.1 mg/L
Sulfate	120	122	—[c]	—	0.1 mg/L
Chromium (dissolved)	70	71	—[c]	—	0.005 mg/L
Purgeable organic compounds[d]	28	40	—[c]	—	Varies
Trace elements	14	14	—[c]	—	Varies

a. Number of samples does not include 10 replicates and 5 blanks collected in 2012. Number of samples was different than the number of sites because four sites were sampled twice, and three sites had pump problems and were not sampled. Number of sites does not include 54 zones from 11 wells sampled as part of the multi-level monitoring program.

b. Minimum detectable concentration for gamma spectroscopic analyses varies depending on radionuclide.

c. No surface water samples collected for this constituent.

d. Each purgeable organic compound water sample is analyzed for 61 purgeable organic compounds.

3.1.2 DOE Headquarters Independent Assessment

In 2010, at DOE-ID's request, the Department of Energy (DOE) Headquarters Office of Independent Oversight within the Office of Health, Safety, and Security conducted an independent assessment of the INL Site environmental monitoring program (DOE 2012). The scope for the assessment included:

- Review of INL Site environmental monitoring activities to ensure that the sitewide environmental monitoring program as a whole is comprehensive and meets the objectives of DOE Order 436.1, Sections 4(c)(2)(a-d), which address protection of public health and the environment for specific media, and (c)(5-6), which address monitoring and meeting data quality objectives
- Review of the INL (BEA), ICP (CWI), and ESER (GSS) contractor environmental monitoring activities to ensure compliance with the requirements of DOE Order 436.1, Sections 4(c)(2)(a-d) and (c)(5-6) for their contract responsibilities
- Determination of whether current monitoring activities meet selected stakeholder (Idaho Department of Fish and Game, state of Idaho, INL Oversight) expectations
- Review of the effectiveness of communication and timely access to monitoring data between site contractors and with DOE-ID on monitoring activities
- Review of the effectiveness of INL self-assessments of environmental monitoring activities
- Confirmation of the effectiveness of data storage and access, including foreseeable technological issues related to data storage, retrievability, and contractor planning to address such issues.
- Confirmation that data quality objectives are appropriate and are being met
- Determination of whether monitoring is adequate for the expanding research and development activities of INL in the city of Idaho Falls
- Review of the INL Site Annual Site Environmental Report production process to ensure that the information reported is comprehensive, technically sound, written in a manner that is understandable to the public and site stakeholders, and that appropriate efforts are being made to ensure the quality and defensibility of data reported.

The Office of Health, Safety, and Security Assessment Team issued a final report detailing positive attributes of the existing program and recommended program enhancements (Table 3-7). DOE-ID directed INL Site contractors to address the overarching recommendation to develop a technical basis for the sitewide monitoring program. In 2012, the INL contractor continued to lead a team consisting of the ICP and ESER contractors to develop the technical basis. All recommendations directed at the ESER Program have been fully addressed and implemented. Other recommendations directed at the INL contractor's monitoring program are being evaluated for potential action. The full Assessment Report is available at http://www.hss.doe.gov/indepoversight/reports/eshevals.html.

Table 3-7. Summary of Results from the 2010 Office of Health, Safety, and Security Assessment of the INL Site Environmental Monitoring Program (DOE 2010).

Positive Attributes	Recommended Program Enhancements
• Database management protocols are comprehensive and provide effective mechanisms for collection, analysis, and retrieval of vast amounts of environmental sampling data generated by INL Site contractors. • Technical and professional staffs are well qualified and knowledgeable. • INL Site contractors have good working relationships with external stakeholders and regulators. • Plan and procedure infrastructure in support of the environmental monitoring and surveillance programs is comprehensive. • Monitoring of potential Endangered Species Act listed species is proactive. • Research and collaboration with institutions of higher learning enhances the knowledge base and the effectiveness of environmental monitoring activities.	• 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. • 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. • Implementation of certain quality assurance protocols and media specific monitoring and surveillance actions were not fully effective.

3.2 Environmental Restoration

Environmental restoration at the INL Site is conducted under the Federal Facility Agreement and Consent Order (FFA/CO) (DOE 1991). The FFA/CO outlines how the INL Site will comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). It sets up a process for DOE-ID to work with its regulators to safely execute cleanup of past release sites at the INL Site.

The INL Site is divided into ten waste area groups (WAGs) (Figure 3-2) as a result of the FFA/CO, and each WAG is further divided into smaller cleanup areas called operable units. Field investigations are used to evaluate potential release sites within each WAG and operable unit when existing data are insufficient to determine the extent and nature of contamination. After each investigation is completed, a determination is made whether a “No Action” or “No Further Action” listing is possible, or if it is appropriate to proceed with an interim cleanup action, the Operable Unit-10-08 Plug-In Remedy action, or further investigation using a remedial investigation/feasibility study. The remedial investigation/feasibility study is used to determine the nature and extent of the problem presented by the past release of contamination and to develop and evaluate options for remedial action. Results from the remedial investigation/feasibility study form the basis for risk assessments and alternative cleanup actions. This information, along with

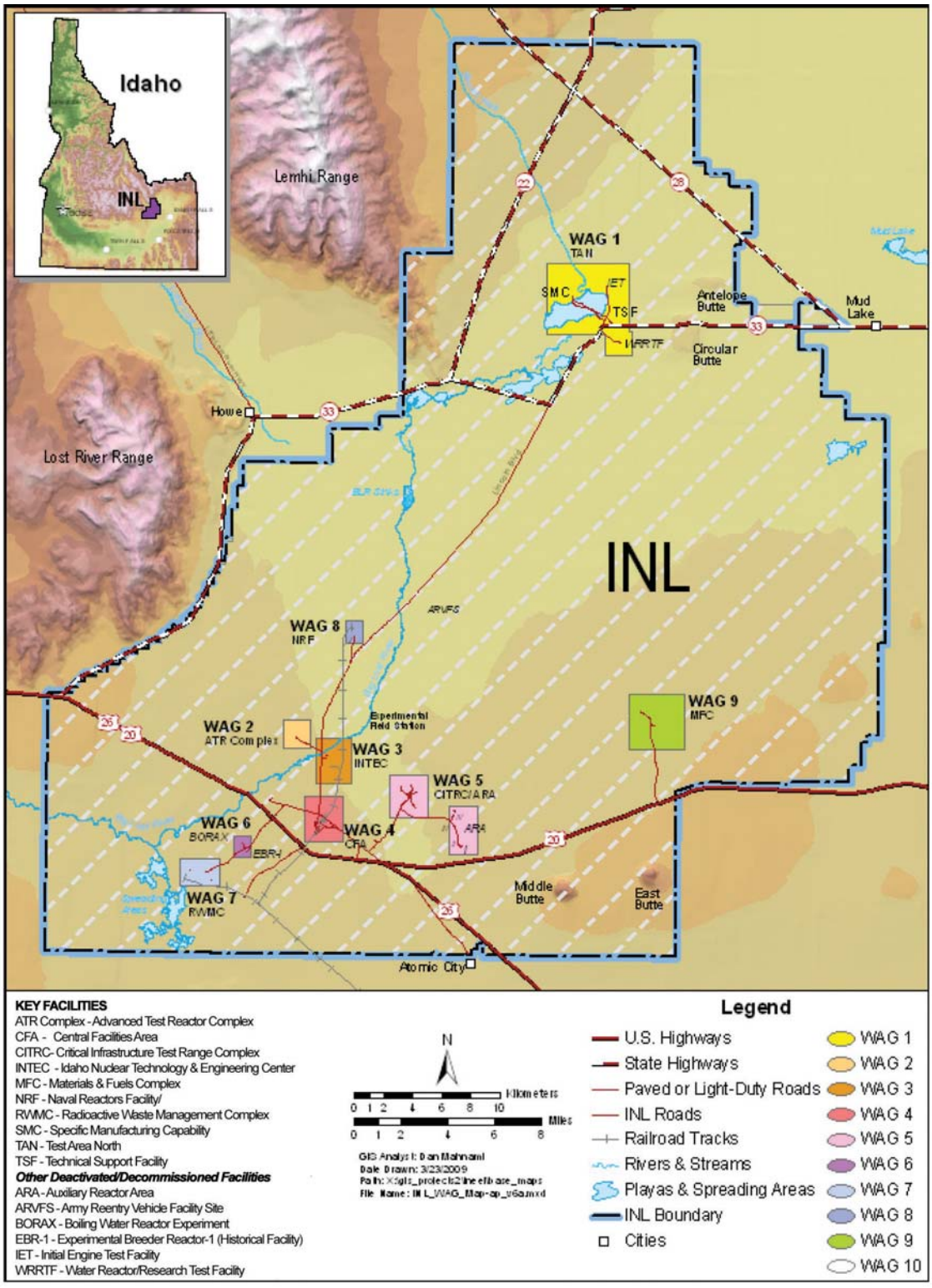


Figure 3-2. Map of the Idaho National Laboratory Site Showing Locations of the Facilities and Corresponding Waste Area Groups.

the regulatory agencies' proposed cleanup plan, is presented to the public in a document called a proposed plan. Proposed plans present cleanup alternatives and recommend a preferred cleanup alternative to the public. After consideration of public comments, DOE, the Environmental Protection Agency, and the state of Idaho develop a record of decision (ROD) selecting a cleanup approach from the alternatives evaluated. Cleanup activities then can be designed, implemented, and completed.

Since the FFA/CO was signed in December 1991, the INL Site has cleaned up release sites containing asbestos, petroleum products, acids and bases, radionuclides, unexploded ordnance and explosive residues, polychlorinated biphenyls, heavy metals, and other hazardous materials. All twenty-four RODs that were scheduled have been signed and are being implemented. Comprehensive remedial investigation/feasibility studies have been completed for WAGs 1, 2, 3, 4, 5, 7, 8, 9, and 6/10 (6 is combined with 10). Closeout activities at WAGs 1 (excluding Operable Unit 1-07B), 2, 4, 5, and 8 have been completed. The WAG 10, Operable Unit 10-08 ROD (Sitewide Groundwater, Miscellaneous Sites and Future Sites [DOE-ID 2009]) was the last ROD and was finalized in September 2009.

Documentation associated with the FFA/CO is publicly available in the CERCLA Administrative Record and can be accessed at http://ar.inel.gov/. The location of each WAG is shown in Figure 3-2. Cleanup progress for each WAG is summarized in the following subsections.

3.2.1 Waste Area Group 1 – Test Area North

Groundwater cleanup for Operable Unit 1-07B continued throughout 2012. The New Pump and Treat Facility generally operated 4 days per week, except for downtime due to maintenance, to maintain trichloroethylene concentrations in the medial zone below specified targets. The in situ bioremediation transitioned into a rebound test in 2012 to determine the effectiveness of the remedy to date. All institutional controls were maintained in 2012.

3.2.2 Waste Area Group 2 – Advanced Test Reactor Complex

All active remediation in WAG 2 is complete. Some elements of the remedy, including monitoring perched water and groundwater under the facility area and maintenance of caps and covers, will continue until the risk posed by contamination left in place is acceptable. All institutional controls and operations and maintenance requirements were maintained in 2012.

3.2.3 Waste Area Group 3 – Idaho Nuclear Technology and Engineering Center

The Idaho CERCLA Disposal Facility (ICDF) disposes of contaminated soils and debris from CERCLA remediation operations to reduce risk to the public and the environment. During 2012, the ICDF was put in a standby mode until shipments of contaminated soil requiring disposal are resumed. The facility continues to receive liquid waste for disposal in the ICDF evaporation ponds.

Remedial actions required by the WAG 3, Operable Unit 3-14 ROD, implemented in 2012, included the reduction of approximately 9 million gallons of anthropogenic recharge to the northern perched water zones. Remedial actions were taken at the Tank Farm Facility to reduce water infiltration that potentially could transport contaminants from the perched water to the underlying aquifer. Perched and groundwater monitoring under and near the facility will continue

until the risk posed by contamination left in place is below target levels. All institutional controls and operations and maintenance requirements were maintained in 2012.

3.2.4 Waste Area Group 4 – Central Facilities Area

Remediation of WAG 4 was completed in 2004. Groundwater monitoring and maintenance of caps and covers will continue until the risk posed by contamination left in place is acceptable. All institutional controls were maintained in 2012.

3.2.5 Waste Area Group 5 – Critical Infrastructure Test Range/Auxiliary Reactor Area

Cleanup activities at WAG 5 are complete. The Remedial Action Report (DOE-ID 2005) was completed in 2005. All institutional controls and operations and maintenance requirements were maintained in 2012.

3.2.6 Waste Area Group 6/10 – Experimental Breeder Reactor I/Boiling Water Reactor Experiment, Miscellaneous Sites, Eastern Snake River Plain Aquifer

The WAG 10, Operable Unit 10-08 ROD (Sitewide Groundwater, Miscellaneous Sites, and Future Sites) was the last INL Site ROD identified and was finalized in September 2009 (DOE-ID 2009). Operable Unit 10-08 addresses eastern Snake River Plain aquifer concerns not covered by other WAGs and future sites that may be discovered. Groundwater monitoring continued in 2012 to verify that there is no unacceptable threat to human health or the environment from commingled plumes or along the southern INL Site boundary. Remediation of unexploded ordnance, in accordance with the Operable Units 6-05 and 10-04 ROD (DOE-ID 2002), continued in 2012. All institutional controls and operations and maintenance requirements were maintained in 2012.

3.2.7 Waste Area Group 7 – Radioactive Waste Management Complex

WAG 7 includes the Subsurface Disposal Area (SDA), a 39-hectare (97-acre) radioactive waste landfill that is the major focus of remedial response actions at the Radioactive Waste Management Complex (Figure 3-3). Waste is buried in approximately 14 of the 39 hectares (35 of the 96 acres) within 21 unlined pits, 58 trenches, 21 soil vault rows, and on Pad A, an above-grade disposal area. Disposal requirements have changed in accordance with laws and practices current at the time of disposal. Initial operations were limited to shallow, landfill disposal of waste generated at the INL Site. Beginning in 1954, the Rocky Flats Plant near Boulder, Colorado, was authorized to send waste to the Radioactive Waste Management Complex for disposal. The Rocky Flats Plant was a nuclear weapons production facility with peak operations during the Cold War era. A variety of radioactive waste streams was disposed of, including process waste (e.g., sludge, graphite molds and fines, roaster oxides, and evaporator salts), equipment, and other waste incidental to production (e.g., contaminated gloves, paper, clothing, and other industrial trash). Much of the Rocky Flats Plant waste was contaminated with transuranic isotopes and solvents (e.g., carbon tetrachloride). In 1970, burial of transuranic waste was prohibited. In 1984, disposal practices were modified to eliminate disposal of mixed waste. Since 1984, only low-level waste was disposed of in the SDA. Disposal of waste from offsite generators was discontinued in the early 1990s, and disposal of contact-handled waste was discontinued at the end of Fiscal Year (FY) 2008. Currently, only remote-handled, low-level waste is being disposed of in the SDA.

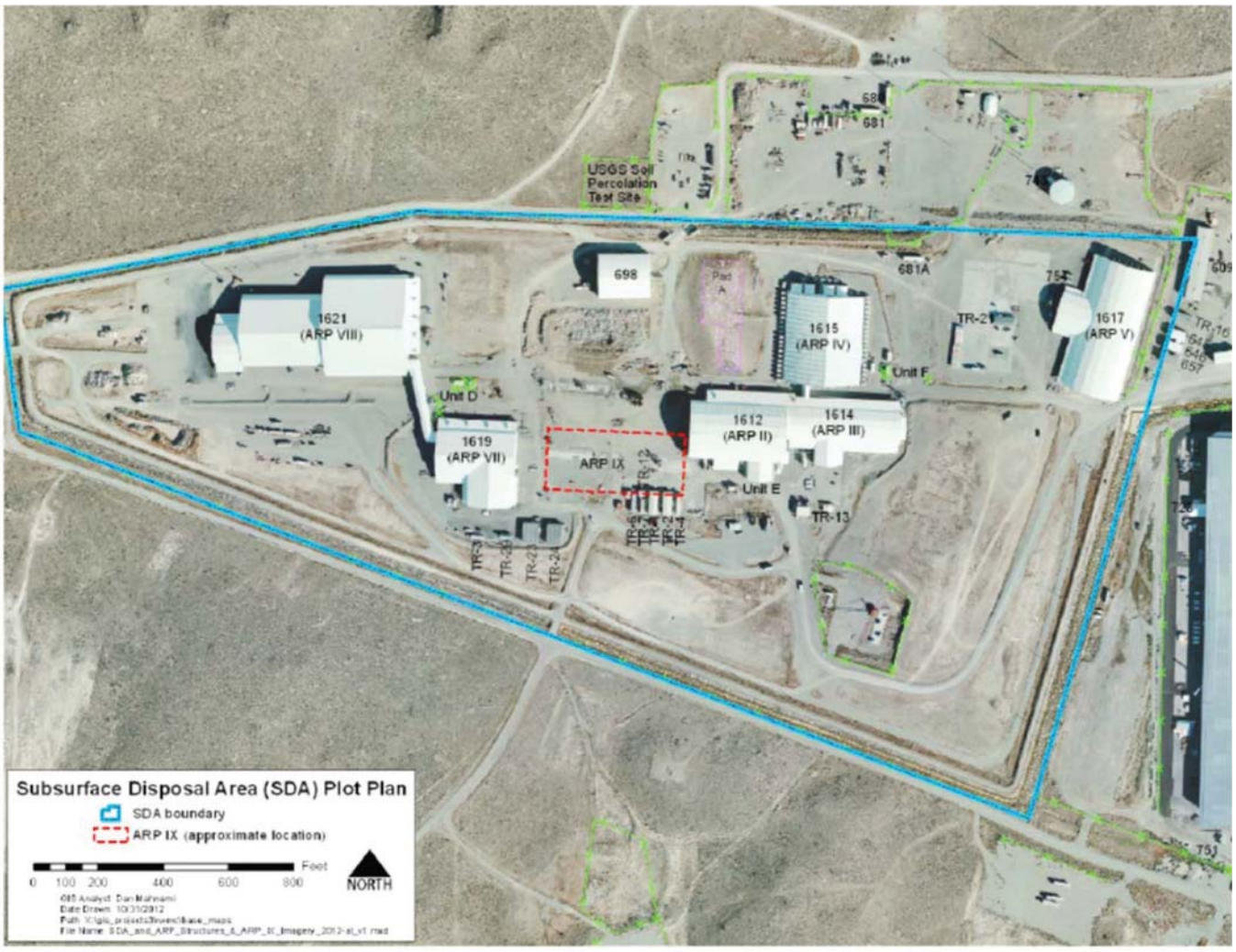


Figure 3-3. Radioactive Waste Management Complex Subsurface Disposal Area (2012).

The Operable Unit 7-13/14 ROD (DOE-ID 2008) was signed in 2008. The ROD is consistent with DOE's obligations for removal of transuranic waste under the *Agreement to Implement U.S. District Court Order Dated May 25, 2006*, between the state of Idaho and DOE, effective July 3, 2008 (DOE 2008). The ROD calls for exhuming and packaging a minimum of 7,485 m^3 (9,790 yd^3) of targeted waste from a minimum combined area of 2.3 hectares (5.69 acres). Targeted waste for retrieval contains transuranic elements (e.g., plutonium), uranium, and collocated organic solvents (e.g., carbon tetrachloride). Targeted waste retrievals in specific areas of the SDA commenced in 2005. The retrieved targeted waste is packaged, certified, and shipped out of Idaho. As of December 2012, 5,684 m^3 (7,434 yd^3) of targeted waste has been retrieved and packaged from a combined area of 1.23 hectares (3.11 acres).

In addition to targeted waste retrieval, the ROD addresses remaining contamination in the SDA through a combination of continued vapor-vacuum extraction and treatment of solvent vapors from the subsurface, in situ grouting of specified waste forms containing mobile contaminants (completed 2010), constructing an evapotranspiration surface barrier over the entire landfill, and long-term management and control following construction. Construction will be complete by approximately 2028. Including the first 100 years of institutional controls and monitoring, this project is expected to cost approximately $1.3 billion.

3.2.8 Waste Area Group 8 – Naval Reactors Facility

Naval Reactors Facility environmental program updates are discussed in the Naval Reactors Facility environmental monitoring reports and are not included in this report.

3.2.9 Waste Area Group 9 – Materials and Fuels Complex

All WAG 9 remediation activities have been completed; however, the industrial waste pond (ANL-01) and interceptor canal (ANL-09) remain under institutional controls The Industrial Waste Pond has elevated levels of chromium in the sediment and will be re-evaluated when it is no longer in use. Cesium-137 levels at the interceptor canal ditch and mound are below action levels but above background. The site will remain under control until the cesium naturally decays to background levels.

Three sites at Materials and Fuels Complex (MFC) were administratively assigned to WAG 10 and remain under institutional controls:

1) The sewage lagoons (ANL-04) pose an ecological risk because of mercury levels in the sludge. In 2012 the lagoons were replaced with new HDPE-lined evaporation ponds. Closure options for the sewage lagoons will be evaluated after the sludge dries and additional samples are collected, analyzed, and compared with remedial action levels.
2) The buried remains of buildings MFC-767 and MFC-795 (ANL-67) are controlled because of asbestos associated with piping left in place when the buildings were removed.
3) The steel shot area north of MFC (ANL-65) is contaminated with metals and scheduled for remediation in 2013.

3.3 Waste Management and Disposition

Waste management and disposition covers a variety of operations and functions, including: (1) storage of waste pending disposition; (2) characterization of waste to allow it to be placed in storage or to be transported, treated, or disposed of; (3) transportation of waste to locations on or off the INL Site for treatment or disposal or both; (4) treatment of waste prior to disposal; and (5) disposal. Safe operations and compliance with applicable federal, state, and local regulations are the highest priorities, along with meeting the commitments made in the Idaho Settlement Agreement (DOE 1995) and the 2012 Idaho National Laboratory Site Treatment Plan (INL-STP) (ICP 2012).

3.3.1 Federal Facility Compliance Act

The Federal Facility Compliance Act requires preparation of a site treatment plan for the treatment of mixed wastes at the INL Site. Mixed wastes contain both radioactive and Resource Conservation and Recovery Act (RCRA)-regulated hazardous components.

In accordance with the INL Site Treatment Plan (ICP 2012), the INL Site began receiving mixed waste from offsite locations for treatment in January 1996. Mixed waste has been received from other sites within the DOE complex, including Hanford, Los Alamos, Paducah, Pantex, Sandia, and six locations managed by the Office of Naval Reactors. A backlog of mixed waste is being managed in RCRA-permitted storage units at the INL Site. During 2012, the INL Site treated or processed 3,281 m^3 (4,291 yd^3) of legacy mixed waste, of that total, 1,100 m^3 was mixed low-level waste shipped offsite for treatment/disposal, and 2,181 m^3 (2,852 yd^3) was mixed contact-handled transuranic waste that was shipped offsite to the Waste Isolation Pilot Plant for disposition.

During 2012, three INL Site Treatment Plan milestones were met and two milestones associated with the Sodium Bearing Waste Treatment Facility were modified. The (P-5) milestone to commence operations was modified from second quarter 2012 to third quarter 2013, and the (P-6) milestone to submit a schedule for system backlog was modified from second quarter 2012 to fourth quarter 2013. The following milestones were completed:

- Calcine Disposition Project – (P-5) Schedule for Table 5-1 (Table 2-1 Milestones/Planning dates) first quarter 2013
- Calcine Disposition Project – (P-7) Submit RCRA Part B application for calcine retrieval, treatment (if necessary) and packaging first quarter 2013
- Commercial Backlog Treatment/Disposal –16 m^3 (21 yd^3).

3.3.2 Advanced Mixed Waste Treatment Project

Operations at AMWTP require retrieval, characterization, treatment, and packaging of transuranic waste currently stored at the INL Site. The vast majority of the waste the AMWTP processes resulted from the manufacture of nuclear components at DOE's Rocky Flats Plant in Colorado. The waste contains industrial debris, such as rags, work clothing, machine parts, and tools, as well as soil and sludge. The waste is contaminated with transuranic radioactive elements (primarily plutonium).

After the waste containers have been retrieved from waste storage, they are examined in the AMWTP Characterization Facility. During characterization, each container is examined to determine its contents. Characterized waste containers that need further treatment before they can be shipped offsite for disposal are either sent to the AMWTP Treatment Facility or to the Drum Treatment Tent in WMF-628. The AMWTP Treatment Facility treats the waste by size-reducing, sorting, and repackaging the waste. Waste sent to the Treatment Facility is transported to different areas within the facility by an intricate system of conveyers, and all waste is handled remotely. The Treatment Facility houses a supercompactor and a shredder for major size-reduction of the waste. Any restricted items, such as liquids or compressed gas cylinders, are removed, and the waste is repackaged. The Drum Treatment Tent primarily treats drums that

contain sludge waste with excess liquids by adding liquid absorbent. The Drum Treatment Tent may also repackage old drums into new drums.

There are two loading areas at the AMWTP. In both loading facilities, the waste containers go through two major steps: payload assembly and TRUPACT II loading. Payload assembly includes grouping the waste into four different configurations consisting of 55-gallon drums, 100-gallon pucks drums (i.e., drums of compacted waste), waste over-packed into Standard Waste Boxes, and waste over-packed into Ten Drum Overpacks. Then, the waste is loaded into the TRUPACT II containers for shipping. A TRUPACT II container is a special double-containment vessel that is approved for waste transport. After the payloads are placed in the TRUPACT II containers, the containers are visually and mechanically inspected before they are certified for travel. Once a TRUPACT II container is certified for travel, the waste is sent 2,092 km (1,300 mi) to its final destination at the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

During 2012, the AMWTP shipped 2,536 m^3 (3,317 yd^3) of stored transuranic waste to the Waste Isolation Pilot Plant, for a cumulative total of 39,694 m^3 (51,918 yd^3) of waste shipped off the INL Site. The AMWTP also shipped offsite 1,430 m^3 (1,870 yd^3) of mixed low-level waste that historically had been managed as stored transuranic waste, for a cumulative total of 9,677 m^3 (12,657 yd^3) of waste shipped offsite. A combined cumulative total of 49,371 m^3 (64,575 yd^3) of stored waste has been shipped offsite. In addition, the AMWTP has shipped a cumulative total of 5,684 m^3 (7,434 yd^3) of buried transuranic waste (see 3.2.7, “Waste Area Group 7 – Radioactive Waste Management Complex”) to the Waste Isolation Pilot Plant.

3.3.3 High-Level Waste and Facilities Disposition

In 1953, reprocessing of spent nuclear fuel began at the Idaho Nuclear Technology and Engineering Center (INTEC), resulting in the generation of liquid high-level waste and sodium-bearing waste. Those wastes were placed into interim storage in underground tanks at the INTEC Tank Farm. Treatment of those wastes began in 1963 through a process called calcining. The resultant waste form, calcine, was placed in storage in stainless steel bins at the Calcine Solids Storage Facility. DOE announced the decision to stop processing spent nuclear fuel in 1992. Calcining of all nonsodium-bearing, liquid, high-level waste was completed on February 20, 1998, four months ahead of the June 30, 1998, Idaho Settlement Agreement milestone. Calcining of remaining sodium-bearing waste began immediately following completion of nonsodium-bearing, liquid, high-level waste treatment, more than three years ahead of the Idaho Settlement Agreement milestone. Per that agreement, all such waste is required to be treated by the end of 2012.

In October 2002, DOE issued the *Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement* (DOE 2002) that included alternatives other than calcination for treatment of the sodium-bearing waste. DOE-ID issued a ROD for this Final Environmental Impact Statement on December 13, 2005 (DOE 2005). This ROD specified steam reforming to treat the remaining sodium-bearing waste at the INTEC Tank Farm. This technology will treat the remaining approximately 3.4 million L (900,000 gal) of liquid, sodium-bearing waste that has been consolidated into three 1.14 million L (300,000 gal) below grade tanks at the INTEC Tank Farm for interim storage. DOE awarded the Idaho Cleanup Project contract in 2005. This contract included the design, construction and operations of a new facility (the Integrated Waste Treatment Unit) for treatment of the sodium-bearing waste.

Construction of the Integrated Waste Treatment Unit (IWTU) was completed in 2012 and approval to operate issued in April 2012. The IWTU is a new facility for treatment of the remaining liquid sodium-bearing waste utilizing the steam reforming process. Processing of the sodium-bearing waste by IWTU has not been initiated due to problems that occurred in June 2012 during initial start-up testing. The facility is undergoing facility hardware and operational modifications to address issues identified during the initial start-up. DOE-ID has negotiated with the state of Idaho Department of Environmental Quality a revised completion date for treatment of the sodium-bearing waste. The revised consent order milestone is December 2014.

Seven other 1.14 million L (300,000 gal) INTEC Tank Farm tanks have been emptied, cleaned, and removed from service in preparation for final closure. With regard to tank closures, DOE issued a final Section 3116 Waste Determination and amended ROD (71 FR 228) in November 2006. Filling the seven cleaned tanks and their surrounding vaults began in November 2006 and was completed in March 2008.

The Final Environmental Impact Statement also included analysis of alternatives for treating the calcined waste. On December 23, 2009, DOE issued an amended ROD (75 FR 1; 75 FR 7) for the treatment of calcine using an industrially mature manufacturing process known as hot isostatic pressing. Issuing the ROD by the end of 2009 met an interim requirement in the 1995 Settlement Agreement. This selected technology presents the flexibility to either:

- Treat calcine in a sealed high-temperature and high-pressure canning process, including using treatment additives necessary to produce a glass-ceramic and volume-reduced monolithic waste form; or
- Treat calcine in a sealed high-temperature and high-pressure canning process without using treatment additives, resulting in an even greater volume reduction.

DOE-ID is now in the process of implementing the ROD by initiating the technology development and design process for applying the hot isostatic pressing (HIP) technology to treat calcine waste. The design effort includes a system to retrieve the existing high-level waste calcine from the consolidated calcine storage facilities (bin sets) and packaging following treatment. A RCRA Part B permit was submitted to the state of Idaho Department of Environmental Quality on November 27, 2012, for the HIP process. The permit is based upon the utilization of the existing IWTU facility to the extent practicable by retrofitting the IWTU to accommodate the HIP process.

3.3.4 Low-Level and Mixed Radioactive Waste

In 2012, more than 203 m^3 (266 yd^3) of mixed low-level waste and 1,741 m^3 (2,277 yd^3) of low-level waste was shipped off the INL Site for treatment or disposal or both. Approximately 26.62 m^3 (35 yd^3) of newly generated, low-level waste was disposed of at the SDA in 2012.

3.4 Environmental Management System

An environmental management system provides a framework of elements following a plan-do-check-act cycle that when established, implemented and maintained; will foster improved environmental performance. An EMS focuses on three core concepts: pollution prevention, environmental compliance, and continuous improvement. The primary system components are (1) environmental policy, (2) planning, (3) implementation and operation, (4) checking and corrective action, and (5) management review.

Executive Order (EO) 13423, “Strengthening Federal Environmental, Energy, and Transportation Management,” mandates that all federal agencies implement environmental management systems at all appropriate organizational levels. DOE Order 436.1, “Departmental Sustainability,” requires compliance with this EO, and further requires that DOE sites use their EMS as a platform for Site Sustainability Plan implementation. Sites must maintain their EMS as being certified to or conforming to the International Organization for Standardization’s (ISO) 14001:2004 in accordance with the accredited registrar provisions or self-declaration instructions.

The three main INL Site contractors have established EMSs for their respective operations. The ICP and INL contractors maintain ISO 14001 systems certified and registered by accredited registrars. Auditors from the registrars conduct periodic surveillances and full audits of the systems to determine improvement or degradation, and eligibility for recertification. The AMWTP contractor’s EMS is self-declared conformant to the ISO standard, based upon conformance audits by independent, external, qualified auditors. DOE strongly supports the management system concept, and its auditors review contractor processes to ensure they meet DOE’s requirements.

3.4.1 Sustainability Program

The Site Sustainability Plan and program implemented sustainable practices in facility design operation, procurement, and program operations that meet the requirements of EO 13514, “Federal Leadership in Environmental, Energy, and Economic Performance,” and DOE Order 436.1, “Departmental Sustainability.” The goal of EO 13514 is “to establish an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal agencies.”

The goal of the INL Site sustainability program is to promote economic, environmental, and social sustainability for the INL Site, helping to ensure its long-term success and viability as a premier DOE national laboratory. The sustainability program focuses on water and greenhouse gas reductions, as well as responsible use and disposal of materials and resources; advancing sustainable building designs; exploring the potential use of renewable energy; reducing utility costs across the INL Site; and supporting cost-effective facilities, services, and program management. The challenge is to minimize the impact of operations on the laboratory. The INL Site is integrating environmental performance improvement in the areas that matter most to its stakeholders and the laboratory, including minimizing the environmental footprint, taking a progressive approach to climate change, and championing energy conservation.

Energy Reduction – The INL Site goal for energy usage is a 30 percent reduction of energy intensity by FY 2015, as compared to the FY 2003 energy intensity baseline. Energy intensity is defined as energy use divided by the building area measured in Btu/ft^2. On average, an annual energy use reduction goal of 3 percent supports meeting the overall goal and provides a means to measure and trend progress.

The INL Site energy intensity for FY 2012 was 157,690 Btu/ft^2 compared to 183,111 Btu/ft^2 in FY-2003 for a calculated reduction of 13.8 percent. This reduction falls short of the desired 21 percent cumulative reduction goal for 2012.

Water Conservation – The INL Site's goal for water usage is a 16 percent reduction of usage intensity by FY 2015, or 2 percent each year, as compared to the FY 2007 Water Usage Intensity Baseline measured in gal/ft^2.

Due to the nature of the various INL Site missions, many of the operations can be cyclical and result in varying usages of water throughout the year and from year to year. In addition, as facilities are removed and processes are shut down, the lower square footage can actually result in an increase in water intensity even as overall water usage is reduced.

The water intensity reduction goal will be very difficult for the INL Site to accomplish. Long payback calculations based on inexpensive water and electric rates make water saving projects cost ineffective. Water usage is so dependent upon process usage and unplanned events such as wildfires and American Recovery and Reinvestment Act-funded additional decontamination and decommissioning (D&D) work, that the remaining 8.5 percent may be very difficult to attain.

As per the water reduction goals found in DOE Order 436.1, the INL Site should be at a ten-percent water intensity reduction at the end of 2012 compared to the 2007 Reportable Water Usage Baseline. The INL Site used a total of 858.9 M gallons of water in 2012, resulting in a water usage intensity of 154.0 gal/ft^2, a decrease of 11.4 percent over the FY 2007 baseline (173.9 gal/ft^2). However, as demonstrated through the water use and building square footage data, the INL Site total water used has decreased from 1,050.9 MG in 2007 to 858.9 MG in 2011, for a total water used reduction of 18.3 percent.

Construction was completed on the new Energy Systems Laboratory in Idaho Falls, which incorporated significant xeriscaping, efficient water fixtures, and water sub-metering. This facility is expected to be a low water user and help to lower the INL Site water use intensity. In addition, all water fixtures in the INL Research Center Office Building (IF-602) were replaced with new low-flow fixtures.

High Performance Sustainable Buildings (HPSB) – The INL Site goal for HPSB is that 15 percent of existing buildings greater than 5,000 gross square feet (gsf) be compliant with the five Guiding Principles (GPs) of HPSBs by FY 2015. There are 27 GPs in five categories, and to achieve compliance with the GPs, all 27 must be met.

The INL Site has 168 buildings that are appropriate to consider for audits and upgrades to implement the GPs. Fifteen percent of these buildings calculates to a minimum of 26 buildings that must meet the GPs by 2015. INL has selected 27 buildings with the highest probability of meeting the GPs. Of these 27 buildings, one is Leadership in Energy and Environmental Design (LEED™) Certified, one is LEED™ Gold Certified, and four are pending LEED™ Gold Certification. The remaining 21 buildings will be targeted for the GPs compliance path.

The LEED™ Construction package for the new Radiological and Environmental Sciences Laboratory (IF-683) in Idaho Falls was submitted during FY 2012.

Metering was installed on three facilities (two at Central Facilities Area [CFA] and one at Materials and Fuels Complex [MFC]) so that electrical data can be compiled for entry into Portfolio Manager. Energy and water reduction projects were completed in FY 2012 for IF-601, IF-616, and IF-654 to further enhance the Energy Star grading for implementation of the Guiding Principles in these facilities.

The INL Site documented compliance with 15 of the 27 Guiding Principles.

Fleet Operations – The INL Site is developing diversified strategies for increasing alternative fuel consumption and reducing carbon emissions associated with light and heavy-duty vehicles. One of the DOE Order 436.1 transportation fuels goals is to increase the use of alternative fuels by 10 percent annually, as compared to the 2005 usage baseline.

In 2012, the INL Site used 194,429 gasoline gallon equivalents of alternative fuels. This represents an increase of 154 percent over the 2005 baseline. These usages are a compilation of all Site contractors and the total of each of the various alternative fuels as reported into the Fleet Automotive Statistical Tool (FAST) database.

The INL Site is actively pursuing E-85 fuel and B20 usage. INL has increased the availability of E-85 and mandated its use while researching and implementing the use of B20 in the INL bus fleet throughout the year and across varied climate conditions.

Additionally, the INL Site is developing diversified strategies for reducing fossil fuel use and carbon emissions associated with light and heavy-duty vehicles. One of the DOE Order 436.1 transportation fuel goals is to reduce petroleum fuels by 2 percent annually through 2020 (30 percent total reduction), as compared to the 2005 usage baseline. There are many opportunities to affect the DOE's petroleum fuel usage by implementing fuel reduction and fuel switching activities at the INL Site.

In 2012, the INL Site used 747,777 gasoline gallon equivalents, a 20.3 percent reduction from 2005. This usage is a compilation of all INL Site contractors.

In 2012, the INL completed the following activities:

- Increased overall bus efficiencies by implementing express routes and eliminating underutilized routes. This was in conjunction with continued efforts in right sizing the fleet with more flex-fuel vehicles and hybrids.
- Incorporated the Park and Ride concept to reduce fuel usage, and developed additional Park and Ride lots for employees at outlying areas.
- Used innovative technology to track and reduce fuel usage such as Global Positioning System, radio-frequency identification fuel rings, and data logger technology to monitor engine performance and driver habits.
- Replaced the INL bus fleet with 52 new motor coaches that run on B20 and have improved fuel mileage by up to 50 percent (3 mpg to 6 mpg).

Greenhouse Gases – EO 13514 mandates that agencies develop specific greenhouse gas (GHG) reductions targets. DOE has set a reduction target of 28 percent for Scope 1 and 2 GHGs and 13 percent reduction in Scope 3 GHG emissions. The EO sets 2008 as the baseline year against which reductions are measured.

Scope 1, 2, and 3 are defined as:

- **Scope 1.** Direct or INL Site-owned emissions that are produced onsite, such as stationary combustion (from fuel combustion), mobile combustion (from fleet vehicles), and fugitive emissions (from refrigerants, onsite landfills, and onsite wastewater treatment). These

include emissions that may benefit another entity or contractor, but for which the INL Site controls or owns the associated process.

- **Scope 2.** Indirect or shared emissions produced by INL's electricity, heat, and steam purchases.
- **Scope 3.** Indirect or shared emissions generated by outsourced activities that benefit the INL Site (occur outside the INL Site's organizational boundaries, but are a consequence of the INL Site's activities). This can include a large number of activities, so the INL Site focuses on transmission and distribution losses, employee commuting, employee travel, contracted waste disposal and contracted wastewater treatment since these categories were identified in the Technical Support Document for required reporting. Other activities that could be included in Scope 3 include the embodied emissions of purchased materials.

Many factors influence the INL Site's GHG emissions, including the large land area on which the Laboratory's facilities are located. The area requires long commutes, an extensive fleet to provide transportation for desert Site workers, and contains many antiquated inefficient facilities built before the current appreciation for energy efficiency and high-performance design. These factors tie directly into the following conclusions from the INL Site's baseline GHG inventory:

- Electricity is the largest contributor to the INL Site's GHG inventory, with over 60 percent of the net anthropogenic CO_2 emissions from Scope 1 and Scope 2
- Other sources with high emissions are stationary combustion and fugitive emissions from the onsite landfills
- Among the sources with low emissions within Scope 1 and 2 are fugitive emissions from refrigerants and onsite wastewater treatment.

The INL Site contractors' EMS provide the framework and process for evaluating and monitoring Scopes 1, 2, and 3 GHG emissions and related reduction activities. On an annual basis, appropriate sustainability targets are developed and monitored through the EMS to support the overall reduction in GHG emissions.

In 2012, the INL reduced Scope 1 and 2 combined GHG emissions 20.3 percent from the 2008 baseline.

As the Environmental Management missions end at various Site locations, overall Scope 3 emissions are expected to decrease. Between 2012 and 2017, employees traveling to and from the Site may be reduced by as many as 2,000 when subcontractors are included. Removing vehicles directly impacts Scope 1 and Scope 3 emissions.

In 2012, the INL reduced Scope 3 GHG emissions 7.3 percent as compared to the 2008 baseline. Transportation fuel was the largest source of GHG emissions for Scope 3. Another source with high emissions was business air travel. Sources with low emissions were contracted waste disposal, contracted wastewater treatment, and business ground travel (rental and personal vehicles).

INL continues to reduce GHGs by transporting employees with a modernized transportation system, taking nearly 2,000 cars per day off the road. By streamlining the INL mass transit system that provides safe, efficient, and sustainable transportation to work for INL employees

throughout the eastern Idaho region, INL encourages travel behavior changes to reduce carbon emissions and fossil fuel consumption and increase highway safety. In doing so, INL models future trends in mass transit to local governments across the region. Other actions include instituting a park and ride system, relocating employees to town offices, use of E-85 and biodiesel fuels (B20), and use of modern buses, vans, and light duty vehicles to reduce carbon emissions.

3.4.2 Pollution Prevention

The Pollution Prevention Program incorporates national and DOE requirements to reduce, reuse, and recycle wastes and pollutants by implementing cost-effective techniques, practices, and programs. Such actions are required by various federal statutes, including, but not limited to the Pollution Prevention Act and RCRA. In 2007, EO 13423, "Strengthening Federal Environmental, Energy, and Transportation Management," was issued. It consolidates and strengthens five EOs and two memoranda of understanding, and establishes new and updated goals, practices and reporting requirements for environmental, energy, and transportation performance and accountability. It also requires more widespread use of EMSs to manage and improve sustainability practices. In 2009, EO 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," was issued. This EO expands on the energy reduction and environmental performance requirements for federal agencies identified in EO 13423.

The Pollution Prevention Program is managed by the INL Site contractors under their EMSs. Its scope incorporates waste prevention and elimination, reduction of environmental releases, environmentally preferable purchasing, environmental stewardship in program planning and operational design, and recycling of solid wastes.

The INL Site Pollution Prevention Plan (DOE-ID 2012b) describes the pollution prevention practices pursued at the INL Site. INL continued the co-mingled recycling and paper shredding programs at the desert Site facilities (CFA, MFC, and Advanced Test Reactor [ATR] Complex) during FY 2012. INL is also working with INL Site contractors to expand co-mingled recycling at other Site facilities. All INL employees are capable of participating in the co-mingled recycling program. ICP also has co-mingled recycling at town facilities and paper recycling at the desert Site facilities. Additionally, ICP is working on implementing co-mingling at INTEC in FY 2013 and is pursuing composting waste diversion for ICP cafeteria consumables.

With the exception of the Specific Manufacturing Capability (SMC), all town and desert site employees have the option to participate in the paper shredding recycling program, which include regular office paper and controlled unclassified information materials for shredding. In FY 2012, INL facilities recycled 219,256 lb of co-mingled materials and 402,820 lb of office paper and cardboard. Additionally, INL diverted or recycled another 401,055 lb of materials, including scrap metal, wood, cooking oil, compostables, and wood pallets. This accounts for approximately 32.8 percent diversion of municipal solid wastes collected at INL facilities.

The INL Site continues to utilize a number of processes to reduce the quantity and toxicity of hazardous chemicals. The processes follow the simple reduce, reuse, and recycle steps to help achieve the overall goal. The INL Site utilizes chemical coordinators and environmental personnel to help ensure requested materials are actually needed, are not available through an exchange/sharing program, and the smallest/most appropriate quantity is being ordered. INL

also stipulates the use of the Massachusetts Institute of Technology Green Chemical alternatives list at http://web.mit.edu/environment/academic/alternatives.html to help chemical coordinators identify “greener” alternatives to requested chemicals. INL currently shares chemicals at the INL Research Center and town facilities (and at the Site when possible); all chemicals are targeted as an overall reduction. Chemical coordinators actively search for existing inventory to preclude new purchases. INL is participating with other national laboratories to establish a chemical reduction guidance that will outline more specific steps and reduction goals for INL. INL has also worked with Procurement to screen subcontractors’ procurement requirements to ensure that less-hazardous chemicals are utilized when available and life-cycle costs are considered prior to purchase. INL and ICP are working actively and continually towards improvement in reduction of inventories through the avenues of acquisition, use, and disposal.

The INL Site Hazardous Waste Management Act/RCRA Permit requires that all operating contractors conduct and complete a source reduction evaluation review and written plan, in accordance with the procedures and format provided in the “EPA Waste Minimization Opportunity Assessment Manual” (EPA 1988). This review and plan was submitted to the Idaho Department of Environmental Quality on March 31, 2011, and every four years thereafter, and must include detailed description of any programs the contractors may have to assist generators of hazardous and mixed waste in reducing the volume (quantity) and toxicity of wastes produced.

AMWTP reduces and minimizes the quantity and toxicity of hazardous chemicals and materials through a procurement process that stresses environmentally preferable purchases. One of the objectives stated in the AMWTP management procedure for the acquisition of material and services is to use recycled-content and bio-based content materials and other environmentally preferable products and services to the maximum practicable extent. Purchase requisitions are screened by an assigned procurement specialist for environmentally preferable materials.

AMWTP has also evaluated possibilities with the use of value engineering activities throughout the year to identify materials that have been initially dispositioned for disposal to determine whether such materials would be suitable for re-use onsite for changes in production. One example of this is the intended re-use of over 1,000 metal pallets for construction of modified six drum overpack containers.

The INL Site diverted 33.1 percent of its non-hazardous solid waste in 2012. INL diverted 33 percent of municipal solid waste from the landfill during the same period. ICP diverted 29 percent and AMWTP diverted 29 percent of municipal solid waste from the landfill in 2012.

INL implemented an interactive drag and drop recycling quiz that was incorporated into the all-employee Environment, Safety, and Health refresher training and was placed on the Recycling Programs’ internal website. A recycle champion award was awarded quarterly to nominated employees for their enthusiasm and participation in the recycling program. INL Dining Services began recycling the used cooking oil through a vendor in FY 2012.

Midway through FY 2012, an interactive display was placed in the new “Dynamic Learning Center.” The display is intended to provide a “hands-on” experience to all new employees with follow-up assessment of material learned. This center is also open to all employees by appointment. INL attempted to revisit the cafeteria waste composting pilot during the summer

of FY 2012, since efforts conducted in FY 2011 did not produce viable compost. Weather conditions, distance between facilities, and lack of volume may prohibit small-scale composting to be conducted onsite. Further evaluation and funding availability will be necessary before a composting program could be implemented.

The diversion of construction and demolition debris during D&D activities for ICP is often problematic due to the potential for radioactive contamination. Diversion of D&D waste is often quite costly, and the wastes are usually disposed of onsite.

The INL Site diverted 29.6% of its construction and demolition debris in FY 2012 (3,971 MT).

Construction waste and landfill acceptance data are analyzed quarterly to track performance against the goals. INL diverted 30% of construction and demolition waste during FY 2012. This included construction and demolition soil reused as landfill cover and asphalt regeneration. ICP diverted 6% of construction and demolition waste in FY 2012. AMWTP diverted 44% of construction and demolition waste in 2012, the majority of which was soil reuse.

Federal Electronics Challenge – The Federal Electronics Challenge is a program that encourages federal facilities and agencies to purchase greener electronic products, reduce impacts of electronic products during use, and manage obsolete electronics in an environmentally responsible way. The INL Site Pollution Prevention Program is one of the leaders in the DOE complex in its electronics stewardship program. In 2012, the INL Site received the 2012 Federal Electronics Challenge Silver Award for reducing the environmental impacts of electronic equipment. The INL Site has received Silver and Bronze Awards in previous years.

Earth Day – DOE-ID, the INL Site contractors, and the ESER contractor participated in the organizing committee for the 2012 Idaho Falls Earth Day celebration, joining forces with the city of Idaho Falls, state agencies, and private business to celebrate a community-based Earth Day on the fourth Saturday of April. Idaho Falls Earth Day features displays of green products, extensive recycling opportunities, live music, and education and outreach opportunities for adults and children. Children are encouraged to participate in essay writing, poster designing, and creating sculptures from trash. The event draws approximately 6,000 people.

Recycling – As part of the previous year's ISO 14001 objective and target for recycling, the INL Site continued to minimize waste by recycling or reusing an estimated 45 percent of sanitary waste from all operations by weight; this includes waste from routine operations and cleanup-stabilization operations.

INL's recycling initiative, which includes commingled recycling and paper shredding, continued to expand through the fourth quarter of 2012. The co-mingled recycling has allowed employees to recycle plastics, metals and assorted paper products in addition to office paper and corrugated cardboard without having to separate them. All office paper from town and site buildings (excluding SMC) can be shredded by a commercial shredding service and recycled.

The first phase of INL's recycling initiative was successfully rolled out to INL's Idaho Falls buildings during FY 2009, followed by SMC in December of 2009. In 2010, the second phase of the initiative was expanded to the remaining Site facilities—ATR Complex, CFA, and MFC. Commingled recycling and paper shredding reduced landfill trash by 30 percent which

corresponds to a 38 percent decrease in the funds that would have been allocated to pay for trash collection.

In 2012, INL facilities recycled 219,256 lb (99,453 kg) of co-mingled materials and 402,820 lb (182,716 kg) of office paper and cardboard. Additionally, INL diverted or recycled another 401,055 lb (181,915 kg) of materials, including scrap metal, wood, cooking oil, compostables, and wood pallets. This accounts for approximately 32.8 percent diversion of municipal solid wastes collected at INL Site facilities.

In summary, the INL Site Pollution Prevention Program continued to successfully meet the goals of the INL Site Pollution Prevention Plan. The INL Site achieved these goals to protect the environment and enhance mission accomplishment while minimizing life-cycle cost and liability of DOE programs. As required, the INL Site provided certifications to the state of Idaho that it has a pollution prevention and waste minimization program in place to "reduce the volume and toxicity of hazardous waste generated…which minimizes the present and future threat to human health and the environment."

3.5 Other Major Environmental Programs and Activities

3.5.1 Decontamination and Decommissioning Activities

The ICP D&D project was officially closed out in September 2012. The project safely decontaminated and decommissioned 223 buildings and structures for a total footprint reduction of over 1.6 million square feet. The project demolished three nuclear reactors, two hot cell facilities, the largest hot shop in the world, a spent fuel reprocessing complex, large laboratory buildings, and numerous warehouses and storage buildings. This effort significantly reduced life-cycle cost and risk by eliminating aging facilities that were no longer needed for the INL Site mission. Additional D&D work will be done in the future as funding allows and as facility missions come to a close.

3.5.2 Spent Nuclear Fuel

Spent nuclear fuel (SNF) is fuel that has been irradiated in a nuclear reactor. SNF contains some unused enriched uranium and radioactive fission products. Because of its radioactivity (primarily from gamma rays), it must be properly shielded. DOE's SNF is from development of nuclear energy technology (including foreign and domestic research reactors), national defense, and other programmatic missions. Several DOE offices manage SNF. Fuel is managed by the ICP contractor at INTEC, the Naval Nuclear Propulsion Program at the Naval Reactors Facility, and the INL contractor at the ATR Complex and MFC. SNF ranging in size from 0.9 kg (2 lb) to 0.45 metric tons (0.5 tons) are managed at the INL Site.

Between 1952 and 1992, SNF was reprocessed at the Idaho Chemical Processing Plant (now called INTEC) to recover fissile material for reuse. However, the need for fuel-grade uranium and plutonium decreased. A 1992 decision to stop reprocessing left a large quantity of SNF in storage pending the licensing and operation of an SNF and high-level waste repository or interim storage facility. Licensing of a repository at Yucca Mountain is being reconsidered, but the Idaho Settlement Agreement requires all INL Site fuel be removed from the state of Idaho by 2035. The Blue Ribbon Commission on America's Nuclear Future, charged with reviewing spent

nuclear fuel management policies, issued a Report to the Secretary of Energy in January 2012 detailing recommendations for creating a safe, long-term solution for managing and disposing of the nation's SNF and high-level radioactive waste.

In 2012, INL Site SNF was stored in both wet and dry conditions. An effort is underway to put all INL Site legacy SNF in dry storage. The Nuclear Materials Disposition team completed all 3,186 fuel handling units of ICP-assigned SNF to dry storage from 2005 to 2010. Descriptions of SNF storage facilities follow.

Fluorinel Dissolution Process and Fuel Storage Facility (CPP-666) – This INTEC facility, also called FAST, is divided into two parts, an SNF storage basin area and the Fluorinel Dissolution Facility, which operated from 1983 to 1992 and is currently being used in remote-handled TRU waste management. The storage area consists of six storage basins currently storing SNF under about 11 million L (3 MG) of water, which provides protective shielding and cooling. All ICP-managed SNF has been removed from the basins and stored in the INTEC dry storage facilities described below. SNF from the ATR, EBR-II reactor and Naval Nuclear Propulsion Program is stored in the basins. Navy SNF is being transferred to the Naval Reactors Facility for dry storage. In 2012, ICP transferred two of 227 shipments of EBR-II SNF to the MFC for processing. The Idaho Settlement Agreement requires SNF to be removed from wet storage by December 2023.

Irradiated Fuel Storage Facility (IFSF, CPP-603) – This INTEC dry SNF storage facility, has 636 storage positions and has provided dry storage since 1973. In 2008, D&D of the old fuel storage basin (the wet side of the facility) was completed. In 2012, the Irradiated Fuel Storage Facility received two shipments (one truck from each) of foreign research reactor spent nuclear fuel from Mexico and Austria. SNF receipt from foreign and domestic research reactors is suspended in 2013. One cask shipment of lightly irradiated spent nuclear fuel was sent from storage at IFSF to Austria for reuse in a university reactor.

Cask Pad (CPP-2707) and Rail Casks – This INTEC facility provides safe dry storage of SNF in transport casks staged on an asphalt pad and on a rail siding.

TMI-2 Independent Spent Fuel Storage Installation (CPP-1774 ISFSI) – This INTEC facility is a U.S. Nuclear Regulatory Commission-licensed dry storage facility for SNF and debris from the Three Mile Island reactor accident. Fuel and debris were transferred to Test Area North on the INL Site for examination, study, and storage following the accident. After the examination, the SNF and debris were transferred to the ISFSI. The ISFSI provides safe, environmentally secure, aboveground storage for the SNF and debris. The facility construction consists of fuel and debris in welded stainless steel canisters, placed in carbon steel casks shielded inside concrete vaults.

Peach Bottom Fuel Storage Facility (CPP-749) – This INTEC facility consists of 193 below-ground vaults of various sizes for dry storage of SNF. The vaults generally are constructed of carbon steel tubes, with some of them containing concrete plugs. All of the tubes are below grade and are accessed from the top using specially designed equipment.

Fort Saint Vrain Independent Spent Fuel Storage Installation – DOE-ID manages this U.S. Nuclear Regulatory Commission-licensed dry storage facility located in Colorado. It contains

about two-thirds of the SNF generated over the operational life of the Fort Saint Vrain reactor. The rest of the SNF from the Fort Saint Vrain reactor is stored in the Irradiated Fuel Storage Facility, described previously. The Nuclear Regulatory Commission granted a 20-year license extension for material possession in this storage facility (2011-2031).

Advanced Test Reactor (TRA-670) – The ATR is located at the ATR Complex. The ATR is a research reactor that performs materials testing for domestic and foreign customers. During routine maintenance outages, spent fuel elements are removed and placed in underwater racks in the ATR canal, also located in Building TRA-670. Fuel elements are allowed to cool before being transferred to the Fluorinel Dissolution Process and Fuel Storage Facility, as described previously. The ATR canal is designated as a working facility rather than a storage facility. The ultimate disposition of ATR or spent fuel may be either recycle or disposition in the repository.

Radioactive Scrap and Waste Facility (MFC-771) – The Radioactive Scrap and Waste Facility has operated since 1964 for the dry storage of SNF and solid radioactive wastes resulting from nuclear energy research and development. This facility is located at MFC. It is a fenced outdoor compound with over 1,000 steel pipe storage vaults set into the ground. The storage vaults are typically 0.6 m (24 in.) in diameter and just over 3.7 m (12 ft) long. The pipe storage vaults have concrete or steel shield plugs inserted into their tops to protect workers from radiation fields and to prevent water intrusion. The storage vaults also are cathodically protected from corrosion. Currently, 19.6 metric tons (43,120 lb) of SNF, mostly from the deactivated EBR-II, is stored in the steel pipe storage vaults.

Since 1996, 3.84 metric tons (8,360 lb) of the original EBR-II inventory has been removed from the Radioactive Scrap and Waste Facility and processed using a dry electrometallurgical process. This process operates at the MFC Fuel Conditioning Facility and results in extracted, fairly pure, low-enriched, uranium metal and also a ceramic and a stainless steel, solid, high-level waste. The extracted low-enriched uranium metal is stored at the Transient Reactor Test Facility Warehouse at MFC. DOE is seeking to provide this extracted uranium to the commercial nuclear fuel fabrication industry for reuse. The two high-level waste forms are expected to be disposed of at a national geologic repository. The Radioactive Scrap and Waste Facility also stores mixed waste (primarily steel reactor components waste contaminated with sodium metal) and is managed under a RCRA hazardous waste storage permit.

3.5.3 Environmental Oversight and Monitoring Agreement

The 2010 Environmental Oversight and Monitoring Agreement (DOE-ID 2010) between DOE-ID; DOE Naval Reactors, Idaho Branch Office; and the state of Idaho maintains the state's program of independent oversight and monitoring established under the first agreement in 1990 that created the state of Idaho INL Oversight Program. The main objectives of the current five-year agreement are to:

- Assess the potential impacts of present and future DOE activities in Idaho
- Assure citizens that all present and future DOE activities in Idaho are protective of the health and safety of Idahoans and the environment
- Communicate the findings to citizens in a manner that provides them the opportunity to evaluate these potential impacts.

The INL Oversight Program's main activities include environmental surveillance; emergency coordination, planning, preparedness and response; impact analyses and public information; and education. More information can be found on the INL Oversight Program website at http://www.deq.idaho.gov/.

3.5.4 Citizens Advisory Board

The INL Site Environmental Management Citizens Advisory Board is a federally appointed citizen panel formed in 1994 that provides advice and recommendations on ICP activities to DOE-ID. The Citizens Advisory Board consists of 12 members who represent a wide variety of key perspectives on issues of relevance to Idaho citizens. They come from a wide variety of backgrounds, including environmentalists, natural resource users, previous INL Site workers, and representatives of local government, health care, higher education, business, and the general public. Their diverse backgrounds assist the ICP/EM program in making decisions and having a greater sense of how the cleanup efforts are perceived by the public. Additionally, one board member represents the Shoshone-Bannock Tribes. Members are appointed by the DOE Environmental Management Assistant Secretary and serve voluntarily without compensation. Three additional liaisons (nonvoting) include representatives from DOE-ID, Environmental Protection Agency Region 10, and the Idaho Department of Environmental Quality. The liaisons provide information to the Citizens Advisory Board on their respective agencies' policies and views.

The Citizens Advisory Board is chartered by DOE through the Federal Advisory Committee Act. The Citizens Advisory Board's charter is to provide input and recommendations to DOE on topics such as cleanup standards and environmental restoration, waste management and disposition, stabilization and disposition of nonstockpile nuclear materials, excess facilities, future land use and long-term stewardship, risk assessment and management, and cleanup science and technology activities. The Citizens Advisory Board has provided over 148 recommendations during its tenure. More information about the Board's recommendations, membership and meeting dates and topics can be found at http://www.inlcab.energy.gov.

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2012 4. Environmental Monitoring Programs (Air)

Chapter 4 Highlights

An estimated total of 2,930 (1.08×10^{14} becquerels) curies of radioactivity, primarily in the form of short-lived noble gas isotopes, was released as airborne effluents from Idaho National Laboratory (INL) Site facilities in 2012. The highest contributors to the total release were the Idaho Nuclear Technology and Engineering Center at 47 percent, the Advanced Test Reactor Complex at 41 percent, and the Radioactive Waste Management Complex at 12 percent of total.

The INL Site environmental surveillance programs emphasize measurements of airborne contaminants because air is the most important transport pathway from the INL Site to receptors living outside the INL Site boundary. Because of this, samples of airborne particulates, atmospheric moisture, and precipitation were collected on the INL Site, at INL Site boundary locations, and at distant communities and were analyzed for radioactivity in 2012.

Over 1,900 charcoal cartridges, collected weekly using a network of low-volume air samplers maintained by the INL contractor and the Environmental Surveillance, Education, and Research contractor, were analyzed for radioiodine during 2012. Iodine-131 was not detected in any samples collected during the year.

Particulates were filtered from air using the same network of low-volume air samplers, and the filters were analyzed for gross alpha activity, gross beta activity, and specific radionuclides, primarily strontium-90, cesium-137, plutonium-239/240, and americium-241. (The INL contractor only analyzes samples for gamma-emitting radionuclides.) Gross alpha and gross beta activities were used primarily for trend analyses and indicated that there were no statistically significant differences between INL Site, boundary, and distant locations. Seasonal variations were also observable in the concentrations. Elevated gross alpha activity levels were noted in late August and throughout September, likely due to naturally-occurring radioactivity in smoke from area fires.

Strontium-90 was reported on numerous air filter composites, with similar values reported at onsite, distant, and boundary stations. Plutonium-238 was reported on one composite at a value near the lower limit of detection.

Also, the Idaho Cleanup Project collected biweekly airborne particulate samples around the perimeters of the Subsurface Disposal Area of the Radioactive Waste Management Complex and the Idaho Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility at the Idaho Nuclear Technology and Engineering Center.

Gross alpha and gross beta activities measured on the filters were comparable with historical results and no new trends were identified in 2012. Detections of americium and plutonium isotopes were comparable to past measurements and are likely due to resuspended soils contaminated from past burial practices at the Subsurface Disposal Area.

Atmospheric moisture and precipitation samples were obtained at the INL Site and off the INL Site and analyzed for tritium. Tritium detected in some samples was most likely present due to natural production in the atmosphere and not INL Site releases. All measured results were below health-based regulatory limits.

4. ENVIRONMENTAL MONITORING PROGRAMS (AIR)

Idaho National Laboratory (INL) Site facilities have the potential to release radioactive and nonradioactive constituents. Pathway vectors, such as air, soil, plants, animals, and groundwater, may transport these constituents to nearby populations (Figure 3-1). Air is the most important radionuclide transport pathway to members of the general public (EG&G 1993). The INL Site air monitoring programs emphasize measurement of airborne radioactive contaminants because air has the potential to transport measureable amounts of radioactive materials to receptors in a relatively short period and can directly expose human receptors located off the INL Site.

This chapter presents results of radiological analyses of airborne effluents and ambient air samples collected on and off the INL Site. The results include those from the INL contractor, the Idaho Cleanup Project (ICP) contractor, and the Environmental Surveillance, Education, and Research Program (ESER) contractor. Table 4-1 summarizes the air monitoring activities on and off the INL Site. Details may be found in the *Idaho National Laboratory Environmental Monitoring Plan* (DOE-ID 2012).

4.1 Organization of Air Monitoring Programs

The INL contractor monitors airborne effluents at individual INL facilities to comply with the Clean Air Act National Emission Standards for Hazardous Air Pollutants (NESHAPs). Section 4.2 summarizes the results of radiological airborne effluent monitoring.

Ambient air monitoring is conducted by the INL contractor, the ESER contractor, and the ICP contractor to ensure that the INL Site remains in compliance with the U.S. Department of Energy (DOE) Orders 435.1, “Radioactive Waste Management,” and 458.1, “Radiation Protection of the Public and the Environment.” The INL contractor collected about 2,000 air samples (primarily on the INL Site) for various radiological analyses in 2012. The INL contractor also collects air moisture samples at four sites to determine tritium concentrations. Results of ambient air monitoring by the INL contractor and ICP contractor are summarized in Section 4.3.

The ESER contractor collects air samples from an area covering approximately 23,309 km^2 (9,000 mi^2) of southeastern Idaho, Jackson, Wyoming, as well as at locations on, around, and distant from the INL Site. The ESER contractor collected approximately 2,000 air samples,

Table 4-1. Air Monitoring Activities by Organization.

Area/Facility[a]	Airborne Effluent Monitoring Programs	Environmental Surveillance Programs					
	Airborne Effluents[b]	Low-volume Charcoal Cartridges (iodine-131)	Low-volume Gross Alpha	Low-volume Gross Beta	Specific Radionuclides[c]	Atmospheric Moisture	Precipitation
ICP Contractor[d]							
INTEC	●		●	●	●		
RWMC	●		●	●	●		
INL Contractor[e]							
MFC	●						
INL/Regional		●	●	●	●	●	
Environmental Surveillance, Education, and Research Program[f]							
INL/Regional		●	●	●	●	●	●

a. INTEC = Idaho Nuclear Technology and Engineering Center, RWMC = Radioactive Waste Management Complex, MFC = Materials and Fuels Complex, INL = INL Site facilities as shown in Table 4-2, Regional = locations outside of the INL Site as shown in Table 4-3.
b. Facilities that required monitoring during 2012 for compliance with 40 CFR 61, Subpart H, "National Emissions Standards for Hazardous Air Pollutants."
c. Gamma-emitting radionuclides are measured by the ICP contractor monthly, by the ESER contractor quarterly, and by the INL contractor quarterly. Strontium-90, plutonium-238, plutonium-239/240, and americium-241 are measured by the ICP and ESER contractors quarterly and by the INL contractor when anomalous gross alpha or beta results exceed threshold levels.
d. The ICP contractor monitors waste management facilities.
e. The INL contractor monitors airborne effluents at MFC and ambient air outside INL Site facilities.
f. The ESER contractor collects samples on, around, and distant from the INL Site.

primarily off the INL Site, for radiological analyses in 2012. The ESER contractor also collects air moisture and precipitation samples at selected locations for tritium analysis. Results of ambient air monitoring by the ESER contractor are discussed in Section 4.3.

The ICP contractor monitors waste management activities on the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC) and at the Idaho Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF). Section 4.4 discusses air sampling by the ICP contractor in support of waste management activities.

The INL Oversight Program, conducted by the state of Idaho Department of Environmental Quality, collects air samples from a series of air monitoring stations, many of which are collocated with the INL and ESER contractors' monitoring stations. The INL Oversight Program reports their data independently at http://www.deq.idaho.gov/inl-oversight/monitoring/reports.aspx.

Unless specified otherwise, the radiological results reported in the following sections are considered statistically positive detections. See the Supplemental Report to this Annual Site Environmental Report entitled *Statistical Methods Used in the Idaho National Laboratory Annual Site Environmental Report* for more information.

4.2 Airborne Effluent Monitoring

Radiological effluent monitoring results are used to estimate doses to members of the public from INL Site airborne releases. Because of this, they are a major component of determining compliance with regulatory dose standards. Each regulated INL Site facility determines its airborne effluent concentrations as required under state and federal regulations. Criteria air pollutants and hazardous air pollutant effluent data for the INL Site are contained in the National Emission Inventory database and can be obtained from the Environmental Protection Agency (EPA) Clearinghouse for Inventories and Emission Factors website (http://www.epa.gov/ttn/chief/index.html). Information on radiological effluents is contained in *National Emission Standards for Hazardous Air Pollutants—Calendar Year 2012*, referred to hereafter as the NESHAPs Report (DOE-ID 2013).

The NESHAPs Report describes three categories of airborne emissions:

- The first category includes sources that require continuous monitoring under the NESHAPs regulation
- The second category consists of releases from other point sources
- The final category is comprised of nonpoint, or diffuse, sources, which include radioactive waste ponds and contaminated soil areas and decontamination and decommissioning of facilities by ICP.

INL Site emissions include all three of these categories, as represented in Table 4-2. During 2012, an estimated 2,930 Ci (1.08×10^{14} Bq) of radioactivity were released to the atmosphere from all INL Site sources, which was within the range of releases from previous years, and continued the downward trend observed over the last ten years.

Approximately 69 percent of the radioactive effluent was from the noble gases argon, krypton, and xenon. A noble gas is inert, which means that it exists in a gaseous state and does

not enter into chemical combination with other elements. Most of the remaining effluent was tritium (Table 4-2 and Figure 4-1). The following facilities were contributors to the total emissions:

- **Idaho Nuclear Technology and Engineering Center (INTEC) Emissions Sources (47.1 percent of total)** – 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 wet-to-dry spent nuclear fuel movements, remote-handled transuranic waste management, radiological and hazardous waste storage facilities, and contaminated equipment maintenance.

  The ICDF 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. There were also minor emissions from the Environmental Protection Agency Radiological Dispersion Device Decontamination Project in CPP-653.

  Most of the INTEC emissions contained krypton-85 (^{85}Kr). Krypton-85 is a radionuclide commonly associated with the nuclear fuel cycle and has a 10-yr half-life. The dose potentially received from ^{85}Kr is primarily external exposure from immersion in a contaminated plume.

- **Advanced Test Reactor (ATR) Complex Emissions Sources (41.3 percent of total)** – Radiological air emissions from ATR Complex are primarily associated with operation of ATR. These emissions include noble gases, iodines, and other mixed fission and activation products, but are primarily relatively short-lived noble gases. Other radiological air emissions are associated with sample analysis, site remediation, and research and development activities. Another emission source is the INL Radioanalytical Chemistry Laboratory, which began operation in the first quarter of 2011. Activities at the lab include wet chemical analysis to determine trace radionuclides, higher level radionuclides, inorganic, and general purpose analytical chemistry. High-Efficiency Particulate Air filtered hoods are located in the laboratory including the radiological control room used for analysis of contaminated samples.

- **Radioactive Waste Management Complex (RWMC) Emissions Sources (11.5 percent of total)** – Emissions from RWMC result from various activities associated with the facilities mission to manage the low-level radioactive site and to temporarily store contact-handled and remote-handled transuranic waste for shipment to other designated facilities for disposal. In addition, various activities are being conducted in the SDA at the RWMC to complete environmental cleanup of the area under CERCLA. These include waste retrieval activities (Accelerated Retrieval Projects [ARP]), and operation of several units that extract volatile organic compounds from the subsurface.

  Potential unabated emissions from the ARP exceed 0.1 mrem/yr (0.001 mSv/yr). By agreement with EPA, the ARP used ambient air monitoring as an alternative to air dispersion calculations to verify compliance with the standard during ARP operation. Real-time monitoring is still conducted using continuous air monitors for detection of off-normal emissions.

Table 4-2. Radionuclide Composition of INL Site Airborne Effluents (2012)[a].

Radionuclide	Half Life[d]	Airborne Effluent (Ci)[b,c] ATR Complex[e]	CFA[e]	INTEC[e]	MFC[e]	RWMC[e]	TAN	Total
Ag-110m	249.9 d	6.01E-06	—[f]	1.96E-13	—	—	—	6.01E-06
Am-241	432.2 y	7.02E-05	1.22E-09	7.32E-08	3.33E-11	4.43E-04	—	5.13E-04
Am-242	16 h	—	—	—	—	2.47E-14	—	2.47E-14
Am-243	7380 y	5.00E-15	1.24E-09	—	3.39E-07	6.52E-14	—	3.40E-07
Ar-39	269 y	1.48E-19	—	—	—	—	—	1.48E-19
Ar-41	1.827 h	7.18E+02	—	—	—	—	—	7.18E+02
Ba-133	10.5 y	1.64E-11	—	—	6.03E-10	—	—	6.19E-10
Ba-137m	2.552 m	—	—	—	—	7.54E-09	—	7.54E-09
Ba-140	12.74 d	6.04E-06	2.16E-14	—	—	—	—	6.04E-06
Be-7	53.3 d	—	—	—	—	6.8E-14	—	6.80E-14
Be-10	1.36E06 y	5.43E-20	—	—	—	—	—	5.43E-20
Bi-210	120 h	7.68E-22	—	—	—	—	—	7.68E-22
Bi-210m	3E6 y	5.73E-28	—	—	—	—	—	5.73E-28
Bi-212	60.6 m	—	—	—	—	2.95E-11	—	2.95E-11
Br-83	2.40 h	1.56E-05	—	—	—	—	—	1.56E-05
C-14	5730 y	9.10E-11	4.02E-13	8.27E-06	9.16E-04	1.12E-01	—	1.13E-01
Ca-45	162.61 d	3.27E-14	—	—	—	—	—	3.27E-14
Cd-109	462.6 d	1.72E-12	5.77E-15	—	1.62E-11	—	—	1.79E-11
Ce-139	137.64 d	5.73E-14	4.49E-10	—	—	—	—	4.49E-10
Ce-141	32.5 d	3.04E-06	8.04E-14	—	—	—	—	3.04E-06
Ce-144	284.3 d	2.47E-04	—	—	8.72E-12	3.01E-11	—	2.47E-04
Cl-36	3.01E5 y	—	—	2.61E-07	—	—	—	2.61E-07
Cm-242	162.8 d	9.90E-15	3.33E-16	—	—	2.47E-14	—	3.49E-14
Cm-243	28.5 y	1.30E-14	—	—	5.36E-12	1.01E-12	—	6.39E-12
Cm-244	18.11 y	1.46E-13	1.46E-08	—	5.36E-12	5.98E-10	—	1.52E-08
Cm-248	3.48E05 y	—	—	—	5.22E-10	—	—	5.22E-10
Co-57	270.9 d	1.62E-11	2.27E-16	—	1.62E-11	—	—	3.25E-11
Co-58	70.8 d	5.66E-05	3.18E-12	—	6.40E-11	—	—	5.66E-05
Co-60	5.271 y	1.34E-02	7.95E-10	1.92E-03	6.29E-07	3.20E-10	—	1.54E-02

Table 4-2. Radionuclide Composition of INL Site Airborne Effluents (2012)[a]. (cont.)

Radionuclide	Half Life[d]	Airborne Effluent (Ci)[b,c] ATR Complex[e]	CFA[e]	INTEC[e]	MFC[e]	RWMC[e]	TAN	Total
Co-60m	10.5 m	1.03E-19	—	—	—	—	—	1.03E-19
Cr-51	27.704 d	9.58E-03	5.55E-11	—	5.12E-11	—	—	9.58E-03
Cs-134	2.062 y	4.11E-05	3.33E-12	1.80E-07	—	1.37E-10	—	4.13E-05
Cs-137	30.0 y	2.11E-02	1.75E-10	1.32E-02	3.47E-07	7.86E-09	—	3.43E-02
Cs-138	32.2 m	2.12E-01	—	—	—	—	—	2.12E-01
Eu-152	13.33 y	4.31E-04	3.69E-12	3.09E-05	—	—	—	4.62E-04
Eu-154	8.8 y	3.74E-04	1.24E-09	7.79E-05	6.00E-09	7.60E-14	—	4.52E-04
Eu-155	4.96 y	7.31E-05	—	1.22E-05	—	—	—	8.53E-05
Eu-156	15.185 d	5.22E-11	—	—	—	—	—	5.22E-11
Fe-55	2.7 y	4.84E-09	7.35E-12	—	3.23E-10	6.95E-12	—	5.18E-09
Fe-59	44.4529 d	6.51E-06	3.66E-14	—	2.24E-11	—	—	6.51E-06
Fe-60	1.5E06 y	1.03E-19	—	—	—	—	—	1.03E-19
Gd-153	241.6 d	—	1.73E-09	—	—	—	—	1.73E-09
Ge-71	11.43 d	3.21E-19	—	—	—	—	—	3.21E-19
H-3	12.35 y	3.81E+02	7.90E-01	1.75E+02	1.76E+00	3.38E+02	3.26E-02	8.96E+02
Hf-175	70 d	9.42E-06	4.17E-15	—	—	—	—	9.42E-06
Hf-178m	3.94 s	2.35E-20	—	—	—	—	—	2.35E-20
Hf-179m	25.05 d	5.34E-20	—	—	—	—	—	5.34E-20
Hf-181	42.39 d	1.20E-04	5.64E-13	—	—	—	—	1.20E-04
Hf-182	9E06 y	2.55E-23	—	—	—	—	—	2.55E-23
Hg-203	46.6 d	7.51E-06	2.43E-19	—	—	—	—	7.51E-06
I-128	24.99 m	1.79E-02	—	—	—	—	—	1.79E-02
I-129	1.57 E07 y	1.16E-07	1.95E-08	2.70E-02	1.59E-07	—	—	2.70E-02
I-131	8.04 d	2.44E-03	3.53E-09	—	3.35E-06	—	—	2.45E-03
I-132	2.3 h	1.30E-04	—	—	—	—	—	1.30E-04
I-133	20.8 h	4.50E-04	—	—	—	—	—	4.50E-04
I-134	52.8 m	2.97E-04	—	—	—	—	—	2.97E-04
I-135	6.61 h	4.35E-04	—	—	—	—	—	4.35E-04
Ir-192	74.02 d	5.76E-21	—	—	—	—	—	5.76E-21

Table 4-2. Radionuclide Composition of INL Site Airborne Effluents (2012)[a]. (cont.)

		Airborne Effluent (Ci)[b,c]						
Radionuclide	Half Life[d]	ATR Complex[e]	CFA[e]	INTEC[e]	MFC[e]	RWMC[e]	TAN	Total
K-40	1.277E08 y	5.97E-14	—	—	—	9.06E-14	—	1.50E-13
Kr-85	10.72 y	1.60E-08	—	1.20E+03	1.34E-03	2.53E-10	—	1.20E+03
Kr-85m	4.48 h	5.70E+00	—	—	—	—	—	5.70E+00
Kr-87	76.3 m	2.10E+01	—	—	—	—	—	2.10E+01
Kr-88	2.84 m	1.61E+01	—	—	—	—	—	1.61E+01
La-140	40.27 h	6.01E-07	—	—	—	—	—	6.01E-07
La-142	92.5 m	1.80E-12	—	—	—	—	—	1.80E-12
Mn-53	3.7 E06 y	7.20E-23	—	—	—	—	—	7.20E-23
Mn-54	312.5 d	3.80E-05	1.45E-11	—	7.12E-11	—	—	3.80E-05
Mn-56	2.5785 h	1.71E-11	—	—	—	—	—	1.71E-11
Mo-93	3.5E03 y	1.01E-09	—	—	—	—	—	1.01E-09
Mo-99	66.0 h	7.74E-05	—	—	—	—	—	7.74E-05
Na-24	15.0 h	1.41E-03	—	—	—	—	—	1.41E-03
Nb-93m	16.1 y	6.48E-13	—	—	—	—	—	6.48E-13
Nb-94	2.03E04 y	3.22E-14	—	—	—	—	—	3.22E-14
Nb-95	35.15 d	3.79E-06	1.72E-13	—	8.04E-12	—	—	3.79E-06
Nb-97	1.23 h	—	—	—	4.8E-12	—	—	4.80E-12
Ni-59	7.5E04 y	4.51E-10	1.90E-13	—	—	—	—	4.51E-10
Ni-63	96 y	6.97E-08	1.69E-11	1.30E-04	1.78E-11	3.19E-10	—	1.30E-04
Np-237	2.14E06 y	2.57E-10	5.12E-10	8.47E-11	6.36E-08	9.98E-10	—	6.55E-08
Np-239	2.355 d	7.80E-05	—	—	—	5.94E-14	—	7.80E-05
Os-185	93.6 d	4.44E-21	—	—	—	—	—	4.44E-21
Os-191	15.4 d	3.88E-06	—	—	—	—	—	3.88E-06
P-32	14.262 d	5.88E-18	—	—	—	—	—	5.88E-18
P-33	25.34 d	3.15E-21	—	—	—	—	—	3.15E-21
Pa-233	27.0 d	9.30E-13	5.10E-10	—	—	—	—	5.11E-10
Pb-205	1.53E07 y	1.72E-21	—	—	—	—	—	1.72E-21
Pb-210	22.3 y	1.92E-13	—	—	—	2.05E-14	—	2.13E-13
Pb-212	13.6 h	—	—	—	—	2.95E-11	—	2.95E-11

Table 4-2. Radionuclide Composition of INL Site Airborne Effluents (2012)[a]. (cont.)

Radionuclide	Half Life[d]	Airborne Effluent (Ci)[b,c] ATR Complex[e]	CFA[e]	INTEC[e]	MFC[e]	RWMC[e]	TAN	Total
Pm-147	2.6234 y	—	3.51E-10	1.60e-05	—	1.35E-10	—	1.60E-05
Po-210	138.38 d	3.03E-21	7.35E-13	—	—	—	—	7.35E-13
Po-212	0.305 m	—	—	—	—	1.89E-11	—	1.89E-11
Po-216	0.15 s	—	—	—	—	2.95E-11	—	2.95E-11
Pr-144	17.3 m	—	—	—	—	3.02E-11	—	3.02E-11
Pu-236	2.9 y	1.60E-14	—	—	—	—	—	1.60E-14
Pu-238	87.74 y	5.83E-14	5.13E-15	6.63E-05	1.12E-11	2.57E-06	—	6.89E-05
Pu-239	24065 y	2.68E-05	1.50E-11	2.91E-04	2.77E-07	1.83E-04	—	5.01E-04
Pu-240	6537 y	1.92E-14	4.18E-16	1.50E-04	9.47E-11	2.74E-05	—	1.77E-04
Pu-241	14.4 y	2.96E-14	1.47E-12	5.30E-03	3.44E-10	9.82E-05	—	5.40E-03
Pu-242	3.8E05 y	1.27E-13	9.58E-11	—	6.56E-12	1.30E-09	—	1.40E-09
Ra-224	3.66 d	—	—	—	—	2.95E-11	—	2.95E-11
Ra-226	1600 y	3.12E-10	—	—	—	1.45E-16	—	3.12E-10
Rb-88	17.8 m	2.21E-01	—	—	—	—	—	2.21E-01
Rb-89	15.2 m	1.63E-01	—	—	—	—	—	1.63E-01
Re-184	38.0 d	3.06E-18	—	—	—	—	—	3.06E-18
Re-184m	165 d	2.35E-18	—	—	—	—	—	2.35E-18
Re-186	3.77 d	8.28E-20	—	—	—	—	—	8.28E-20
Re-186m	2.0E05 y	8.28E-20	—	—	—	—	—	8.28E-20
Re-187	5E10 y	3.45E-17	—	—	—	—	—	3.45E-17
Re-188	17.005 h	8.63E-05	—	—	—	—	—	8.63E-05
Rh-106	368.2 d	—	—	—	—	3.06E-15	—	3.06E-15
Ru-103	39.26 d	7.38E-11	7.44E-15	—	—	—	—	7.38E-11
Ru-106	373.59 d	1.00E-05	—	—	—	3.06E-15	—	1.00E-05
Sb-122	2.7238 d	4.74E-07	—	—	—	—	—	4.74E-07
Sb-124	60.2 d	4.59E-06	6.27E-13	—	—	—	—	4.59E-06
Sb-125	2.77 y	3.48E-11	1.10E-12	1.50E-06	2.96E-07	1.13E-11	—	1.80E-06
Sc-46	83.83 d	3.89E-06	1.62E-13	—	—	—	—	3.89E-06
Si-32	100 y	5.34E-18	—	—	—	—	—	5.34E-18

Table 4-2. Radionuclide Composition of INL Site Airborne Effluents (2012)[a]. (cont.)

		Airborne Effluent (Ci)[b,c]						
Radionuclide	Half Life[d]	ATR Complex[e]	CFA[e]	INTEC[e]	MFC[e]	RWMC[e]	TAN	Total
Sm-151	90 y	—	—	0.00021	—	—	—	2.10E-04
Sn-113	115.09 d	8.74E-12	—	—	1.62E-11	—	—	2.49E-11
Sr-85	64.84 d	3.01E-10	—	1.50E-11	—	—	—	3.16E-10
Sr-89	50.5 d	3.25E-06	—	—	7.35E-09	—	—	3.26E-06
Sr-90	29.12 y	3.75E-02	4.02E-12	1.13E-02	1.71E-05	1.57E-08	1.02E-06	4.88E-02
Sr-91	9.5 h	1.48E-10	—	—	—	—	—	1.48E-10
Sr-92	2.7 h	1.15E-10	—	—	—	—	—	1.15E-10
Ta-179	1.8 y	1.34E-14	—	—	—	—	—	1.34E-14
Ta-180m	7.1E15 y	5.01E-33	—	—	—	—	—	5.01E-33
Ta-182	114.43 d	1.08E-05	—	—	—	—	—	1.08E-05
Ta-183	5.1 d	8.91E-10	—	—	—	—	—	8.91E-10
Tc-99	2.13E05 y	2.08E-11	1.69E-10	7.29E-07	—	—	—	7.29E-07
Tc-99m	6.02 h	8.38E-05	—	—	—	—	—	8.38E-05
Te-123m	119.7 d	1.32E-15	—	—	—	—	—	1.32E-15
Te-129	1.16 h	—	—	—	1.20E-12	—	—	1.20E-12
Th-228	1.9116 y	2.12E-11	—	—	—	2.95E-11	—	5.07E-11
Th-229	7340 y	3.60E-16	—	—	—	—	—	3.60E-16
Th-230	7.7E04 y	2.90E-14	—	—	—	—	—	2.90E-14
Th-232	1.4E10 y	3.09E-11	2.58E-14	—	—	8.12E-12	—	3.90E-11
Th-234	24.1 d	1.34E-13	—	—	—	—	—	1.34E-13
Tl-204	3.77 y	3.81E-21	—	—	—	—	—	3.81E-21
Tl-208	3.05 m	—	—	—	—	1.06E-11	—	1.06E-11
U-232	72 y	6.87E-15	4.44E-17	—	—	2.89E-11	—	2.89E-11
U-233	1.585E05 y	1.95E-11	7.55E-08	4.61E-08	6.87E-06	1.14E-09	—	6.99E-06
U-234	2.457E05 y	3.96E-13	2.58E-12	4.09E-07	2.64E-08	2.06E-11	3.35E-11	4.36E-07
U-235	7.038E08 y	5.60E-12	1.20E-13	2.21E-08	8.43E-10	4.73E-12	2.34E-12	2.29E-08
U-236	4.468E09 y	1.08E-15	—	3.07E-10	—	—	—	3.07E-10
U-238	4.5E09 y	1.69E-09	8.57E-11	1.02E-07	5.40E-11	2.62E-10	1.86E-10	1.04E-07
V-49	330 d	3.21E-19	—	—	—	—	—	3.21E-19

Table 4-2. Radionuclide Composition of INL Site Airborne Effluents (2012)[a]. (cont.)

Radionuclide	Half Life[d]	Airborne Effluent (Ci)[b,c] ATR Complex[e]	CFA[e]	INTEC[e]	MFC[e]	RWMC[e]	TAN	Total
W-181	121.2 d	4.08E-09	—	—	—	—	—	4.08E-09
W-185	75.1 d	6.87E-08	—	—	—	—	—	6.87E-08
W-187	23.9 h	3.20E-05	—	—	—	—	—	3.20E-05
W-188	69.78 d	2.59E-08	—	—	—	—	—	2.59E-08
Xe-133	5.245 d	3.84E+00	—	—	—	—	—	3.84E+00
Xe-135	9.09 h	1.87E+01	—	—	—	—	—	1.87E+01
Xe-135m	15.29 m	1.01E+01	—	—	—	—	—	1.01E+01
Xe-138	14.17 m	3.72E+01	—	—	—	—	—	3.72E+01
Y-88	106.64 d	3.43E-13	3.00E-10	—	—	—	—	3.00E-10
Y-90	64.0 h	2.19E-03	—	—	—	7.52E-09	—	2.19E-03
Y-92	3.54 h	2.34E-12	—	—	—	—	—	2.34E-12
Zn-65	243.9 d	7.85E-05	2.23E-11	—	—	—	—	7.85E-05
Zr-95	63.98 d	6.61E-06	1.72E-13	—	8.44E-12	—	—	6.61E-06
Zr-97	16.9 h	1.71E-11	—	—	—	—	—	1.71E-11
Totals		1.21E+03	7.90E-01	1.38E+03	1.76E+00	3.38E+02	3.26E-02	2.93E+03

a. Radionuclide release information provided by the INL contractor.
b. One curie (Ci)= 3.7 x 10^{10} becquerels (Bq)
c. Includes only those radionuclides with a total INL Site release that potentially contribute > 1E-05 mrem (1E-07 mSv) dose.
d. d = days, h = hours, m = minutes, ms = milliseconds, s = seconds, y = years
e. ATR = Advanced Test Reactor, CFA = Central Facilities Area, INTEC = Idaho Nuclear Technology and Engineering Center, MFC = Materials and Fuels Complex, RWMC = Radioactive Waste Management Complex, including Advanced Mixed Waste Treatment Project, TAN = Test Area North, including Specific Manufacturing Capability.
f. A long dash signifies the radionuclide was not reported to be released to air from the facility in 2012.

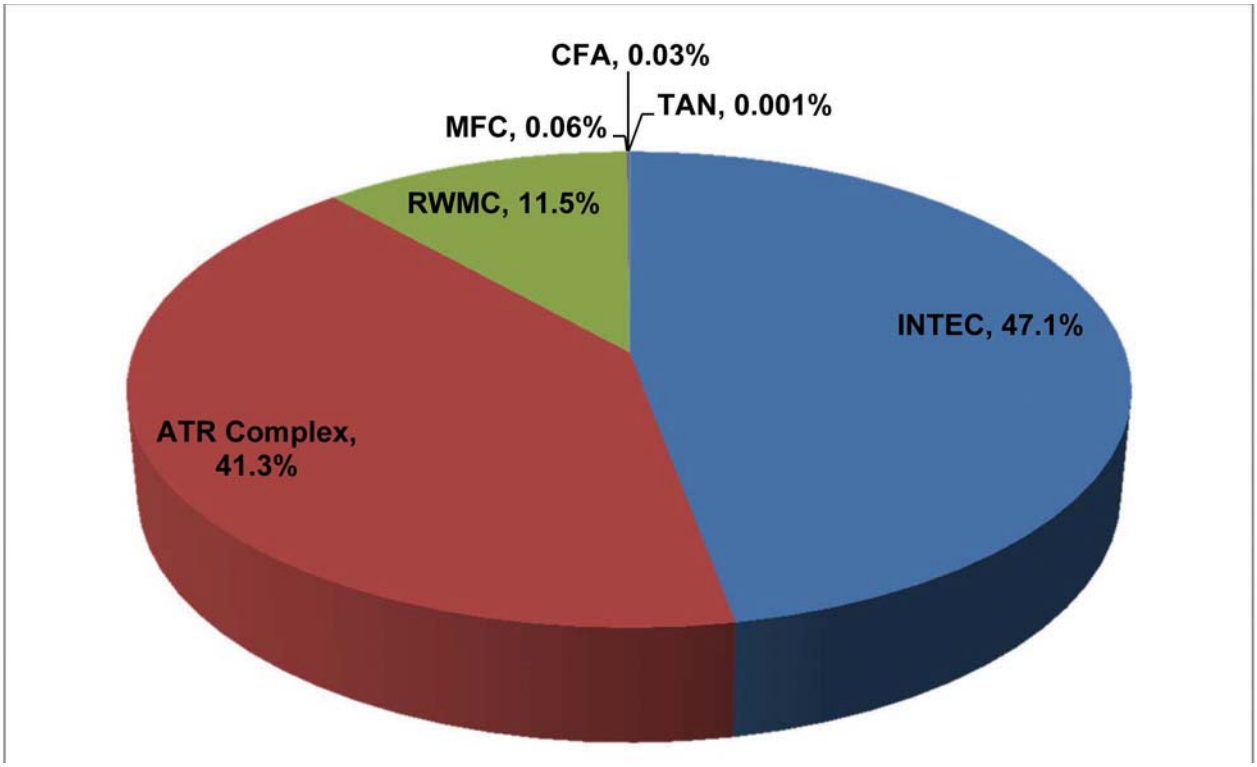


Figure 4-1. Percent Contributions, by Facility, to Total INL Site Airborne Radionuclide Releases (2012).

Prior to November 20, 2012, the RWMC processed (sort and repackage) radionuclide contaminated soils and sludge within the ARP-V enclosure, and after November 20 sludge from the AMWTP facility was processed at WMF-1617 (ARP-V enclosure). The AMWTP sludge processing activity is designed to ensure contact-handled stored transuranic waste is compliant with off-site disposal facility waste acceptance criteria by removing prohibited waste items (e.g., free liquids). The emissions from RWMC were estimated to be almost exclusively tritium.

- **Materials and Fuels Complex (MFC) Emissions Sources (0.06 percent of total)** - Radiological air emissions are primarily associated with spent fuel treatment at the Fuel Conditioning Facility, waste characterization at the Hot Fuel Examination Facility, and fuel research and development at the Fuel Manufacturing Facility. These facilities are equipped with continuous emission monitoring systems. On a regular basis, the effluent streams from Fuel Conditioning Facility, Hot Fuel Examination Facility, Fuel Manufacturing Facility and other non-continuous emission monitoring radiological facilities are sampled and analyzed for particulate 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. Radiological emissions also

occurred from ICP decontamination and decommissioning activities in MFC-766, Sodium Boiler Building.

- **Central Facilities Area (CFA) Emissions Sources (0.03 percent of total)** - Minor emissions occur from CFA facilities where work with small quantities of radioactive materials is routinely conducted. This includes sample preparation and verification and radiochemical research and development. Other minor emissions result from groundwater usage.
- **Test Area North (TAN) Emissions Sources (<0.01 percent of total)** – The main emissions sources at TAN are from the Specific Manufacturing Capability (SMC) project, and the New Pump and Treat Facility. Radiological air emissions from SMC are associated with processing of depleted uranium. Potential emissions are uranium isotopes and associated radioactive progeny. The main purpose of the New Pump and Treat Facility is to reduce concentrations of trichloroethylene and other volatile organic compounds in the medial portion of the Operable Unit 1-07B contamination groundwater plume at TAN to below drinking water standards. Low levels of strontium-90 and tritium are also present in the treated water and are released to the atmosphere by the treatment process.

The INL Site dose was calculated using all sources that emitted radionuclides to the environment (DOE-ID 2013). Radiological dose to the public is discussed further in Chapter 8 of this report.

4.3 Ambient Air Monitoring

The INL, ICP, and ESER contractors' environmental surveillance programs monitor air pathways on and off the INL Site for radionuclides. Figure 4-2 shows the regional ambient air monitoring locations.

Filters generally are collected weekly from a network of low-volume air monitors. At each monitor, a pump pulls air (about 57 L/min [2 ft^3/min]) through a 5-cm (2-in.), 1.2-µm membrane filter and a charcoal cartridge. The membrane filters are collected weekly and analyzed in a laboratory for gross alpha and beta activity. Gross alpha and beta results generally are considered screenings because specific radionuclides are not identified. Rather, the results reflect a mix of alpha- and beta-emitting radionuclides. Gross alpha and beta radioactivity in air samples are usually dominated by the presence of naturally occurring radionuclides. Because of this, gross alpha and gross beta radioactivity is, with rare exceptions, detected in each air filter collected. If the results are higher than normal, sources other than background radionuclides may be suspected, and then other laboratory techniques can be used to identify specific radionuclides of concern. Gross alpha and beta activity also are examined over time and between locations to detect trends, which might indicate the need for more specific analyses.

The filters are composited quarterly by the ESER and INL[1] contractors and monthly by

[1] The INL contractor altered the ambient air monitoring program for technical reasons in 2008. This included ceasing routine analysis for ^{90}Sr and alpha-emitting radionuclides and changing the gamma spectrometry analysis frequency from quarterly to semiannual composites. In March 2011, quarterly composites were reinstated. The quarterly composites are analyzed for gamma-emitting radionuclides in accordance with DOE Regulatory Guide 0173T (DOE 1991).

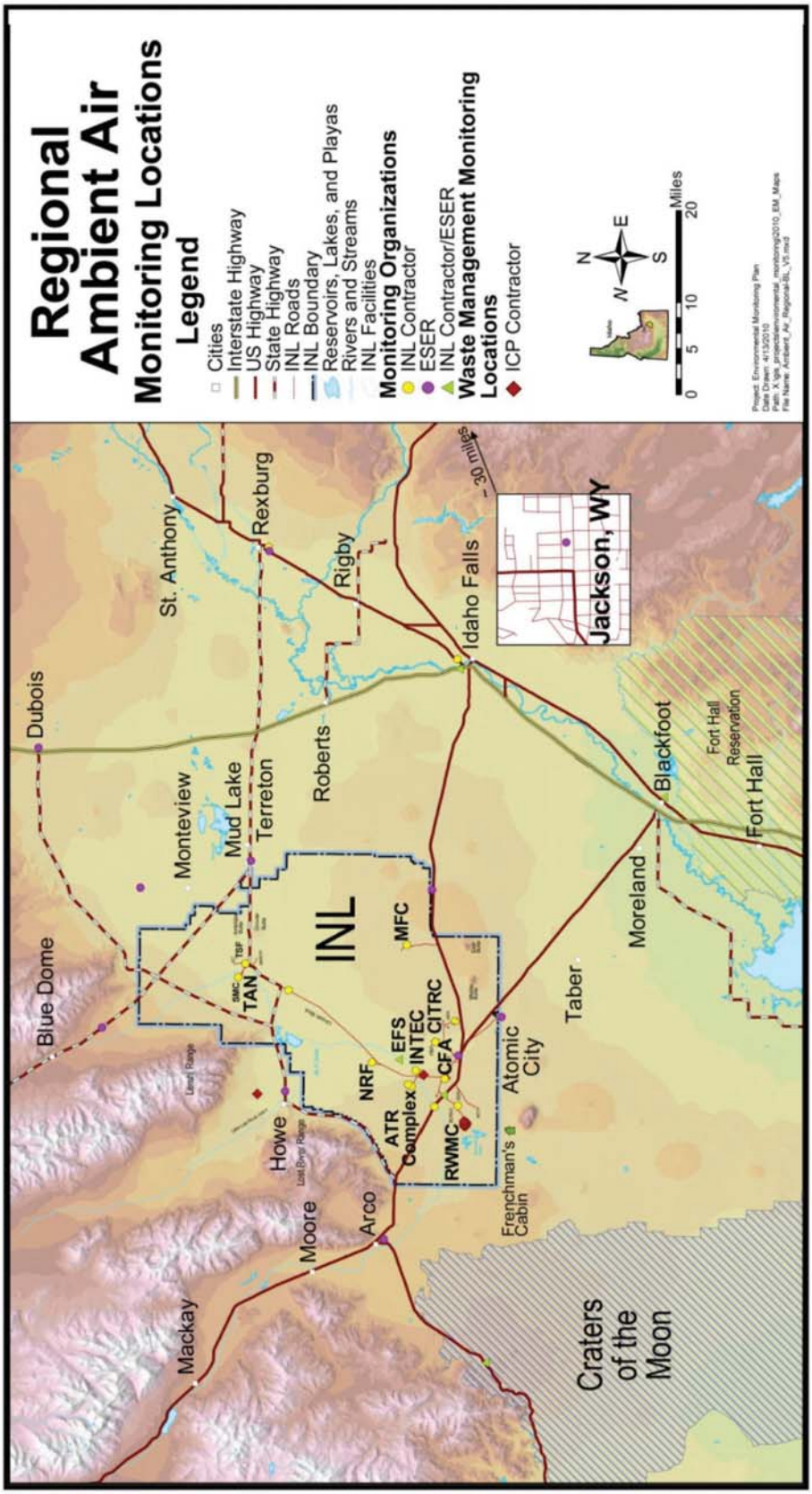


Figure 4-2. INL Site Environmental Surveillance Air Sampling Locations.

the ICP contractor for laboratory analysis of gamma-emitting radionuclides, such as cesium-137 (^{137}Cs). Cesium-137 is a man-made radionuclide and is present in soil on and off the INL Site from historical INL Site activities and global fallout. The contaminated soil particles can become airborne and subsequently filtered by air samplers. Naturally occurring gamma-emitting radionuclides that are typically detected in air filters include beryllium-7 (^{7}Be) and potassium-40 (^{40}K).

The ESER and ICP contractors also use laboratories to radiochemically analyze the quarterly and monthly composited samples for selected alpha- and beta-emitting radionuclides. These radionuclides include americium-241 (^{241}Am), plutonium-238 (^{238}Pu), plutonium-239/240 ($^{239/240}$Pu), and strontium-90 (^{90}Sr). They were selected for analysis because they have been detected historically in air samples and may be present due to resuspension of surface soil particles contaminated by INL Site activities or global fallout. The INL contractor currently screens for certain actinides (uranium-235, uranium-238, and ^{241}Am) using the quarterly gamma spectrometry analysis of the composited air samples.

Charcoal cartridges are collected and analyzed weekly for iodine-131 (^{131}I) by the INL and ESER contractors. Iodine-131 is of particular interest because it is produced in relatively large quantities by nuclear fission, is readily accumulated in human and animal thyroids, and has a half-life of eight days. This means that any elevated level of ^{131}I in the environment could be from a recent release of fission products.

The ESER and INL contractors monitor tritium in atmospheric water vapor in ambient air on the INL Site at the Experimental Field Station (EFS) and Van Buren Boulevard, and off the INL Site at Atomic City, Blackfoot, Craters of the Moon, Idaho Falls, and Rexburg. Air passes through a column of molecular sieve, which is an adsorbent material that adsorbs water vapor in the air. Columns are sent to a laboratory for analysis when the material has adsorbed sufficient moisture to obtain a sample. The laboratory extracts water from the material by distillation and determines tritium concentrations by liquid scintillation counting. Tritium typically is present in air moisture due to natural production in the atmosphere, although it also is released by INL Site facilities (Table 4-2).

Precipitation samples are collected by the ESER contractor at EFS, Central Facilities Area (CFA), and Idaho Falls and analyzed for tritium using liquid scintillation counting in a laboratory.

4.3.1 Ambient Air Monitoring Results

Gaseous Radioiodines – The INL contractor collected and analyzed approximately 1,000 charcoal cartridges in 2012. There were no statistically positive detections of ^{131}I. During 2012, the ESER contractor analyzed 936 cartridges, looking specifically for ^{131}I. Of these 936 cartridges, there were no statistically positive detections of ^{131}I.

Gross Activity – All air filters were analyzed for gross alpha activity and gross beta activity. Gross alpha and gross beta measurements were assessed in terms of historical measurements and trends between locations and contractors, as well as over time. All measurements were included in these assessments, even the few that were not considered to be detected, to make the statistical analyses more robust. For more information see the discussion of “less-than-detectable values” in the document entitled *Statistical Methods in the Idaho National Laboratory Annual Site Environmental Report*, which is a supplement to this report.

- **Gross Alpha.** Gross alpha concentrations measured in individual INL contractor samples ranged from a low of -4 x 10^{-16} ± 5.4 × 10^{-16} µCi/mL collected at Test Area North on January 25, 2012, to a high of 9.6 × 10^{-15} ± 2.1 × 10^{-15} µCi/mL collected at Gate 4 on August 15, 2012. Gross alpha concentrations measured in weekly ESER contractor samples ranged from a minimum of -0.28 × 10^{-15} µCi/mL at Rexburg during the week ending August 29, 2012, to a maximum of 7.2 × 10^{-15} µCi/mL during the same week at Blackfoot. All results were within the range of historical measurements and less than the Derived Concentration Standard (DCS) of 4 × 10^{-14} µCi/mL for ^{241}Am (see Table A-1 of Appendix A).

  INL and ESER contractor gross alpha activity data differed little when analyzed by location grouping, as illustrated in Figure 4-3. In this figure, median concentrations measured at INL Site and offsite locations (boundary and distant) are plotted for each week of the year. Each median weekly concentration was computed using all measurements, including negative values and statistically undetected results. Both data sets (INL contractor and ESER contractor) indicate that gross alpha concentrations measured at INL Site and offsite locations follow a similar pattern with respect to time. Somewhat elevated gross alpha concentrations were noted during the second half of August and during the month of September (weeks 33 through 39 on Figure 4-3). During this period, very smoky conditions were present throughout the sampling area due to several large wildfires. Fires release naturally-occurring polonium-210 that has been taken up from the soil by vegetation, and this can lead to higher-than-average gross alpha concentrations.

  Median annual gross alpha concentrations calculated by the INL contractor ranged from 9.14 × 10^{-16} µCi/mL at Blackfoot and Craters of the Moon to 1.78 × 10^{-15} µCi/mL at Experimental Field Station. Median annual gross alpha concentrations calculated by the ESER contractor for each location ranged from 1.0 × 10^{-15} µCi/mL at Arco to 1.5 × 10^{-15} µCi/mL at Blackfoot (Table 4-3). The median annual gross alpha concentrations were typical of those detected previously and well within those measured historically.

- **Gross Beta.** Gross beta concentrations in ESER contractor samples were fairly consistent with those of INL contractor samples. Weekly gross beta concentrations in INL contractor samples ranged from a low of 2.1 × 10^{-15} ± 1.1 × 10^{-15} µCi/mL at the Rest Area monitoring location on June 6, 2012, to a high of 8.86 × 10^{-14} ± 8.5 × 10^{-15} µCi/mL at RWMC on September 19, 2012. Weekly gross beta concentrations detected in individual ESER contractor samples ranged from a low of 6.9 × 10^{-15} µCi/mL on October 17, 2012, at Idaho Falls to a high of 6.5 × 10^{-14} µCi/mL on March 14, 2012, at Atomic City. These results are within the range of past measurements.

  Figure 4-4 displays the median weekly gross beta concentrations for the ESER and INL contractors at INL Site, boundary, and distant sampling groups in 2012, as well as historical median and range of data measured by the ESER contractor during the 10-year period from 2002 through 2011. In general, median airborne radioactivity levels for the three groups (on INL Site, boundary, and distant locations) tracked each other closely throughout the year. These data are typical of the annual fluctuation pattern for natural gross beta concentrations in air, with higher values typically occurring at the beginning and end of the calendar year

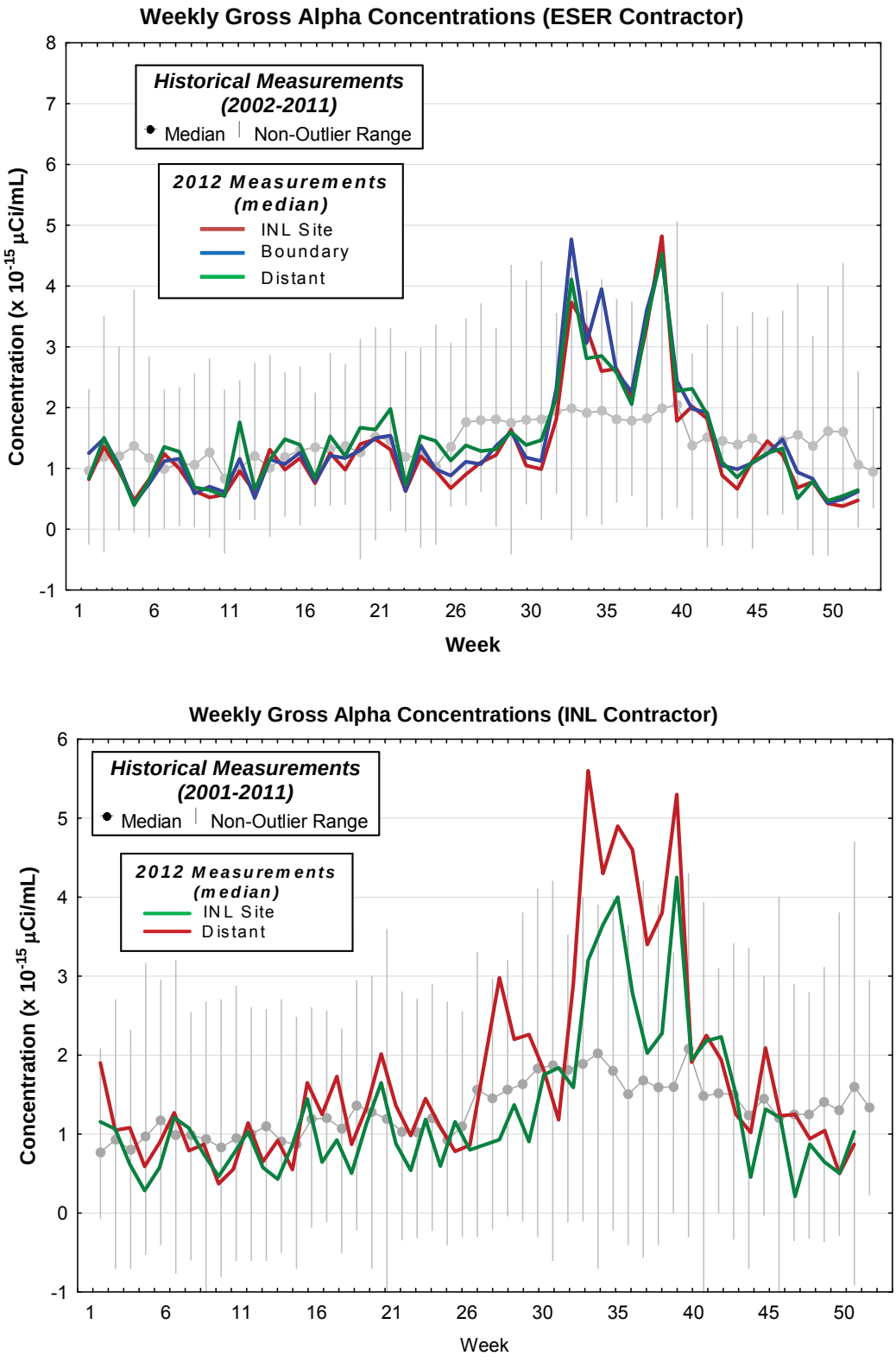


Figure 4-3. Median Weekly Gross Alpha Concentrations in Air (2012).

Table 4-3. Median Annual Gross Alpha Concentrations in Air (2012).

Group	Location[a]	No. of Samples[b]	Range of Concentrations[c] ($\times 10^{-15}$ µCi/mL)	Annual Median[c] ($\times 10^{-15}$ µCi/mL)
		ESER Contractor		
Distant	Blackfoot CMS	50	0.29 – 7.2	1.5
	Craters of the Moon	52	0.20 – 4.9	1.1
	Dubois	50	0.45 – 4.7	1.2
	Idaho Falls	52	0.30 – 4.9	1.3
	Jackson	50	-0.27 – 4.1	1.3
	Rexburg CMS	52	-0.28 – 6.4	1.5
			Distant Median:	1.3
Boundary	Arco	52	0.38 – 4.6	1.0
	Atomic City	50	0.30 – 5.1	1.1
	Blue Dome	52	0.20 – 5.9	1.1
	Federal Aviation Administration Tower	52	0.24 – 5.3	1.1
	Howe	51	0.32 – 4.9	1.3
	Monteview	51	0.41 – 4.6	1.3
	Mud Lake	52	0.43 – 4.8	1.4
			Boundary Median:	1.2
INL Site	EFS	52	0.26 – 4.8	1.1
	Main Gate	52	0.38 – 7.1	1.2
	Van Buren	52	0.32 – 4.2	1.1
			INL Site Median:	1.1
		INL Contractor		
Distant	Blackfoot	51	-0.30– 8.7	0.9
	Craters of the Moon	49	-0.37 – 5.0	0.9
	Idaho Falls	51	-0.06 – 3.5	1.2
	Rexburg	51	0.01 – 6.1	1.5
			Distant Median:	1.1
INL Site	ARA	51	-0.40 – 5.3	1.2
	ATR Complex (south side)	51	-0.23 – 6.2	1.4
	ATR Complex (NE corner)	51	-0.37 – 6.1	1.4
	CFA	50	0.03 – 5.6	1.3
	CITRC	50	-0.33 – 7.8	1.6
	INTEC (west side)	51	-0.13 – 7.5	1.2
	EBR-I	51	-0.07 – 7.1	1.2
	EFS	50	-0.02 – 5.5	1.8
	Gate 4	50	-0.24 – 9.6	1.2
	INTEC (NE corner)	51	-0.27 – 6.3	1.3
	MFC	50	0.01 – 8.6	1.3
	NRF	49	-0.12 – 7.4	1.3
	Rest Area	50	-0.24 – 6.9	1.3
	RWMC	51	-0.09 – 5.5	1.5
	SMC	48	0.18 – 5.6	1.5
	TAN	51	-0.40 – 7.1	1.3
	Van Buren	51	-0.23 – 6.2	1.4
			INL Site Median:	1.4

a. ARA = Auxiliary Reactor Area, ATR = Advanced Test Reactor, CFA = Central Facilities Area, CITRC = Critical Infrastructure Test Range Complex, CMS = Community Monitoring Station, EBR-I = Experimental Breeder Reactor No. 1, EFS = Experimental Field Station, INTEC = Idaho Nuclear Technology and Engineering Center, MFC = Materials and Fuels Complex, NRF = Naval Reactors Facility, RWMC = Radioactive Waste Management Complex, SMC = Specific Manufacturing Capability, TAN = Test Area North. See Figure 3-2 for locations on INL Site.

b. Includes valid (i.e., sufficient volume) samples only. Does not include duplicate measurements.

c. All measurements, including those <3s, are included in this table and in computation of median annual values. A negative result indicates that the measurement was less than the laboratory background measurement.

during winter inversion conditions (see sidebar). An inversion can lead to natural radionuclides being trapped close to the ground. In 2012, the end of year inversion periods did not materialize as strongly as commonly found. The maximum median weekly gross beta concentration was 4.3×10^{-14} µCi/mL, which is significantly below the DCS of 240×10^{-14} µCi/mL (see Table A-1 of Appendix A) for the most restrictive beta-emitting radionuclide in air (radium-228 [^{228}Ra]).

ESER contractor median annual gross beta concentrations ranged from 2.2×10^{-14} µCi/mL at Craters of the Moon and Idaho Falls to 2.7×10^{-14} µCi/mL at Blackfoot and Rexburg (Table 4-4). INL contractor data ranged from a median annual concentration of 2.4×10^{-14} µCi/mL at Craters of the Moon, to 2.64×10^{-14} µCi/ mL at SMC. All results detected by the ESER and INL contractors were well within valid measurements taken within the last 13 years (Figure 4-4). This indicates that the fluctuation patterns over the entire sampling network are representative of natural conditions and are not caused by a localized source, such as a facility or activity at the INL Site.

What is an inversion?

Usually within the lower atmosphere, the air temperature decreases with height above the ground. This is largely because the atmosphere is heated from below as solar radiation warms the earth's surface, which, in turn, warms the layer of the atmosphere directly above it. A meteorological **inversion** is a deviation from this normal vertical temperature gradient such that the temperature increases with height above the ground. A meteorological inversion is typically produced whenever radiation from the earth's surface exceeds the amount of radiation received from the sun. This commonly occurs at night or during the winter when the sun's angle is very low in the sky.

- **Gross Activity Statistical Comparisons.** Statistical comparisons were made using the gross alpha and gross beta radioactivity data collected from the INL Site, boundary, and distant locations (see the supplemental report, *Statistical Methods Used in the Idaho National Laboratory Annual Site Environmental Report*, for a description of methods used). If the INL Site were a significant source of offsite contamination, contaminant concentrations would be statistically greater at boundary locations than at distant locations. There were no statistical differences among annual concentrations collected from the INL Site, boundary, and distant locations in 2012. There were a few statistical differences between weekly boundary and distant data sets collected by the ESER contractor during the 52 weeks of 2012 that can be attributed to expected statistical variation in the data and not to INL Site releases. Quarterly reports detailing these analyses are provided at http://www.gsseser.com/Publications.htm. INL contractor data sets from samples collected on the INL Site and distant locations were compared, and there were no statistical differences.

Specific Radionuclides – The ESER contractor found numerous detections of ^{90}Sr throughout 2012. Detectable concentrations ranged from 2.4×10^{-17} µCi/mL at the Van Buren Gate in the fourth quarter to 1.5×10^{-16} µCi/mL at Jackson in the third quarter. Similar concentrations were found at distant, boundary, and INL Site locations (Table 4-5). These concentrations were similar to those found in 2011 when the ESER contractor began using a new laboratory for this analysis. The minimum detection limit reported by the laboratory for ^{90}Sr is approximately 2.0×10^{-17} µCi/mL. The DCS for ^{90}Sr in air is 2.5×10^{-11} µCi/mL.

Plutonium-238 was also reported (Table 4-5) on the composite from Mud Lake from the third quarter at a value just above the minimum detection limit. The reported value of 3.5×10^{-18} µCi/mL was 0.009 percent of the DCS for this radionuclide.

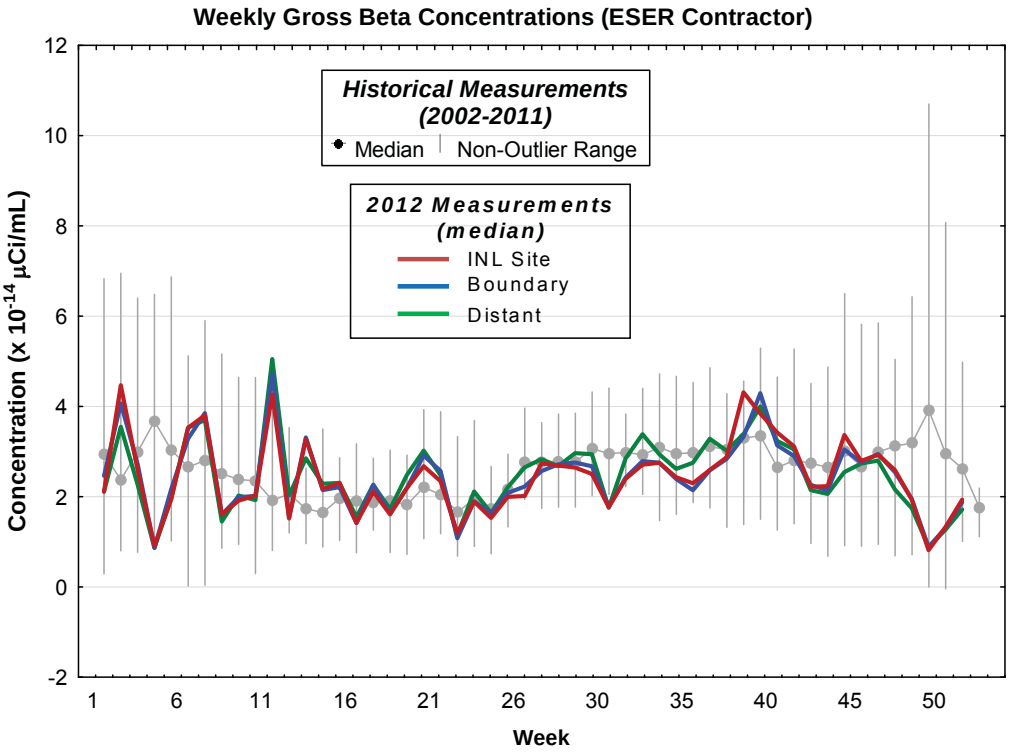
Table 4-4. Median Gross Beta Concentrations in Air (2012).

Group	Location[a]	No. of Samples[b]	Range of Concentrations[c] ($\times 10^{-14}$ µCi/mL)	Annual Median[c] ($\times 10^{-14}$ µCi/mL)
		ESER Contractor		
Distant	Blackfoot CMS	50	0.90 – 5.9	2.7
	Craters of the Moon	52	0.71– 4.0	2.2
	Dubois	50	0.82 – 4.3	2.3
	Idaho Falls	52	0.69– 4.2	2.2
	Jackson	50	0.82 – 6.0	2.5
	Rexburg CMS	52	0.85 – 5.8	2.7
			Distant Median:	2.4
Boundary	Arco	52	0.84 – 4.3	2.4
	Atomic City	50	0.71 – 6.5	2.4
	Blue Dome	52	0.84 – 4.3	2.4
	Federal Aviation Administration Tower	52	0.76 – 5.0	2.3
	Howe	51	0.82 – 4.3	2.4
	Monteview	51	0.94 – 4.5	2.4
	Mud Lake	52	0.94 – 5.1	2.6
			Boundary Median:	2.4
INL Site	EFS	52	0.79 – 4.7	2.3
	Main Gate	52	0.83 – 5.7	2.3
	Van Buren	52	0.81 – 4.3	2.4
			INL Site Median:	2.3
		INL Contractor		
Distant	Blackfoot	51	0.76 – 4.4	2.4
	Craters of the Moon	49	0.64 – 4.7	2.2
	Idaho Falls	51	0.61 – 4.7	2.4
	Rexburg	51	0.80 – 8.3	2.5
			Distant Median	2.4
INL Site	ARA	51	0.69 – 4.3	2.4
	ATR Complex (south side)	51	0.88 – 4.1	2.5
	ATR Complex (NE corner)	51	0.59 – 5.9	2.4
	CFA	50	0.45 – 4.2	2.5
	CITRC	50	0.87 – 4.4	2.5
	INTEC (west side)	51	0.40 – 4.6	2.3
	EBR-I	51	0.54 – 7.7	2.3
	EFS	50	0.94 – 4.5	2.6
	Gate 4	50	0.88 – 5.9	2.6
	INTEC (NE corner)	51	0.77 – 4.6	2.5
	MFC	50	0.53 – 3.8	2.5
	NRF	49	0.60 – 8.2	2.5
	Rest Area	50	0.21 – 4.0	2.5
	RWMC	51	0.73 – 8.9	2.4
	SMC	48	0.74 – 4.5	2.6
	TAN	51	0.63 – 4.0	2.6
	Van Buren	51	0.86 – 4.4	2.5
			INL Site Median:	2.5

a. ARA = Auxiliary Reactor Area, ATR = Advanced Test Reactor, CFA = Central Facilities Area, CITRC = Critical Infrastructure Test Range Complex, CMS = Community Monitoring Station, EBR-I = Experimental Breeder Reactor No. 1, EFS = Experimental Field Station, INTEC = Idaho Nuclear Technology and Engineering Center, MFC = Materials and Fuels Complex, NRF = Naval Reactors Facility, RWMC = Radioactive Waste Management Complex, SMC = Specific Manufacturing Capability, TAN = Test Area North.

b. Includes valid samples only. Does not include duplicate measurements.

c. All measurements, including those <3s, are included in this table and in computation of median annual values.



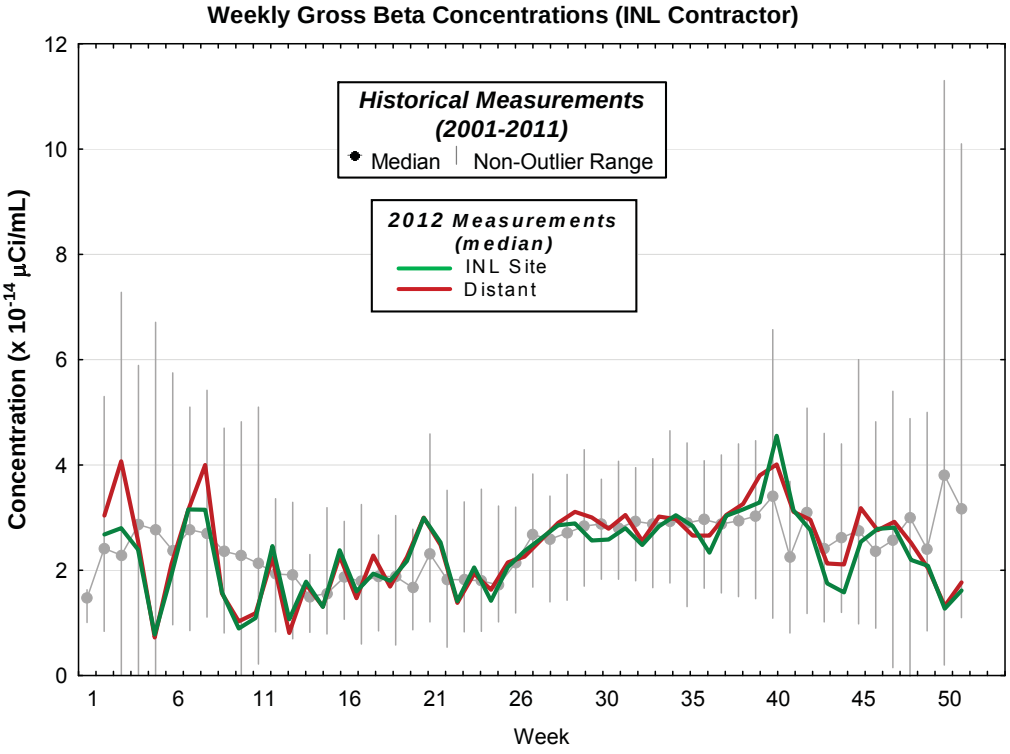


Figure 4-4. Median Weekly Gross Beta Concentrations in Air (2012).

Table 4-5. Human-made Radionuclides Detected in ESER Contractor Air Samples (2012).[a]

Radionuclide	Result (µCi/mL)	Location	Group	Quarter Detected
Sr-90	$(5.22 \pm 1.05) \times 10^{-17}$	Atomic City	Boundary	2nd
	$(6.13 \pm 1.05) \times 10^{-17}$	Craters of the moon	Distant	2nd
	$(9.89 \pm 1.54) \times 10^{-17}$	Dubois	Distant	2nd
	$(6.42 \pm 1.07) \times 10^{-17}$	Federal Aviation Administration	Boundary	2nd
	$(6.72 \pm 1.69) \times 10^{-17}$	Blackfoot	Distant	3rd
	$(7.92 \pm 1.27) \times 10^{-17}$	EFS	INL Site	3rd
	$(1.48 \pm 0.96) \times 10^{-16}$	Jackson	Distant	3rd
	$(3.48 \pm 0.98) \times 10^{-17}$	Main Gate	INL site	3rd
	$(3.27 \pm 0.91) \times 10^{-17}$	Monteview	Boundary	3rd
	$(3.99 \pm 0.92) \times 10^{-17}$	Monteview (QA replicate)	Boundary	3rd
	$(4.37 \pm 0.84) \times 10^{-17}$	EFS	INL Site	4th
	$(5.49 \pm 0.99) \times 10^{-17}$	Howe	Boundary	4th
	$(2.45 \pm 0.76) \times 10^{-17}$	Mud Lake	Boundary	4th
	$(2.91 \pm 0.63) \times 10^{-17}$	Arco (QA replicate)	Boundary	4th
	$(2.35 \pm 0.68) \times 10^{-17}$	Van Buren	INL Site	4th
Pu-238	$(3.51 \pm 1.05) \times 10^{-18}$	Mud Lake	Boundary	3rd

a. Results ± 1s. Results shown are ≥ 3s.

Natural ^{7}Be was detected in numerous ESER and INL contractor composite samples at concentrations consistent with past concentrations. Atmospheric ^{7}Be results from reactions of galactic cosmic rays and solar energetic particles with nitrogen and oxygen nuclei in earth's atmosphere. No other radionuclides were detected in the quarterly composite samples.

4.3.2 Atmospheric Moisture Monitoring Results

The INL contractor collected atmospheric moisture samples at the EFS and Van Buren Boulevard on the INL Site and at Idaho Falls and Craters of the Moon off the INL Site. During 2012, 37 samples were collected and one statistically positive detection was measured. Tritium was detected at Idaho Falls at a concentration of $1.84 \times 10^{-12} \pm 5.8 \times 10^{-13}$ µCi/mL on January 4, 2012. It is not likely to represent releases from the INL Site as the amount of tritium released during the year (reported as 896 Ci in Table 4-2) was calculated to result in a concentration at Idaho Falls less than that detected. The measured result most likely represents tritium from natural production in the atmosphere by cosmic ray bombardment, residual weapons testing fallout, and possible analytical variations, rather than tritium from INL Site operations.

During 2012, the ESER contractor collected 55 atmospheric moisture samples at Atomic City, Blackfoot, Idaho Falls, and Rexburg. Table 4-6 presents the range of values detected at each station by quarter. Tritium was detected in 27 samples, ranging from a low of 1.1×10^{-13} µCi/mL at Idaho Falls to a high of 11.8×10^{-13} µCi/mL at Rexburg. The highest concentration of tritium

Table 4-6. Ranges of Tritium Concentrations Detected in ESER Contractor Atmospheric Moisture Samples (2012).[a]

Location	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
		(× 10^{-13} µCi/mL)		
Atomic City	ND[b]	6.3 – 6.9	5.2 – 5.6	ND
Blackfoot	3.6 – 4.0	3.7 – 5.4	3.0 – 9.3	5.6[c]
Idaho Falls	ND	6.4 – 11.7	8.6	1.1
Rexburg	4.8– 5.1	7.5 – 11.8	8.5 – 11.2	7.0

a. Results shown are ≥ 3s.
b. ND = not detected.
c. When a single value is reported, tritium was detected in only one sample.

detected in an atmospheric moisture sample since 1998 was 38 × 10^{-13} µCi/mL at Atomic City. The results are within historical measurements and are probably natural in origin. The highest observed tritium concentration is far below the DCS for tritium in air (as hydrogen tritium oxygen) of 1.4 × 10^{-8} µCi/ mL (see Table A-1 of Appendix A).

4.3.3 Precipitation Monitoring Results

The ESER contractor collects precipitation samples weekly at EFS, when available, and monthly at CFA and off the INL Site in Idaho Falls. A total of 43 precipitation samples were collected during 2012 from the three sites. Tritium concentrations were detected in 16 samples, and detectable results ranged from 80 pCi/L at EFS to 357 pCi/L at Idaho Falls. Table 4-7 shows the concentration ranges by quarter for each location. The highest concentration is well below the DCS level for tritium in water of 1.9 × 10^{6} pCi/L. The concentrations are well within the historical normal range at the INL Site. The maximum concentration measured since 1998 was 553 pCi/L at EFS in 2000. The results are well within measurements made by the Environmental Protection Agency in Region 10 (Alaska, Idaho, Oregon, and Washington) for the past ten years (http://www.epa.gov/enviro/html/erams/).

4.3.4 Suspended Particulates Monitoring Results

In 2012, the ESER contractor measured concentrations of suspended particulates using filters collected from the low-volume air samplers. The filters are 99 percent efficient for collection of particles greater than 0.3 µm in diameter. That is, they collect the total particulate load greater than 0.3 µm in diameter.

Mean annual particulate concentrations ranged from 9 µg/m^3 at Blue Dome to 28 µg/m^3 at Blackfoot. In general, particulate concentrations were higher at offsite locations than at the INL Site stations. This is most likely influenced by agricultural activities off the INL Site.

Table 4-7. Ranges of Tritium Concentrations Detected in ESER Contractor Precipitation Samples (2012).[a]

Location[b]	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
		(pCi/L)		
CFA	86[c]	100 - 167	118	ND[d]
EFS	107 - 147	162 - 177	ND	80 - 249
Idaho Falls	105	166	356	ND

a. Results shown are ≥ 3s.
b. CFA = Central Facilities Area, EFS = Experimental Field Station.
c. When a single value is reported, tritium was detected in only one sample.
d. ND = not detected.

4.4 Waste Management Surveillance Monitoring

4.4.1 Gross Activity

The ICP contractor conducts environmental surveillance in and around waste management facilities to comply with DOE Order 435.1, "Radioactive Waste Management." Currently, ICP waste management operations occur at the SDA at RWMC and the ICDF at INTEC and have the potential to emit radioactive airborne particulates. The ICP contractor collected samples of airborne particulate material from the perimeters of these waste management areas in 2012 (Figure 4-5). The ICP contractor also collected samples from a control location north of Howe, Idaho (Figure 4-2), to compare with the results of the SDA and ICDF. Samples were obtained using suspended particulate monitors similar to those used by the INL and ESER contractors. The air filters are 4 in. in diameter and are changed out on the closest working day to the 1st and the 15th of each month. Gross alpha and gross beta activity were determined on all suspended particulate samples.

Table 4-8 shows the gross alpha and gross beta monitoring results. The results that were received for the SDA and ICDF are comparable to historical results, and no new trends were identified.

4.4.2 Specific Radionuclides

In 2012, no man-made, gamma-emitting radionuclides were detected at the SDA at RWMC or at the ICDF at INTEC.

Table 4-9 shows man-made specific alpha- and beta-emitting radionuclides detected in air samples analyzed using radiochemistry in 2012. These detections are consistent with levels measured in air at RWMC in previous years, and are attributed to resuspension of soils in and adjacent to RWMC. The values and locations for plutonium and americium detections remained

Figure 4-5. Locations of Low-volume Air Samplers at Waste Management Areas. (RWMC [top] and ICDF [bottom]).

Table 4-8. Gross Activity Concentrations Measured in ICP Contractor Air Samples (2012).[a]

Activity	Low (µCi/mL)	High (µCi/mL)	Annual Mean (µCi/mL)
Subsurface Disposal Area (SDA)			
Gross Alpha	$(1.07 \pm 1.95) \times 10^{-16}$ 2nd half of January at SDA 2.3	$(2.91 \pm 0.46) \times 10^{-14}$ 2nd half of August at Howe 400.4	4.36×10^{-15}
Gross Beta	$(9.35 \pm 1.20) \times 10^{-15}$ 2nd half of February at SDA 4.3	$(9.54 \pm 1.06) \times 10^{-14}$ 2nd half of September at Howe 400.4	3.08×10^{-14}
Idaho CERCLA Disposal Facility (ICDF)			
Gross Alpha	$(2.69 \pm 2.24) \times 10^{-16}$ 2nd half of February at INT 100.3	$(1.87 \pm 0.24) \times 10^{-14}$ 2nd half of August at INT 100.3	5.25×10^{-15}
Gross Beta	$(8.86 \pm 1.16) \times 10^{-15}$ 2nd half of February at INT 100.3	$(7.65 \pm 0.80) \times 10^{-14}$ 2nd half of September at INT 100.3	3.42×10^{-14}

a. Results ± 1s.

consistent from 2011 to 2012. The detections shown in Table 4-9 are likely due to resuspension of contaminated soils as a result of early burial practices (Markham et al. 1978), from previously flooded areas inside or northeast of the SDA, and fugitive emissions from the ARP. Recent studies of radionuclide concentrations in soils (VanHorn et al. 2012) confirm that $^{239/240}$Pu and ^{241}Am still are present in measurable amounts in surface soils surrounding RWMC, with maximum concentrations northeast of the SDA. Measurable amounts of ^{238}Pu and ^{90}Sr also have been reported in surface soils north of the SDA and in surface soils at several locations immediately outside the INTEC fence line, including locations near the ICDF and the Integrated Waste Treatment Unit. The ICP contractor will continue to closely monitor these radionuclides to identify trends.

Table 4-9. Human-made Radionuclides Detected in ICP Contractor Air Samples (2012).[a]

Radionuclide	Result (µCi/mL)	Location	Quarter Detected
Am-241	$(6.39 \pm 2.08) \times 10^{-18}$	SDA[b] 4.2	1st
	$(9.67 \pm 2.32) \times 10^{-18}$	SDA 4.3	1st
	$(6.42 \pm 2.11) \times 10^{-18}$	SDA 6.3	1st
	$(1.28 \pm 0.27) \times 10^{-17}$	SDA 4.2	2nd
	$(6.96 \pm 0.73) \times 10^{-17}$	SDA 4.3	2nd
	$(6.32 \pm 1.72) \times 10^{-18}$	SDA 11.3	2nd
	$(2.25 \pm 0.26 \times 10^{-17}$	SDA 1.3	3rd
	$(1.88 \pm 0.23) \times 10^{-17}$	SDA 2.3	3rd
	$(1.46 \pm 0.12) \times 10^{-16}$	SDA 4.2	3rd
	$(1.01 \pm 0.09) \times 10^{-16}$	SDA 4.3	3rd
	$(6.24 \pm 1.36) \times 10^{-18}$	SDA 6.3	3rd
	$(1.02 \pm 0.19) \times 10^{-17}$	SDA 9.3	3rd
	$(6.05 \pm 1.49) \times 10^{-18}$	SDA 2.3	4th
	$(6.83 \pm 1.16) \times 10^{-18}$	SDA 4.2	4th
	$(1.04 \pm 0.16) \times 10^{-17}$	SDA 4.3	4th
	$(5.41 \pm 1.39) \times 10^{-18}$	SDA 11.3	4th
Pu-238	$(2.17 \pm 0.68) \times 10^{-18}$	SDA 6.3	1st
	$(6.39 \pm 1.78) \times 10^{-18}$	SDA 4.3	2nd
Pu-239/240	$(3.51 \pm 1.12) \times 10^{-18}$	SDA 4.2	1st
	$(4.07 \pm 1.03) \times 10^{-18}$	SDA 4.3	1st
	$(3.14 \pm 0.35) \times 10^{-17}$	SDA 6.3	1st
	$(9.64 \pm 2.04) \times 10^{-18}$	SDA 4.2	2nd
	$(2.55 \pm 0.24) \times 10^{-16}$	SDA 4.3	2nd
	$(6.76 \pm 1.95) \times 10^{-18}$	SDA 6.3	2nd
	$(2.61 \pm 0.35) \times 10^{-17}$	SDA 1.3	3rd
	$(4.35 \pm 1.28) \times 10^{-18}$	SDA 2.3	3rd
	$(5.69 \pm 0.60) \times 10^{-17}$	SDA 4.2	3rd
	$(6.82 \pm 0.77) \times 10^{-17}$	SDA 4.3	3rd
	$(4.39 \pm 1.01) \times 10^{-18}$	SDA 6.3	3rd
	$(7.02 \pm 1.65) \times 10^{-18}$	SDA 9.3	3rd
	$(4.78 \pm 1.15) \times 10^{-18}$	SDA 11.3	3rd
	$(4.85 \pm 1.39) \times 10^{-18}$	SDA 4.2	4th
	$(1.07 \pm 0.23) \times 10^{-17}$	SDA 4.3	4th
Sr-90	$(7.25 \pm 1.92) \times 10^{-17}$	Howe[c] 400.4	3rd
	$(6.62 \pm 1.99) \times 10^{-17}$	SDA 4.3	4th
	$(4.22 \pm 1.32) \times 10^{-17}$	SDA 6.3	4th
	$(4.34 \pm 1.31) \times 10^{-17}$	INT 100.3[d]	4th

a. Results ± 1s. Results shown are ≥ 3s.
b. SDA = Subsurface Disposal Area.
c. Howe = Control.
d. Located at Idaho CERCA Disposal Facility.

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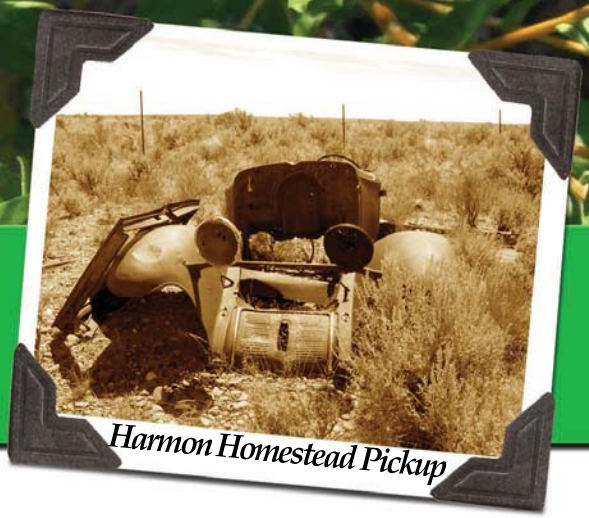
5. Compliance Monitoring for Liquid Effluents, Drinking Water, and Surface Water

2012



Harmon Homestead Pickup

Chapter 5 Highlights

Liquid effluents, drinking water, and surface water runoff were monitored in 2012 by the Idaho National Laboratory (INL) contractor and the Idaho Cleanup Project (ICP) contractor for compliance with applicable regulatory standards established to protect human health and the environment.

Wastewater discharged to land surfaces and evaporation ponds at the INL Site is regulated by the state of Idaho groundwater quality and wastewater rules and requires a wastewater reuse permit. During 2012, permitted facilities were:

- Central Facilities Area (CFA) Sewage Treatment Plant
- Idaho Nuclear Technology and Engineering Center (INTEC) New Percolation Ponds
- Advanced Test Reactor (ATR) Complex Cold Waste Pond
- Materials and Fuels Complex (MFC) Industrial Waste Ditch and Industrial Waste Pond.

These facilities were sampled for parameters required by their facility-specific permits. No permit limits were exceeded in 2012.

Additional liquid effluent and groundwater monitoring were performed in 2012 at ATR Complex, CFA, INTEC, and MFC to comply with environmental protection objectives of the Department of Energy (DOE). All parameters were below applicable health-based standards, with the exception of some groundwater samples in one perched water well upgradient of the INTEC New Percolation Ponds that had elevated aluminum, iron, and manganese results that exceeded secondary constituent standards. It appears these were due to sediment within the well and are not representative of the groundwater upgradient of the ponds.

Nine drinking water systems were monitored by the INL contractor in 2012 for parameters required by “Idaho Rules for Public Drinking Water Systems.” Water samples collected from drinking water systems were well below drinking water limits for all relevant regulatory parameters. Because workers are potentially impacted from radionuclides in the CFA distribution system, the dose from ingesting tritium to a CFA worker was calculated. The dose was estimated to be 0.21 mrem (0.0021 mSv) for 2012. This is below the Environmental Protection Agency standard of 4 mrem/yr (0.04 mSv/yr) for public drinking water.

Two drinking water systems were monitored by the ICP contractor at the Radioactive Waste Management Complex (RWMC) and INTEC. All parameters were below their respective drinking water limits in 2012. Surface water runoff from the Subsurface

Disposal Area of the RWMC was sampled by the ICP contractor in 2012 for radionuclides in compliance with DOE limits. Results were within historical measurements, with americium-241, plutonium-239/240, and strontium-90 similar to the previous years' results and well below DOE derived concentration standards.

5. COMPLIANCE MONITORING FOR LIQUID EFFLUENTS, GROUNDWATER, DRINKING WATER, AND SURFACE WATER

This chapter presents analytical results of water samples collected by the Idaho National Laboratory (INL) contractor (Battelle Energy Alliance, LLC) and Idaho Cleanup Project (ICP) contractor (CH2M-WG Idaho, LLC) at the INL Site and the Research and Education Campus (Idaho Falls facilities). Included in this chapter are descriptions and results of liquid effluent and related groundwater monitoring, drinking water monitoring, and surface water runoff monitoring conducted for compliance with regulatory limits and permits.

To improve the readability of this chapter, data tables are only included that compare monitoring results to specified discharge limits, permit limits, or maximum contaminant levels. Data tables for other monitoring results are provided in Appendix C.

5.1 Summary of Monitoring Programs

The INL contractor and ICP contractor monitor drinking water, liquid effluent, surface water runoff, and groundwater that could be impacted by INL Site operations and activities. This monitoring is conducted to comply with applicable laws and regulations, U.S. Department of Energy (DOE) orders, and other requirements (e.g., wastewater reuse permit requirements).

Table 5-1 presents compliance monitoring performed at the INL Site. A comprehensive discussion and maps of environmental monitoring performed by various organizations within and around the INL Site may be found in the *Idaho National Laboratory Site Environmental Monitoring Plan* (DOE-ID 2012).

5.2 Liquid Effluent and Related Groundwater Compliance Monitoring

The INL contractor and ICP contractor monitor constituents of concern in liquid waste influent, effluent, and groundwater in the vicinity of and downgradient of the liquid releases. Wastewater is discharged to the ground surface at the following areas:

- Percolation ponds southwest of the Idaho Nuclear Technology and Engineering Center (INTEC), Materials and Fuels Complex (MFC) Industrial Waste Pond, and the Advanced Test Reactor (ATR) Complex Cold Waste Pond
- A sprinkler irrigation system at the Central Facilities Area (CFA) used during the summer months to apply industrial and treated sanitary wastewater.

Discharge of wastewater to the land surface is regulated by wastewater rules (Idaho Administrative Procedures Act [IDAPA] 58.01.16 and .17). A wastewater reuse permit normally

Table 5-1. Water Monitoring at the INL Site for Regulatory Compliance.

Area/Facility	Media				
	Liquid Effluent (Permitted)[a]	Liquid Effluent (Surveillance)	Groundwater (Permitted)	Drinking Water	Surface Runoff
ICP Contractor					
Idaho Nuclear Technology and Engineering Center	•	•	•	•	
Radioactive Waste Management Complex				•	•
INL Contractor					
Advanced Test Reactor Complex	•	•	•	•	
Central Facilities Area[b]	•	•		•	
Materials and Fuels Complex	•	•	•	•	
Critical Infrastructure Test Range Complex				•	
Test Area North/Technical Support Facility				•	
TAN/CTF (SMC)				•	

a. In 2009, the City of Idaho Falls assumed responsibility for the semiannual liquid effluent monitoring conducted at the Research and Education Campus.
b. Includes Weapons Range, Experimental Breeder Reactor I, and Main Gate.

requires monitoring of nonradioactive parameters in the influent waste, effluent waste, and groundwater, as applicable. However, some facilities may have specified radiological parameters monitored for surveillance purposes (not required by regulations). The liquid effluent and groundwater monitoring programs implement the ground water quality standards presented in the “Idaho Ground Water Quality Rule” (IDAPA 58.01.11) for INL Site constituents. The permits specify annual discharge volumes, application rates, and effluent quality limits. Annual reports (ICP 2013a, 2013b; INL 2013a, 2013b, 2013c) were prepared and submitted to the Idaho Department of Environmental Quality (DEQ) as required for permitted facilities.

During 2012, the INL contractor and ICP contractor monitored, as required by the permits, the following facilities (Table 5-2):

- CFA Sewage Treatment Plant
- INTEC New Percolation Ponds
- ATR Complex Cold Waste Pond
- MFC Industrial Waste Ditch and Industrial Waste Pond.

The following subsections present results of wastewater and groundwater monitored to comply with facility-specific permits.

Additional effluent parameters are monitored to comply with environmental protection objectives of DOE Order 458.1. Section 5.3 discusses the results of liquid effluent surveillance monitoring.

Table 5-2. Status of Wastewater Reuse Permits.

Facility	Permit Status at End of 2012	Explanation
Advanced Test Reactor Complex Cold Waste Pond	Renewal permit application submitted	DEQ[a] issued Permit #LA-000161-01 on February 26, 2008, modified on August 20, 2008, and expires on February 25, 2013. A renewal permit application (INL 2012) was submitted to DEQ in August 2012.
Central Facilities Area Sewage Treatment Facility	Permit issued	DEQ issued Permit #LA-000141-03 on March 17, 2010. The permit will expire on March 16, 2015.
Idaho Nuclear Technology and Engineering Center New Percolation Ponds	Permit issued	DEQ issued Permit #LA-000130-05 on March 14, 2012. The permit will expire on March 14, 2017.
Materials and Fuels Complex Industrial Waste Pond and Industrial Waste Ditch	Permit issued	In 2010 DEQ issued Permit LA-000160-01, effective May 1, 2010 to April 30, 2015. The DEQ issued Permit WRU-I-0160-01 (formerly LA-000160-01), Modification 1 on June 21, 2012.

a. DEQ = Idaho Department of Environmental Quality

5.2.1 Research and Education Campus

Description – The City of Idaho Falls is authorized by the Clean Water Act, National Pollutant Discharge Elimination System to set pretreatment standards for nondomestic wastewater discharges to publicly owned treatment works. The INL contractor facilities in Idaho Falls are required to comply with the applicable regulations in Chapter 1, Section 8 of the Municipal Code of the City of Idaho Falls.

The Industrial Wastewater Acceptance Permit for the INL Research Center specifies special conditions and compliance schedules, prohibited discharges, reporting requirements, monitoring requirements, and effluent concentration limits for specific parameters.

Wastewater Monitoring Results – In 2009, the City of Idaho Falls assumed responsibility for the semiannual monitoring conducted at the Research and Education Campus. The 2012 monitoring results complied with all applicable regulations established in the municipal code. Analytical results are available upon request from the City of Idaho Falls.

5.2.2 Central Facilities Area Sewage Treatment Facility

Description – The CFA Sewage Treatment Facility serves all major buildings at CFA. The treatment facility is southeast of CFA, approximately 671 m (2,200 ft) downgradient of the nearest drinking water well.

A 1,500-L/min (400-gal/min) pump applies wastewater from a 0.2-ha (0.5-acre) lined, polishing pond to approximately 30 ha (74 acres) of sagebrush steppe grassland through a computerized center pivot irrigation system.

Wastewater Monitoring Results for the Wastewater Reuse Permit – DEQ issued a permit for the CFA Sewage Treatment Plant on March 17, 2010. The permit requires effluent monitoring and soil sampling in the wastewater land application area (soil samples are only required in 2010 and 2013). Effluent samples are collected from the pump pit (prior to the pivot irrigation system) monthly during land application. All samples are 24-hour flow proportional composites, except pH and coliform samples, which are grab samples.

No wastewater samples were collected in 2012 because evaporation was adequate to maintain the desired water level in the pond, consequently no wastewater was land applied via the center pivot irrigation system.

Groundwater Monitoring Results for the Wastewater Reuse Permit – The wastewater reuse permit does not require groundwater monitoring at the CFA Sewage Treatment Facility.

5.2.3 Advanced Test Reactor Complex Cold Waste Pond

Description – The Cold Waste Pond (CWP) is located approximately 137 m (450 ft) from the southeast corner of the ATR Complex compound and approximately 1.2 km (¾ of a mile) southwest of the Big Lost River channel (Figure 5-1). The existing CWP was excavated in 1982. It consists of two cells, each with dimensions of 55 × 131 m (180 × 430 ft) across the top of the berms, and a depth of 3 m (10 ft). Total surface area for the two cells at the top of the berms is approximately 1.44 ha (3.55 acres). Maximum capacity is approximately 10.22 MG.

Figure 5-1. Permit Monitoring Locations for the ATR Complex Cold Waste Pond.

Wastewater discharged to the CWP consists 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. DEQ issued a wastewater reuse permit for the pond in February 2008. A permit renewal application was submitted to DEQ on August 21, 2012 (INL 2012).

Wastewater Monitoring Results for the Wastewater Reuse Permit – The industrial wastewater reuse permit requires monthly sampling of the effluent to the CWP. The permit sets monthly concentration limits for total suspended solids (100 mg/L) and total nitrogen (20 mg/L), and the results (minimum, maximum, and median) of those permit-limited parameters are shown in Table 5-3. During 2012, neither total suspended solids nor total nitrogen exceeded the permit limit. The minimum, maximum, and median results of all parameters monitored are presented in Table C-1.

Concentrations of sulfate and total dissolved solids are higher during reactor operation because of evaporative concentration of the corrosion inhibitors and biocides added to the reactor cooling water.

Groundwater Monitoring Results for the Wastewater Reuse Permit – To measure potential impacts from the CWP, the permit requires groundwater monitoring in April and October at five wells (Figure 5-1; Table C-2).

Aluminum, iron, and manganese were elevated in some of the unfiltered samples because of suspended aquifer matrix material or rust in the well water. The metals concentrations in the filtered samples were below the applicable standards.

Table 5-3. Total Nitrogen and Total Suspended Solids Effluent Monitoring Results at Advanced Test Reactor Complex Cold Waste Pond (2012).[a]

Parameter	Minimum	Maximum	Median	Permit Limit
Total nitrogen[b] (mg/L)	0.927	3.377	1.071	20
Total suspended solids (mg/L)	4 U[c]	4 U	4 U	100

a. Duplicate samples were collected in January and the results for the duplicate samples are included in the summary.
b. Total nitrogen is calculated as the sum of total Kjeldahl nitrogen and nitrate + nitrite, as nitrogen.
c. U flag indicates the result was below the detection limit.

5.2.4 Idaho Nuclear Technology and Engineering Center New Percolation Ponds and Sewage Treatment Plant

Description – The INTEC New Percolation Ponds are comprised of two unlined ponds excavated into the surficial alluvium and surrounded by bermed alluvial material (Figure 5-2). Each pond is 93 m × 93 m (305 ft × 305 ft) at the top of the berm and is approximately 3 m (10 ft) deep. Each pond is designed to accommodate a continuous wastewater discharge rate of 3 MG per day.

The INTEC New Percolation Ponds receive discharge of only nonhazardous industrial and municipal wastewater. Industrial wastewater (i.e., service waste) from INTEC operations consists of steam condensates, noncontact cooling water, water treatment effluent, boiler blowdown wastewater, storm water, and small volumes of other nonhazardous liquids. Municipal wastewater (i.e., sanitary waste) is treated at the INTEC Sewage Treatment Plant prior to discharge to the New Percolation Ponds.

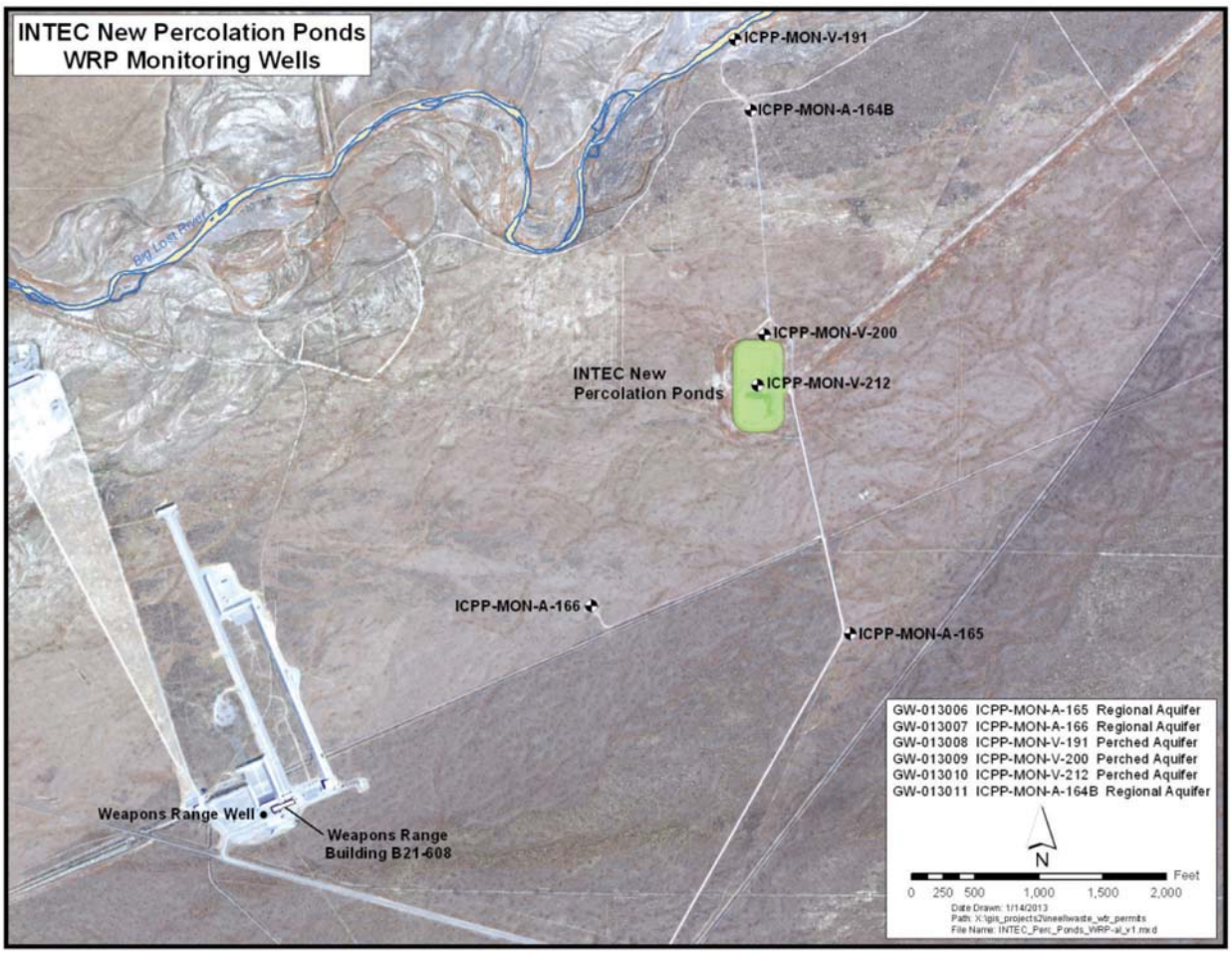


Figure 5-2. Permit Monitoring Locations for INTEC New Percolation Ponds *(Weapons Range Well is not a permitted well and is shown for location reference only)*.

The Sewage Treatment Plant is located east of INTEC, outside the INTEC security fence, and treats and disposes of sewage, septage, and other nonhazardous industrial wastewater at INTEC. The Sewage Treatment Plant depends on natural biological and physical processes (digestion, oxidation, photosynthesis, respiration, aeration, and evaporation) to treat the sanitary waste in four lagoons. After treatment in the lagoons, the effluent is combined with the service waste and discharged to the INTEC New Percolation Ponds.

The INTEC New Percolation Ponds are permitted by DEQ to operate as a wastewater reuse facility under Wastewater Reuse Permit LA-000130-05 (Neher 2012). The renewed permit became effective on March 14, 2012.

Wastewater Monitoring Results for the Wastewater Reuse Permit – Monthly samples were collected from:

- CPP-769 – influent to Sewage Treatment Plant
- CPP-773 – effluent from Sewage Treatment Plant prior to combining with service waste
- CPP-797 – combined effluent prior to discharge to the INTEC New Percolation Ponds.

As required by the permit, all samples are collected as 24-hour flow proportional composites, except pH and total coliform, which are collected as grab samples. The permit specifies the parameters that must be monitored for each location, but the permit does not set discharge limits for any of the parameters monitored at CPP-769, CPP-773, or CPP-797. The monitoring results (minimum, maximum, and average) for CPP-769, CPP-773, and CPP-797 are presented in Tables C-3, C-4, and C-5, respectively.

The permit specifies maximum daily and yearly hydraulic loading rates for the INTEC New Percolation Ponds. Table 5-4 shows the maximum daily flow and the yearly total flow to the INTEC New Percolation Ponds. As the table shows, the maximum daily flow and the yearly total flow to the INTEC New Percolation Ponds were below the permit limits during 2012.

Groundwater Monitoring Results for the Wastewater Reuse Permit – To measure potential impacts to groundwater from the INTEC New Percolation Ponds, the permit requires that groundwater samples be collected from six monitoring wells as shown in Figure 5-2 and listed in Table 5-5.

The permit requires that groundwater samples be collected semiannually during April/May and September/October and lists which parameters must be analyzed. Contaminant concentrations in the compliance wells are limited by primary constituent standards and

Table 5-4. Hydraulic Loading Rates for INTEC New Percolation Ponds (2012).

	2012 Flow	Permit Limit
Maximum daily (MG)	0.767	3
Yearly total (MG)	167.511	1,095

Table 5-5. INTEC New Percolation Ponds Wastewater Reuse Permit Monitoring Wells.

Wells	Purpose	Location (see Figure 5-2)
Aquifer Wells		
ICPP-MON-A-164B (GW-013011)	Background, noncompliance point; the renewed permit replaced Well ICPP-MON-A-167 with Well ICPP-MON-A-164B as the upgradient aquifer well.	Upgradient of the New Percolation Ponds
ICPP-MON-A-165 (GW-013006)	Permit compliance point	Downgradient of the New Percolation Ponds
ICPP-MON-A-166 (GW-013007)	Permit compliance point	Downgradient of the New Percolation Ponds
Perched Water Wells		
ICPP-MON-V-191 (GW-013008)	Background, noncompliance point	North of the New Percolation Ponds and just south of the Big Lost River
ICPP-MON-V-200 (GW-013009)	Permit compliance point	Adjacent to (north of) the New Percolation Ponds
ICPP-MON-V-212 (GW-013010)	Permit compliance point	Adjacent to (between) the New Percolation Ponds

secondary constituent standards specified in IDAPA 58.01.11, “Ground Water Quality Rule.” All permit-required samples are collected as unfiltered samples, except aluminum, iron, manganese, and silver. The results of dissolved concentrations (i.e., filtered samples) of these four parameters are used for secondary constituent standard compliance determinations.

Table C-6 shows the 2012 water table elevations and depth to water table, determined prior to purging and sampling, and the analytical results for all parameters specified by the permit for the aquifer wells. Table C-7 presents similar information for the perched water wells. As Table C-6 shows, all of the permit-required parameters associated with the aquifer wells were below their respective primary constituent standards and secondary constituent standards during the 2012 reporting year. As Table C-7 shows, all but three of the parameters associated with the perched water wells were below their respective primary constituent standards or secondary constituent standards during the 2012 reporting year.

The dissolved concentrations of aluminum, iron, and manganese in perched water Well ICPP-MON-V-191 were the only groundwater parameters to exceed the secondary constituent standards. The elevated concentrations in the samples collected from this well are most likely the result of metals from the collected sediment within the well and are not representative of the groundwater upgradient of the New Percolation Ponds. Because Well ICPP-MON-V-191 is an upgradient, noncompliance point, and is outside the zone of influence of the New Percolation Ponds, these exceedances were not considered permit noncompliances.

5.2.5 Materials and Fuels Complex Industrial Waste Ditch and Industrial Waste Pond

Description – The wastewater reuse permit issued by DEQ for the MFC Industrial Waste Ditch and Pond became effective May 1, 2010. The MFC Industrial Waste Pond was first excavated in 1959 and has a design capacity of 285 MG at a maximum water depth of 13 ft (Figure 5-3).

Industrial wastewater discharged to the pond via the Industrial Waste Pipeline consists primarily of noncontact cooling water, boiler blowdown, cooling tower overflow, air wash flows, and steam condensate.

Wastewater composed of mixed cooling tower blowdown, intermittent reverse osmosis effluent, and discharge to a laboratory flows from the MFC-768 Power Plant to Ditch C via the Industrial Wastewater Underground Pipe.

Wastewater Monitoring Results for the Wastewater Reuse Permit – The industrial wastewater reuse permit requires monthly sampling of the effluent to the pond discharged to the Industrial Waste Pipeline. The permit requires quarterly samples of the discharge to Ditch C from the Industrial Wastewater Underground Pipe. The permit sets monthly concentration limits for total suspended solids (100 mg/L) and total nitrogen (20 mg/L), and the results of those permit-limited parameters are summarized in Table 5-6. During 2012, neither total suspended solids nor total nitrogen exceeded the permit limit. The minimum, maximum, and median results of all parameters monitored for the permit are presented in Tables C-8 and C-9.

Groundwater Monitoring Results for the Wastewater Reuse Permit – To measure potential impacts from the Industrial Waste Pond, the permit requires groundwater monitoring in April/May and September/October at one upgradient and two downgradient wells (Figure 5-3).

The analytical results are summarized in Table C-10. Analyte concentrations in the downgradient wells were essentially indistinguishable from background levels in the upgradient well.

Table 5-6. Total Nitrogen and Total Suspended Solids Effluent Monitoring Results at MFC Industrial Waste Pipeline (2012).[a]

Parameter	Minimum	Maximum	Median	Permit Limit
Total nitrogen[b] (mg/L)	<2.12	7.12	2.325	20
Total suspended solids (mg/L)	4 U[c]	4 U	4 U	100

a. Duplicate samples were collected in June and the results for the duplicate samples are included in the data summary.
b. Total nitrogen is calculated as the sum of total Kjeldahl nitrogen and nitrate + nitrite, as nitrogen.
c. U flag indicates the result was below the detection limit.

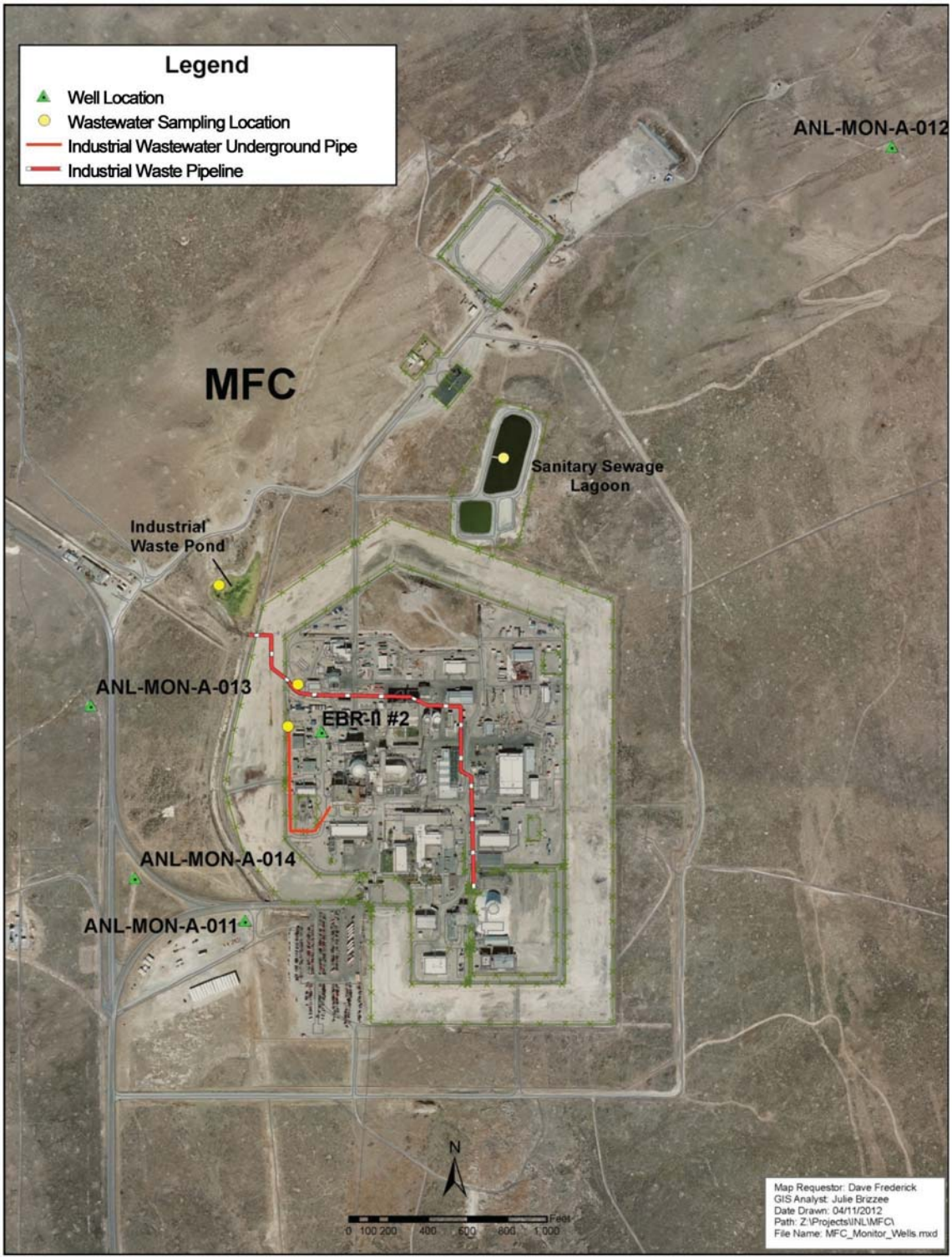


Figure 5-3. Wastewater and Groundwater Sampling Locations at the MFC.

5.3 Liquid Effluent Surveillance Monitoring

The following sections discuss results of additional liquid effluent monitoring performed at each facility. As stated in Section 5.2, additional constituents of concern specified in the Idaho groundwater quality standards also are monitored. This additional monitoring is performed to comply with environmental protection objectives of DOE Order 458.1.

5.3.1 Advanced Test Reactor Complex

The effluent to the CWP receives a combination of process water from various ATR Complex facilities. Table C-11 lists wastewater surveillance monitoring results for those parameters with at least one detected result. Radionuclides detected in groundwater samples are summarized in Table C-12. The tritium concentrations are below the Idaho groundwater primary constituent standard for tritium (20,000 pCi/L), which is the same as the Environmental Protection Agency health-based maximum contaminant level (MCL) for tritium in drinking water.

5.3.2 Central Facilities Area

The effluent from the CFA Sewage Treatment Facility is monitored according to the wastewater reuse permit. No wastewater was land-applied in 2012, so no samples were collected at the treatment facility.

5.3.3 Idaho Nuclear Technology and Engineering Center

Table C-13 summarizes the additional monitoring conducted during 2012 at the INTEC Sewage Treatment Plant and INTEC New Percolation Ponds and shows the analytical results for parameters that were detected in at least one sample during the year. All additional parameters were within their expected historical concentration levels.

Groundwater samples for radiological parameters were collected from four wells (aquifer Wells ICPP-MON-A-165 and ICPP-MON-A-166, and perched water Wells ICPP-MON-V-200 and ICPP-MON-V-212) near the INTEC New Percolation Ponds in April and September 2012. These samples were collected to satisfy the surveillance objectives of DOE Order 458.1. As shown in Table C-13, the gross alpha activity was below the 15-pCi/L action level, and the gross beta activity was below the 40-pCi/L action level in all four monitoring wells.

5.3.4 Materials and Fuels Complex

The Secondary Sanitary Lagoon and Industrial Waste Pond are sampled quarterly for gross alpha, gross beta, gamma spectroscopy, and tritium (Figure 5-3). Annual samples are collected for selected isotopes of americium, curium, iron, strontium, plutonium, and uranium. In addition, the Secondary Sanitary Lagoon is sampled annually for selected metals, nutrients, and other parameters. Tables C-14 and C-15 summarize the results for analytes detected in at least one sample. Results are consistent with past measurements.

5.4 Drinking Water Monitoring

The INL and ICP contractors monitor drinking water to ensure it is safe for consumption and to demonstrate that it meets federal and state regulations. Drinking water parameters are regulated by the state of Idaho under authority of the Safe Drinking Water Act. Parameters with

primary MCLs must be monitored at least once every three years. Parameters with secondary MCLs are monitored every three years based on a recommendation by the Environmental Protection Agency. Many parameters require more frequent sampling during an initial period to establish a baseline, and subsequent monitoring frequency is determined from the baseline results.

Currently, the INL Site has 12 drinking water systems. The INL contractor and ICP contractor monitor these systems to ensure a safe working environment. The INL contractor monitors nine of these drinking water systems, ICP contractor monitors two, and NRF has one. According to the "Idaho Rules for Public Drinking Water Systems" (IDAPA 58.01.08), INL Site drinking water systems are classified as either nontransient or transient, noncommunity water systems. The five INL contractor transient, noncommunity water systems are at the Experimental Breeder Reactor I (EBR-I), Gun Range (Live Fire Test Range), Critical Infrastructure Test Range Complex (CITRC), Test Area North/Technical Support Facility (TAN/TSF), and the Main Gate. The four remaining INL contractor water systems are classified as nontransient, noncommunity water systems. These systems are located at CFA, MFC, ATR Complex, and TAN/Contained Test Facility. The two ICP contractor nontransient, noncommunity water systems are INTEC and the Radioactive Waste Management Complex (RWMC).

As required by the state of Idaho, the INL contractor and the ICP contractor Drinking Water Programs use Environmental Protection Agency-approved (or equivalent) analytical methods to analyze drinking water in compliance with current editions of IDAPA 58.01.08 and 40 Code of Federal Regulations Parts 141 – 143. State regulations also require that analytical laboratories be certified by the state or by another state whose certification is recognized by Idaho. DEQ oversees the certification program and maintains a list of approved laboratories.

Because of historic or problematic contaminants in the drinking water systems, the INL contractor and the ICP contractor monitor certain parameters more frequently than required by regulation. For example, bacterial analyses are conducted monthly rather than quarterly at all nine INL contractor drinking water systems and at one ICP contractor drinking water system during months of operation. Because of known groundwater plumes near two INL contractor drinking water wells and one ICP contractor drinking water well, additional sampling is conducted for tritium at CFA, for trichloroethylene at TAN/TSF, and for carbon tetrachloride at RWMC.

5.4.1 INL Site Drinking Water Monitoring Results

During 2012, the INL contractor collected 244 routine samples and 17 quality control samples from nine INL Site drinking water systems. In addition to routine samples, the INL contractor also collected from nine nonroutine samples after a water main was repaired, a building put into service, or maintenance repairs. Drinking water systems at EBR-I, CITRC, Gun Range, MFC, ATR Complex, and TAN/CTF were well below drinking water limits for all regulatory parameters; therefore, they are not discussed further in this report. In addition, all water systems were sampled for nitrates. All water systems results were less than half of the MCL of 5 mg/L. The highest results 2.56 mg/L at CFA and 2.20 mg/L at MFC. No compliance samples were positive (present) for bacteria in 2012.

5.4.2 Central Facilities Area

The CFA water system serves approximately 600 people daily. Since the early 1950s, wastewater containing tritium was disposed of to the eastern Snake River Plain aquifer through injection wells and infiltration ponds at INTEC and the ATR Complex. This wastewater migrated south-southwest and is the suspected source of tritium contamination in the CFA water supply wells. Disposing of wastewater through injection wells was discontinued in the mid-1980s. In general, tritium concentrations in groundwater have been decreasing (Figure 5-4) because of changes in disposal techniques, diffusion, dispersion, recharge conditions, and radioactive decay.

Prior to 2007, compliance samples for the CFA water distribution system were collected semiannually from Well CFA #1 at CFA-651 and Well CFA #2 at CFA-642, and quarterly from the distribution manifold at CFA-1603. Because the results were consistently below the MCL for tritium, the INL contractor decreased the tritium sampling frequency to semiannually at the CFA-1603 manifold and annually at the wells. Since October 2011, only CFA #1 Well has been used.

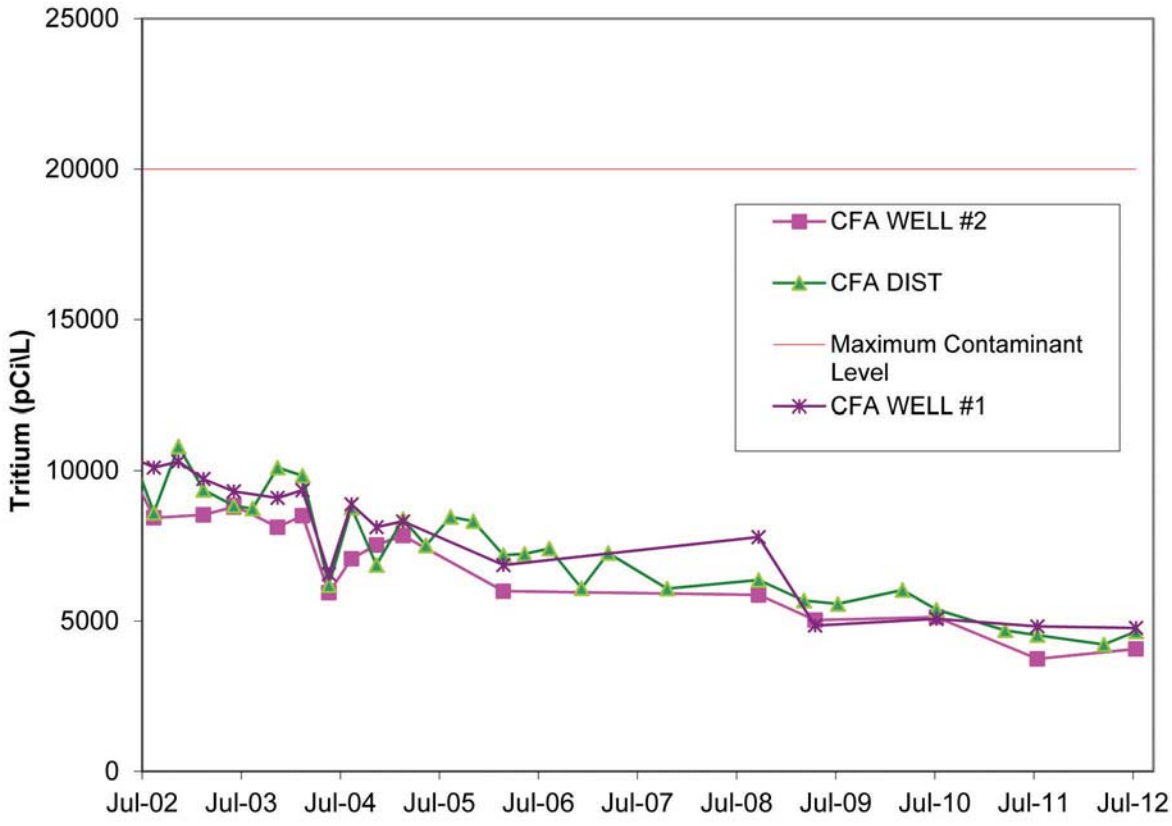


Figure 5-4. Tritium Concentrations in CFA Well and Distribution System (2002 – 2012). Note: Since October 2011 only CFA #1 Well has been used.

CFA Worker Dose – Because of the potential impacts to workers at CFA from an upgradient plume of radionuclides in the eastern Snake River Plain aquifer, the potential effective dose equivalent from radioactivity in water was calculated. For the 2012 dose calculation, it was assumed that each worker's total daily water intake would come from the CFA drinking water distribution system. This assumption overestimates the actual dose because workers typically consume only about half their total intake during working hours and typically work only 240 days rather than 365 days per year. The estimated annual effective dose equivalent to a worker from consuming all their drinking water at CFA during 2012 was 0.21 mrem (2.1 µSv), below the Environmental Protection Agency standard of 4 mrem/yr for public drinking water systems.

5.4.3 Idaho Nuclear Technology and Engineering Center

Drinking water for INTEC is supplied by two wells, CPP-04 and ICPP-POT-A-012, located north of the facility. A disinfectant residual (chlorine) is maintained throughout the distribution system. Samples were collected from the point of entry to the distribution system (CPP-614) and from various buildings throughout the distribution system. During 2012, the following drinking water samples were collected at INTEC:

- 29 routine (compliance) samples
- 2 quality control samples (one field duplicate and one performance evaluation sample)
- 82 nonroutine samples (82 bacterial construction/special samples).

All parameters monitored at INTEC were below their respective drinking water limits in 2012.

5.4.4 Radioactive Waste Management Complex

The RWMC production well is located in Building WMF-603 and is the source of drinking water for RWMC and the Advanced Mixed Waste Treatment Project. A disinfectant residual (chlorine) is maintained throughout the distribution system. Samples were collected from the source (WMF-603), from the point of entry to the distribution system (WMF-604), and from various buildings throughout the distribution system.

During 2012, the following drinking water samples were collected at RWMC:

- 13 routine (compliance) samples
- 19 quality control samples (three field blanks, eight field duplicates, four trip blanks, and four performance evaluation samples)
- 41 nonroutine samples (35 bacterial construction/special samples, and six samples for 524.2 volatile organics).

Historically, carbon tetrachloride had been detected in samples collected at the WMF-603 Production Well and the WMF-604 point of entry to the distribution system (Figure 5-5). In July 2007, a packed tower air stripping treatment system was placed into operation to treat the water. During 2012, carbon tetrachloride was not detected (<0.5 µg/L) in any of the samples collected at the WMF-604 point of entry to the distribution system.

In 2011, a total xylenes result exceeded the detection level of 0.5 µg/L in a sample collected from the WMF-604 point of entry to the distribution system. Although the result was below the MCL of 10,000 µg/L, DEQ placed the RWMC drinking water system on a quarterly monitoring

schedule. During 2012, total xylenes were detected in the WMF-604 first quarter sample (0.5 µg/L) and fourth quarter sample (0.8 µg/L), and were not detected in second or third quarter samples (Table 5-7). Total xylenes were not detected in any of the quarterly samples collected from the WMF-603 Production Well in 2012.

All other RWMC-monitored parameters were below their respective drinking water limits in 2012.

5.4.5 Test Area North/Technical Support Facility

Well TSF #2 supplies drinking water to less than 25 employees at TSF. The facility is served by a chlorination system. TSF #2 is sampled for surveillance purposes only (not required by regulations), and the distribution system is the point of compliance (required by regulations).

In the past, trichloroethylene contamination has been a concern at TSF. The principal source of this contamination was an inactive injection well (TSF-05). Although regulations do not require sampling Well TSF #2, samples are collected to monitor trichloroethylene concentrations due to the historical contamination. Since mid-2006, concentrations appear to be declining, but this will have to be confirmed with the collection of additional data.

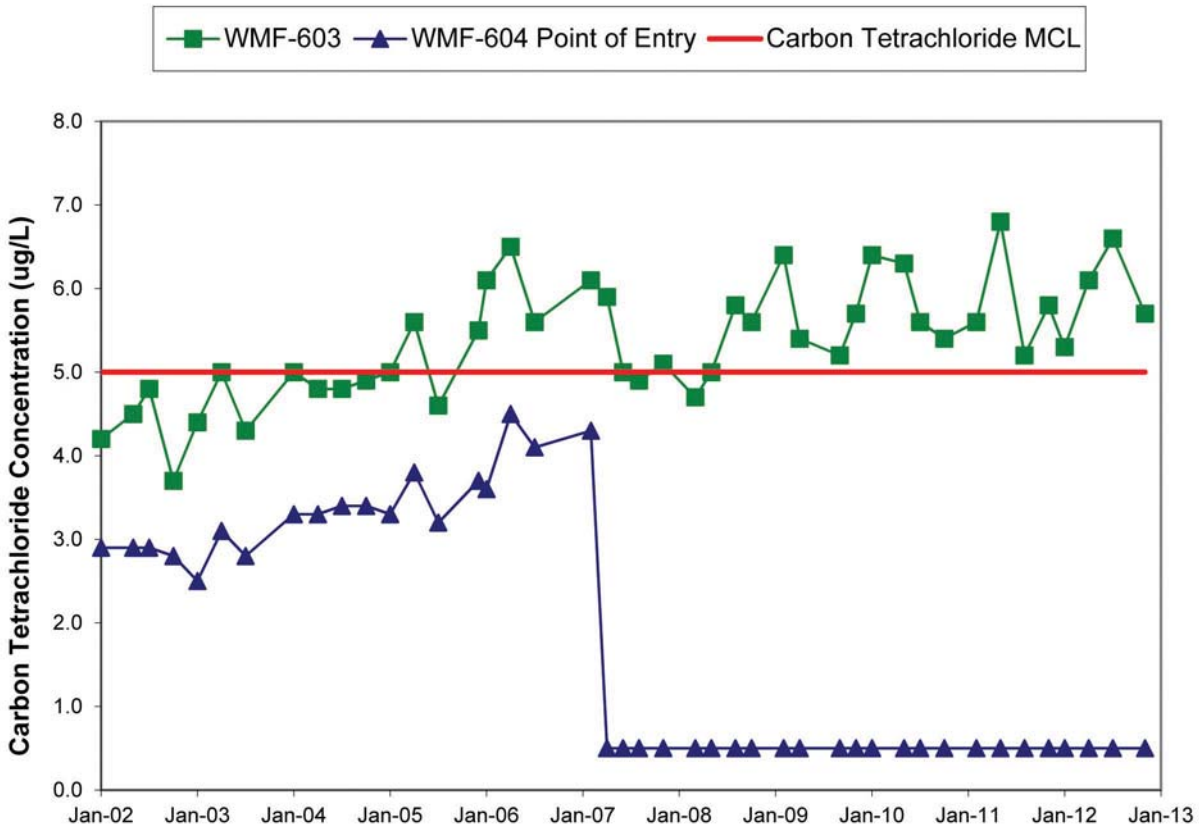


Figure 5-5. Carbon Tetrachloride Concentrations in RWMC WMF-603 Production Well and WMF-604 Point of Entry into the Distribution System (2002 – 2012).

Table 5-7. Results for Total Xylenes at WMF-603 and WMF-604 (2012).

Location	Total Xylenes Results (µg/L)				
	1/25/12	4/26/12	7/18/12	11/12/12	MCL[a]
WMF-603 Production Well	<0.5	<0.5	<0.5	<0.5	NA[b]
WMF-604 Point of Entry	0.5	<0.5	<0.5	0.8	10,000

a. MCL = Maximum contaminant level (see Table A-3).
b. NA = Not applicable. Maximum contaminant level applies to the point of entry to the distribution system.

Figure 5-6 illustrates the trichloroethylene concentrations in both Well TSF #2 and the distribution system. Table 5-8 summarizes the trichloroethylene concentrations at TSF #2 and the distribution system. The mean concentration at the distribution system for 2012 was less than the reporting limit of 0.5 µg/L.

5.5 Waste Management Surveillance Surface Water Sampling

In compliance with DOE Order 435.1, the ICP contractor collects surface water runoff samples at the RWMC Subsurface Disposal Area (SDA) from the location shown in Figure 5-7. Near the end of 2009, a lift station was installed, and the sampling point is now at the lift station. Surface water is collected to determine if radionuclide concentrations exceed administrative control levels or if concentrations have increased significantly compared to historical data. A field blank is also collected for comparison. Because of changes in the area and the change to the lift station as the sampling point, samples were collected monthly the first quarter during 2011 and then quarterly during the remainder of 2011 to more closely monitor these changes. Samples were collected quarterly during all of 2012.

Radionuclides could be transported outside the RWMC boundaries via surface water runoff. Surface water runs off the SDA only during periods of rapid snowmelt or heavy precipitation. At these times, water may be pumped out of the SDA retention basin into a drainage canal, which directs the flow outside RWMC. The canal also carries runoff from outside RWMC that has been diverted around the SDA.

Table 5-9 summarizes the specific alpha and beta results of human-made radionuclides. No human-made gamma-emitting radionuclides were detected. The americium-241, plutonium-238, plutonium-239/240, and strontium-90 concentrations are approximately the same as those detected in previous years and are well below the DOE derived concentration standards and MCLs. The ICP contractor will sample quarterly during 2013, when water is available, and evaluate the results to identify any potential abnormal trends or results that would indicate the need to conduct further investigation.

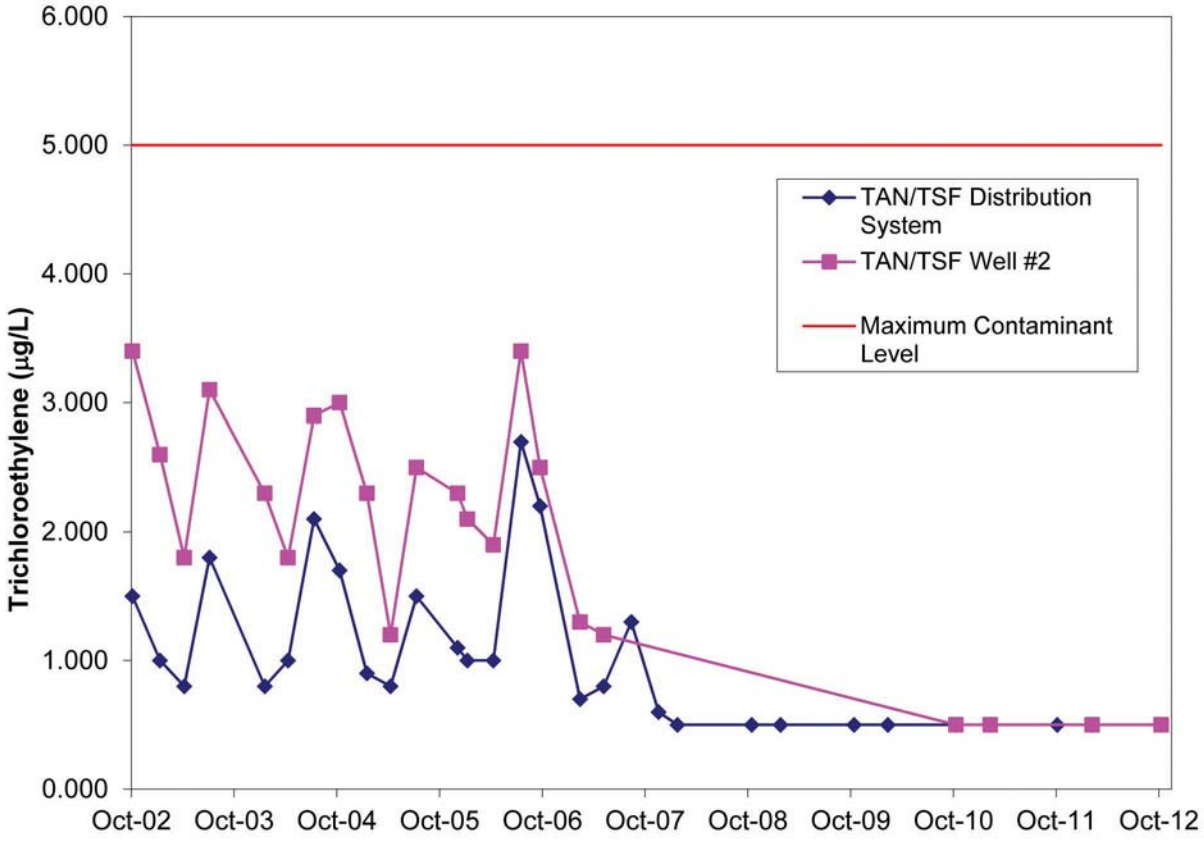


Figure 5-6. Trichloroethylene Concentrations in Technical Support Facility Drinking Water Well and Distribution System (2002 – 2012).

Table 5-8. Trichloroethylene Concentrations at Test Area North/Technical Support Facility Well #2 and Distribution System (2012).

Location	Number of samples	Trichloroethylene Concentration (µg/L)			
		Minimum	Maximum	Mean	MCL[a]
TAN/TSF #2 (612)	2	<0.5	<0.5	<0.5	NA[b]
TAN/TSF Distribution (610)	2	<0.5	<0.5	<0.5	5.0

a. MCL = Maximum contaminant level (see Table A-3).

b. NA = Not applicable. Maximum contaminant level applies to the distribution system only.

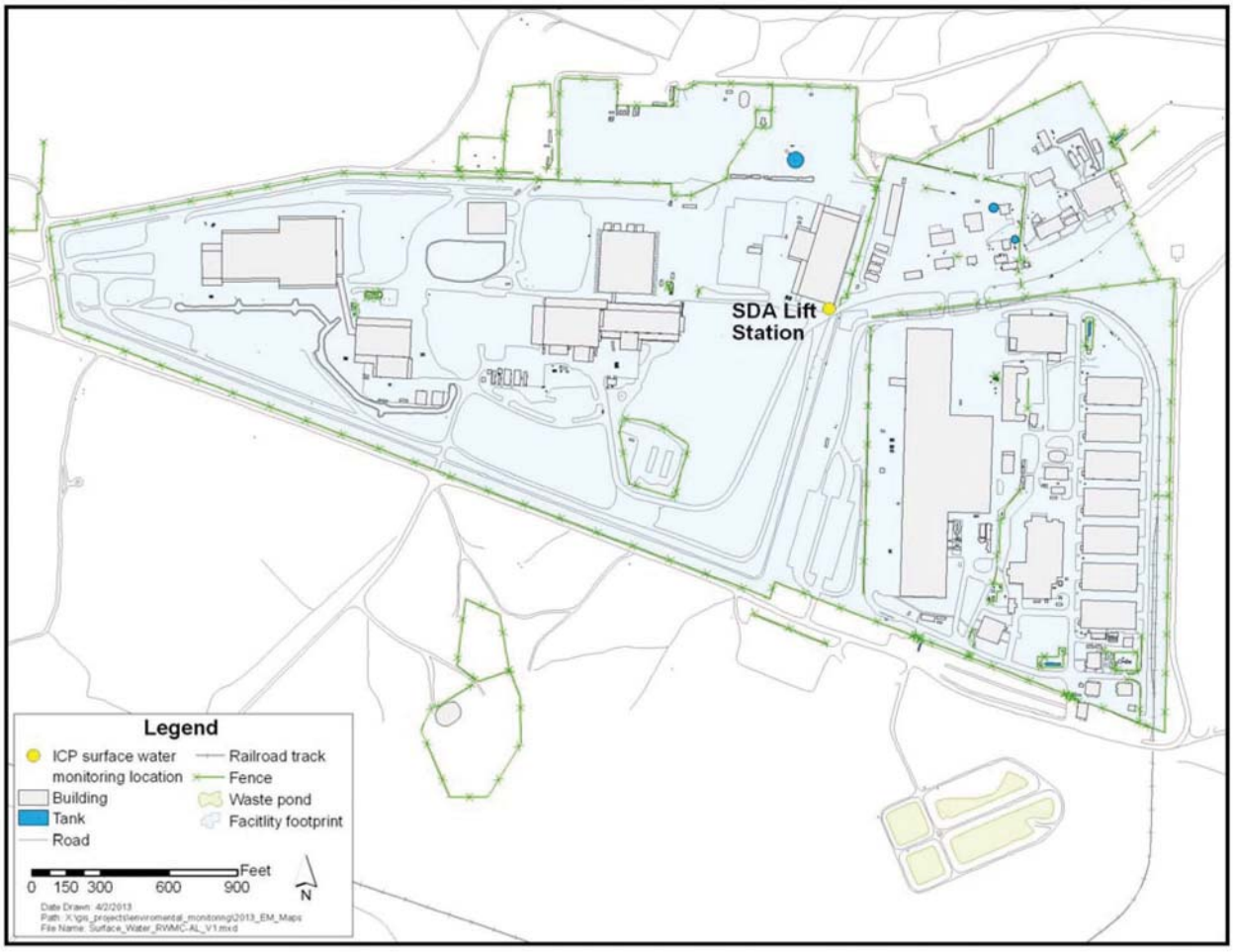


Figure 5-7. Surface Water Sampling Location at RWMC Subsurface Disposal Area.

Table 5-9. Radionuclides Detected in Surface Water Runoff at the RWMC Subsurface Disposal Area (2012).

Parameter	Maximum Concentration[a] (pCi/L)	% Derived Concentration Standard[b]
Americium-241	1.11 ± 0.09	0.65
Plutonium-238	$(1.59 \pm 0.53) \times 10^{-2}$	0.01
Plutonium-239/240	$(4.78 \pm 0.44) \times 10^{-1}$	0.34
Strontium-90	$(4.17 \pm 0.83) \times 10^{-1}$	0.04

a. Result ± 1s. Results shown are ≥ 3s.
b. See Table A-2.

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IDAPA 58.01.17, 2012, "Recycled Water Rule," Idaho Administrative Procedures Act, Idaho Department of Environmental Quality.

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INL, 2013c, *2012 Annual Industrial Wastewater Reuse Report for the Idaho National Laboratory Site's Materials and Fuels Complex Industrial Waste Ditch and Industrial Waste Pond*, INL/EXT-12-27900, Idaho National Laboratory.

Neher, Erick, Idaho Department of Environmental Quality, letter to David P. Hutchison, CH2M-WG Idaho, LLC, March 14, 2012, "INL INTEC Industrial Wastewater Reuse Permit No. LA-000130-05 Issuance," CCN 313286.

2012

6. Environmental Monitoring Programs - Eastern Snake River Plain Aquifer

Chapter 6 Highlights

One potential pathway for exposure from contaminants released at the Idaho National Laboratory (INL) Site is through the groundwater pathway. Historic waste disposal practices have produced localized areas of chemical and radiochemical contamination beneath the INL Site in the eastern Snake River Plain aquifer. These areas are regularly monitored by the U.S. Geological Survey (USGS) and reports are published showing the extent of contamination plumes. Results for some monitoring wells within the plumes show decreasing concentrations of tritium and strontium-90 over the past 20 years. The decrease is probably the result of radioactive decay, discontinued disposal, dispersion, and dilution within the aquifer.

USGS sampled 27 groundwater monitoring wells and one perched well for 61 purgeable (volatile) organic compounds in groundwater at the INL Site. Several purgeable organic compounds continue to be found by the USGS in monitoring wells, including drinking water wells, at the INL Site. The concentration of tetrachloromethane (carbon tetrachloride) was above the U.S. Environmental Protection Agency maximum contaminant level (MCL) during all 12 months of 2012 in the production well at the Radioactive Waste Management Complex (RWMC). Concentrations have increased with time in that well. Tetrachloromethane also exceeded the MCL in one annual sample and trichloroethane exceeded the MCL in one annual sample collected at each of two other regional groundwater monitoring wells. Concentrations of three other detected purgeable organic compounds were below MCLs and state of Idaho groundwater primary constituent standards for these constituents. Concentrations of chloride, nitrate, sodium, and sulfate are historically above background concentrations in many wells, but are below the applicable standards. The chromium result in one well that had exceeded the MCL in the past was below the MCL in 2012.

Groundwater surveillance monitoring required in area-specific Records of Decision under the Comprehensive Environmental Response, Compensation, and Liability Act was performed in 2012.

At Test Area North, in situ bioremediation (ISB) has been used to reduce the concentration of volatile organic compounds in the aquifer. The strategy is to promote the growth of naturally occurring bacteria that are able to break down organic compounds. In 2012 sodium lactate solution and whey powder were injected to produce anaerobic conditions for efficient biologically mediated breakdown of trichloroethane (TCE). The last injection was made in April 2012 and the ISB rebound test began in July 2012. The anaerobic conditions remain in place and TCE concentrations are below MCLs in all the former ISB injection wells.

Data collected from seven groundwater wells in the vicinity of the Advanced Test Reactor Complex show declining concentrations of chromium, strontium-90, and tritium. Chromium and tritium levels have declined faster than modeling predicted.

Groundwater collected from 14 monitoring wells at the Idaho Nuclear Technology and Engineering Center indicated strontium-90 concentrations exceeded the MCL at nine well locations sampled. Technitium-99 and nitrate also exceeded the MCL in at least one well each, but continue to show lower concentrations than those observed in previous years. Other constituents measured were all below MCL.

Monitoring of groundwater for the Central Facilities Area (CFA) landfills consists of sampling seven wells for metals, volatile organic compounds, and anions and two wells for volatile organic compounds. Iron and aluminum were detected above the secondary MCL in two landfill wells. Seven volatile organic compounds were detected in groundwater downgradient of the CFA landfills, but all were below established MCL. The source of these compounds is unknown as soil gas samples do not indicate a source in the landfills. Four wells were also sampled downgradient of the CFA for nitrate to monitor a nitrate plume. The nitrate concentration in one well downgradient of the CFA continued to exceed its maximum contaminant level in 2012, but the concentration was within levels observed historically.

At the RWMC, 2,915 analyses were performed in 2012 for radionuclides, inorganic constituents, volatile organic compounds, and 1,4-dioxane. Carbon tetrachloride and trichloroethylene were detected above the reporting level of 1 µg/L at six and four monitoring locations, respectively. Carbon tetrachloride was above the MCL in one sample. All other results were below the MCLs. Concentrations show little change relative to 2011 detections and are consistent with historical trends. Chlorine-36 was detected in one sample upgradient of the RWMC and is thought to be an anomalous result. Uranium-238 was detected in one sample above the background reporting threshold.

Drinking water and springs were sampled by the Environmental Surveillance, Education, and Research contractor in the vicinity of the INL Site and analyzed for gross alpha and gross beta activity, and tritium. Results were consistent with historical measurements and do not indicate any impact from historical INL Site releases. The Big Lost River was also sampled once in 2012 and results do show any contamination originating from INL Site operations.

6. ENVIRONMENTAL MONITORING PROGRAM – EASTERN SNAKE RIVER PLAIN AQUIFER AND OFFSITE SURFACE WATER

This chapter discusses the hydrogeology of the Idaho National Laboratory (INL) Site and presents results from eastern Snake River Plain aquifer studies conducted by the INL contractor, Idaho Cleanup Project (ICP) contractor, and the U.S. Geological Survey (USGS). Results are compared for informational purposes to the following:

- State of Idaho groundwater primary and secondary constituent standards (Idaho Administrative Procedures Act [IDAPA] 58.01.11)
- U.S. Environmental Protection Agency (EPA) health-based maximum contaminant levels (MCLs) for drinking water (40 CFR 141)
- U.S. Department of Energy (DOE) Derived Concentration Standards for ingestion of water (DOE Order 458.1).

Results also are reviewed to determine compliance with all the applicable regulatory guidelines, and if exceedances are reported, regulatory agencies are notified so appropriate actions can be addressed.

Finally, this chapter presents the Environmental Surveillance, Education, and Research (ESER) contractor's surface water and offsite drinking water monitoring results.

6.1 Summary of Monitoring Programs

The USGS INL Project Office performs groundwater monitoring, analyses, and studies of the eastern Snake River Plain aquifer under and adjacent to the INL Site. USGS utilizes an extensive network of strategically placed monitoring wells on the INL Site (Figures 6-1 and 6-2) and at locations throughout the eastern Snake River Plain. Chapter 3, Section 3.1, summarizes the USGS routine groundwater surveillance program. In 2012, USGS personnel collected and analyzed about 1,300 samples for radionuclides and inorganic constituents, including trace elements and approximately 40 samples for purgeable organic compounds. USGS has the National Water Quality Laboratory and the Radiological and Environmental Sciences Laboratory analyze samples.

As detailed in Chapter 3, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) activities at the INL Site are divided into 10 Waste Area Groups (WAGs) (Figure 6-3). Each WAG addresses specific groundwater contaminants. WAG 10 has been designated as the INL Site-wide WAG and addresses the combined impact of the individual contaminant plumes. As individual records of decision are approved for each WAG, many of the groundwater monitoring activities are turned over to the Long-Term Stewardship Program to consolidate monitoring activities.

The ESER contractor collects drinking water samples off the INL Site, as well as samples from natural surface waters. This includes the Big Lost River, which occasionally flows through the INL Site, and springs downgradient of the INL Site.

Table 6-1 presents the various groundwater, drinking water, and surface water monitoring activities performed on and around the INL Site. Details may be found in the *Idaho National Laboratory Site Environmental Monitoring Plan* (DOE-ID 2012a) and the *Idaho National Laboratory Groundwater Monitoring Contingency Plan Update* (DOE-ID 2012b).

6.2 Hydrogeology of the Idaho National Laboratory Site

The INL Site occupies approximately 2,300 km^2 (890 mi^2) at the northwestern edge of the eastern Snake River Plain, with the INL Site boundaries coinciding with the Mud Lake sub-

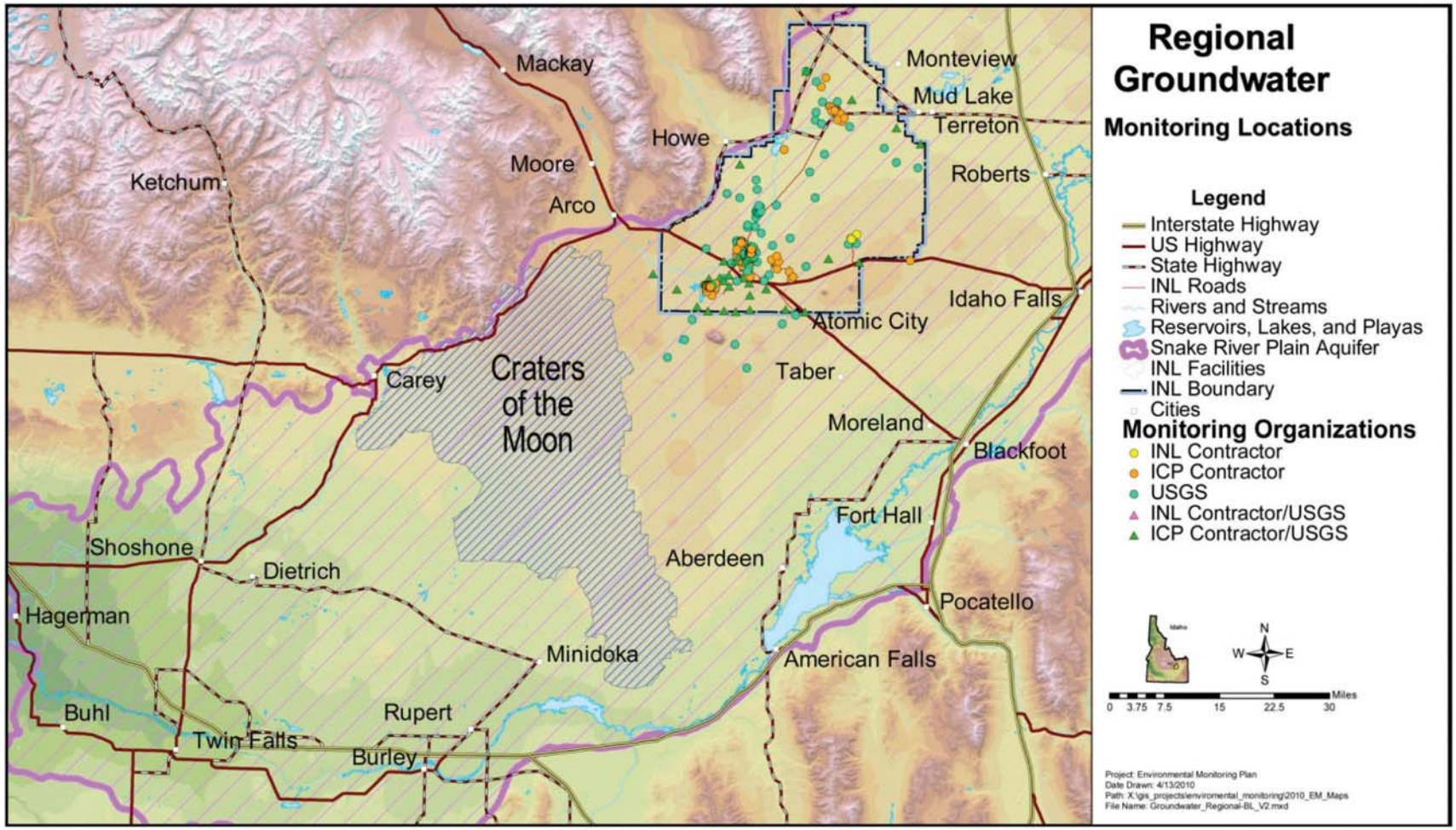

Figure 6-1. Regional Groundwater Monitoring Locations.

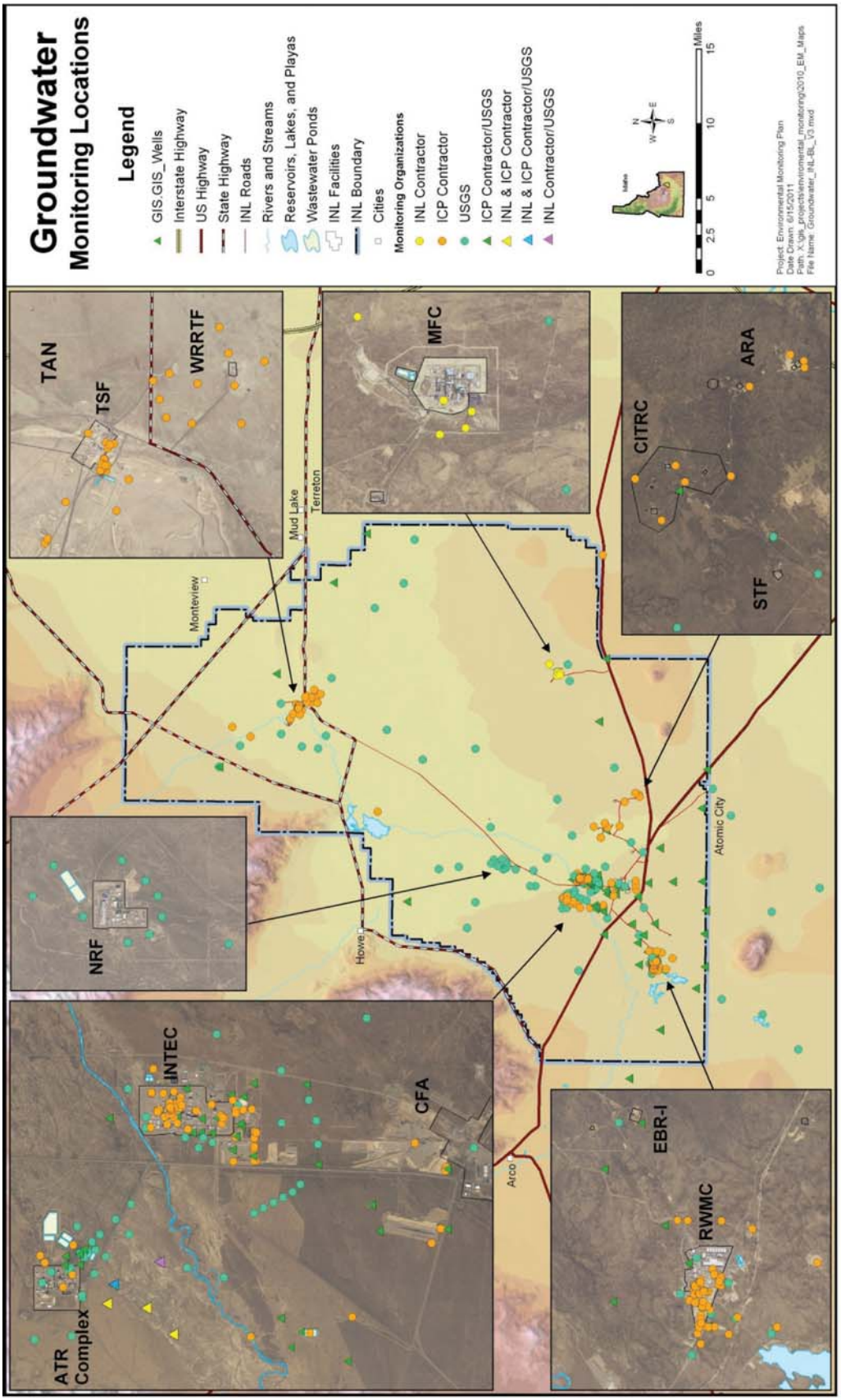

Figure 6-2. INL Site Groundwater Monitoring Locations.

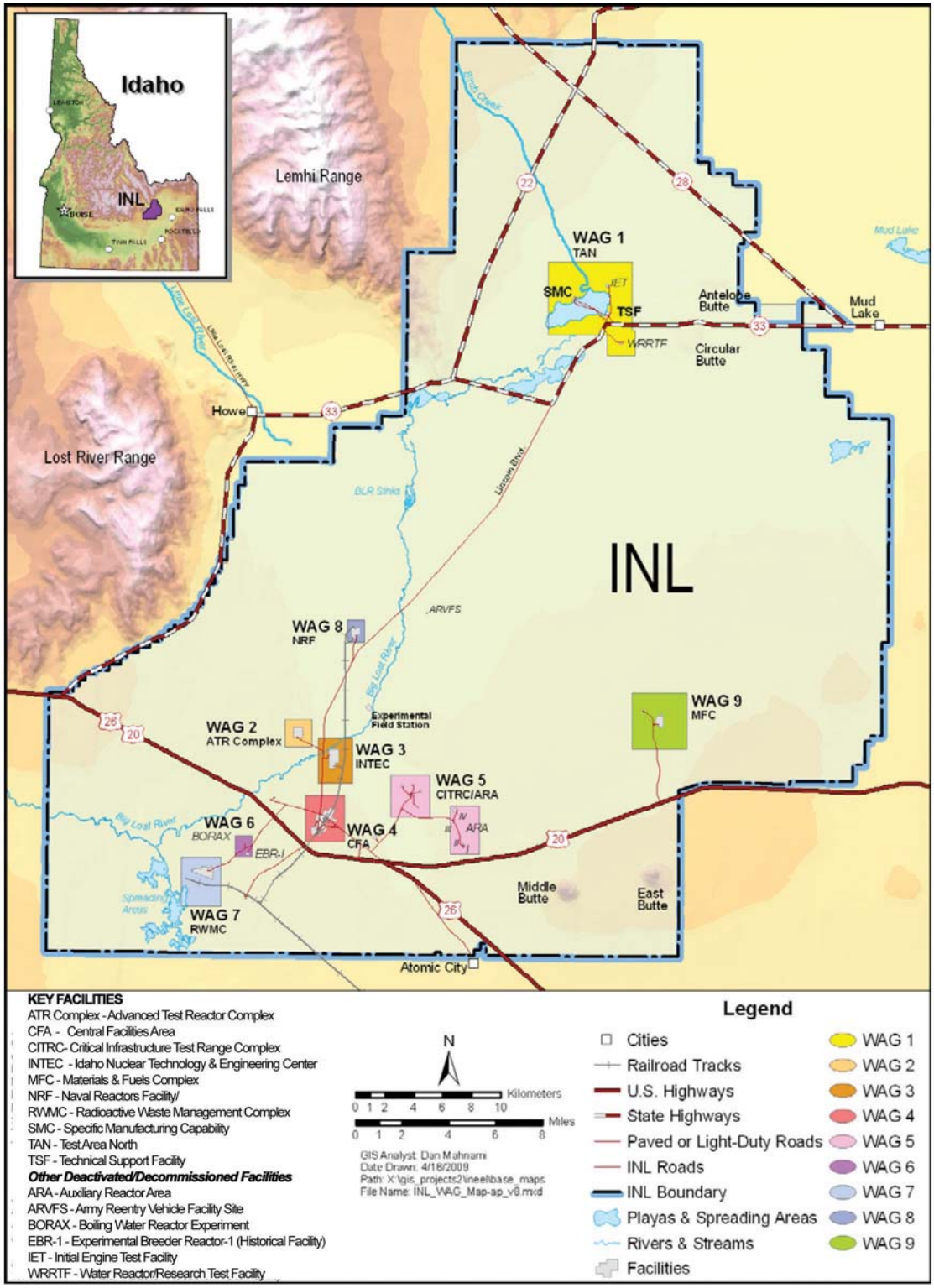

Figure 6-3. Map of the INL Site Showing Locations of Facilities and Corresponding WAGs.

Table 6-1. Monitoring of the Eastern Snake River Plain Aquifer and Surface Water on and Around the INL Site.

Area/Facility	Monitoring Activity				
	Groundwater Quality (Radiological)	Groundwater Quality (Nonradiological)	CERCLA Groundwater Monitoring	Offsite Drinking Water[a]	Surface Water[b]
ICP Contractor					
Advanced Test Reactor Complex			•		
Central Facilities Area			•		
Idaho Nuclear Technology and Engineering Center			•		
Power Burst Facility/Critical Infrastructure Test Range Complex			•		
Test Area North			•		
Radioactive Waste Management Complex			•		
INL Contractor					
Materials and Fuels Complex			•		
Environmental Surveillance, Education, and Research Program					
INL Site/Distant				•	•
U.S. Geological Survey					
INL Site/Distant	•	•			•

a. Compliance monitoring of INL Site drinking water is discussed in Chapter 5. Results of surveillance of drinking water samples collected off the INL Site are reported in this chapter.

b. Liquid effluent, waste pond, and surface water runoff monitoring is addressed in Chapter 5. Surveillance of natural surface waters (rivers and springs) by the Environmental Surveillance, Education, and Research Program is presented in this chapter. Surface water samples are also collected by the U.S. Geological Survey (see http://id.water.usgs.gov/projects/INL/monitor.html) but are not discussed in this report.

basin and the Big Lost Trough. The eastern Snake River Plain aquifer was formed by a unique sequence of tectonic, volcanic, and sedimentologic processes associated with the migration of the North American tectonic plate southwestward across the Yellowstone hot spot, or mantle plume (Geslin et al. 1999). Most of the basalt lava flows that host the aquifer and comprise the overlying vadose zone are very porous and permeable due to emplacement processes and fracturing during cooling. Rubble zones between lava flows and cooling fractures allow very rapid flow of water in the saturated zone, rapid infiltration of water and contaminants, and deep penetration of air into the vadose zone. Alluvial, eolian, and lacustrine sediments interbedded within the basalt sequence are generally fine-grained, commonly serving as aquitards below the water table, and affecting infiltration and contaminant transport in the vadose zone (Smith 2004).

The subsiding eastern Snake River Plain 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. A northeast–southwest-directed extension of the eastern Snake River Plain produces significant anisotropy to the hydraulic conductivity of the rocks (Smith 2004).

The Big Lost Trough receives sediment primarily from Basin and Range fluvial systems of the Big Lost River, Little Lost River, and Birch Creek. The Big Lost Trough contains a more-than-200-m (650-ft)-thick succession of lacustrine, fluvial, eolian, and playa sediments, recording high-frequency Quaternary climatic fluctuations interbedded with basalt flows. Alternating deposition of clay-rich lacustrine sediments and sandy fluvial and eolian sediments in the central part of the basin was in response to the interaction of fluvial and eolian systems with Pleistocene Lake Terreton, which also, in part, is responsible for the modern day Mud Lake.

Numerous studies suggest the hydraulic gradient of the eastern Snake River Plain aquifer is to the south/southwest (Figure 6-4), with velocities ranging from 0.5 to 6.1 m/day (2 to 20 ft/day). This velocity is much faster than most studied aquifers and is attributed to the eastern Snake River Plain architecture and porous media.

6.3 Hydrogeologic Data Management

Over time, hydrogeologic data at the INL Site have been collected by a number of organizations, including USGS, current and past contractors, and other groups. The INL Site Hydrogeologic Data Repository maintains and makes the data generated by these groups available to users and researchers.

The ICP Site Sample and Analysis Management Program was established to provide consolidated environmental sampling activities and analytical data management. The Sample and Analysis Management Program provides a single point of contact for obtaining analytical laboratory services and managing cradle-to-grave analytical data records.

The USGS data management program involves putting all data in the National Water Information System, which is available on the internet at: http://waterdata.usgs.gov/id/nwis/qw.

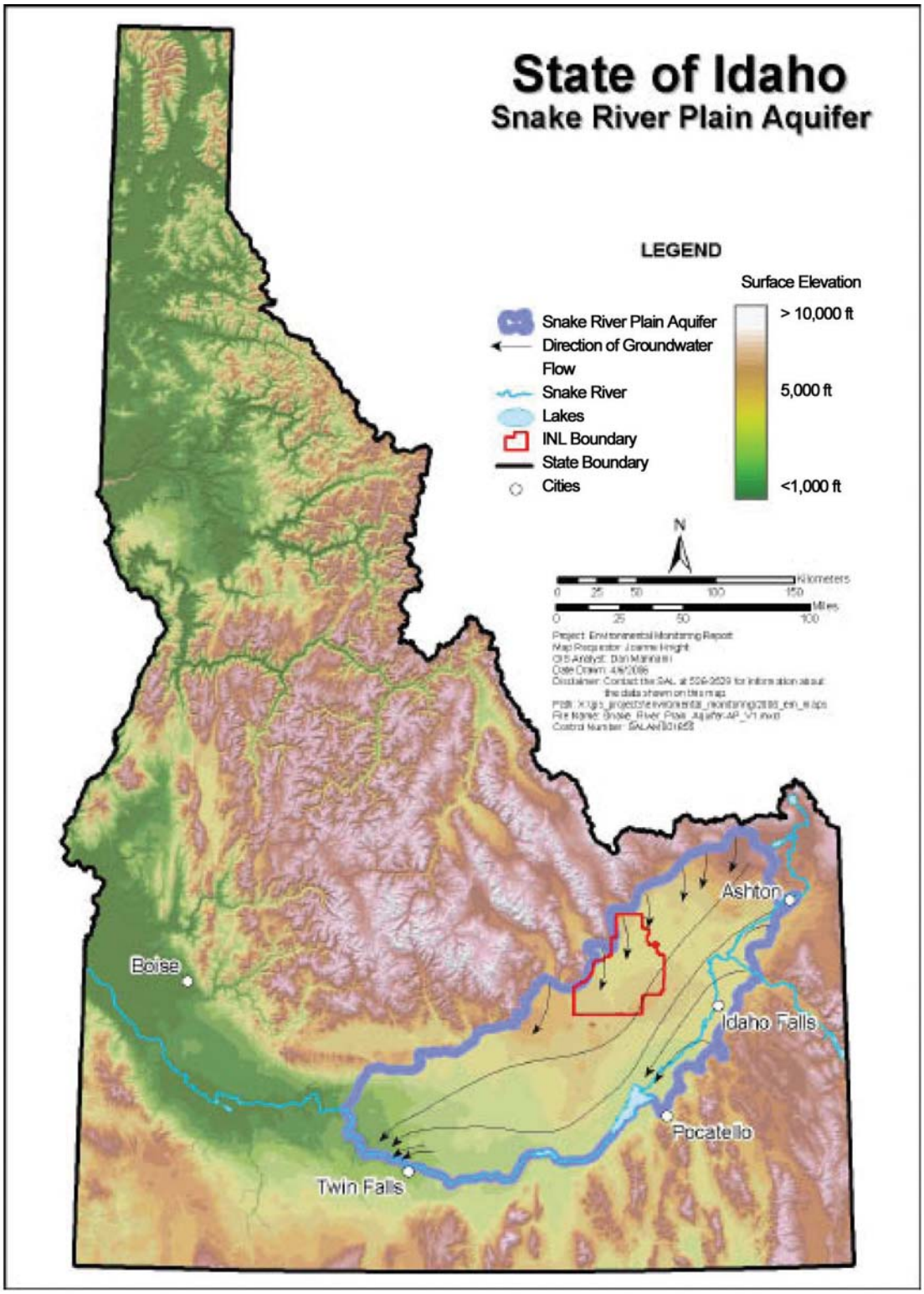

Figure 6-4. Location of the INL Site in Relation to the Eastern Snake River Plain Aquifer.

6.4 Aquifer Studies of the Idaho National Laboratory Site and the Eastern Snake River Plain Aquifer

The eastern Snake River Plain aquifer serves as the primary source for drinking water and crop irrigation in the Upper Snake River Basin. A description of the hydrogeology of the INL Site and water movement in the aquifer is given in Section 6.2. Further information may be found in numerous USGS publications. Some of these publications can be accessed at http://id.water.usgs.gov/projects/INL/pubs.html or requested from the USGS INL Project Office by calling (208) 526-2438. During 2012, USGS INL Project Office personnel published six documents covering hydrogeologic conditions and monitoring at the INL Site. The abstracts to these reports are presented in Chapter 10.

6.5 U.S. Geological Survey Radiological Groundwater Monitoring at the Idaho National Laboratory Site

Historic waste disposal practices have produced localized areas of radiochemical contamination in the eastern Snake River Plain aquifer beneath the INL Site. The 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 (^{90}Sr), and iodine-129 (^{129}I). Injection at INTEC was discontinued in 1984 and the injection well was 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 to be closed, and the new INTEC percolation ponds went into operation in August 2002.

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

The average combined rate of tritium wastewater disposed of at ATR Complex and INTEC was highest from 1952 to 1983 (910 Ci/yr [3.37 × 10^{13} Bq/yr]), decreased during 1984 to 1991 (280 Ci/yr [1.04 × 10^{14} Bq/yr]), and continued to decrease during 1992 to 1995 (107 Ci/yr [3.96 × 10^{12} Bq/yr]). From 1952 to 1998, the INL Site disposed of about 93 Ci (3.44 × 10^{12} Bq) of ^{90}Sr at ATR Complex and about 57 Ci (2.11 × 10^{12} Bq) at INTEC. Wastewater containing ^{90}Sr was never directly discharged to the aquifer at ATR Complex; however, at INTEC, a portion of the ^{90}Sr was injected directly to the aquifer. From 1996 to 1998, the INL Site disposed of about 0.03 Ci (1.11 × 10^{9} Bq) of ^{90}Sr to the INTEC infiltration ponds (Bartholomay et al. 2000). An additional 18,100 Ci (6.70 × 10^{14} Bq) of ^{90}Sr was reported to have leaked at the INTEC Tank Farm (Cahn et al. 2006).

Presently, ^{90}Sr is the only radionuclide that continues to be detected by the ICP contractor and USGS above the primary constituent standard in some surveillance wells between INTEC and Central Facilities Area (CFA). Other radionuclides (e.g., gross alpha) have been detected above their primary constituent standard in wells monitored at individual WAGs.

Tritium – Because tritium is equivalent in chemical behavior to hydrogen, a key component of water, it has formed the largest plume of any of the radiochemical pollutants at the INL Site. The configuration and extent of the tritium contamination area, based on the most recent published USGS data (2008), are shown in Figure 6-5 (Davis 2010). The area of contamination within the 0.5-pCi/L contour line decreased from about 103 km^2 (40 mi^2) in 1991 to about 52 km^2 (20 mi^2) in 1998 (Bartholomay et al. 2000).

The area of elevated tritium concentrations near 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 ATR Complex (USGS-065) and INTEC (USGS-114) have continually shown the highest tritium concentrations in the aquifer over recent time (Figure 6-6). For this reason, these two wells are considered representative of maximum concentration trends in the rest of the aquifer. The average tritium concentration in USGS-065 near ATR Complex decreased from 4,400 +/- 120 pCi/L in 2011 to 3,550 +/- 110 pCi/L in 2012; the tritium concentration in USGS-114 south of INTEC increased from 7,000 +/- 260 pCi/L in 2011 to 7,250+/-160 pCi/L in 2012.

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 both wells USGS-065 and USGS-114 dropped below this limit in 1997 as a result of radioactive decay (tritium has a half-life of 12.3 years), ceased tritium disposal, advective dispersion, and dilution within the aquifer.

Strontium-90 – The configuration and extent of ^{90}Sr in groundwater, based on the latest published USGS data, are shown in Figure 6-7 (Davis 2010). The contamination originates from INTEC from historic injection of wastewater. No ^{90}Sr was detected by USGS in the eastern Snake River Plain aquifer near ATR Complex during 2012, the most recent year for which published results are available. All ^{90}Sr at ATR Complex was disposed of to infiltration ponds in contrast to the direct injection that occurred at INTEC. At ATR Complex, ^{90}Sr is retained in surficial sedimentary deposits, interbeds, and perched groundwater zones. The area of ^{90}Sr contamination from INTEC is approximately the same as it was in 1991.

The ^{90}Sr trend over the past 20 years (1991 – 2011) in Wells USGS-047, USGS-057 and USGS-113 is shown in Figure 6-8. 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 through this period. The general decrease is probably the result of radioactive decay (^{90}Sr has a half-life of 29.1 years), discontinued ^{90}Sr disposal, advective dispersion, and dilution within the aquifer. The variability of concentrations in some wells was thought to be due, in part, to a lack of recharge from the Big Lost River that would dilute the ^{90}Sr. Other reasons also may include increased disposal of other chemicals into the INTEC percolation ponds that may have changed the affinity of ^{90}Sr on soil and rock surfaces, causing it to become more mobile (Bartholomay et al. 2000).

Summary of other USGS Radiological Groundwater Monitoring – USGS collects samples annually from select wells at the INL Site for gross alpha, gross beta, gamma

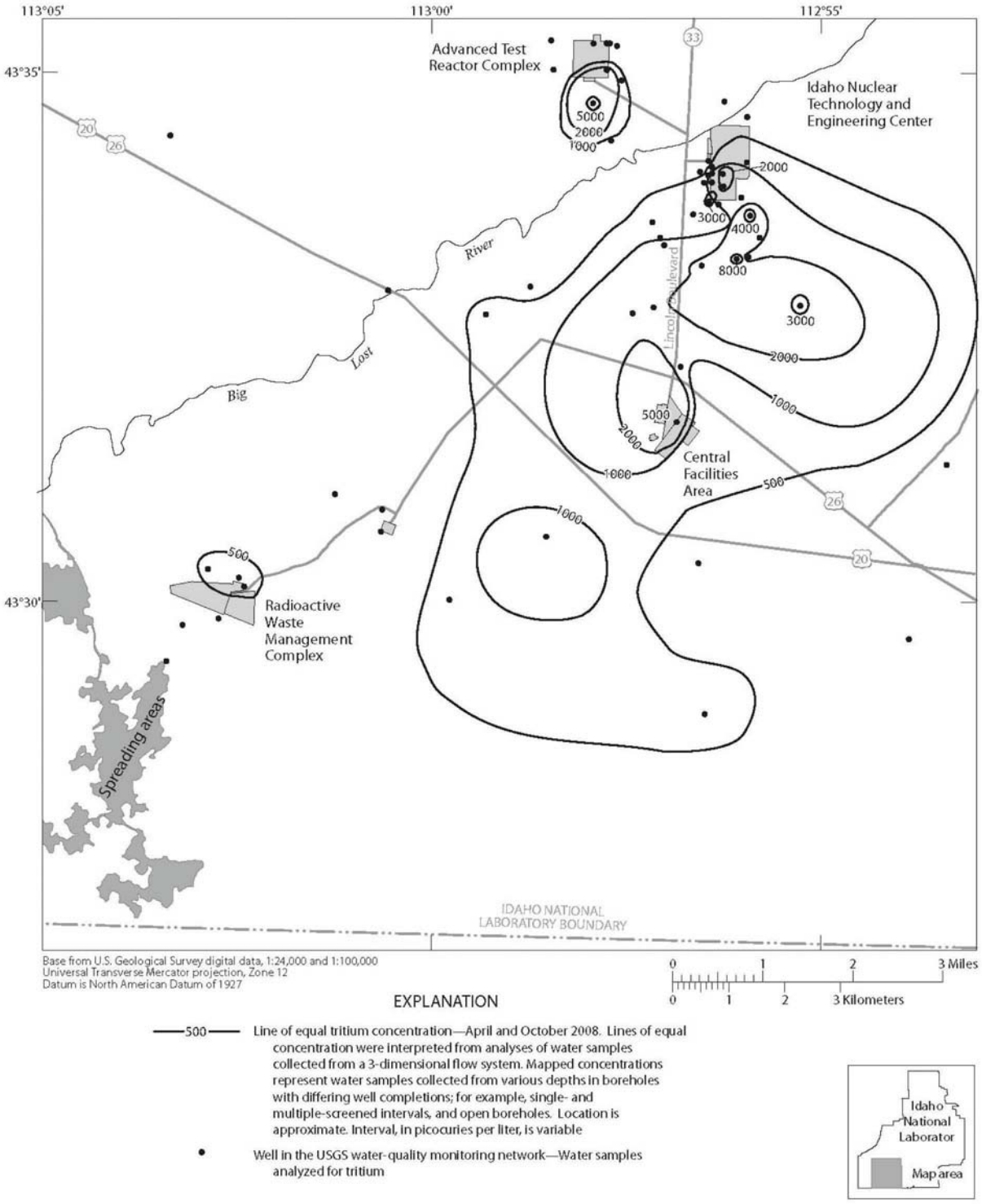

Figure 6-5. Distribution of Tritium in the Eastern Snake River Plain Aquifer on the INL Site in 2008 (from Davis 2010).

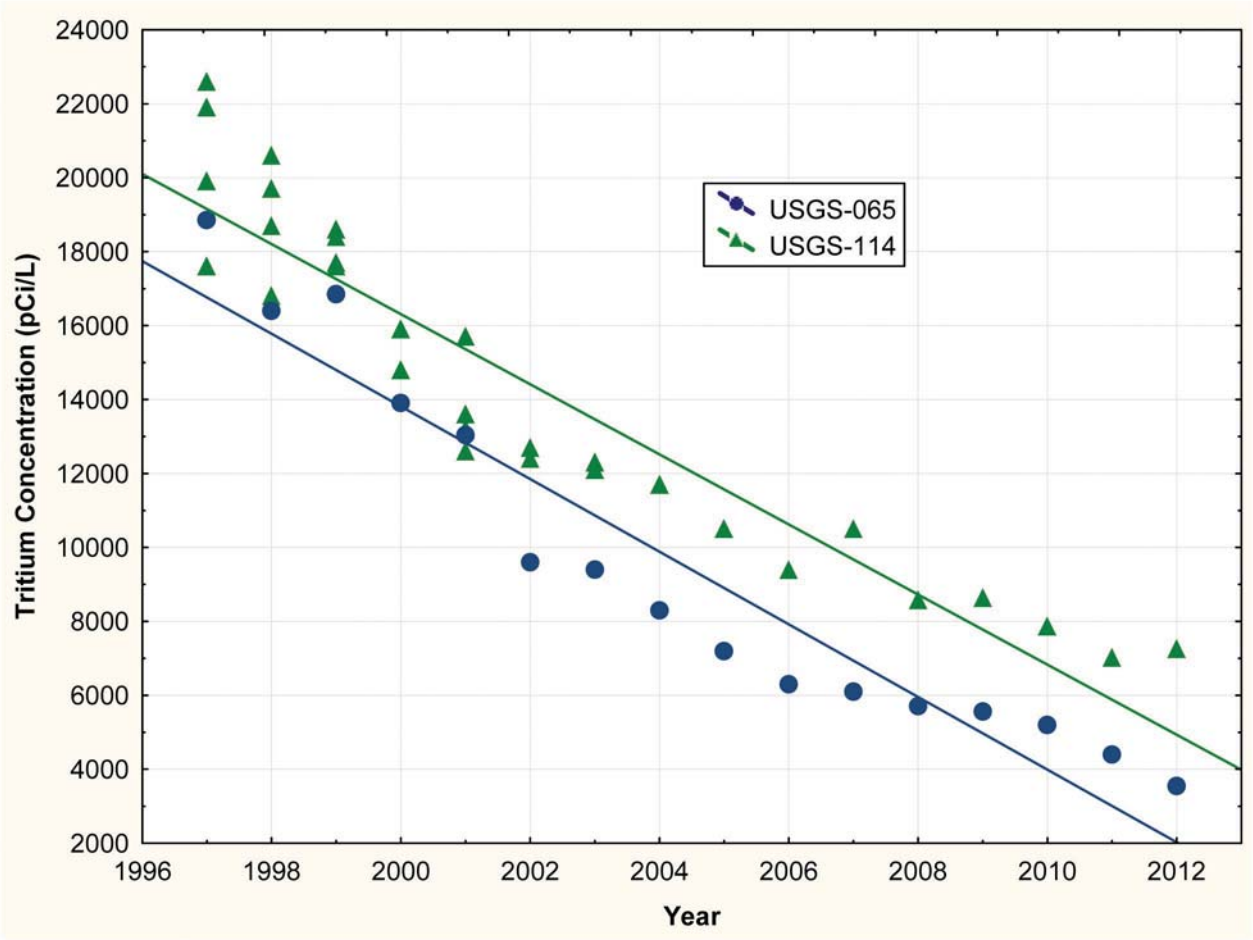

Figure 6-6. Long-Term Trend of Tritium in Wells USGS-065 and -114 (1997 – 2012).

spectroscopy analyses, and plutonium and americium isotopes (Table 3-6). Results for wells sampled in 2012 are available at http://waterdata.usgs.gov/id/nwis/. Monitoring results for 2006 – 2008 are summarized in Davis (2010). During 2006 – 2008, concentrations of cesium-137 (^{137}Cs), plutonium-238, plutonium-239/240, and americium-241 in all samples analyzed were less than the reporting level. During 2006-07, concentrations of gross-alpha particle radioactivity in 58 wells sampled were less than the reporting level. In 2008, reportable concentrations of gross alpha radioactivity were observed in 24 of the 58 wells and ranged from 2.3 +/-0.7 to 6.6 +/-1.3 pCi/L. The change in the amount of reportable concentrations was attributed to increasing the sensitivity of the analyses and changing the radionuclide reported for gross alpha radioactivity (Davis 2010). Beta particle radioactivity exceeded the reporting level in 37 of 58 wells sampled, and concentrations ranged from 2.8 +/-0.9 to 21.6+/-1.8 pCi/L (Davis 2010).

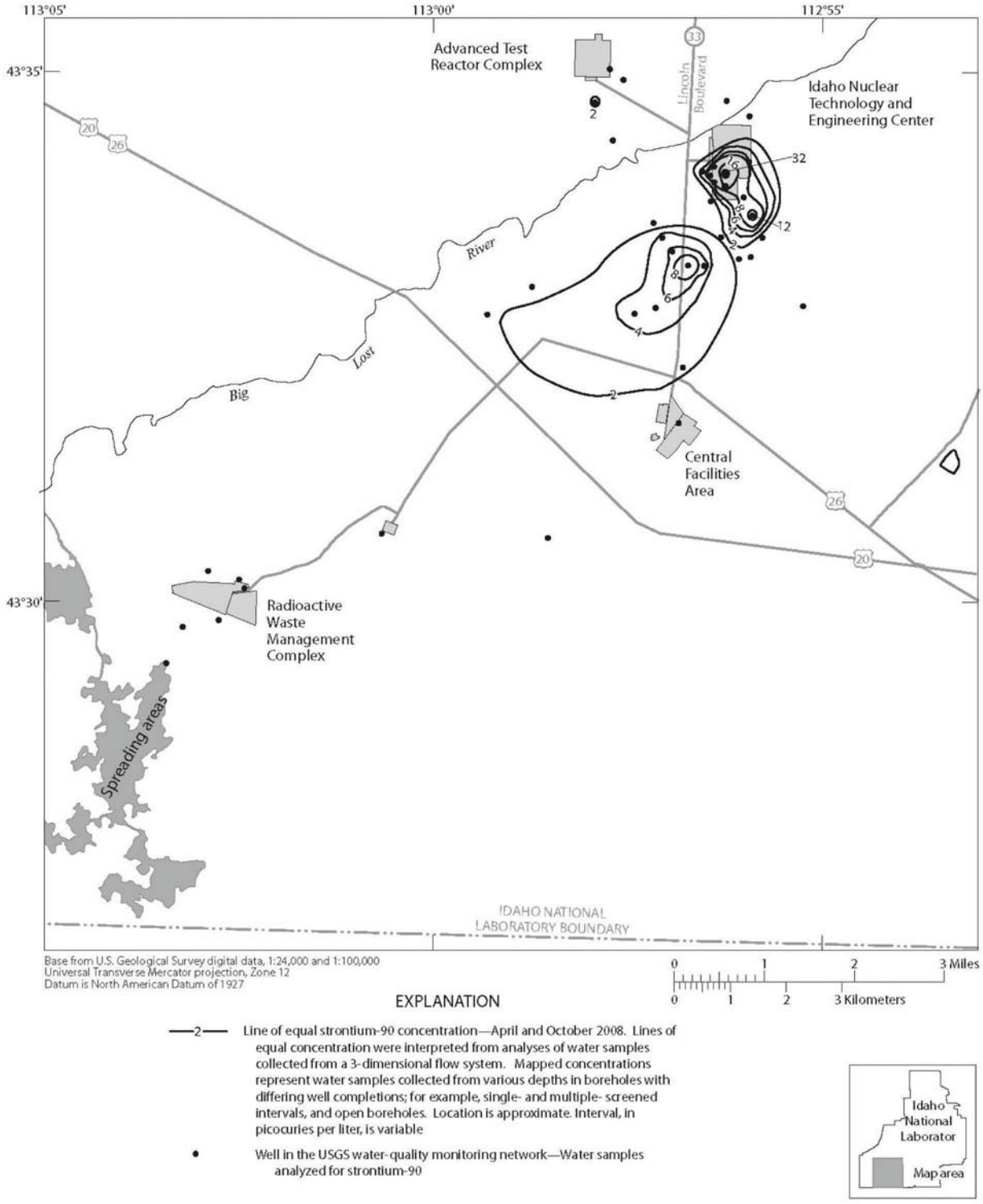

Figure 6-7. Distribution of ^{90}Sr in the Eastern Snake River Plain Aquifer on the INL Site in 2008 (from Davis 2010).

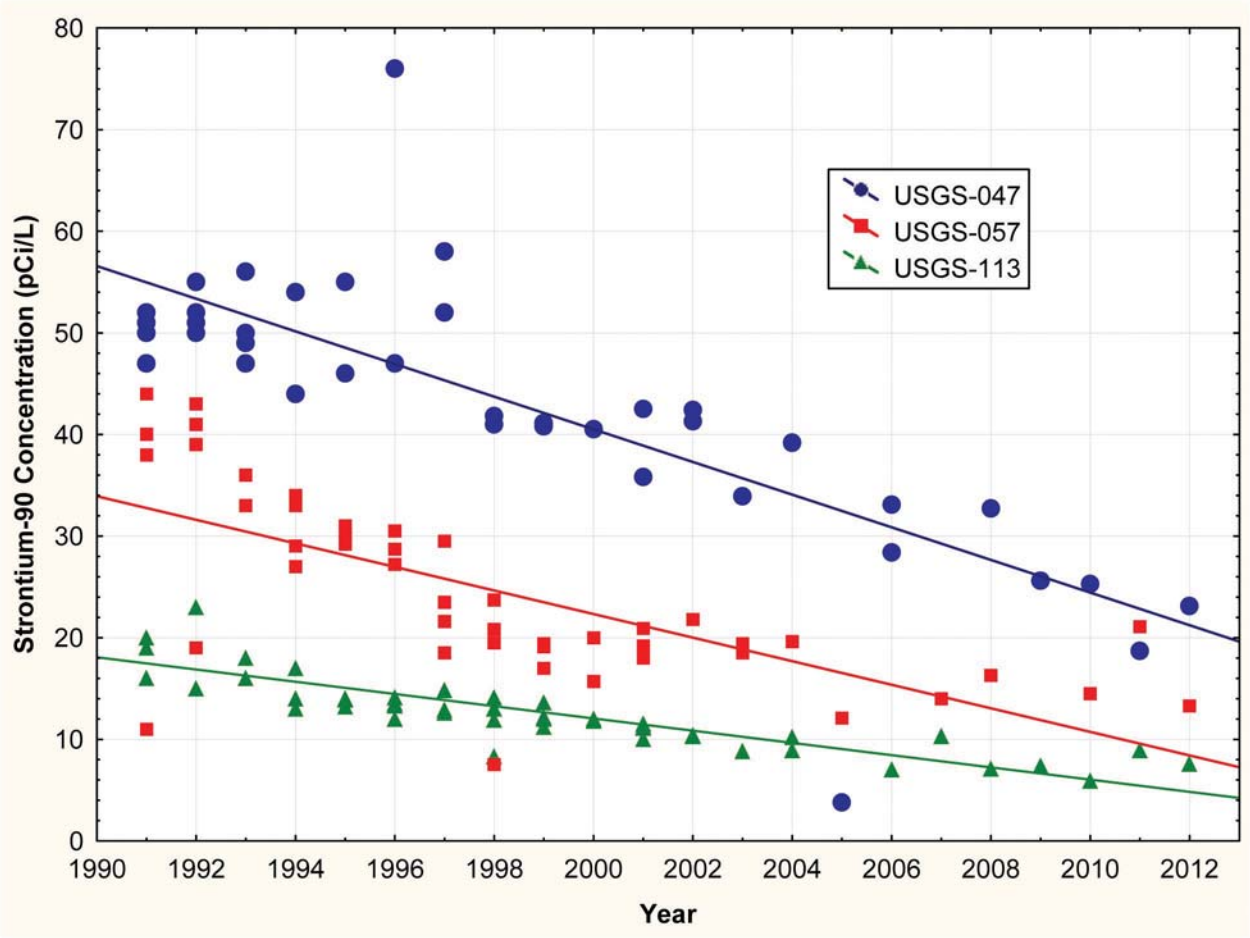

Figure 6-8. Long-Term Trend of ^{90}Sr in Wells USGS-047, -057 and -113 (1991 – 2012).

USGS periodically has sampled for ^{129}I in the eastern Snake River Plain aquifer, and monitoring programs from 1977, 1981, 1986, and 1990 – 1991 were summarized in Mann et al. (1988) and Mann and Beasley (1994). USGS evaluated results from samples collected in 2003 and 2007, and Bartholomay (2009) discusses the results. The USGS sampled for ^{129}I in wells at the INL Site in the fall of 2011 and in the spring and summer of 2012, and results will be published in a future USGS report. Average concentrations of 19 wells sampled in 1990 – 1991, 2003, and 2007 decreased from 0.975 pCi/L in 1990 – 1991 to 0.25 pCi/L in 2007. The maximum concentration in 2007 was 1.16 ± 0.04 pCi/L, which exceeded the drinking water MCL (1 pCi/L). The average concentrations of the 19 wells sampled in 2003 and 2007 did not differ; however, slight increases and decreases of concentrations in several areas around INTEC were evident in the aquifer. The decreases are attributed to the discontinued disposal and to dilution and dispersion in the aquifer. The increases may be due to movement of remnant perched water below INTEC. The configuration and extent of ^{129}I in groundwater, based on the 2007 USGS data (most current to date), are shown in Figure 6-9 (Bartholomay 2009).

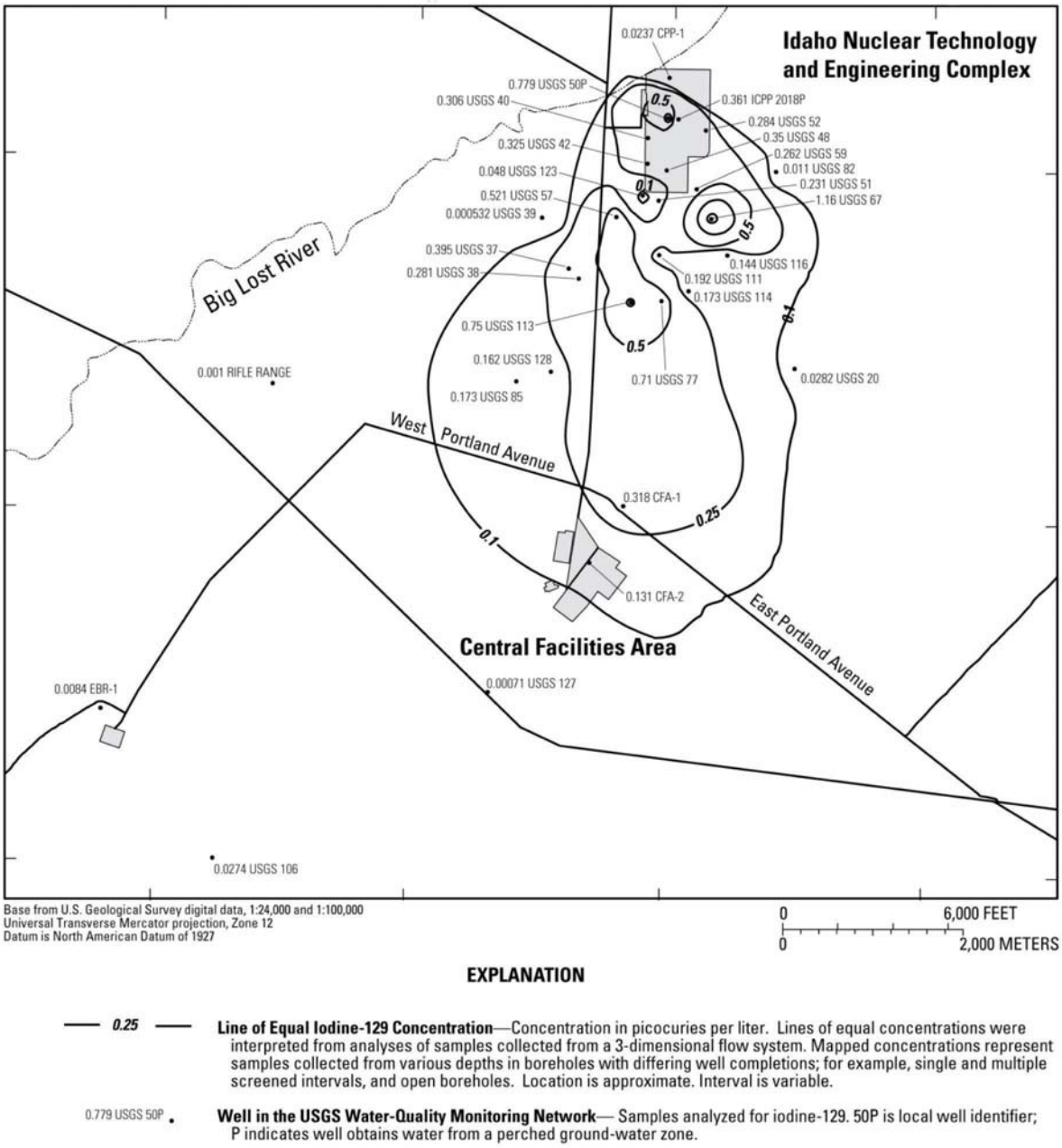

Figure 6-9. Distribution of ^{129}I in the Snake River Plain Aquifer on the INL Site in 2007 (from Bartholomay 2009).

6.6 U.S. Geological Survey Nonradiological Groundwater Monitoring at the Idaho National Laboratory Site

USGS collects samples annually from select wells at the INL Site for chloride, sulfate, sodium, fluoride, nitrate, chromium, and selected other trace elements, total organic carbon, and purgeable organic compounds (Table 3-6). Davis (2010) provides a detailed discussion of results for samples collected during 2006 – 2008. Chromium had a concentration at the MCL of 100 µg/L in Well 65 in 2005 (Davis 2008) and 2009, but its concentration was below the MCL in 2012 at 78 µg/L. Concentrations of chloride, nitrate, sodium, and sulfate historically have been above background concentrations in many wells at the INL Site, but concentrations were below established MCLs or secondary maximum contaminant levels in all wells during 2008 (Davis 2010).

USGS sampled for purgeable (volatile) organic compounds in groundwater at the INL Site during 2012. Samples from 27 groundwater monitoring wells and one perched well were collected and submitted to the USGS National Water Quality Laboratory in Lakewood, Colorado, for analysis of 61 purgeable organic compounds. USGS reports describe the methods used to collect the water samples and ensure sampling and analytical quality (Mann 1996; Bartholomay et al. 2003; Knobel et al. 2008). Nine purgeable organic compounds were detected above the laboratory reporting level of 0.2 or 0.1 µg/L in at least one well on the INL Site (Table 6-2). The production well at the Radioactive Waste Management Complex (RWMC) is monitored monthly, and concentrations of tetrachloromethane (also known as carbon tetrachloride) exceeded the MCL of 5 µg/L during all 12 months in 2012 (Table 6-3). Tetrachloromethane also exceeded the

Table 6-2. Purgeable Organic Compounds in Annual USGS Well Samples (2012).

Constituent	GIN 2	RWMC-M7S	USGS-087	USGS-119	USGS-120	USGS-130
Tetrachloromethane (µg/L) (MCL=5)[a]	ND[b]	8.43	4.65	0.36	0.91	ND
Trichloromethane (µg/L) (MCL=100)	0.13/0.18	1.23	0.32	ND	ND	0.23
1,1,1-Trichloroethane (µg/L) (PCS=200)[c]	ND	0.59	0.21	ND	ND	0.16
Tetrachloroethene (µg/L) (MCL=5)	1.94/1.82	0.54	0.17	ND	ND	ND
Trichloroethene (µg/L) (PCS=5)	6.74/7.61	3.59	1.06	ND	0.11	2.94

a. MCL = maximum contaminant level from Environmental Protection Agency in micrograms per liter (40 CFR 141).
b. ND = not detected.
c. PCS = primary constituent standard values from IDAPA 58.01.11.

Table 6-3. Purgeable Organic Compounds in Monthly Production Well Samples at the RWMC (2012).

Constituent	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept[a]	Oct	Nov	Dec
Tetrachloromethane (µg/L) (MCL=5)[b]	7.86	7.20	8.63	8.99	7.90	9.12	9.26	8.84	7.28	5.31	6.90	7.95
Trichloromethane (µg/L) (MCL=100)[c]	2.20	2.05	2.76	3.09	2.15	2.22	2.45	2.26	2.02	1.76	2.14	2.06
Tetrachloroethene (µg/L) (PCS=5)[d]	0.421	0.366	0.432	0.450	0.396	0.402	0.412	0.36	0.320	0.293	0.350	0.368
1,1,1-Trichloroethane (µg/L) (PCS=200)	0.530	0.485	0.590	0.604	0.468	0.496	0.505	0.481	0.430	0.35	0.420	0.462
Trichloroethene (µg/L) (PCS=5)	4.13	3.79	4.67	4.88	3.89	3.98	4.00	4.00	3.07	3.22	3.40	3.62

a. The September sample also had concentrations in micrograms per liter of 0.368 for bromodichloromethane; 1.57 for tribromomethane; and 0.506 for dibromochloromethane.

b. MCL = maximum contaminant level values from the Environmental Protection Agency (40 CFR 141).

c. The MCL for total trihalomethanes is 100 g/L This MCL is based on concentrations of bromodichloromethane, dibromochloromethane, tribromomethane and trichloromethane.

d. PCS = primary constituent standard values from IDAPA 58.01.11.

MCL in one sample collected from RWMC M7S. Trichloroethene exceeded the MCL of 5 µg/L from two samples collected from well GIN 2 at Test Area North (TAN) (Table 6-2). None of the other measured constituents were above their respective primary constituent standard. Annual average concentrations of tetrachloromethane in the production well at RWMC generally have increased through time (Davis 2010).

6.7 Comprehensive Environmental Response, Compensation, and Liability Act Groundwater Monitoring During 2012

CERCLA activities at the INL Site are divided into WAGs that roughly correspond to the major facilities, with the addition of the INL Site-wide WAG 10. Locations of the various WAGs are shown on Figure 6-3. The following subsections provide an overview of groundwater sampling results. More detailed discussions of the CERCLA groundwater sampling can be found in the WAG-specific monitoring reports within the CERCLA Administrative Record at http://ar.inel.gov. WAG 8 is managed by the Naval Reactors Facility and is not discussed in this report.

6.7.1 Summary of Waste Area Group 1 Groundwater Monitoring Results

Groundwater is monitored at WAG 1 to measure the progress of the remedial action at TAN. The groundwater plume at TAN has been divided into three zones for the three different remedy components. The monitoring program and the results are summarized by zone in the following paragraphs.

Hot Spot Zone (trichloroethene [TCE] concentrations exceeding 20,000 µg/L) — In situ bioremediation (ISB) is used in the hot spot (TSF-05) to promote bacterial growth by supplying essential nutrients to bacteria that occur naturally in the aquifer and are able to break down contaminants. The hot spot concentration was defined using data from 1997 (Figure 6-10) and is not reflective of current concentrations.

The 2012 ISB operations consisted of injections of sodium lactate solution and whey powder to produce anaerobic conditions for efficient biologically mediated breakdown of TCE. ISB maintained effective anaerobic reductive dechlorination conditions, as evidenced by complete degradation of TCE to ethene in the vicinity of the injection wells. Because the amount of contactable residual source in the aquifer has declined to the point of diminishing return, the last ISB injection prior to transitioning into a rebound test was made in April 2012. With regulatory agency concurrence, the ISB rebound test began in July 2012. Since starting the ISB rebound test, anaerobic conditions remain in place, and TCE concentrations are below MCLs in all the former ISB injection wells.

Data from Wells TAN-28, TAN-30A, TAN-1860, and TAN-1861 located downgradient of the hot spot are used to determine if ISB operations have reduced the downgradient flux of contaminants. Trends in TCE concentrations at wells TAN-30A and TAN-1861 generally indicate that flux from the hot spot has been reduced at these wells, but the flux has not been reduced sufficiently at Wells TAN-28 and TAN-1860.

Overall, the 2012 groundwater monitoring data indicate that the ISB hot spot remedy is reducing the concentration of volatile organic compounds (VOCs) in and near the hot spot zone, and progress toward the remedial action objectives is being made (DOE-ID 2013a).

Medial Zone (TCE concentrations between 1,000 and 20,000 µg/L) — A pump and treat process has been used in the medial zone. The pump and treat process involves extracting contaminated groundwater, treating through air strippers, and reinjecting treated groundwater into the aquifer. The New Pump and Treat Facility was generally operated Monday through Thursday, except for shut downs due to maintenance. All 2012 Pump and Treat Facility compliance samples were below the discharge limits. TCE concentrations used to define the medial zone are based on data collected in 1997 before remedial actions started (Figure 6-10) and do not reflect current concentrations. Trichloroethene concentrations in the medial zone wells are significantly lower than the historically defined concentration range of 1,000 to 20,000 µg/L. The TCE concentrations were less than 75 µg/L in Wells TAN-33, TAN-36, and TAN-44 past the New Pump and Treat Facility extraction wells.

Distal Zone (TCE concentrations between 5 and 1,000 µg/L) — Monitored natural attenuation is the remedial action for the distal zone of the plume as defined by 1997 TCE concentrations (Figure 6-10). Monitored natural attenuation is the sum of physical, chemical, and biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. Engineering and administrative controls are in place to protect current and future users from health risks associated with groundwater contamination until concentrations decline through natural attenuation to below the MCL.

Trichloroethene data collected in 2012 from the distal zone wells indicate that additional data are needed to confirm that the monitored natural attenuation part of the remedy is on track with the model predictions for all wells in the distal portion of the plume. The TCE data from the plume expansion wells suggest that plume expansion has occurred but is within the limits allowed in the Record of Decision Amendment (DOE-ID 2001).

Radionuclide Monitoring — Strontium-90 and ^{137}Cs data at wells in the source area show elevated concentrations compared to concentrations prior to starting ISB. The elevated concentrations are probably due to ISB creating conditions in the aquifer that enhance ^{90}Sr and ^{137}Cs mobility. Strontium-90 and ^{137}Cs trends will be evaluated during the ISB rebound test to determine if they will meet the remedial action objective of declining to below MCLs by 2095.

6.7.2 Summary of Waste Area Group 2 Groundwater Monitoring Results

Groundwater samples were collected from seven aquifer wells at WAG 2, ATR Complex, during 2012. The locations of the wells sampled for WAG 2 are shown on Figure 6-11. Aquifer samples were analyzed for ^{90}Sr, gamma-emitting radionuclides, tritium, and chromium (unfiltered and filtered). Unfiltered samples were used to obtain the total chromium concentration in the sample, including chromium adsorbed onto suspended particulates; filtered samples are used to obtain the dissolved chromium concentration. The data for the October 2012 sampling event will be included in the Fiscal Year 2013 Annual Report for WAG 2 when it is finalized. The October 2012 sampling data are summarized in Table 6-4.

The only analyte to occur above its MCL was unfiltered chromium in one aquifer well. The highest unfiltered chromium concentration occurred in Well TRA-07, but the filtered chromium concentration was 88.3 µg/L and was below the MCL of 100 µg/L in this well. The filtered

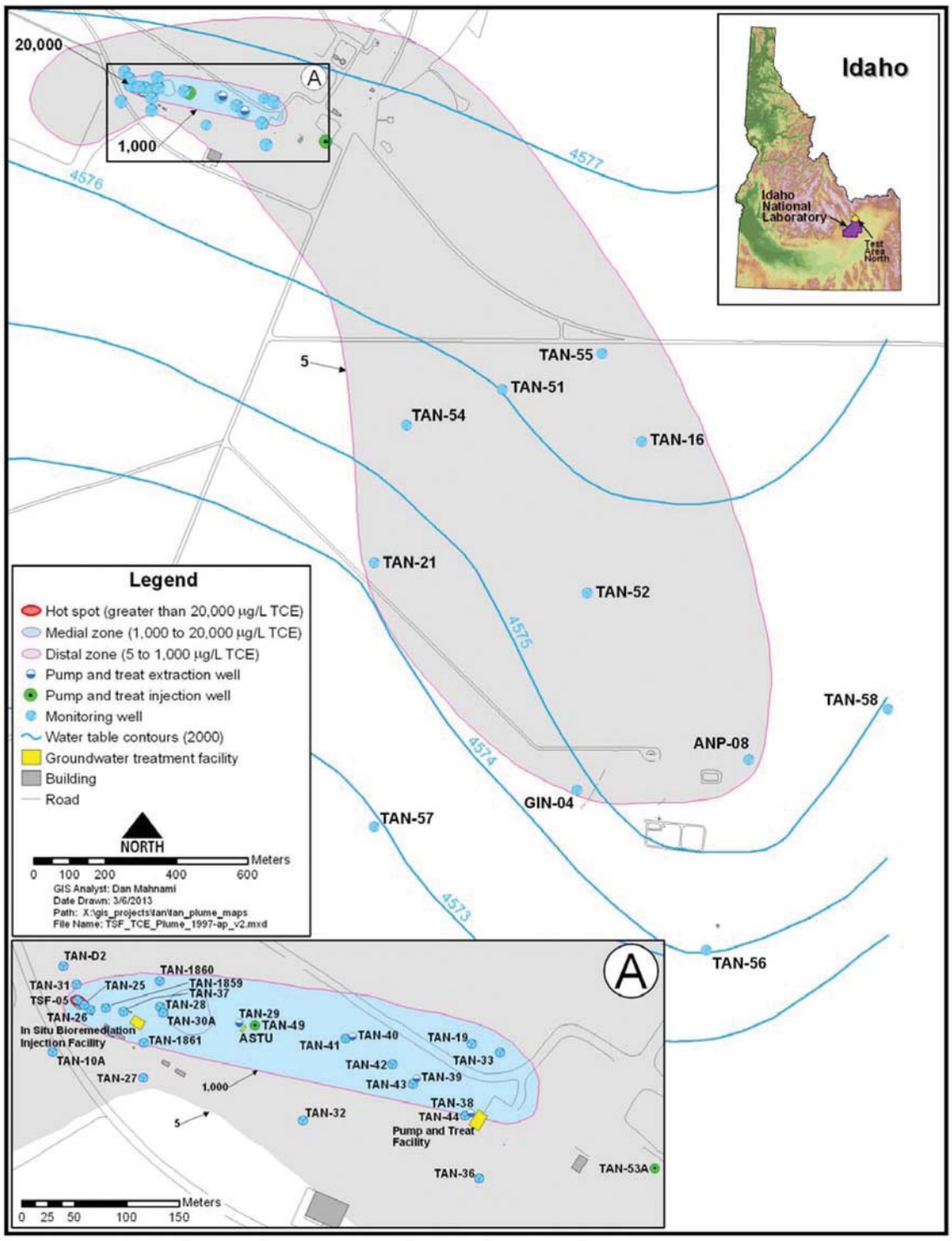

Figure 6-10. Trichloroethene Plume at TAN in 1997.

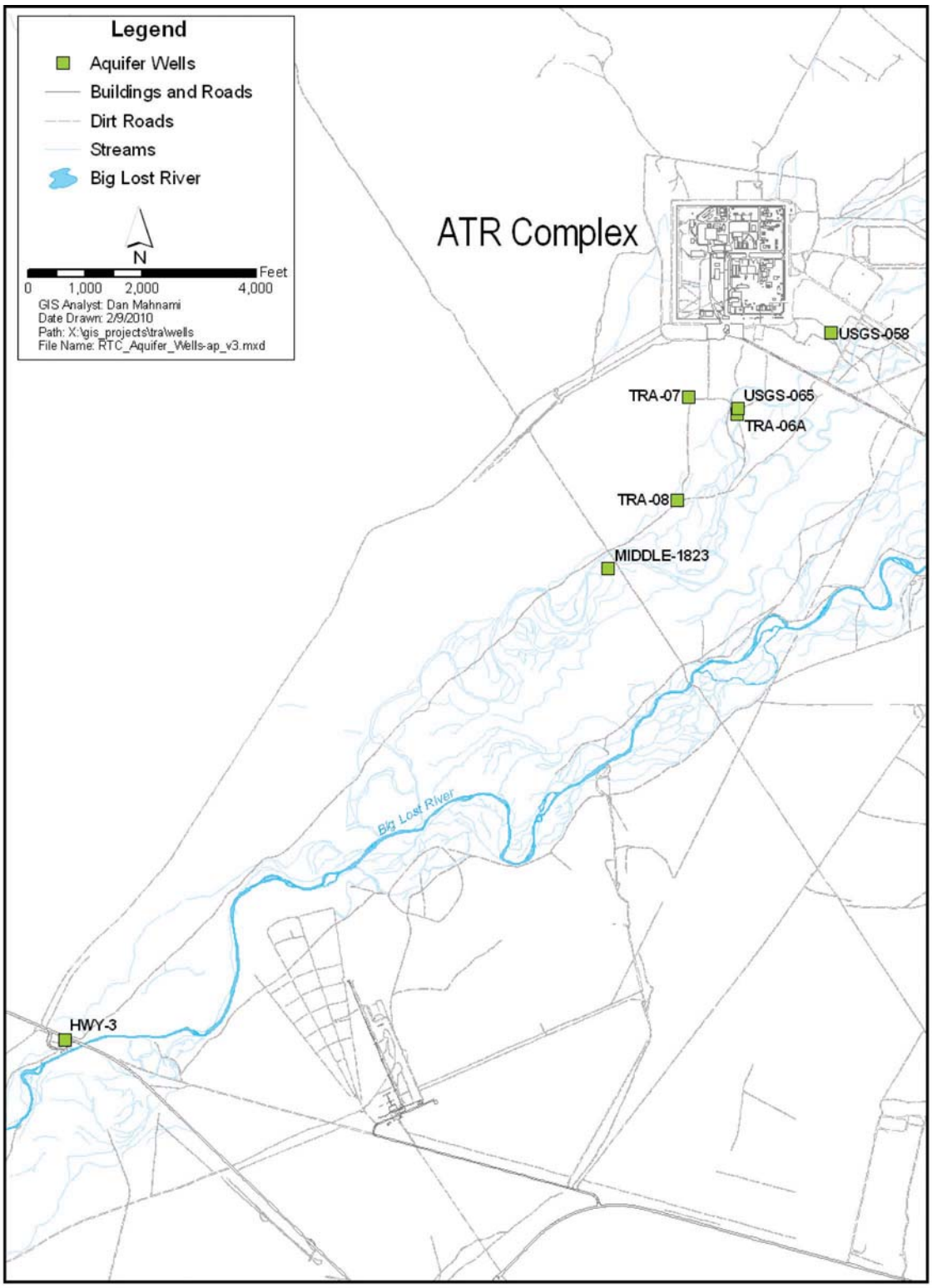

Figure 6-11. Locations of WAG 2 Aquifer Monitoring.

Table 6-4. WAG 2 Aquifer Groundwater Quality Summary for 2012.

Analyte	MCL[a]	Background[b]	Maximum	Minimum	Number of Wells above MCL
Chromium (filtered) (µg/L)	100	2–3	88.3	1.1	0
Chromium (unfiltered) (µg/L)	100	NA[c]	**102**[d]	1.8	1
Sr-90 (pCi/L)	8	0	ND[e]	ND	0
Tritium (pCi/L)	20,000	75–150	7,240	ND	0

a. MCL = maximum contaminant level
b. Background concentrations are from Knobel et al. (1992), except tritium, which is from Orr et al. (1991).
c. NA = not applicable
d. **Bold** value exceeds MCL.
e. ND = not detected

chromium concentration in Well USGS-065 was also elevated at 81.5 µg/L. The chromium concentrations in both TRA-07 and USGS-065 both show long-term downward trends in chromium concentration.

Well TRA-08 is the only aquifer well that has had consistent ^{90}Sr concentrations in the past, but ^{90}Sr was below detection limits in the October 2012 sample. The ^{90}Sr concentrations in TRA-08 had been decreasing since its first occurrence in 2005 and dropped below detection limits in October 2010.

Although tritium concentrations were above background concentrations in all aquifer wells sampled, except for the Highway 3 well, tritium concentrations were below the MCL of 20,000 pCi/L in all wells sampled.

Chromium and tritium concentrations in the aquifer have declined faster than predicted by the WAG 2 models used for the Operable Unit 2-12 Record of Decision and the revised modeling performed after the first five-year review (DOE-NE-ID 2005).

The October 2012 eastern Snake River Plain aquifer water table map prepared for the vicinity of ATR Complex was consistent with previous maps showing similar groundwater flow directions. Water levels in the vicinity of ATR Complex fell approximately 0.37 feet (0.11 m) on average from October 2011 to October 2012.

6.7.3 Summary of Waste Area Group 3 Groundwater Monitoring Results

At INTEC, groundwater samples were collected from 14 eastern Snake River Plain aquifer monitoring wells during 2012 (Figure 6-12). Groundwater samples were analyzed for a suite of radionuclides and inorganic constituents, and the data are summarized in the 2012 annual report

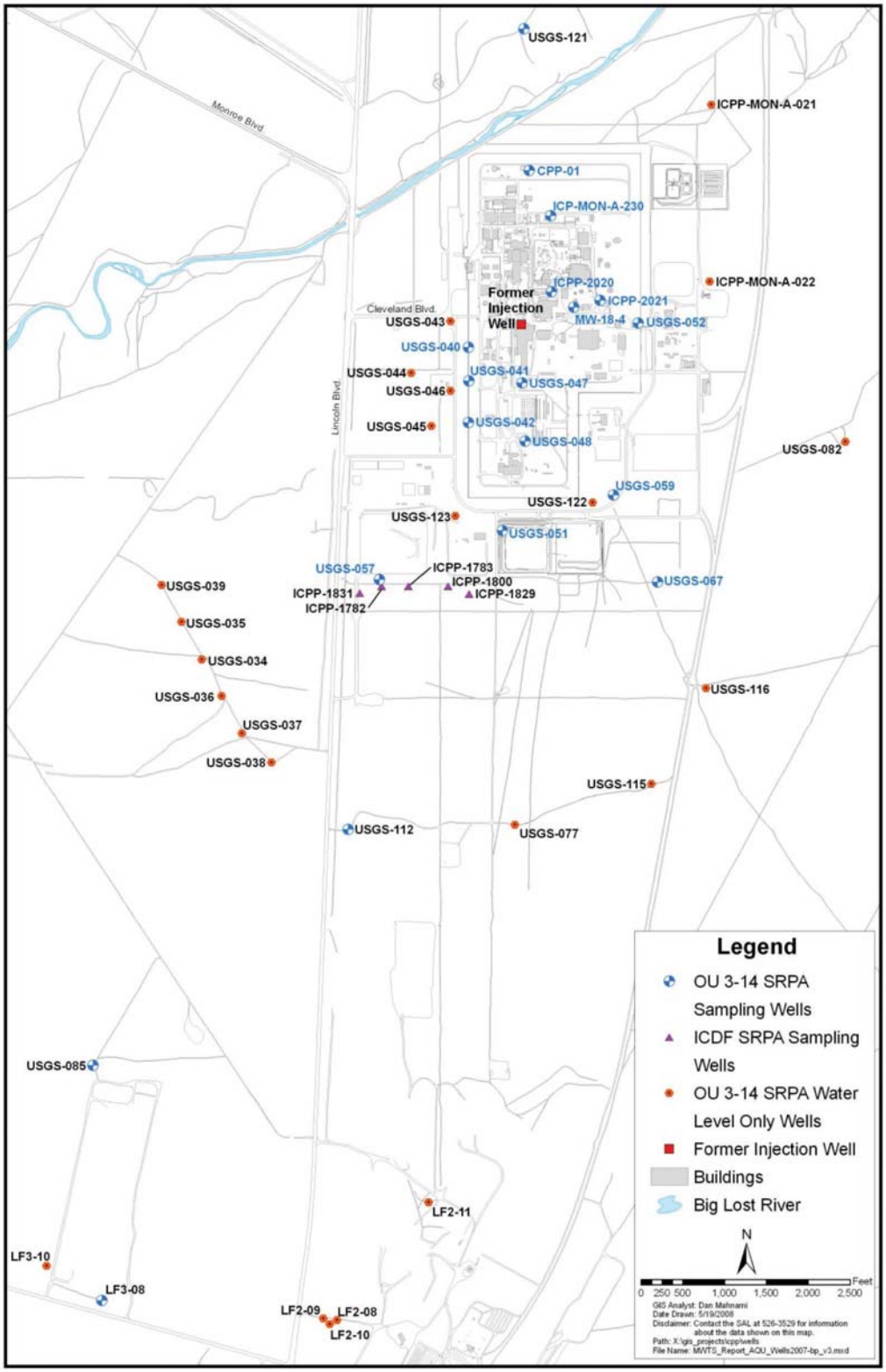

Figure 6-12. Locations of WAG 3 Monitoring Wells.

(DOE-ID 2013b). Table 6-5 summarizes the maximum concentrations observed, along with the number of MCL exceedances reported for each constituent.

Strontium-90, technetium-99 (^{99}Tc), ^{129}I, and nitrate exceeded their respective drinking water MCLs in one or more of the eastern Snake River Plain aquifer monitoring wells at or near INTEC, with ^{90}Sr exceeding its MCL by the greatest margin. Strontium-90 concentrations remained above the MCL (8 pCi/L) at nine of the well locations sampled. All well locations showed similar or slightly lower ^{90}Sr levels compared to those reported during the previous sampling events.

As in the past, ^{99}Tc was detected above the MCL (900 pCi/L) in two monitoring wells within INTEC, but concentrations were below the MCL at all other locations. During 2012, the highest ^{99}Tc level in eastern Snake River Plain aquifer groundwater was at monitoring Well ICPP-MON-A-230 (1,450 pCi/L) located north of the INTEC Tank Farm. All wells sampled showed stable or declining trends from the previous reporting period.

Nitrate was detected in all wells sampled during this reporting period. The highest concentration was reported at Well ICPP-2021 (14.3 mg/L as N). This was the only location where the nitrate concentration exceeded the MCL (10 mg/L as N). This well is located relatively close to the Tank Farm, and shows groundwater quality impacts attributed to past releases of Tank Farm liquid waste. Nitrate concentrations are similar or slightly lower than observed in previous years.

Iodine-129 concentrations were below detection limits at most wells locations. The highest ^{129}I concentration was reported at Well USGS-67 (1.02 UJ ± 0.44 pCi/L) located southeast of INTEC. This value exceeded the ^{129}I derived MCL (1 pCi/L). According to the data validation report, the “UJ” data qualifier flag was assigned because “the radionuclide identification was made using the 29.6 keV photopeak, however there were no supporting photopeaks identified at 33.6 keV or 39.6 keV.” Iodine-129 was not detected in a field duplicate sample collected from this same well location (USGS-67) (0.439 U ± 0.231 pCi/L). Iodine-129 concentrations in groundwater have declined significantly from concentrations observed during the 1980s and 1990s. None of the wells showed a significant increase in ^{129}I levels since the previous reporting period.

Tritium was detected in nearly all of the wells sampled, but none of the groundwater samples exceeded the tritium MCL (20,000 pCi/L). The highest tritium concentrations in groundwater were reported at Well USGS-51 (4,460 pCi/L) and Well MW-18-4 (4,300 pCi/L). Tritium concentrations have declined at nearly all locations over the past few years.

During the reporting period, no plutonium isotopes were detected in any of the eastern Snake River Plain aquifer groundwater samples. Uranium-238 was detected at all eastern Snake River Plain aquifer well locations, with the highest concentration at Well ICPP-MON-A-230 (1.15 pCi/L) north of the Tank Farm. The ^{238}U results are consistent with background concentrations reported for eastern Snake River Plain aquifer groundwater. Similarly, uranium-234 (^{234}U) also was detected in all groundwater samples, with concentrations ranging as high as 1.8 pCi/L at Well ICPP-MON-A-230. Uranium-234 is the daughter product of alpha decay of the long-lived, naturally occurring ^{238}U. Ratios of ^{234}U/^{238}U were similar to background ^{234}U/^{238}U activity ratios of 1.5 to 3.1 reported for the eastern Snake River Plain aquifer.

Table 6-5. Summary of Constituents Detected in WAG 3 Aquifer Monitoring Wells (FY 2012).

Constituent	EPA MCL[a]	Units	Snake River Plain Aquifer Groundwater – March 2012		
			Maximum Reported Value	Number of Results[b]	Results > MCL[b]
Gross alpha	15	pCi/L	3.19 J[c]	16	0
Gross beta	NA[d]	pCi/L	720	16	NA
Cesium-137	200	pCi/L	ND[e]	16	0
Strontium-90	8	pCi/L	**16.9**[f]	16	9
Technetium-99	900	pCi/L	**1,450**	16	2
Iodine-129	1	pCi/L	**1.02 UJ**[g]	16	1
Tritium	20,000	pCi/L	4,460	16	0
Plutonium-239	15	pCi/L	ND	16	0
Plutonium-239/240	15	pCi/L	ND	16	0
Uranium-233/234	15	pCi/L	1.8	16	0
Uranium-235	15	pCi/L	0.105 J	16	0
Uranium-238	15	pCi/L	1.15	16	0
Alkalinity	NA	mg/L	160	16	NA
Calcium	NA	mg/L	72.1	16	NA
Chloride	250	mg/L	133	16	0
Magnesium	NA	mg/L	24.6	16	NA
Nitrate (as N)	10	mg/L	**14.3**	16	1
Potassium	NA	mg/L	5.3	16	NA
Sodium	NA	mg/L	33	16	NA
Sulfate	250	mg/L	39.6	16	0
Total dissolved solids	500	mg/L	400	16	0

a. EPA = Environmental Protection Agency; MCL = maximum contaminant level.
b. Includes field duplicates.
c. Data-qualifier flag: J = estimated value.
d. NA = not applicable.
e. ND = constituent not detected in any sample.
f. **Bolded** values exceed MCL.
g. Data-qualifier flag: UJ = not detected, quantitation limit is an estimate.

Uranium-235 was reported in groundwater samples from three monitoring wells at concentrations ranging from non-detect (<0.12 pCi/L, estimated detection limit) to 0.105 pCi/L (estimated value). An evaluation of uranium in groundwater near RWMC indicates that eastern Snake River Plain aquifer background ^{235}U activities are generally less than 0.15 pCi/L (95 percent upper tolerance limit). Reported ^{235}U concentrations in groundwater at INTEC have historically been slightly above the background level, which is consistent with limited uranium impacts to groundwater from past operations at INTEC.

The 2012 groundwater contour map is similar in shape to the maps prepared for previous years, although water elevations vary slightly from year to year in response to wet-dry climate cycles. Groundwater levels declined during 2000–2005 as a result of the drought during this period. However, as a result of near normal precipitation during 2005–2012 and corresponding periods of flow of the Big Lost River, groundwater levels have remained relatively constant during this period.

6.7.4 Summary of Waste Area Group 4 Groundwater Monitoring Results

The WAG 4 groundwater monitoring consists of two different components: (1) CFA landfill monitoring and (2) monitoring of a nitrate plume south of CFA. Groundwater monitoring for the CFA landfills consisted of sampling seven wells for metals (filtered), VOCs, and anions (nitrate, chloride, fluoride, and sulfate) and two wells for VOCs only in accordance with the long-term monitoring plan (DOE-ID 2009). Four wells downgradient of CFA were sampled for nitrate and other anions to monitor a nitrate plume south of CFA. The CFA monitoring well locations are shown on Figure 6-13. Analytes detected in groundwater are compared to regulatory levels in Table 6-6. A complete list of the groundwater sampling results is contained in the 2012 Monitoring Report (DOE-ID 2013c).

In the nitrate monitoring wells, nitrate, at 16.5 mg/L-N, continued to exceed its groundwater MCL of 10 mg/L N for sensitive populations in Well CFA-MON-A-002, downgradient of CFA. Nitrate concentrations in CFA-MON-A-002 have been in the range of 15 to 21 mg/L-N since 1997. The nitrate concentration of 9.01 mg/L-N in Well CFA-MON-A-003 is below the MCL and within its historic range of 8 to 11 mg/L-N. Except for a 2005 spike, nitrate concentrations in Well CFA-MON-A-003 have been relatively consistent since monitoring started in 1995.

Chloroform, 1,1,1-trichloroethane, 1,2,4-trimethylbenzene, 1,2-butanone, 2-hexanone, methylcylcohexane, and toluene were the VOCs detected downgradient from the CFA landfills in the 2012 sampling event. Except for 1,1,1-trichloroethane, concentration of the above compounds in soil gas samples were low, with maximum concentrations of less than 100 ppbv. The compound 1,2,4 trimethylbenzene was not detected in any soil gas samples. The source of the chloroform, 1,2,4 trimethylbenzene, butanone, 2-hexanone, and toluene in the groundwater is uncertain because the soil gas samples do not indicate a source in the landfills for these compounds that appears capable of causing the groundwater contamination. Methylcyclohexane was not analyzed for in the vapor samples.

The compound 1,1,1-trichloroethane was detected in groundwater from Well CFA-1932 at a concentration of 0.11 µg/L and was near the detection limit. This detection may be the result of vapor migration from the landfills. However, the concentration in groundwater is below the MCL of 200 µg/L.

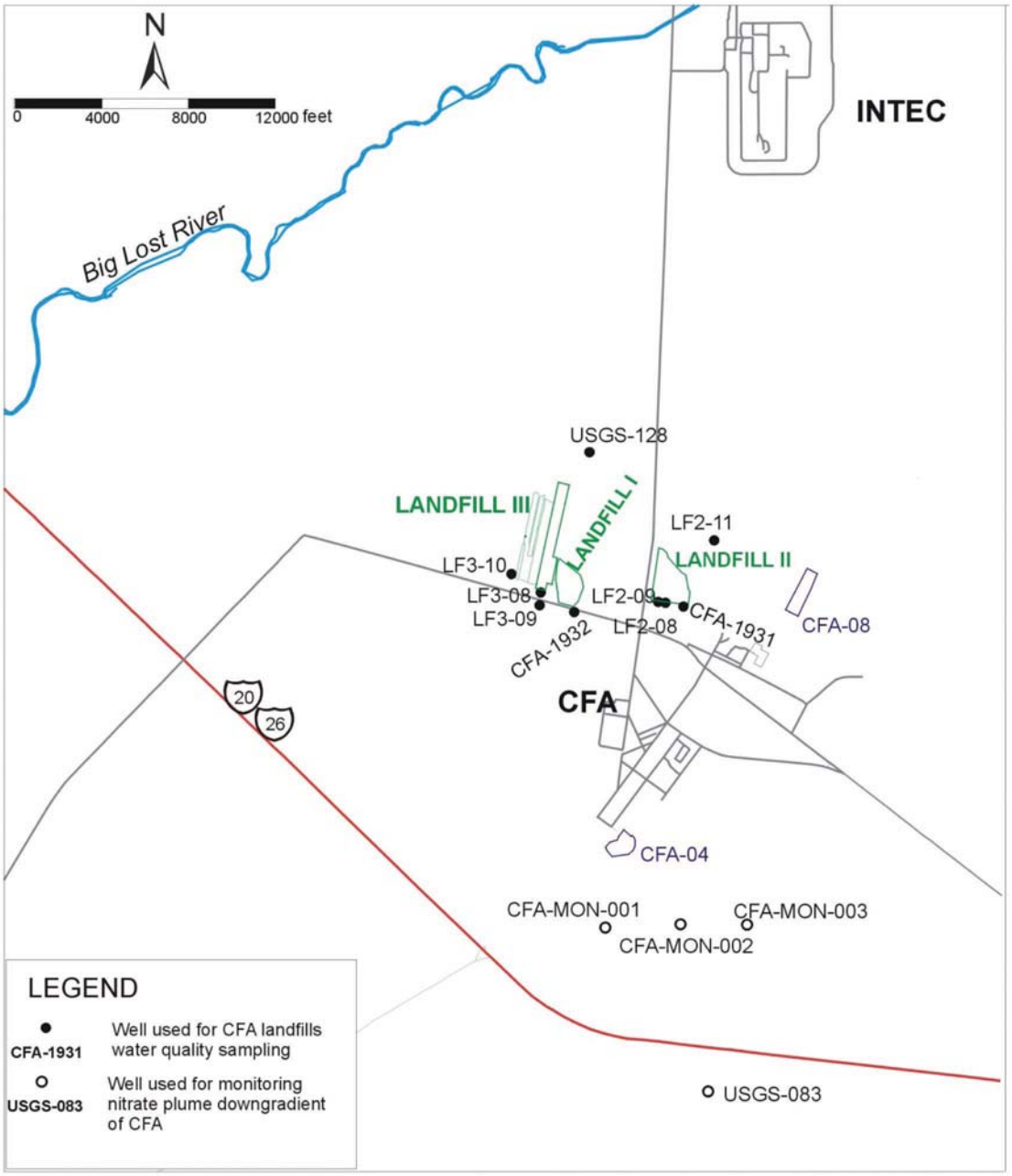

Figure 6-13. Locations of WAG 4/CFA Monitoring Wells Sampled in 2012.

Water-level measurements taken in the CFA area in 2012 suggest that after the sharp drop in water levels from 2000 to 2005, water levels appear to be stabilizing because they have changed little since 2005. A water table map produced from water levels collected in August 2012 was consistent with previous maps in terms of gradients and groundwater flow directions (DOE-ID 2013c).

Table 6-6. Comparison of WAG 4 Groundwater Sampling Results to Regulatory Levels (2012).

Compound	MCL[a] or SMCL[b]	Maximum Detected Value	Number of Wells above MCL or SMCL
Downgradient Central Facilities Area Wells			
Chloride (mg/L)	*250*[c]	58.9	0
Fluoride (mg/L)	**2**[d]	0.233	0
Sulfate (mg/L)	*250*	27.8	0
Nitrate/nitrite (mg-N/L)	10	**16.5**	1
Central Facilities Area Landfill Wells			
Anions			
Chloride (mg/L)	*250*	71.0	0
Fluoride (mg/L)	2	0.218	0
Sulfate (mg/L)	*250*	37.5	0
Nitrate/nitrite (mg-N/L)	10	2.82	0
Common Cations			
Calcium (µg/L)	None	55,600	NA[e]
Magnesium (µg/L)	None	16,800	NA
Potassium (µg/L)	None	5,620	NA
Sodium (µg/L)	None	34,500	NA
Inorganic Analytes			
Antimony (µg/L)	6	ND[f]	0
Aluminum (µg/L)	*50–200*	35.2	0
Arsenic (µg/L)	10	1.9	0
Barium (µg/L)	2,000	109	0
Beryllium (µg/L)	4	0.44	0
Cadmium (µg/L)	5	ND	0
Chromium (µg/L)	100	38.7	0
Copper (µg/L)	1,300/*1,000*	2	0
Iron (µg/L)	300	117	0
Lead (µg/L)	15[c]	0.33	0
Manganese (µg/L)	50	7.6	0
Mercury (µg/L)	2	0.088	0
Nickel (µg/L)	None	54.1	NA
Selenium (µg/L)	50	ND	0
Silver (µg/L)	*100*	ND	0
Thallium (µg/L)	2	ND	0
Vanadium (µg/L)	None	3.9	NA
Zinc (µg/L)	*5,000*	39.5	0
Detected Volatile Organic Compounds			
1,2,4-trimethylbenzene (µg/L)	None	0.158	0
2-butanone (µg/L)	None	0.892	0
2-hexanone (µg/L)	None	0.621	0
Chloroform (µg/L)	100	0.974	0
Methylcyclohexane (µg/L)	None	0.106	0
Toluene (µg/L)	1,000	2.76	0
1,1,1-trichloroethane (µg/L)	200	0.115	0

a. MCL = max. contaminant level.
b. SMCL = secondary max. contaminant level.
c. Numbers in *italics* are for the secondary MCL.
d. **Bold** values exceed an MCL or a secondary SMCL.
d. NA = not applicable.
e. ND = not detected.

6.7.5 Summary of Waste Area Group 5 Groundwater Monitoring Results

Groundwater was not monitored for WAG 5 in 2012. Groundwater monitoring for WAG 5 was concluded in November 2006 in accordance with the recommendations from the first five-year review (DOE-NE-ID 2007).

6.7.6 Summary of Waste Area Group 7 Groundwater Monitoring Results

Aquifer samples collected in the vicinity of RWMC in 2012 were analyzed for radionuclides, inorganic constituents, VOCs, and 1,4-dioxane. Of the 2,915 analyses performed on RWMC aquifer samples collected in 2012, 24 met reportable criteria. Table 6-7 lists relevant analytes that were detected above background reporting thresholds, detection limits, or quantitation limits.

Carbon tetrachloride and trichloroethylene were detected at concentrations above the reporting (quantitation) limit of 1 µg/L in 2012. Carbon tetrachloride was detected at six monitoring locations. One location, Well M7S (see Figure 6-14), had one sample and its associated field duplicate (taken in November 2012) that slightly exceeded the MCL of 5 µg/L. Figure 6-15 shows the annual concentration history of carbon tetrachloride at Well M7S. Trichloroethylene was detected at four locations below the MCL. Concentrations show little change relative to 2011 detections and are consistent with historical levels.

In May 2012, chlorine-36 was detected in Wells M4D, M7S, M13S, and M14S at concentrations ranging from 23 to 115 pCi/L. Though well below the MCL, these detections were surprising because three of the four wells are upgradient of RWMC, and chlorine-36 had not been detected previously in any of these locations. In November 2012, chlorine-36 was not detected in any location, thus negating the apparently anomalous results from the May event.

Uranium-238 was not detected in May 2012. It was detected at Well OW-2 in November 2012 at a concentration slightly above the background reporting threshold of 0.84 pCi/L

In general, concentrations of relevant analytes in the aquifer at RWMC are relatively stable or trending slightly downward.

6.7.7 Summary of Waste Area Group 9 Groundwater Monitoring Results

Five wells (four monitoring and one production) at the Materials and Fuels Complex (formerly Argonne National Laboratory-West) are sampled twice a year for selected radionuclides, metals, total organic carbon, total organic halogens, and other water quality parameters as required under the WAG 9 Record of Decision (Figure 6-16; ANL-W 1998). The reported concentrations of analytes that were detected in at least one sample are summarized in Table 6-8. Overall, the data show no discernable impacts from activities at the Materials and Fuels Complex.

6.7.8 Summary of Waste Area Group 10 Groundwater Monitoring Results

In accordance with the monitoring plan (DOE-ID 2012c), groundwater samples are collected for WAG 10 every two years at the locations shown on Figure 6-17. No groundwater samples were collected in 2012. The WAG 10 monitoring wells will be sampled in 2013.

Table 6-7. Summary of WAG 7 Aquifer Sampling and Analyses for Relevant Analytes in 2012.

Analyte	Number of Wells Sampled	Number of Analyses[a]	Number of Reportable Detections[b]	Concentration		Number of Detections Greater Than Maximum Contaminant Level	MCL[c]
				Maximum	Units		
Carbon tetrachloride	14	30	12	5.43	µg/L	2	5 µg/L
Trichloroethylene	14	30	7	2.65	µg/L	0	5 µg/L
Chlorine-36	14	30	4	115±16	pCi/L	0	700 pCi/L
Uranium-238	14	30	1	0.89±0.17	pCi/L	NA	NA

a. The number of analyses includes duplicate samples collected for quality control purposes.

b. Reported results are relevant analytes at concentrations greater than background reporting thresholds or quantitation limits, along with other analytes detected above maximum contaminant levels (MCLs). Background reporting thresholds do not apply to carbon tetrachloride and trichloroethylene because background concentrations in the Snake River Plain Aquifer are essentially zero; therefore, laboratory quantitation limits are used as reporting limits for volatile organic compounds.

c. MCL = maximum contaminant level. MCLs are from "National Primary Drinking Water Regulations" (40 CFR 141).

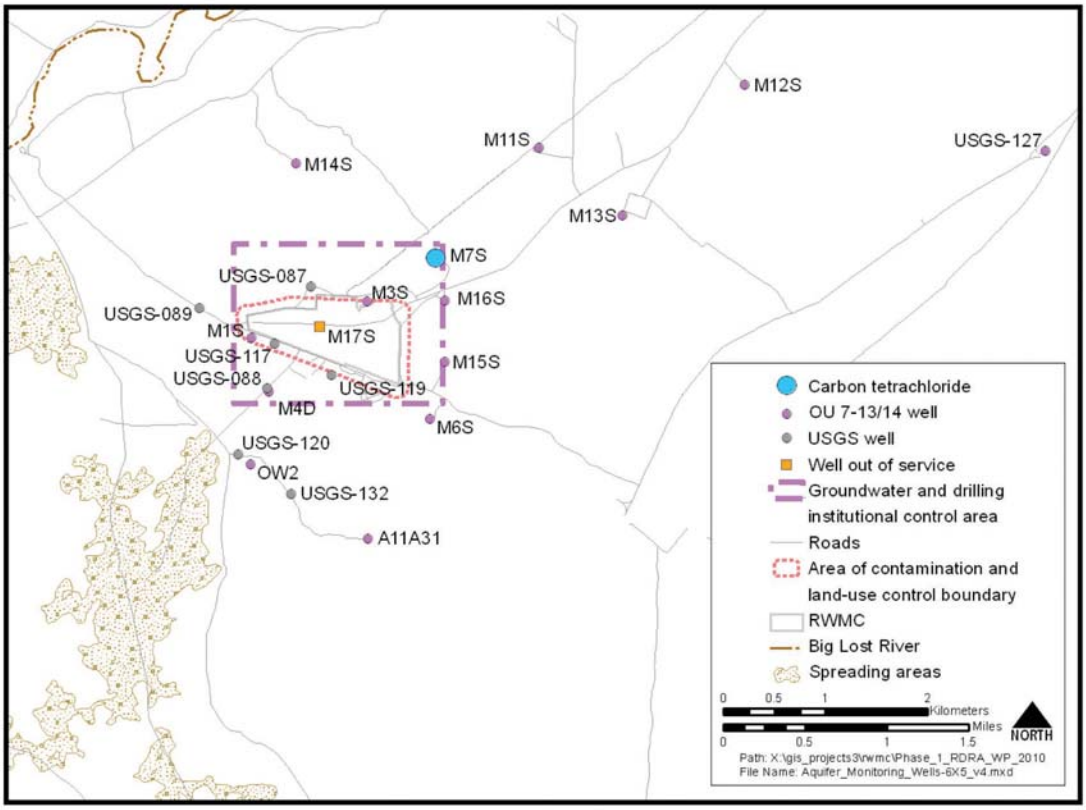

Figure 6-14. Location of Aquifer Monitoring Well M7S Where Carbon Tetrachloride Exceeded the MCL in May 2012.

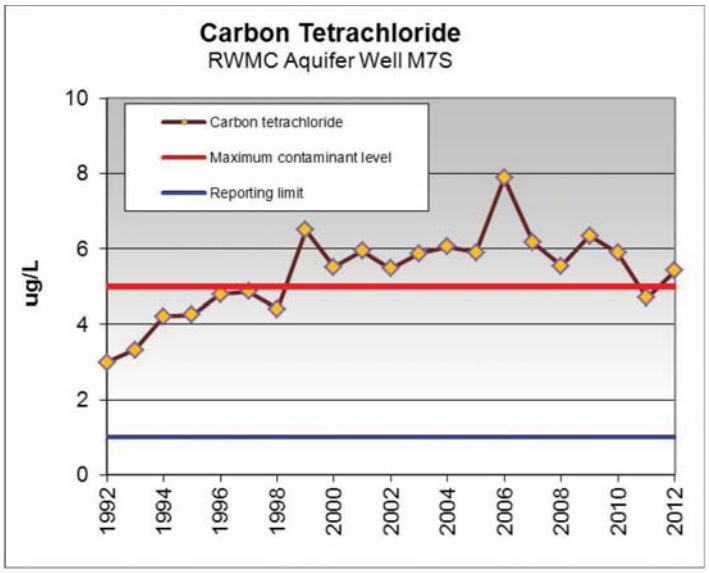

Figure 6-15. Annual Average Carbon Tetrachloride Concentrations in Aquifer Monitoring Well M7S North of the RWMC.

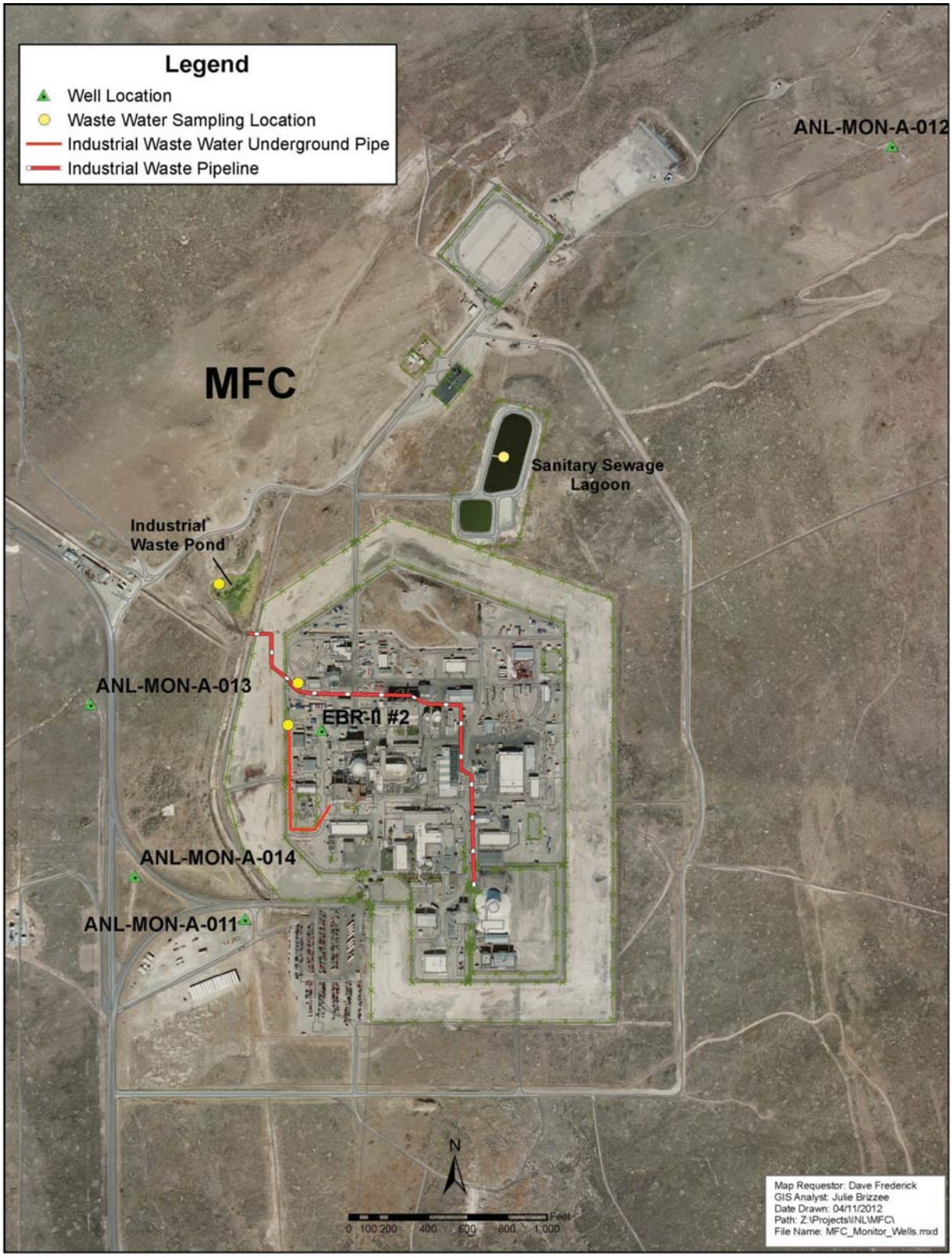

Figure 6-16. Locations of WAG 9 Wells Sampled in 2012.

Table 6-8. Comparisons of Detected Analytes to Drinking Water Standards at WAG 9 Monitoring Wells (2012).

Well:	ANL-MON-A-011		ANL-MON-A-012		ANL-MON-A-013		ANL-MON-A-014		EBR-II[a] No. 2		PCS/SCS[b]
Sample Date:	5/30/12	9/26/12	5/23/12	9/25/12	5/23/12	9/25/12	5/23/12	9/25/12	5/30/12	9/26/12	
Radionuclides[c]											
Gross alpha (pCi/L)	2.36 ± 0.832	ND[d]	3.07± 0.971	2.46 ± 0.989	ND	3.22 ± 1.11	ND (ND)[e]	ND	2.92 ± 0.974	ND	15 pCi/L
Gross beta (pCi/L)	3.05 ± 0.865	4.42 ± 1.35	ND	4.11 ± 1.29	4.76 ± 1.12	9.39 ± 1.39	4.22 ± 1.1 (4.18 ± 1)	ND	3.38 ± 0.927	4.53 ± 1.3	4 mrem/yr
Uranium-233/234 (pCi/L)	1.39 ± 0.209	1.29 ± 0.207	1.11 ± 0.139	1.29 ± 0.212	1.19 ± 0.153	1.26 ± 0.203	1.34 ± 0.158 (1.28 ± 0.166)	1.76 ± 0.257	1.31 ± 0.239	1.59 ± 0.267	186,000
Uranium-238 (pCi/L)	0.628 ± 0.127	0.559 ± 0.125	0.531 ± 0.0848	0.604 ± 0.132	0.639 ± 0.101	0.591 ± 0.127	0.578 ± 0.0903 (0.455 ± 0.0856)	0.614 ± 0.132	0.728 ± 0.163	0.627 ± 0.149	9.9
Metals											
Aluminum (µg/L)	19.1	5.9	10.7	7.4	8	5.3	7 (10.7)	7	4.3	3	200
Arsenic (µg/L)	1.9	2.2	1.7	2.7	2.1	2.7	1.6 (1.8)	2.7	1.8	2.3	50
Barium (µg/L)	33.9	38.3	36.6	39.7	34.1	35.4	34.2 (34.7)	36.1	35	36.1	2,000
Calcium (mg/L)	37	36.8	37.9	38.5	37.7	37.5	37.7 (37.4)	37.5	37.2	37	NE[f]
Chromium (µg/L)	2.7	2.5 U[g]	3.5	4.1	3.4	3.2	3.9 (3.6)	2.5 U	2.5 U	2.5 U	100
Copper (µg/L)	3.3	3.2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U (6.6)	2.5 U	2.5 U	2.5 U	1,300
Iron (µg/L)	50 U [50 U]	**318**[h] [50 U][i]	93.8 [50 U]	114 [50 U]	127 [50 U]	170 [50 U]	88.6 (183) [50 U (50 U)]	124 [50 U]	50 U [50 U]	50 U [50 U]	300
Lead (µg/L)	0.59	0.52	0.5 U	0.5 U	0.6	0.5 U	0.5 U (0.76)	0.5 U	1	0.5 U	15
Magnesium (mg/L)	11.9	11.8	11.5	11.8	12.2	12.1	12.1 (11.9)	12.1	11.8	11.7	NE
Manganese (µg/L)	2.5 U	3.1	3.2	2.5 U	2.6	2.6	2.5 U (2.8)	2.5 U	2.5 U	2.5 U	
Nickel (µg/L)	2.5 U	2.5 U (2.5 U)	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U (2.5 U)	2.5 U	6	3.2	NE
Potassium (mg/L)	3.37	3.13	3.64	3.5	3.3	3.15	3.37 (3.37)	3.19	3.38	3.12	NE
Selenium (µg/L)	0.54	0.57	0.54	0.68	0.55	0.58	0.57 (0.64)	0.55	0.58	0.62	50

Table 6-8. Comparisons of Detected Analytes to Drinking Water Standards at WAG 9 Monitoring Wells (2012). (cont.)

Well:	ANL-MON-A-011		ANL-MON-A-012		ANL-MON-A-013		ANL-MON-A-014		EBR-II[a] No. 2		PCS/SCS[b]
Sodium (mg/L)	18	17	18.3	17.7	19.2	18.2	18.2 (18.3)	17.3	18.3	17	NE
Vanadium (µg/L)	5.3	4.7	4.3	5.5	5	6	4.7 (4.4)	5.3	7.4	4.6	NE
Zinc (µg/L)	3.1	5.5	4.3	4.1	2.5 U	2.5 U	2.5 U (6)	2.5 U	22	8.6	5,000
Anions											
Chloride (mg/L)	18.5	18.6	17.3	17.9	19	18	18.7 (18.7)	18.5	19	18.7	250
Nitrate-as nitrogen (mg/L)	2.04	2.04	1.93	1.97	2.02	2.03	2 (2)	2.01	2	2	10
Phosphorus (mg/L)	0.01 U	0.0137	0.0125	0.015	0.0139	0.0145	0.0128 (0.0234)	0.0143	0.01 U	0.0134	NE
Sulfate (mg/L)	17.5	16.9	16.8	16.7	19.2	18.3	18.6 (18.5)	17.5	18.1	17.3	250
Water Quality Parameters											
Alkalinity (mg/L)	134	136	137	140	137	139	136 (134)	137	137	136	NE
Bicarbonate alkalinity (mg/L)	134	136	137	140	137	139	136 (134)	137	137	136	NE
Total dissolved solids (mg/L)	237	232	238	234	251	235	252 (254)	234	243	238	500
Total organic carbon (mg/L)	1 U	1 U	1 U	1 U	1.24	1.15	1 U (1 U)	1 U	1 U	1 U	NE

a. EBR-II = Experimental Breeder Reactor II.
b. PCS = primary constituent standard; SCS = secondary constituent standard.
c. Result ± 1s.
d. ND = not detected.
e. Results in parentheses are field duplicate.
f. NE = not established. A primary or secondary constituent standard has not been established for this constituent.
g. U = not detected at the concentration shown.
h. Concentrations shown in **bold** are above the Ground Water Quality Rule SCS. Filtered sample results, shown in brackets, are below the SCS.
i. Results in brackets are filtered (i.e., dissolved) concentrations.

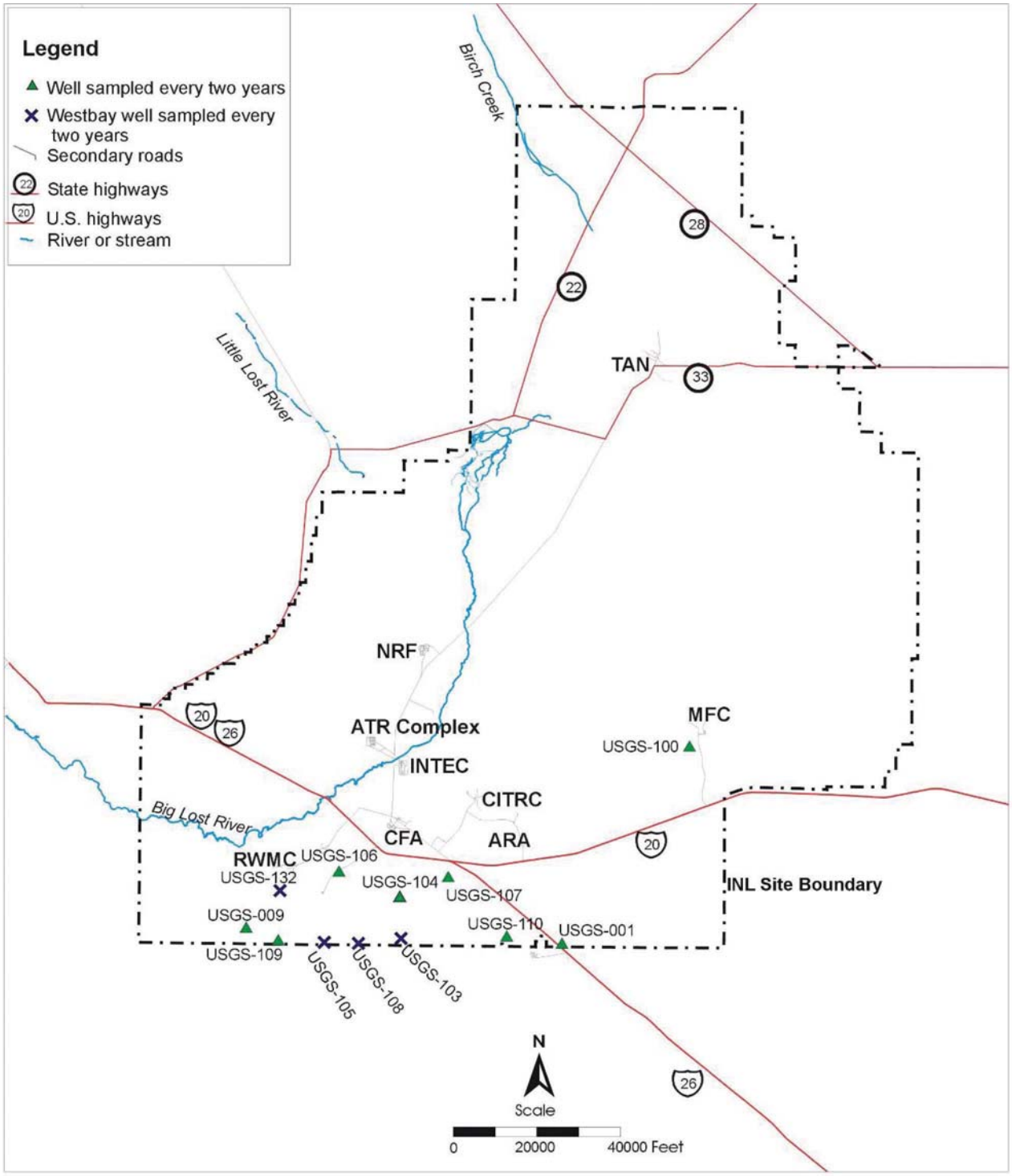

Figure 6-17. Locations and Sampling Frequency for Wells to be Sampled for Operable Unit 10-08 (note that wells were not sampled in 2012, but will be sampled in 2013).

6.8 Offsite Drinking Water Sampling

As part of the offsite monitoring program performed by the ESER contractor, drinking water samples were collected off the INL Site for radiological analyses in 2012. Two locations, Shoshone and Minidoka, which are downgradient of the INL Site, were co-sampled with the state of Idaho Department of Environmental Quality (DEQ) INL Oversight Program (IOP) in May and November. ESER also collected samples at Mud Lake, Atomic City, Craters of the Moon, Howe, Idaho Falls, Minidoka, and the public rest area at Highway 20/26. A control sample (bottled water) was obtained from a local grocery store. The samples were analyzed for gross alpha and beta activities and for tritium. The ESER contractor results are shown in Table 6-9. IOP results are reported quarterly and annually and can be accessed at http://www.deq.idaho.gov/inl-oversight.

Gross alpha activity was not detected in any samples collected. Gross beta activity was detected in all valid drinking water samples collected by ESER, except for the control sample. Gross beta activity has been measured at these levels historically in offsite drinking water samples. The results are below the screening MCL of 8 pCi/L for ^{90}Sr. This MCL is extremely conservative because the radionuclides contributing to the gross beta activity are most likely naturally-occurring decay products of thorium and uranium, which are present in the aquifer, and not ^{90}Sr, which is a man-made radionuclide.

Tritium was detected in some of the drinking water samples (including one of the control samples) collected in 2012. The results were within historical measurements and well below the EPA MCL of 20,000 pCi/L

6.9 Surface Water Sampling

Surface water was co-sampled with DEQ IOP in May and November 2012 at three springs located downgradient of the INL Site: Alpheus Springs near Twin Falls; Clear Springs near Buhl; and a trout farm near Hagerman (see Figure 6-18). ESER contractor results are shown in Table 6-10. Gross alpha activity was not detected in any sample. Gross beta activity was detected in all three surface water samples. The highest result was measured at Alpheus Springs and the lowest at Hagerman. Alpheus Springs has historically shown higher results, occasionally above 8 pCi/L, and is most likely due to natural decay products of thorium and uranium that dissolve into water as it passes through the surrounding basalts of the eastern Snake River Plain aquifer.

Tritium was not detected in any of the surface water samples collected by the ESER contractor.

The ESER contractor also collected surface water samples from the Big Lost River on the INL Site. The Big Lost River is an intermittent, ephemeral body of water that flows only during periods of high spring runoff and releases from the Mackay dam, which impounds the river upstream of the INL Site. The river flows through the INL Site and enters a depression, where the water flows into the ground, called Big Lost River Sinks (see Figure 6-18). The river then mixes with other water in the eastern Snake River Plain Aquifer. Water in the aquifer then emerges about 100 miles (160 km) away at Thousand Springs near Hagerman and other springs downstream of Twin Falls.

Table 6-9. Gross Alpha, Gross Beta, and Tritium Concentrations in Offsite Drinking Water Samples Collected by the ESER Contractor in 2012.

Location	Sample Results (pCi/L)[a]		
	Gross Alpha		
	Spring 2012	Fall 2012	EPA MCL[b]
Atomic City	ND[c]	ND	15 pCi/L
Control (bottled water)	ND	ND	15 pCi/L
Craters of the Moon	ND	ND	15 pCi/L
Howe	ND	ND	15 pCi/L
Idaho Falls	ND	ND	15 pCi/L
Minidoka	ND	ND	15 pCi/L
Mud Lake (Well #2)	ND	ND	15 pCi/L
Rest Area (Highway 20/26)	ND	ND	15 pCi/L
Shoshone	ND	ND	15 pCi/L
	Gross Beta		
	Spring 2012	Fall 2012	EPA MCL
Atomic City	3.78 ± 0.60	3.66 ± 0.61	4 mrem/yr (8 pCi/L ^{90}Sr)[d]
Control (bottled water)	ND	ND	4 mrem/yr (8 pCi/L ^{90}Sr)
Craters of the Moon	2.63 ± 0.62	2.52 ± 0.59	4 mrem/yr (8 pCi/L ^{90}Sr)
Howe	4.50 ± 0.60	1.75 ± 0.57	4 mrem/yr (8 pCi/L ^{90}Sr)
Idaho Falls	2.59 ± 0.58	4.29 ± 0.64	4 mrem/yr (8 pCi/L ^{90}Sr)
Minidoka	3.44 ± 0.59	3.96 ± 0.60	4 mrem/yr (8 pCi/L ^{90}Sr)
Mud Lake (Well #2)	5.45 ± 0.68	6.57 ± 0.68	4 mrem/yr (8 pCi/L ^{90}Sr)
Rest Area (Highway 20/26)	3.08 ± 0.64	1.96 ± 0.57	4 mrem/yr (8 pCi/L ^{90}Sr)
Shoshone	3.30 ± 0.55	3.28 ± 0.57	4 mrem/yr (8 pCi/L ^{90}Sr)
	Tritium		
	Spring 2012	Fall 2012	EPA MCL
Atomic City	ND	ND	20,000 pCi/L
Control (bottled water)	ND	116 ± 22	20,000 pCi/L
Craters of the Moon	ND	78 ± 22	20,000 pCi/L
Howe	ND	ND	20,000 pCi/L
Idaho Falls	ND	112 ± 23	20,000 pCi/L
Minidoka	ND	ND	20,000 pCi/L
Mud Lake (Well #2)	ND	ND	20,000 pCi/L
Rest Area (Highway 20/26)	186 ± 30	104 ± 22	20,000 pCi/L
Shoshone	ND	ND	20,000 pCi/L

a. Result ± 1s
b. EPA = Environmental Protection Agency; MCL = Maximum Contaminant Level.
c. ND = not detected (results < 3s)
d. The MCL for gross beta activity is not established. However, the EPA drinking water standard of 4 mrem/y for public drinking water systems is applied a conservative screening level of 8 pCi/L (the MCL for strontium-90) is used.

Table 6-10. Gross Alpha, Gross Beta, and Tritium Concentrations in Surface Water Samples Collected by the ESER Contractor in 2012.

Location	Sample Results (pCi/L)[a]		
	Gross Alpha		
	Spring[b]	Fall[b]	EPA MCL[c]
Alpheus Springs (Twin Falls)	ND[d]	ND	15 pCi/L
Clear Springs (Buhl)	ND	ND	15 pCi/L
Bill Jones Hatchery (Hagerman)	ND	ND	15 pCi/L
BLR[e] at Highway 20/26 rest area	ND	No water	15 pCi/L
BLR at EFS	ND	No water	15 pCi/L
BLR near INTEC	ND	No water	15 pCi/L
BLR near NRF	ND	No water	15 pCi/L
BLR at BLR Sinks	ND	No water	15 pCi/L
Birch Creek (control)	ND	No water	15 pCi/L
	Gross Beta		
	Spring	Fall	EPA MCL
Alpheus Springs (Twin Falls)	6.98 ± 0.68	6.55 ± 0.65	4 mrem/yr (8 pCi/L ^{90}Sr)[f]
Clear Springs (Buhl)	3.48 ± 0.58	5.47 ± 0.61	4 mrem/yr (8 pCi/L ^{90}Sr)
Bill Jones Hatchery (Hagerman)	2.41 ± 0.60	ND	4 mrem/yr (8 pCi/L ^{90}Sr)
BLR at Highway 20/26 rest area	ND	No water	4 mrem/yr (8 pCi/L ^{90}Sr)
BLR at EFS	2.60 ± 0.61	No water	4 mrem/yr (8 pCi/L ^{90}Sr)
BLR near INTEC	3.07 ± 0.61	No water	4 mrem/yr (8 pCi/L ^{90}Sr)
BLR near NRF	3.21 ± 0.62	No water	4 mrem/yr (8 pCi/L ^{90}Sr)
BLR at BLR Sinks	4.24 ± 0.64	No water	4 mrem/yr (8 pCi/L ^{90}Sr)
Birch Creek (control)	2.70 ± 0.64	No water	4 mrem/yr (8 pCi/L ^{90}Sr)
	Tritium		
	Spring	Fall	EPA MCL
Alpheus Springs (Twin Falls)	ND	ND	20,000 pCi/L
Clear Springs (Buhl)	ND	ND	20,000 pCi/L
Bill Jones Hatchery (Hagerman)	ND	ND	20,000 pCi/L
BLR at Highway 20/26 rest area	ND	No water	20,000 pCi/L
BLR at EFS	ND	No water	20,000 pCi/L
BLR near INTEC	93 ± 28	No water	20,000 pCi/L
BLR near NRF	116 ± 28	No water	20,000 pCi/L
BLR at BLR Sinks	128 ± 29	No water	20,000 pCi/L
Birch Creek (control)	ND	No water	20,000 pCi/L

a. Result ± 1s
b. The springs and hatchery were sample on May 7 and November 8, 2012. The Big Lost River was sampled on June 8, 2012, when water was available in the river.
c. EPA = Environmental Protection Agency; MCL = Maximum Contaminant Level.
d. ND = not detected (results < 3s).
e. BLR = Big Lost River.
f. The MCL for gross beta activity is not established. However, the EPA drinking water standard of 4 mrem/y for public drinking water systems is applied a conservative screening level of 8 pCi/L (the MCL for strontium-90) is used.

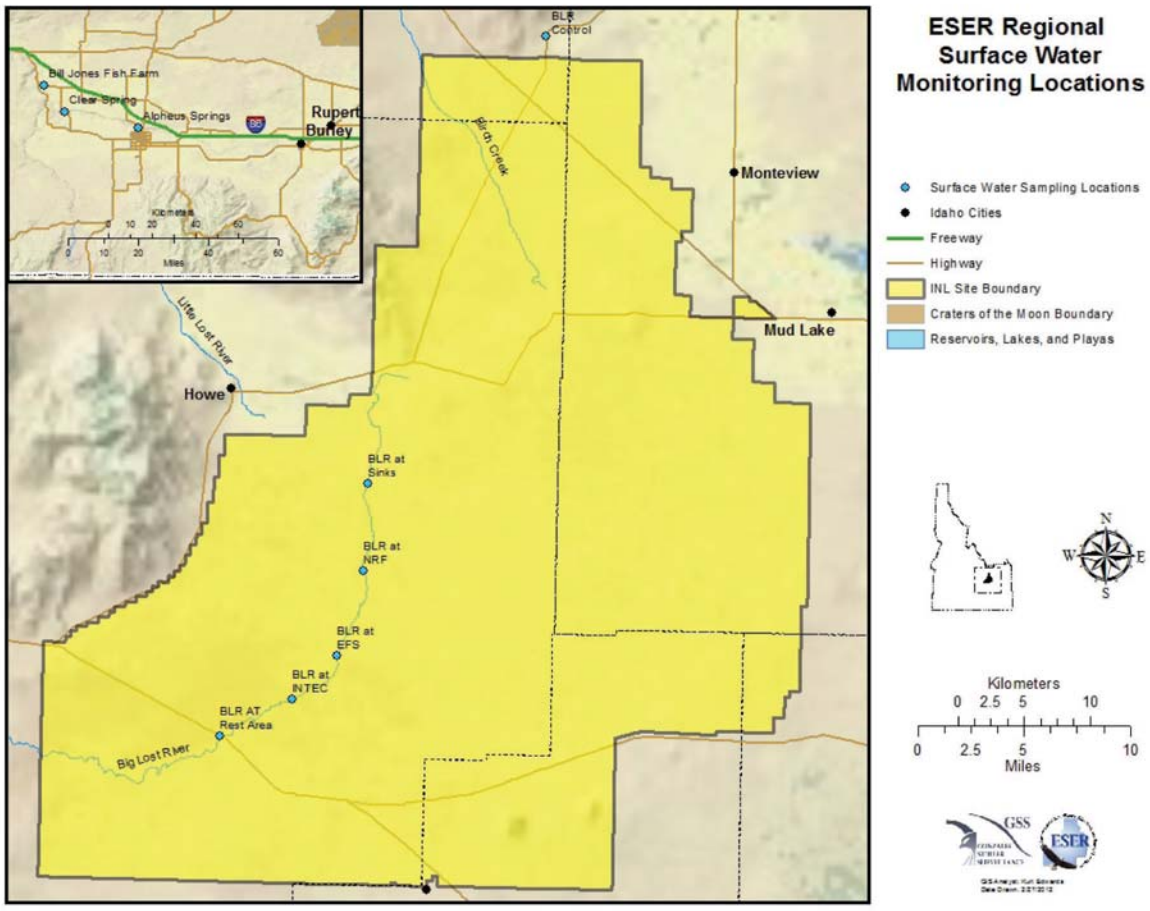

Figure 6-18. Detailed Map of ESER Program Surface Water Monitoring Locations.

In 2012, the Big Lost River had sufficient water flowing through it to collect samples at the following locations on June 8: the public rest stop on State Highway 20/26; along Lincoln Boulevard near INTEC; along Lincoln Boulevard near the Naval Reactors Facility; at the Experimental Field Station; and at the Big Lost River Sinks. A control sample was also collected from the Birch Creek drainage near the northern INL Site boundary.

Gross alpha activity was not detected in any of the samples, including the Birch Creek control. Gross beta activity was detected in most samples, including the Birch Creek control, at levels below the screening MCL for ^{90}Sr (8 pCi/L). It was not detected in the public rest stop sample.

Tritium was detected in three of five Big Lost River samples, however, at levels well below the MCL (20,000 pCi/L) and at levels consistent with those measured last year. The source of the tritium is most likely from remnants in the atmosphere from earlier bomb testing, as well as natural production in the atmosphere which then enters surface water through precipitation. It was not detected in the control sample collected from Birch Creek.

Samples from the Big Lost River and Birch Creek were also analyzed for gamma-emitting radionuclides. No human-made gamma-emitting radionuclides were detected in any of the samples.

Lost River Irrigation Project
Headgate ca. 1908

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7. Environmental Monitoring Programs - Agricultural Products, Wildlife, Soil, and Direct Radiation

2012

Sheepherder Cairn

Chapter 7 Highlights

Idaho National Laboratory (INL) Site-released radionuclides may be assimilated by agricultural products and game animals which humans may then consume. These media are thus sampled because of the potential transfer of radionuclides to people through food chains.

Radionuclides may also be deposited on soils and can be measured on the surface with detectors or in the laboratory through radioanalysis of samples. Direct radiation measurements detect ionizing radiation in the environment.

Some human-made radionuclides were detected in agricultural products (milk, lettuce, alfalfa, and elk forage) collected in 2012. However, the results could not be directly linked to operations at the INL Site.

No human-made gamma-emitting radionuclides were detected in any road-killed mammals sampled in 2012. However, several human-made radionuclides were detected in some samples of waterfowl collected on ponds at the INL Site. Concentrations of several of the man-made radionuclides were higher in waterfowl taken from ponds in the vicinity of the Advanced Test Reactor Complex than in control and other pond samples. The ducks most likely received the contamination while accessing the Advanced Test Reactor Complex ponds area. Results were similar to those found in the previous few years and significantly lower than in previous research studies.

Cesium-137 was analyzed in all soil samples collected off the INL Site. In addition, strontium-90 and plutonium-239,240 were detected in at least half of the samples analyzed. These radionuclides are associated with historical aboveground nuclear tests and the results track the expected decrease in concentration over time. They could not be directly associated with any INL Site releases. Americium-241, plutonium isotopes, and strontium-90 were detected in soil samples collected at the Radioactive Waste Management Complex at levels consistent with or lower than those observed historically. They are attributed to previous flooding and increased operational activity in the Subsurface Disposal Area.

Cesium-137 was measured in all INL Site surface soils surveyed using an in-situ gamma detector. These measurements are performed annually at and around specific INL Site facilities. Areas of known contamination, from historic activities on the INL Site, had higher scan results. Other areas showed results consistent with background levels from global fallout. Some in situ measurements around facilities also indicate the presence of other radionuclides associated with past INL Site operations.

Direct radiation measurements made at boundary and distant locations were consistent with background levels. The average annual dose equivalent from external exposure was 133 mrem at boundary locations and 130 mrem at distant locations. Radiation measurements taken in the vicinity of waste storage and soil contamination areas near INL Site facilities were consistent with previous measurements. Direct radiation measurements using a radiometric scanner system at the Radioactive Waste Management Complex were greater than background levels but lower than measurements taken prior to 2011. This is due to the fact that the active pit was covered in 2009.

7. ENVIRONMENTAL MONITORING PROGRAMS – AGRICULTURAL PRODUCTS, WILDLIFE, SOIL, AND DIRECT RADIATION

This chapter summarizes results of environmental monitoring of agricultural products, wildlife, soil, and direct radiation on and around the Idaho National Laboratory (INL) Site during 2012. Details of these programs may be found in the *Idaho National Laboratory Site Environmental Monitoring Plan* (DOE-ID 2012). The INL, Idaho Cleanup Project (ICP), and Environmental Surveillance, Education, and Research Program (ESER) contractors monitor soil, vegetation, biota, and direct radiation on and off the INL Site to comply with applicable U.S. Department of Energy (DOE) orders and other requirements. The focus of INL and ICP contractor monitoring is on the INL Site, particularly on and around facilities (Table 7-1). The ESER contractor's primary responsibility is to monitor the presence of contaminants in media off the INL Site which may originate from INL Site releases (Table 7-1).

7.1 Agricultural Products and Biota Sampling

Agricultural products and game animals are sampled by the ESER contractor because of the potential transfer of radionuclides to people through food chains (Figure 3-1).

7.1.1 Milk

Milk is sampled to monitor the pathway from potentially contaminated, regionally grown feed to cows to milk, which is then ingested by humans. During 2012, the ESER contractor collected 127 milk samples at various locations off the INL Site (Figure 7-1) and from commercially-available milk from outside the state of Idaho. The number and location of the dairies can vary from year to year as farmers enter and leave the business. Milk samples were collected weekly in Idaho Falls and monthly at other locations around the INL Site. All samples were analyzed for gamma-emitting radionuclides, including iodine-131 (^{131}I) and cesium-137 (^{137}Cs). During the second and fourth quarters, samples were analyzed for strontium-90 (^{90}Sr) and tritium.

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 (^{134}Cs) and ^{137}Cs, can dominate the ingestion dose regionally after a severe nuclear event such as the Chernobyl

Table 7-1. Environmental Monitoring of Agricultural Products, Biota, Soil, and Direct Radiation at the Idaho National Laboratory Site.

Area/Facility[a]	Media							
	Agricultural Products (milk, wheat, and potatoes)	Biota (waterfowl, large game animals)	Biota (vegetation)	CERCLA Ecological (Soil, sediment, water, vegetation, and animals)	Soil	In-Situ Gamma Spectrometry (^{137}Cs in soil)	Direct Radiation (global positioning radiometric scanner)	Direct Radiation (TLD/OSLDs)
Environmental Surveillance, Education, and Research Program Contractor								
INL Site/Regional	•	•	•	•	•			•
Idaho National Laboratory Contractor								
CFA (WRP)				•				
INL Site						•		•
Regional								•
Idaho Cleanup Project Contractor								
RWMC			•		•		•	

a. CFA (WRP) = Wastewater Reuse Permit soil sampling at Central Facilities Area
INL Site = Idaho National Laboratory Site facility areas and areas between facilities
RWMC = Radioactive Waste Management Complex.

accident (Kirchner 1994) or the 2011 accident at Fukushima in Japan. Iodine-131 has a short half-life (8 days) and therefore does not persist in the environment. Past releases from experimental reactors at the INL Site and fallout from atmospheric nuclear weapons tests and Chernobyl are no longer present. A small amount of ^{131}I (approximately 2.4 mCi in 2012) is still released by the Advanced Test Reactor (ATR) at the INL Site but is not detected in air samples collected at the INL Site boundary (Chapter 4). Iodine-131 was not detected in any milk sample during 2012.

Cesium-137 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 if in soluble form 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

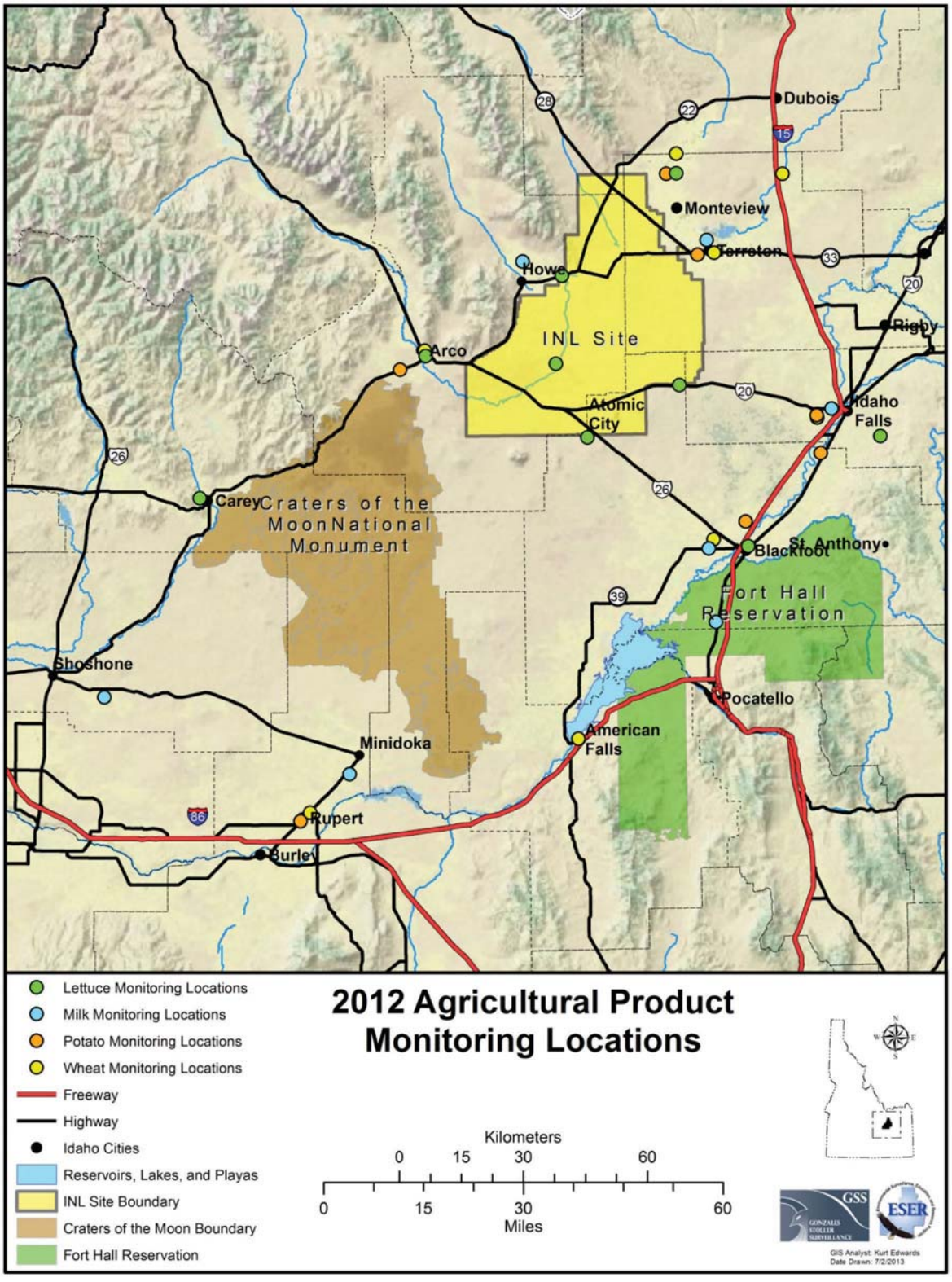

Figure 7-1. Locations of Agricultural Product Samples Collected (2012).

in all environmental media at the INL Site. Regional sources include releases from INL facilities and resuspension of previously contaminated soil particles. Cesium-137 was reported in one milk sample collected in October at exactly the lower detection limit. A subsequent recount of the sample did not indicate the presence of ^{137}Cs.

Strontium-90 is an important radionuclide because it behaves like calcium and can deposit in bones. Strontium-90, like ^{137}Cs, 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, compared to ^{137}Cs, and therefore comparatively mobile in ecosystems. Strontium-90 was detected in nine of 13 milk samples analyzed, including the two control samples from outside the state. Concentrations ranged from 0.07 pCi/L at Terreton to 2.13 pCi/L at Howe (Figure 7-2). While the maximum value in 2012 is at the upper end of the range during the past five years shown in Figure 7-2, these levels were consistent with historical levels and with levels reported by the U.S. Environmental Protection Agency (EPA) as resulting from worldwide fallout deposited on soil and taken up by cows through ingestion of grass. Results from EPA Region 10 (which includes Idaho) of ten samples collected over a 10-year period (2002-2011) ranged from 0 to 1.2 pCi/L (EPA 2013).

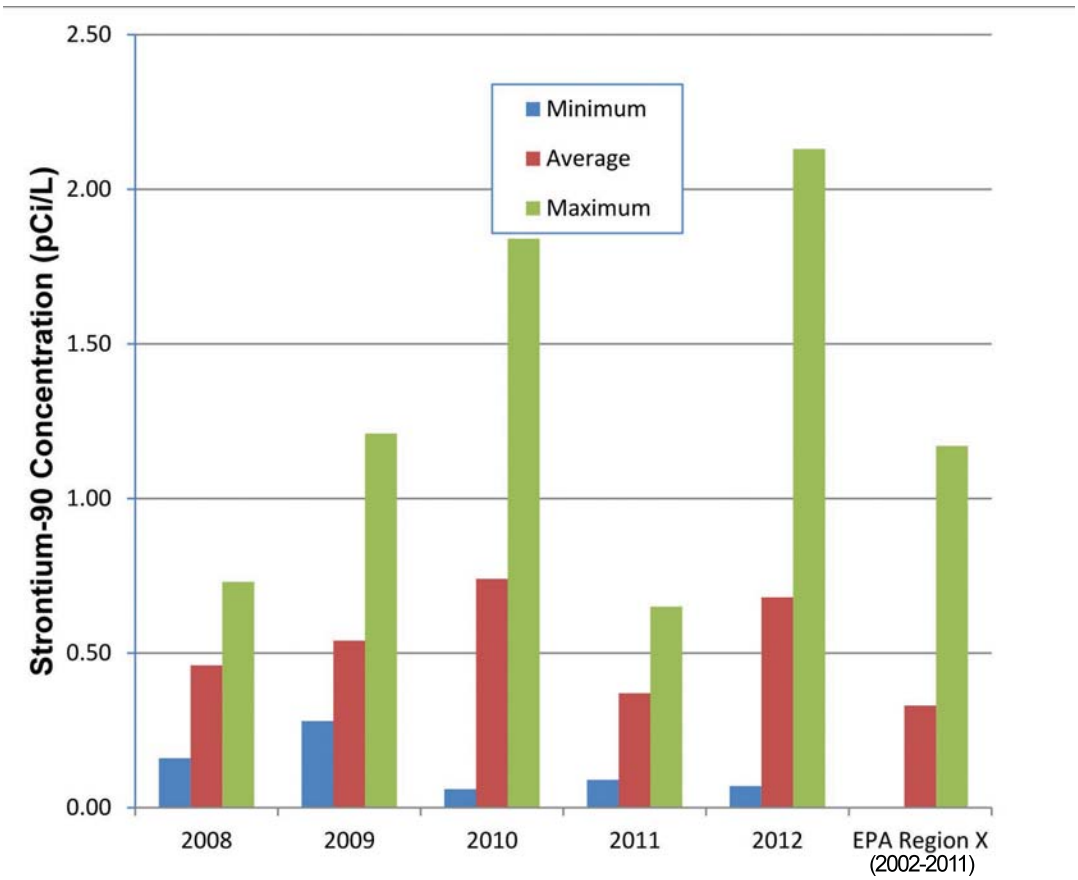

Figure 7-2. Strontium-90 Concentrations in Milk (2008 – 2012).

DOE has established Derived Concentration Standards (DCSs) for radionuclides in air and water. A DCS is the concentration of a radionuclide in air or water that would result in a dose of 100 mrem from ingestion, inhalation, or immersion in a gaseous cloud for one year. There is no established DCS for foodstuffs such as milk. For reference purposes, the DCS for ^{90}Sr in water is 1,100 pCi/L. The maximum observed value in milk samples (2.13 pCi/L) is, therefore, approximately 0.2 percent of this DCS for drinking water.

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 from plants that contain water. Tritium was detected in eight of 12 milk samples analyzed at concentrations ranging from 75 pCi/L in Rupert to 139 pCi/L in Dietrich. These concentrations are similar to those of previous years and are consistent with those found in atmospheric moisture and precipitation samples. The DCS for tritium in water is 19,000 pCi/L. The maximum observed value in milk samples is about 0.7 percent of the DCS.

7.1.2 Lettuce

Lettuce was sampled in 2012 because radionuclides in air can be deposited on soil and plants, which can then be ingested by people (Figure 3-1). Uptake of radionuclides by plants may occur by root uptake from soil or absorption of deposited material on leaves. For most radionuclides, uptake by foliage is the dominant process for contamination of plants (Amaral et al. 1994). For this reason, green leafy vegetables like lettuce have higher concentration ratios of radionuclides to soil than other kinds of plants. The ESER contractor collects lettuce samples every year from areas on and adjacent to the INL Site. The number and locations of gardens have changed from year to year depending on whether or not vegetables were available. Some home gardens were replaced with portable lettuce planters (Figure 7-3) because the availability of lettuce from home gardens was unreliable at some key locations. Also, the planters can be placed and lettuce collected at areas previously unavailable to the public, such as on the INL Site and near air samplers. The planters can allow radionuclides deposited from air to accumulate on the soil and plant surfaces throughout the growth cycle. The planters are placed in the spring, filled with soil, sown with lettuce seed, and self-watered through a reservoir.

Five lettuce samples were collected from portable planters at Arco, Atomic City, the Experimental Field Station, the Federal Aviation Administration Tower, and Monteview. In addition, samples were obtained from home gardens at Blackfoot, Carey, Howe, and Idaho Falls. A control sample from an out-of-state location was obtained, and a duplicate sample was collected at Howe. The samples were analyzed for ^{90}Sr and gamma-emitting radionuclides. Strontium-90 was detected in five of the 11 lettuce samples collected. The maximum ^{90}Sr concentration of 164 pCi/kg, measured in the lettuce sample from the onsite Experimental Field Station, was above the range of concentrations detected in the past 5 years (0-112 pCi/kg) but was similar to those seen in some previous years. This result was most likely fallout from past weapons testing and not INL Site operations. Strontium-90 is present in the environment as a residual of fallout from aboveground nuclear weapons testing, which occurred between

Figure 7-3. Portable Lettuce Planter.

1945 and 1980. Figure 7-4 shows the average and range of all measurements (including those below detection levels) from 2008 through 2012. No other human-made radionuclides were detected in any of the lettuce samples. Although ^{137}Cs from nuclear weapons testing fallout is measureable in soils, the ability of vegetation such as lettuce to incorporate cesium from soil in plant tissue is much lower than for strontium (Fuhrmann et al. 2003; Ng et al. 1982; Schulz 1965). In addition, the availability of ^{137}Cs to plants depends highly on soil properties, such as clay content or alkalinity, which can act to bind the radionuclide (Schulz 1965). Soils in southeast Idaho tend to be moderately to highly alkaline. Strontium, on the other hand, has a tendency to form compounds that are comparatively soluble. These factors could help explain why ^{90}Sr was detected in lettuce and ^{137}Cs was not.

For more detail see http://www.or.nrcs.usda.gov/pnw_soil/id_reports.html.

7.1.3 Grain

Grain (including wheat and barley) is sampled because it is a staple crop in the region. The ESER contractor collected nine grain samples from areas surrounding the INL Site in 2012 and obtained one commercially-available sample from outside the state of Idaho. The locations were selected because they are typically farmed for grain and are encompassed by the air surveillance network. Exact locations may change as growers rotate their crops. No human-made, gamma-

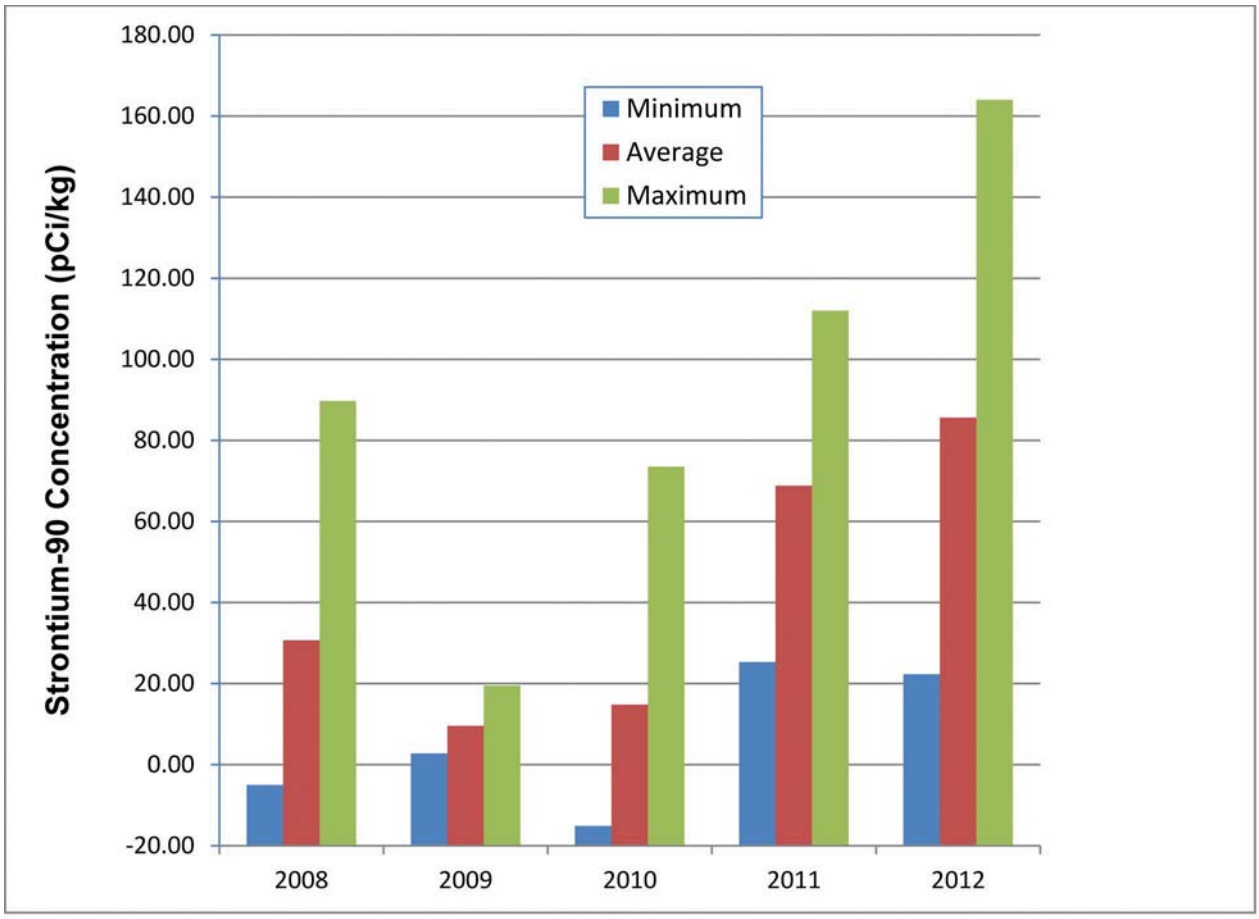

Figure 7-4. Strontium-90 Concentrations in Lettuce (2008 – 2012).

emitting radionuclides were found in any samples. None of the ten grain samples collected in 2012 contained detectable concentrations of ^{90}Sr either.

The concentrations of ^{90}Sr measured in grain are generally less than those measured in lettuce. Agricultural products such as fruits and grains are naturally lower in radionuclides than green, leafy vegetables (Pinder et al. 1990). No other human-made radionuclides were detected in any of the samples. As discussed in Section 7.1.2, strontium in soil from fallout is more bioavailable to plants than cesium.

7.1.4 Potatoes

Potatoes are collected because they are one of the main crops grown in the region and are of special interest to the public. Because they are not exposed to airborne contaminants, they are not typically considered a key part of the ingestion pathway. Potatoes were collected by the ESER contractor at eight locations in the vicinity of the INL Site and obtained from one location outside eastern Idaho. None of the nine potato samples collected during 2012 contained a detectable concentration of any human-made, gamma-emitting radionuclides or ^{90}Sr.

7.1.5 Alfalfa

In addition to analyzing milk, the ESER contractor began collecting data in 2010 on alfalfa consumed by milk cows. This was in response to the DOE Headquarters Independent Oversight Assessment of the Environmental Monitoring program at the Idaho National Laboratory Site conducted during that year. The assessment team commented, with reference to the milk sampling program, that the ESER contractor should consider sampling locally grown alfalfa offsite, along with collection of alfalfa usage data. Questionnaires were sent to each milk provider concerning what they feed their cows. All of the dairies feed their cows locally-grown alfalfa. A sample of alfalfa was collected in June from a farm in Terreton, the agricultural area where the highest potential offsite air concentration was calculated by the National Oceanic and Atmospheric Administration Air Resources Laboratory – Field Research Division (see Figure 8-5). (Note: The highest offsite air concentration used for estimating doses was located south of the INL Site; however, there is no agriculture conducted there.) The sample was divided into three subsamples and analyzed for gamma-emitting radionuclides and ^{90}Sr. No human-made gamma-emitting radionuclides were detected in any of the subsamples. Strontium-90 was found in one of the three subsamples at a level just above the detection limit. The measured value of 145 pCi/kg is similar to results from the first year of sampling and similar to typical concentrations in lettuce.

7.1.6 Large Game Animals

Muscle, liver, and thyroid samples were collected by the ESER contractor from two game animals (both mule deer) accidentally killed on INL Site roads. The samples were analyzed for ^{137}Cs because it is an analogue of potassium and is readily incorporated into muscle and organ tissues. Thyroids were analyzed for iodine-131 because when assimilated by higher animals, it selectively concentrates in the thyroid gland and is, thus, an excellent bioindicator of atmospheric releases.

No ^{131}I was detected in either of the thyroid samples. No ^{137}Cs or other human-made gamma-emitting radionuclides were found in any of the muscle or liver samples.

In 1998 and 1999, four pronghorn, five elk, and eight mule deer muscle samples were collected as background samples from hunters across the western United States, 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 1999). Each background sample had small, but detectable, ^{137}Cs 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. With the exception of an immature deer sampled in 2008 that had elevated ^{137}Cs concentrations, all detected values have been between about 4 and 11 pCi/kg.

7.1.7 Waterfowl

Waterfowl are collected each year by the ESER contractor at ponds on the INL Site and at a location off the INL Site. Nine ducks were collected during 2012: three each from the ATR Complex wastewater ponds, the Materials and Fuels Complex (MFC) wastewater ponds, and a control location near American Falls Reservoir. Each sample was divided into the following three subsamples: (1) edible tissue (muscle, gizzard, heart, and liver), (2) external portion (feathers,

feet, and head), and (3) all remaining tissue. All samples were analyzed for gamma-emitting radionuclides, ^{90}Sr, plutonium-238 (^{238}Pu), plutonium-239/240 ($^{239/240}$Pu), and americium-241 (^{241}Am). These radionuclides were selected because they are often measured in liquid effluents from some INL Site facilities (Chapter 5).

Several human-made radionuclides were detected in at least one subsample from one of the ducks collected at the ATR Complex ponds, including ^{137}Cs, cobalt-60 (^{60}Co), ^{90}Sr, and zinc-65 (^{65}Zn). Cesium-137 and ^{60}Co were found in the edible tissue portion of this duck. Strontium-90 was detected in the remaining tissue and ^{65}Zn was measured in the remainder and external portions of the same duck. Cesium-137 was found in the remainder portion of two of the control ducks but not in the edible tissues. No human-made radionuclides were detected in birds from the MFC location. Radionuclide concentrations measured in the tissues of the duck from ATR Complex with measurable concentrations are shown in Figure 7-5.

Because most of the detected human-made radionuclides were found in ducks from ATR Complex and not at other locations, it is assumed that this facility is the source of these radionuclides. The ducks were not taken directly from the two-celled, Hypalon®-lined radioactive wastewater evaporation pond, but rather from an adjacent sewage lagoon. However, the ducks likely used the evaporation pond. Concentrations of ^{137}Cs in 2012 were somewhat higher than those in 2011 but well within the range for the previous few years; ^{60}Co was about the same as the previous year. Both ^{90}Sr and ^{65}Zn concentrations were considerably lower. In addition, concentrations were lower in 2012 than those of a 1994 – 1998 study (Warren et al. 2001). Further information on potential doses from consuming waterfowl is presented in Chapter 8.

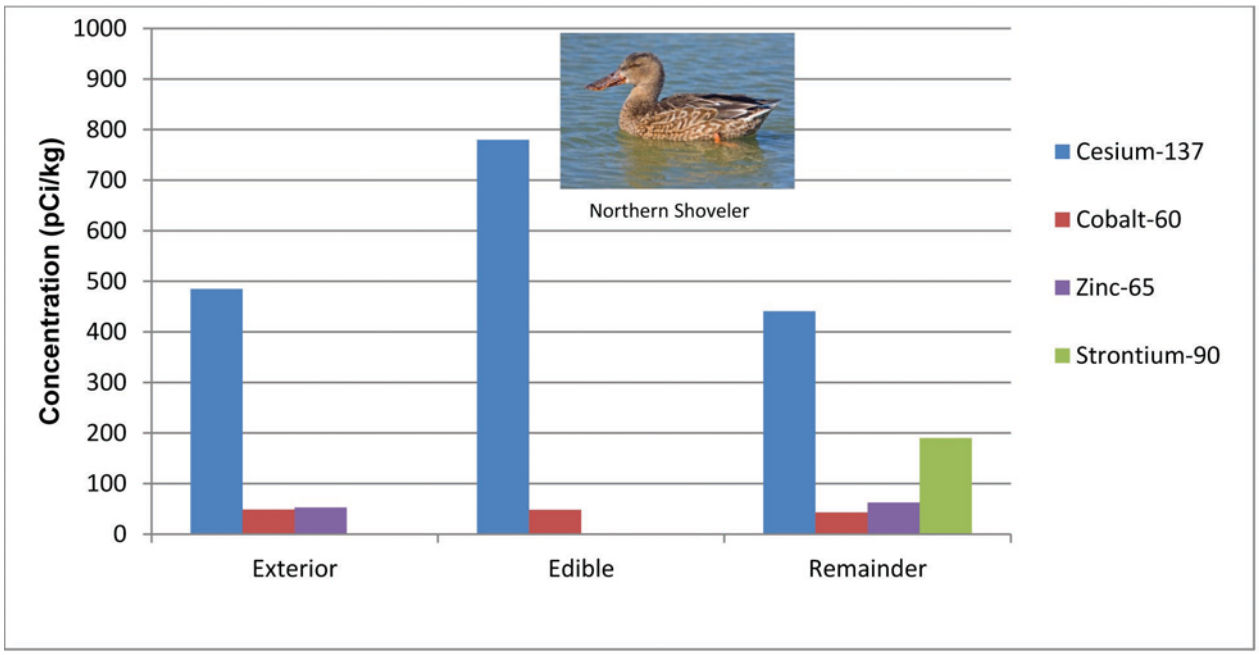

Figure 7-5. Radionuclide Concentrations Detected in Tissues of Waterfowl (2012).

7.2 Soil Sampling and In Situ Gamma Spectrometry

7.2.1 Soil Sampling off the INL Site

Aboveground nuclear weapons testing has resulted in many radionuclides being distributed throughout the world via atmospheric deposition. Cesium-137, ^{90}Sr, ^{238}Pu, $^{239/240}$Pu, and ^{241}Am are radionuclides that may be detected in soil because of global fallout but could also be present from INL Site operations. These radionuclides are of particular interest because of their abundance resulting from nuclear fission events (e.g., ^{137}Cs and ^{90}Sr) or from their persistence in the environment due to long half-lives (e.g., $^{239/240}$Pu, with a half-life of 24,110 years). Soil samples are collected by the ESER contractor every two years (in even-numbered years). Soil sampling locations are shown in Figure 7-6. A new location was added in 2010 at Frenchman's Cabin located at the southern boundary of the INL Site. This location has been the site of the maximally exposed individual for EPA dose calculations performed to comply with EPA requirements during recent years (see Chapter 8). Soil samples are analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{241}Am, and plutonium radionuclides.

Soil was sampled by the ESER contractor in 2012. No ^{241}Am or ^{238}Pu was detected in any sample. Cesium-137 was above the detection limit in all the samples collected, and ^{90}Sr was present in about half the samples. Plutonium-239/240 was above the detection limit in 11 out of 14 samples analyzed. This radionuclide had not been detected during the previous two sampling cycles but a lower detection limit was achieved this year by the analytical laboratory. Results for ^{137}Cs, $^{239/240}$Pu, and ^{90}Sr from the beginning of sampling in 1975 to 2012 are presented in Figure 7-7.

Aboveground nuclear weapons testing has been extremely limited since 1975, and no tests have occurred since 1980, so no ^{137}Cs and ^{90}Sr have been deposited on soil from sources outside the INL Site in that time. It would be expected that the concentrations of these two radionuclides would decrease over time from the levels measured in 1975 at a rate consistent with their approximate 30-year half-lives unless the INL Site was having an impact. Figure 7-7 shows that ^{137}Cs follows the expected decay line fairly closely. Strontium-90 has been tracking below the expected line during the past several sampling cycles. This may be because the samples represent the top 12.5 cm (5 in.) of soil and some of the ^{90}Sr may have migrated to deeper levels, and some of the ^{90}Sr may have been taken up by vegetation. No accumulation of either radionuclide on soil by INL Site operations is indicated.

No particular trend is indicated in the graph of $^{239/240}$Pu concentrations over time in Figure 7-7. This is consistent with the long half-life of the radionuclide, but the graph also does not indicate any accumulation over time from INL Site operations.

7.2.2 Wastewater Reuse Permit Soil Sampling at Central Facilities Area

The Wastewater Reuse Permit for the Central Facilities Area Sewage Treatment Facility allows nonradioactive wastewater to be pumped from the treatment lagoons to the ground surface by sprinkler irrigation. The permit requires collection of soil samples at ten locations within the land application area in 2010 and 2013. No soil samples were collected in 2012.

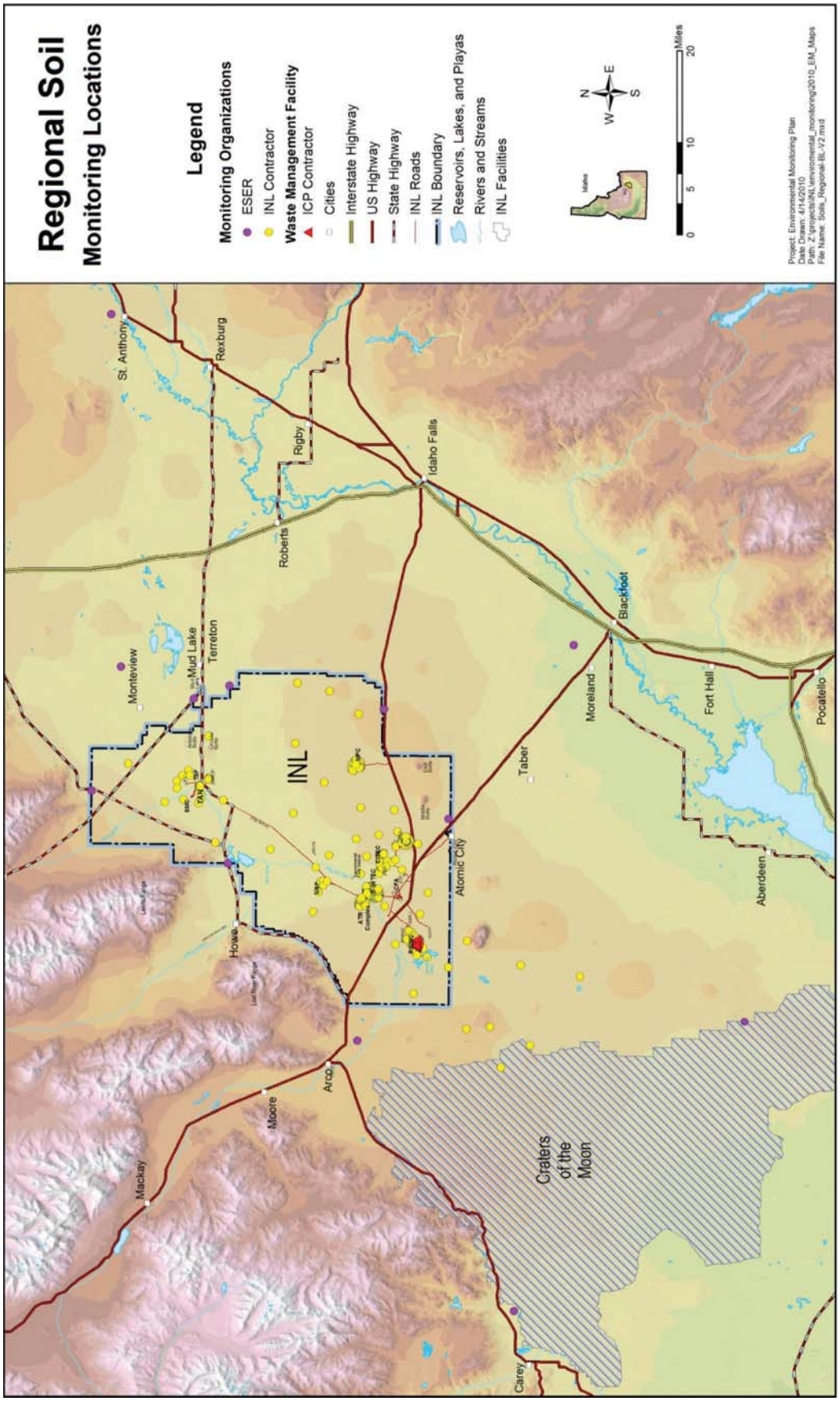

Figure 7-6. Soil Sampling Locations.

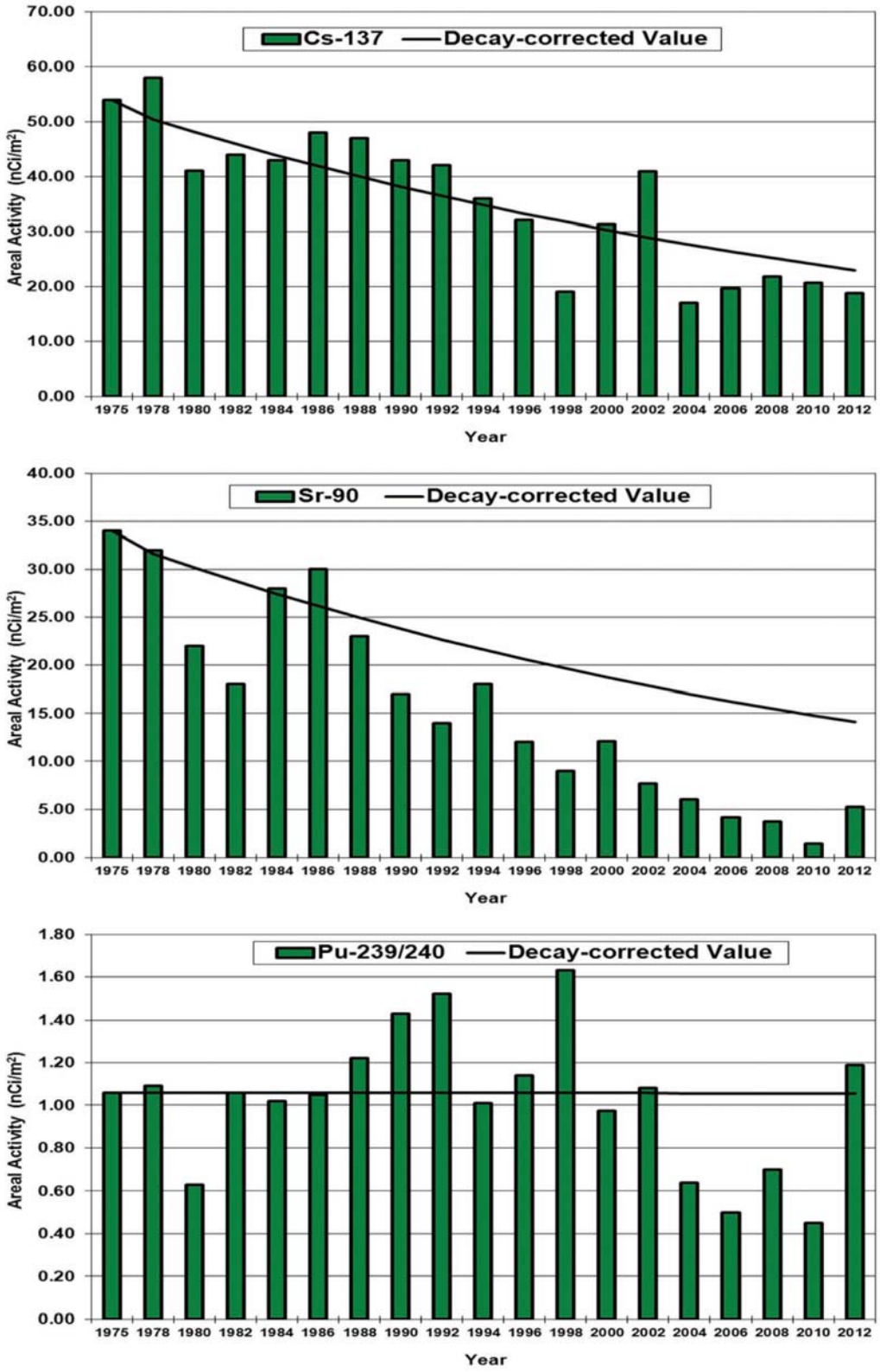

Figure 7-7. Mean Activities in Surface (0 – 12 cm [0 – 5 in.]) Soils off the INL Site (1975 – 2012).
Note: The graph uses all data points regardless of whether or not they exceeded 3s detection limit

7.2.3 In-Situ Gamma Spectrometry

In-situ gamma spectrometry using portable high purity germanium detectors is a technique that measures the gamma-ray fluence rate from a gamma-emitting source for the purpose of obtaining the activity or concentration of radioactive materials (Shebell et al. 2003). The most common application of in-situ gamma-ray spectrometry has been the measurement of gamma-emitting radionuclides, such as ^{137}Cs, in surface soils. The technique is a rapid and cost effective way to assay surface soil for gamma-emitting radionuclides, especially as part of site characterization. Results in this report are those that were true positive detects. This means that the reported isotopic concentration was greater than three times the reported uncertainty for that isotope.

The INL contractor performed 61 field-based gamma spectrometry measurements in 2012 using several high purity germanium detector measurement systems based on the methodology described in the Environmental Measurements Laboratory Procedures Manual (DOE 1997). A summary of 2012 measured results, historical mean background values, and 99 percent upper threshold values based on grab sampling is presented in Table 7-2. Measured ^{137}Cs concentrations are reported for all measurement locations. Appendix D shows facility maps with the positive detect values. At the Radioactive Waste Management Complex (RWMC), positive detect values of ^{241}Am were noted at three locations along the east and north boundary areas. These values are primarily due to the shine from above-ground waste storage and disposal operations sites. Five elevated ^{60}Co values were also noted. At ATR Complex, seven locations showed very low concentrations (positive detects) of ^{60}Co, and one location showed a positive detect for ^{241}Am. Cesium-134 was detected eleven times. Idaho Nuclear Technology and Engineering Center (INTEC) results showed one positive detect for ^{60}Co, two for ^{238}U, and thirteen for ^{134}Cs. At the Auxiliary Reactor Area, eleven positive detects for ^{134}Cs and one positive detect for ^{238}U were noted. Two positive detects for ^{134}Cs were observed at Critical Infrastructure Test Range Complex (CITRC). For the large grid, three positive detects for ^{134}Cs were noted. At MFC, seven positive detects were recorded for ^{134}Cs, and single positive detects were noted for ^{60}Co and ^{238}U. At Test Area North-Specific Manufacturing Capability (TAN-SMC), there was one ^{238}U and four ^{134}Cs positive detects.

Although some of the measured concentrations of the anthropogenic radionuclides exceed the 95 percent/99 percent Upper Concentration Limit, the values are consistent with levels observed in the past. Additionally, the locations of the positive detections are typically near existing operational facilities, such as INTEC and the ATR Complex, and the activity is attributed to historical releases. Other positive detections occurred near inactive facilities, or facilities that have been removed such as Auxiliary Reactor Area and TAN, and are attributed to residual contamination from historical releases.

The anthropogenic radionuclides detected in INL Site soils in 2012 included ^{137}Cs, ^{134}Cs, ^{60}Co, and ^{241}Am. Cesium-137 has a half-life of 30.2 years and originates as a fallout fission product from nuclear weapons testing or from past effluent or stack releases. Cesium-137 is strongly retained on clay soils, which limits plant uptake and it is not readily soluble in fresh water. Cesium-137 human metabolism resembles that of potassium, so it can be uniformly distributed in the body. The mean background concentration of ^{137}Cs at the INL is documented to be 0.44 pCi/g and the upper threshold limit is 1.61 pCi/g based on results from historical

Table 7-2. In-Situ Gamma Scan Results for INL Site Locations (2012) (all values in pCi/g).

Location	Radionuclide detected	Number of Observations	Minimum	Maximum	Mean	INL Mean Background Value[a]	95%/99% UCL[b]
ARA	Cs-134	11	0.05	0.08	0.06	NA[c]	NA
ARA	Cs-137	12	0.09	1.62	0.56	0.44	1.61
ARA	U-238	1	----	5.47	----	1.04	2.15
CITRC	Cs-134	2	0.058	0.08	0.07	NA	NA
CITRC	Cs-137	2	0.16	0.17	0.17	0.44	1.61
INTEC	Co-60	1	----	0.033	----	NA	NA
INTEC	Cs-134	13	0.05	0.08	0.07	NA	NA
INTEC	Cs-137	14	0.53	2.72	1.57	0.44	1.61
INTEC	U-238	2	4.2	5.56	4.88	1.04	2.15
Large Grid	Cs-134	3	0.06	0.063	0.06	NA	NA
Large Grid	Cs-137	3	0.13	0.24	0.19	0.44	1.61
MFC	Co-60	1	----	0.20	----	NA	NA
MFC	Cs-134	7	0.05	0.07	0.06	NA	NA
MFC	Cs-137	8	0.1	0.22	0.16	0.44	1.61
MFC	U-238	1	----	2.58	----	1.04	2.15
NRF	Cs-134	2	0.03	0.08	0.06	NA	NA
NRF	Cs-137	2	0.14	0.16	0.15	0.44	1.61
NRF	U-238	2	3.96	4.31	4.13	1.04	2.15
ATR Complex	Co-60	7	0.03	0.11	0.05	NA	NA
ATR Complex	Cs-134	11	0.02	0.1	0.07	NA	NA
ATR Complex	Cs-137	11	0.08	0.83	0.34	0.44	1.61
ATR Complex	Eu-152	1	----	0.78	----	NA	NA
ATR Complex	Am-241	1	----	0.04	----	0.005	0.025
RWMC	Cs-134	5	0.06	0.08	0.07	NA	NA
RWMC	Cs-137	6	0.08	2.10	0.4	0.44	1.61
RWMC	Am-241	3	0.72	3.83	1.83	0.005	0.025
TAN-SMC	Cs-134	4	0.04	0.06	0.05	NA	NA
TAN-SMC	Cs-137	4	0.11	0.37	0.19	0.44	1.61
TAN-SMC	U-238	1	----	4.33	----	1.04	2.15

a. INL mean background and upper tolerance limit values are from S.M. Rood, G.A. Harris, and G.J. White, 1996, *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations at the Idaho National Engineering Laboratory*, INEL-94/0250, Rev. 1, August 1996.

b. 95%/99% upper confidence limit (UCL) values give 95% confidence of encompassing the smallest 99% of the background concentrations.

c. NA = Not available. Not documented in Rood et al. (1996).

grab sampling of soils. Cesium-134 is an activation product produced in nuclear reactors and has a half-life of 2.1 years. Cobalt-60 is also an activation product produced in reactors and has a half-life of 5.3 years. Americium-241 is a decay product of ^{241}Pu and has a half-life of 432 years. Americium-241 does not occur in nature; however, some americium may be found in the environment as the result of atmospheric testing of nuclear weapons and disposal of wastes.

7.3 Direct Radiation

Thermoluminescent dosimeters (TLDs) measure cumulative exposures in air (in milliRoentgen or mR) to ambient ionizing radiation. TLDs detect changes in ambient exposures attributed to handling, processing, transporting, or disposing of radioactive materials. TLDs are sensitive to beta energies greater than 200 kilo-electron volts (keV) and to gamma energies greater than 10 keV. The TLD packets contain four lithium fluoride chips and are placed about 1 m (about 3 ft) above the ground at specified locations (Figure 7-8). The four chips provide replicate measurements at each location.

Beginning with the May 2010 distribution of dosimeters, the INL contractor began using optically stimulated luminescence dosimeters (OSLDs) collocated with the traditional TLDs. Similar to TLDs, OSLDs measure the ambient dose equivalent (in mrem). This quantity approximates the effective dose received by a human from external exposure to ambient ionizing radiation (http://hps.org/publicinformation/ate/q10433.html).

InLight® OSLDs, manufactured and analyzed by Landauer Inc., were used by the INL contractor in 2012. Each OSLD contains four aluminum oxide detectors that are sensitive to ionizing radiation ranging in energy from 5 keV to 20 MeV, with a minimum ambient dose equivalent reporting of 5 mrem. The primary advantage of the OSLD technology to the traditional TLD is that the nondestructive reading of the OSLD allows for dose verification (i.e., the dosimeter can be read multiple times without destruction of the accumulated signal inside the aluminum oxide chips). TLDs, on the other hand, are heated and once the energy is released, they cannot be reread. The sampling periods for 2012 were from November 2011 through April 2012 (spring collection) and from May through October 2012 (fall collection).

The 2012 results for both types of dosimeters collected by the INL contractor are provided in Appendix D. Locations of the dosimeters maintained on the INL Site are shown in Figures D-10 through D-19. The results for these locations are tabulated in the figures and in Table D-11. The TLD measurements are reported in units of exposure (mR), while OSLD data are reported in units of ambient dose equivalent (mrem). For comparison purposes, the TLD data can be converted from mR to ambient dose equivalent[1] (mrem) in tissue through use of a conversion factor of 1.03 mrem/mR. This conversion factor was derived through determination that for 662 keV gamma rays from ^{137}Cs, one R corresponds to an absorbed dose of ~0.95 rad for soft tissue (Cember 1996) and that the absorbed dose-to-ambient dose equivalent conversion

[1] For calendar years 2010 through 2012, the ambient dose equivalents, reported as mrem, may actually overestimate the true doses at the locations shown in Appendix D. This is because the OSLDs were shipped via airline to the Landauer facility in Glenwood, Illinois, where they were read, and accumulated additional dose during transit. No transit controls were included and therefore the added doses were not subtracted from the results presented in Appendix D. Procedures have been amended to include transit controls in 2013.

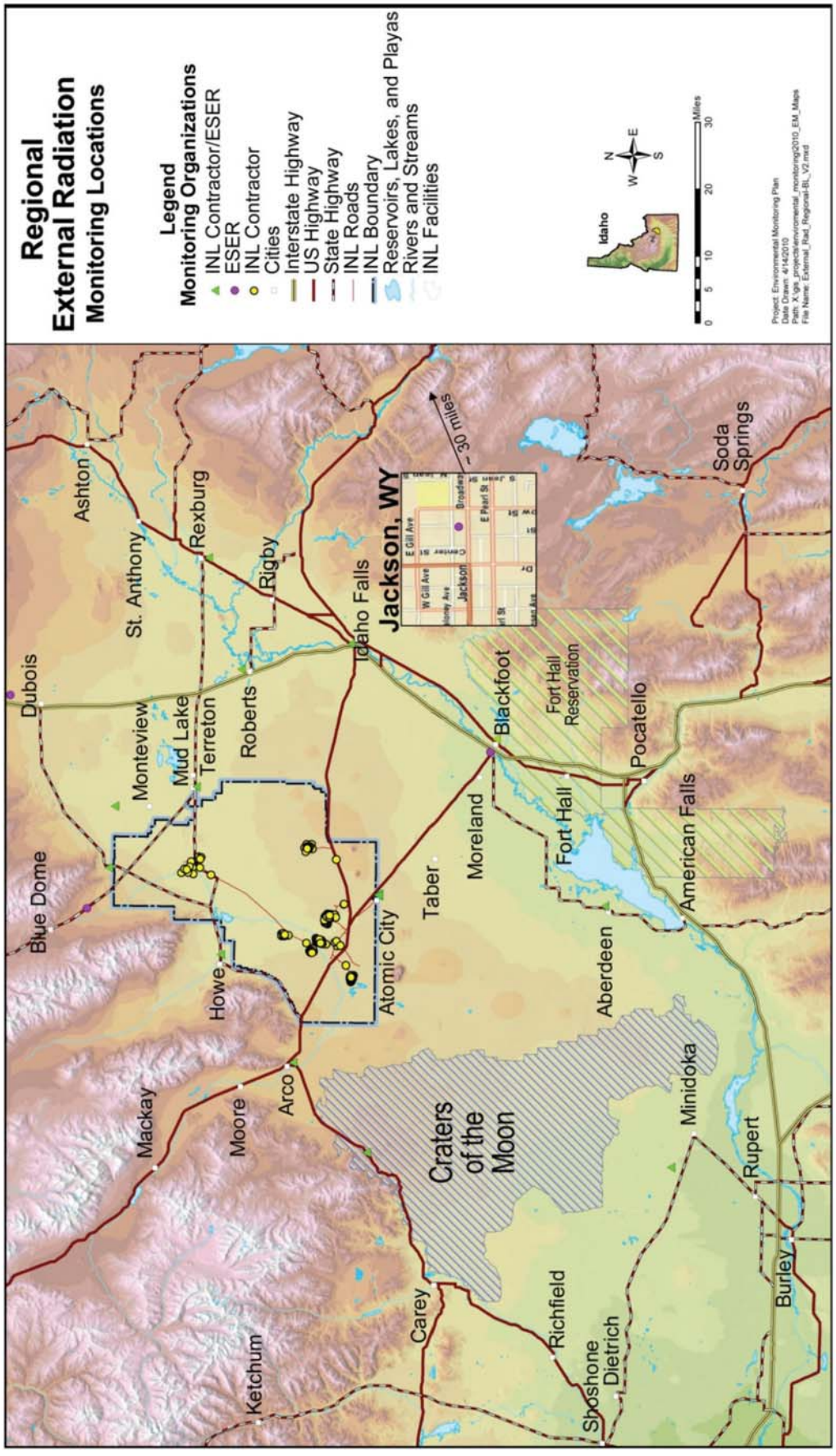

Figure 7-8. Regional Direct Radiation Monitoring Locations.

factor in tissue is about 1.09 rem/rad (ICRU 1992). Similarly, the OSLD ambient dose equivalent measurements can be converted to mR exposure data by dividing by 1.03.

Dosimeters on the INL Site are placed at facility perimeters, concentrated in areas likely to show the highest gamma radiation readings. Other dosimeters on the INL Site are located near radioactive materials storage areas and along roads. For decades, the number and locations of INL Site area dosimeters have been relatively constant; however, factors affecting potential exposures have changed. These changes include a reduced number of operating nuclear reactors, personnel, and waste shipments; numerous buildings and facilities have undergone decontamination and demolition; and radionuclide-contaminated ponds and soil areas have been remediated. Because of these changes and because years of TLD exposures at many established locations were equivalent to natural background, in November 2008, the INL contractor reduced the number of INL Site TLD locations while ensuring area exposures are still being measured. Additionally, in May, 2011, additional monitoring locations were added near select Research and Education Campus facilities in Idaho Falls. These locations include IF-627, which is near the new DOE-Idaho Operations Office Radiological and Environmental Sciences Laboratory, and IF-675, which is the Portable Isotopic Neutron Spectroscopy facility. For the purposes of environmental monitoring, the Idaho Falls Facilities are collectively referred to as the "INL REC Group."

The maximum exposure recorded by a TLD on the INL Site during 2012 was 198 mR (equivalent to an effective dose of 204 mrem) at INTEC (Figure D-14). The corresponding effective dose measured with the OSLD was 205 mrem. This location, ICPP O-15, is near controlled radioactive material areas where movement and storage of materials affect the exposure rate. This exposure is comparable to that of 157 mR (TLD) and 201 mrem (OSLD) observed in 2010.

The ESER contractor deployed OSLDs in November 2011 and ran a side-by-side field comparison with TLDs during 2012. Idaho State University also conducted a laboratory study, as well as analyzed results from the field study for the ESER contractor, during 2012. The purpose of these studies was to investigate the feasibility of replacing TLDs exclusively with OSLDs. The results[2] of these studies are presented in Appendix B and provide a technical basis for the ESER program to convert from TLDs to OSLDs at the INL Site.

The measured cumulative environmental radiation exposure in milliroentgens (mR) for locations off the INL Site from November 2011 through October 2012 is shown in Table 7-3 for two adjacent sets of TLDs maintained by the ESER and INL contractor. For purposes of comparison, annual exposures from 2008 through 2011 also are included for each location.

The mean annual exposures from distant locations in 2012 were 122 mR measured by the ESER contractor TLDs and 134 mR measured by the INL contractor TLDs. For boundary locations, the mean annual exposures were 123 mR measured by the ESER contractor TLDs and 131 mR measured by the INL contractor TLDs. Combining both ESER and INL contractors'

[2] The OSLDs used in the ESER field study could not be compared with those of the INL contractor because the transit doses were not accounted for in the INL contractor's measurements (see Footnote 1 on the previous page). Comparable methods for routine monitoring were developed and adopted for 2013.

Table 7-3. Annual Environmental Radiation Exposures (2008 – 2012).

Location	2008		2009		2010		2011		2012	
	ESER[a]	INL[b] Contractor	ESER	INL Contractor	ESER	INL Contractor	ESER	INL Contractor	ESER	INL Contractor
	(mR)									
Distant Group										
Aberdeen	128 ± 9	132 ± 9	130 ± 6	128 ± 9	130 ± 6	133 ± 9	126 ± 6	128 ± 9	129 ± 9	135±9
Blackfoot[c]	110 ± 8	NA	110 ± 6	NA	113 ± 6	NA	112 ± 6	NA	120 ± 8	NA
Blackfoot (CMS)[c,d]	118 ± 8	111 ± 8	122 ± 6	113 ± 8	120 ± 6	114 ± 8	121 ± 6	114 ± 8	113 ± 8	124±9
Craters of the Moon	116 ± 6	117 ± 8	120 ± 5	125 ± 9	121 ± 5	135 ± 9	119 ± 6	118 ± 8	122 ± 8	136±9
Dubois[c]	100 ± 7	NA	103 ± 5	NA	104 ± 5	NA	100 ± 5	NA	107 ± 7	NA
Idaho Falls	121 ± 8	117 ± 8	120 ± 6	121 ± 8	124 ± 6	121 ± 8	124 ± 6	118 ± 8	127 ± 9	133±9
Jackson[c]	102 ± 7	NA	102 ± 5	NA	102 ± 5	NA	101 ± 5	NA	102 ± 7	NA
Minidoka	109 ± 8	112 ± 8	111 ± 5	111 ± 8	114 ± 6	119 ± 8	116 ± 4	115 ± 8	115 ± 8	129±9
Rexburg	135 ± 9	116 ± 8	138 ± 7	118 ± 8	152 ± 7	128 ± 9	138 ± 7	124 ± 9	150 ± 10	135±9
Roberts	129 ± 9	132 ± 9	130 ± 6	130 ± 9	--[e]	143 ± 10	134 ± 7	133 ± 9	139 ± 10	149±10
Mean	117 ± 8	120 ± 8	119 ± 6	121 ± 8	120 ± 6	126 ± 9	119 ± 6	121 ± 8	122 ± 8	134±9
Boundary Group										
Arco	119 ± 8	121 ± 8	121 ± 6	124 ± 9	128 ± 6	129 ± 9	130 ± 6	130 ± 9	126 ± 9	134±9
Atomic City	126 ± 9	120 ± 8	122 ± 6	120 ± 8	127 ± 6	122 ± 8	121 ± 6	123 ± 8	132 ± 9	132±9
Blue Dome[c]	106 ± 7	N/A	107 ± 5	NA	105 ± 5	NA	105 ± 5	NA	107 ± 7	NA
Howe	117 ± 8	116 ± 8	116 ± 6	117 ± 8	117 ± 6	119 ± 8	111 ± 5	114 ± 8	122 ± 8	127±9
Monteview	115 ± 8	120 ± 8	116 ± 5	119 ± 8	119 ± 6	128 ± 9	112 ± 6	116 ± 8	122 ± 8	131±9
Mud Lake	128 ± 9	129 ± 9	130 ± 6	135 ± 9	134 ± 7	138 ± 10	134 ± 7	132 ± 9	138 ± 10	142±9
Birch Creek Hydro	110 ± 8	114 ± 8	112 ± 6	113 ± 8	--[f]	NA	109 ± 5	112 ± 8	113 ± 8	119±8
Mean	117 ± 8	120 ± 8	118 ± 6	121 ± 8	122 ± 6	127 ± 9	116 ± 6	121 ± 8	123 ± 8	131±9

a. ESER = Environmental, Surveillance, Education and Research
b. INL = Idaho National Laboratory
c. The INL contractor does not sample at this location.
d. CMS = Community Monitoring Station
e. Dosimeter was missing at one of the collection times.
f. Reader malfunctioned during measurement of dosimeter.

TLDs, the average annual exposure of the distant group was 129 mR. The average annual exposure for the boundary group was 127 mR. The average annual exposure for both groups was 128 mR. The average annual dose equivalent resulting from external exposure was estimated by converting the exposure measured in free air (mR) to dose equivalent (in mrem) by the factor of 1.03 reported for ^{137}Cs radiation by ANSI (1983). The average annual dose, using both INL and ESER data, was thus estimated to be 133 mrem for the boundary group, 130 mrem for the distant group, and 132 mrem for both groups.

Table 7-4 summarizes the calculated effective dose a hypothetical individual would receive on the Snake River Plain from various natural background radiation sources (cosmic and terrestrial). This table includes the latest recommendations of the National Council on Radiation Protection and Measurements (NCRP) in *Ionizing Radiation Exposure of the Population of the United States* (NCRP 2009).

Table 7-4. Calculated Effective Dose from Natural Background Sources (2012).

Source of Radiation Dose	Total Average Annual Dose	
	Calculated (mrem)	Measured[a] (mrem)
External irradiation		
Terrestrial	76[b]	NA[c]
Cosmic	57[d]	NA
Subtotal	*133*	*132*
Internal irradiation (primarily ingestion)[e]		
Potassium-40	15	
Thorium-232 and uranium-238	13	
Others (carbon-14 and rubidium-87)	1	
Internal irradiation (primarily inhalation)[d]		
Radon-222 (radon) and its short-lived decay products	212	
Radon-220 (thoron) and its short-lived decay products	16	
Total	*390*	

a. Calculated by converting the average annual external exposure (128 mR) measured by ESER and INL to dose equivalent (mrem) using a conversion factor of 1.03 (ANSI 1983).
b. Estimated using concentrations of naturally-occurring radionuclide concentrations in soils in the Snake River Plain.
c. NA indicates terrestrial and cosmic radiation parameters were not measured individually but were measured collectively using thermoluminescent devices.
d. Estimated from Figure 3-4 of NCRP Report No. 160.
e. Values reported for average American adult in Table 3.14 of NCRP Report No. 160.

The terrestrial natural background radiation exposure estimate is based on concentrations of naturally occurring radionuclides found in soil samples collected from 1976 through 1993, as summarized by Jessmore et al. (1994). Concentrations of naturally occurring radionuclides in soil do not change significantly over this relatively short period. Data indicated the average concentrations of ^{238}U, thorium-232 (^{232}Th), and potassium-40 (^{40}K) were 1.5, 1.3, and 19 pCi/g, respectively. The calculated external dose equivalent received by a member of the public from ^{238}U plus decay products, ^{232}Th plus decay products, and ^{40}K based on the above-average area soil concentrations were 21, 28, and 27 mrem/yr, respectively, for a total of 76 mrem/yr (Mitchell et al. 1997). Because snow cover can reduce the effective dose Idaho residents receive from soil, a correction factor must be made each year to the estimated 76 mrem/yr. However, for 2012, this did not change the 76 mrem/yr value because there were only six days during the November 2011 through October 2012 period of dosimeter measurement with measurable snow cover.

The cosmic component varies primarily with increasing altitude. Using Figure 3.4 in NCRP Report No. 160 (NCRP 2009), it was estimated that the annual cosmic radiation dose near the INL Site is about 57 mrem. Cosmic radiation may vary slightly because of solar cycle fluctuations and other factors.

Based on this information, the sum of the terrestrial and cosmic components of external radiation dose to a person residing on the Snake River Plain in 2012 was estimated to be 133 mrem/yr. This is not distinguishable from the 132 mrem/yr measured at distant locations by the ESER and INL contractor TLDs after conversion from mR to mrem in tissue. Measured values are very close, and within normal variability, of the calculated background doses. Therefore, it is unlikely that INL Site operations contributed to background radiation levels at distant locations in 2012.

The component of background dose that varies the most is inhaled radionuclides. According to the NCRP, the major contributor of effective dose received by a member of the public from ^{238}U plus decay products is short-lived decay products of radon (NCRP 2009). The amount of radon in buildings and groundwater depends, in part, upon the natural radionuclide content of soil and rock of the area. The amount of radon also varies among buildings of a given geographic area depending upon the materials each contains, the amount of ventilation and air movement, and other factors. The United States average of 212 mrem/yr was used in Table 7-4 for this component of the total background dose. The NCRP also reports that the average dose received from thoron, a decay product of ^{232}Th, is 16 mrem.

People also receive an internal dose from ingestion of ^{40}K and other naturally-occurring radionuclides in environmental media. The average ingestion dose to an adult living in the U.S. was reported in NCRP Report No. 160 to be 29 mrem/yr (NCRP 2009).

With all of these contributions, the total background dose to an average individual living in southeast Idaho was estimated to be approximately 390 mrem/yr (Table 7-4). This value was used in Table 8-4 to calculate background radiation dose to the population living within 50 miles of INL Site facilities.

7.4 Waste Management Surveillance Sampling

Vegetation and soil are sampled, and direct radiation is measured at RWMC to comply with DOE Order 435.1, “Radioactive Waste Management” (2001).

7.4.1 Vegetation Sampling at the Radioactive Waste Management Complex

At RWMC, vegetation is collected from four major areas (see Figure 7-9) (due to construction, vegetation was not available in RWMC Area 4) and a control location approximately 7 miles south of the Subsurface Disposal Area (SDA) at the base of Big Southern Butte. Russian thistle is collected in even-numbered years if available. However, due to increased activity and traffic in the SDA, there was not enough Russian thistle available to collect a representative sample in 2012.

7.4.2 Soil Sampling at the Radioactive Waste Management Complex

The ICP contractor samples soil every 3 years. The triennial soil sample was collected during 2012. Soil samples were collected to a depth of 5 cm (2 in.) at the RWMC locations shown in

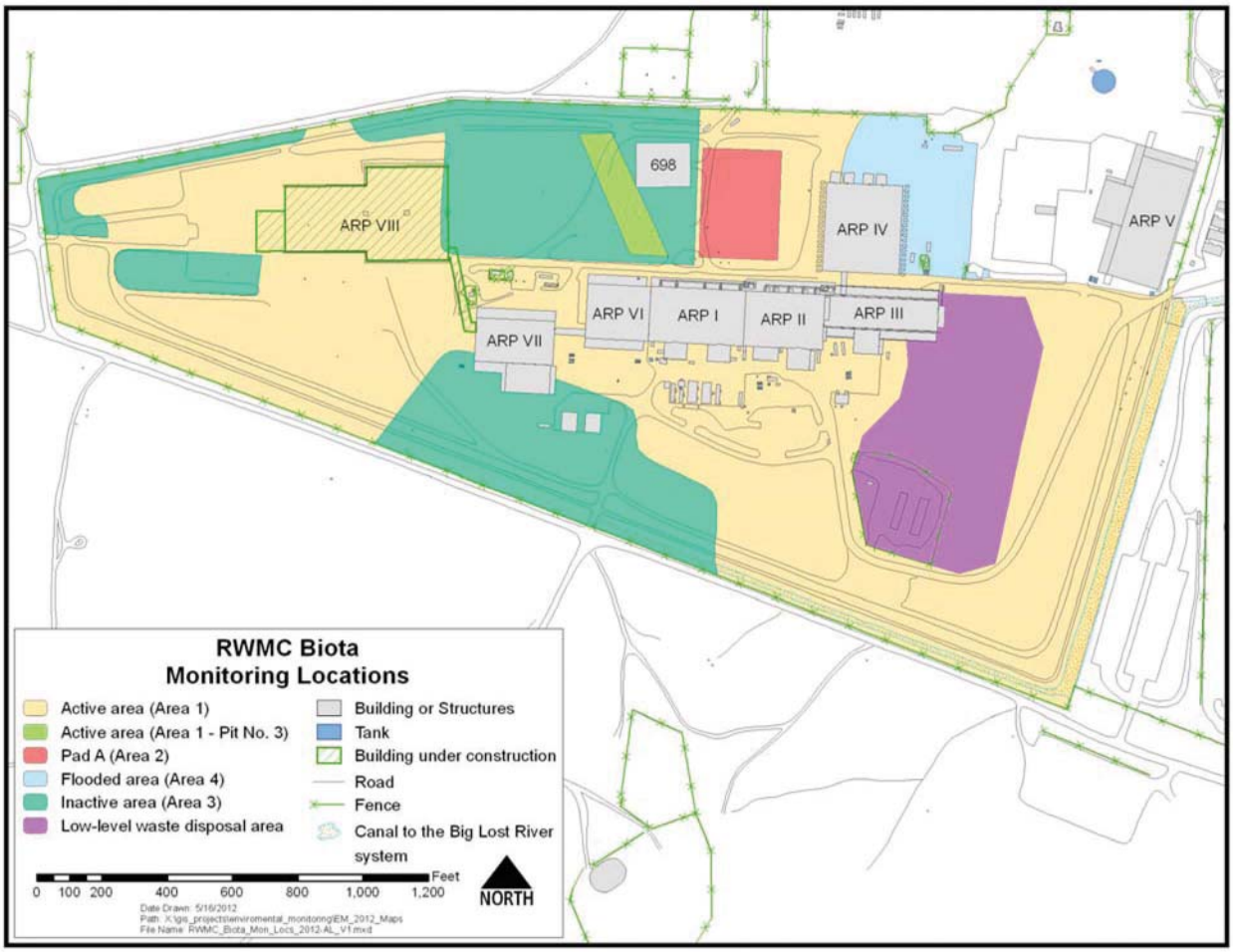

Figure 7-9. Four Vegetation Sampling Areas at the Radioactive Waste Management Complex.

Figure 7-6. The soils were analyzed for gamma-emitting radionuclides, and no results were reported that exceeded three sigma. Selected samples were analyzed by radiochemistry for specific alpha- and beta-emitting radionuclides. Positive results were reported for ^{241}Am, ^{238}Pu, $^{239/240}$Pu, and ^{90}Sr. These results are far below the Environmental Concentration Guides (EG&G Idaho 1986) established for soils (Table 7-5).

The Environmental Concentration Guides were calculated to establish INL Site-specific dose guidelines for decontamination and decommissioning projects. Each Environmental Concentration Guide represents the concentration of a radionuclide in soil that would conservatively result in a dose of 100 mrem in the first year after release from an area to a hypothetical subsistence farmer.

All detected concentrations are consistent with or lower than historical concentrations measured at RWMC. These results are attributable to previous flooding and increased operational activity in the SDA, including the Accelerated Retrieval Project (construction and operations).

7.4.3 Direct Radiation at the Radioactive Waste Management Complex

A vehicle-mounted global positioning radiometric scanner was used to conduct soil surface radiation (gross gamma) surveys at the SDA to complement soil sampling. The system utilizes a Trimble Global Positioning System and two plastic scintillation detectors connected to a personal computer on board the vehicle. The global positioning radiometric scanner system data are differentially corrected and transmitted via satellites, and geographic coordinates (latitude and longitude) are recorded at least every 2 seconds. The vehicle was driven less than or equal to 5 miles per hour, with the detector height at 36 in. above the ground.

Table 7-5. Radionuclides Detected in Radioactive Waste Management Complex Soils (2012).

Parameter	Minimum Concentration[a] (pCi/g)	Maxiumum Concentration[a] (pCi/g)	% ECG[b] (pCi/g)
Sr-90	1.23E-02	1.78E-01	0.20
Am-241	2.02E-02	4.63E-01	1.16
Pu-238	2.19E-03	1.51E-02	0.003
Pu-239/240	3.60E-02	5.25E-01	0.045

a. Result ±1s. Results shown are ≥3s.

b. ECG = Environmental Concentration Guide (EG&G 1986).

Figure 7-10 shows the radiation readings from the 2012 annual survey. Although readings vary slightly from year to year, the 2012 results for most areas are comparable to previous years' measurements. The active low-level waste pit was covered during 2009, and as a result of the reduced shine, elevated measurements from the buried waste in pits and trenches are more visible. In 2012, the maximum gross gamma radiation measurement on the SDA was 14,950 counts per second, compared to the 2011 measurement of 19,753. The maximum 2010, 2011, and 2012 readings were measured at the western end of the SVR-7 soil vault row. Results were noted slightly above background levels in the area next to WMF-698. Even though these results are close to background levels, the ICP contractor will conduct additional surveys and sampling during 2013 to identify any potential trends.

7.5 CERCLA Ecological Monitoring

Ecological monitoring at the INL Site was conducted in accordance with the Record of Decision for Operable Unit 10-04 (DOE-ID 2002) developed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq., 1980). The selected remedy was no action with long-term ecological monitoring to reduce uncertainties in the INL Site-wide ecological risk assessment.

Yearly sampling and surveys occurred from 2003 through 2008 to characterize contaminant levels, evaluate possible effects, and collect population-level data (VanHorn and Haney 2007). In general, samples for contaminant analysis and effects were collocated to minimize sources of variability. Terrestrial samples were collected from surface soil, subsurface soil, *Peromyscus maniculatus* (deer mice), *Artemisia tridentata* (sagebrush), and *Agropyron cristatum* (crested wheatgrass) in areas near INL Site facilities and from background areas. Aquatic samples were collected from sediments, surface water, and plants in facility ponds and an aquatic background area. Effects data for deer mice included kidney-to-body-weight and liver-to-body-weight ratios, and histopathology of kidney and liver. Toxicity testing included deer mice, earthworms, and seedlings. Populations of birds, reptiles, plants, small mammals, and soil fauna were surveyed for presence, absence, abundance, and diversity. Data were compiled in a summary report (VanHorn et al. 2012).

Six years of data and observations detected minimal effects. Differences between areas near facilities and background areas were slight, and may be attributable wholly or partly to natural variability. Because monitoring substantially reduced uncertainties in the INL Site-wide ecological risk assessment and increased confidence that the no action decision is protective, further ecological monitoring under CERCLA is not required.

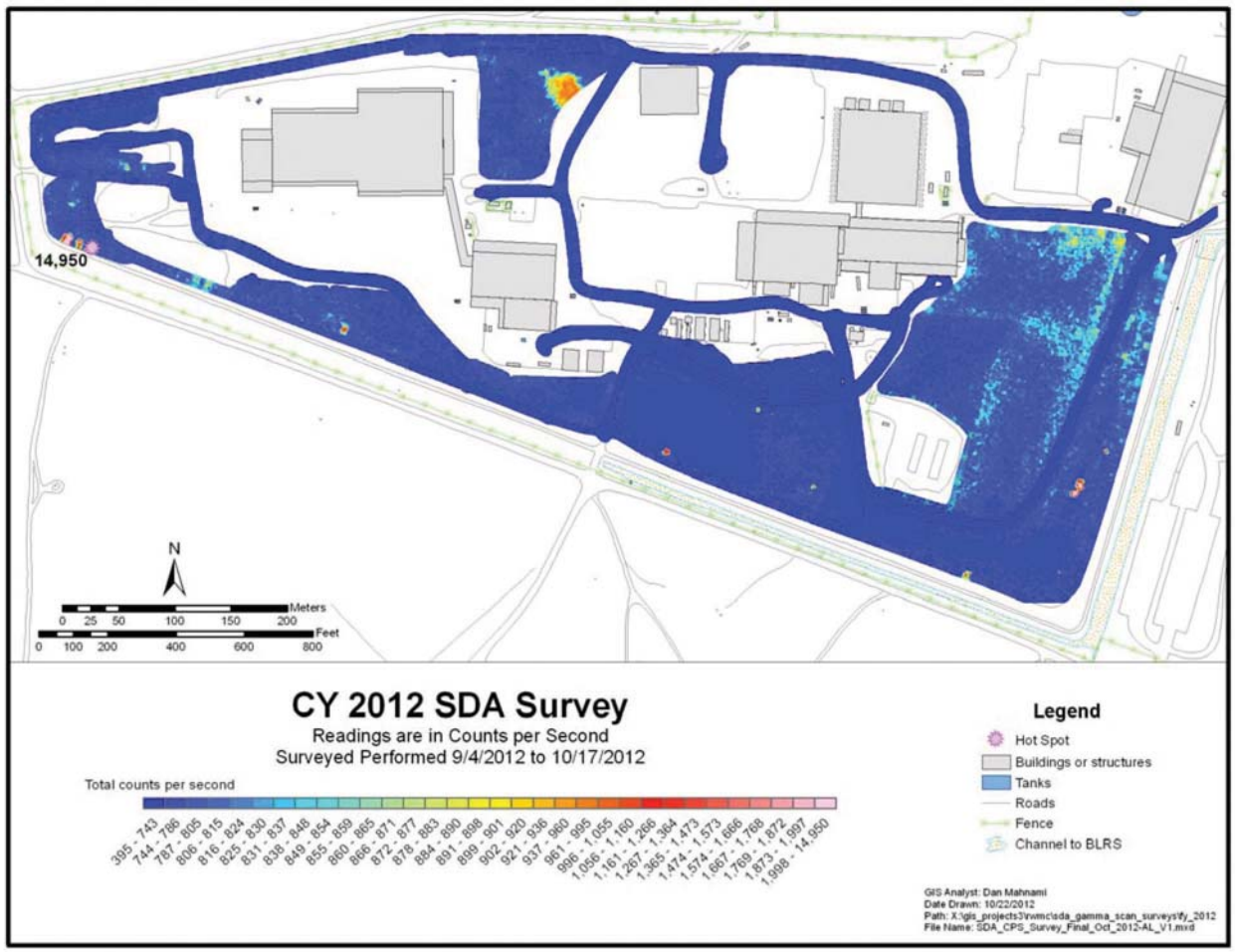

Figure 7-10. Radioactive Waste Management Complex Surface Radiation Survey (2012).

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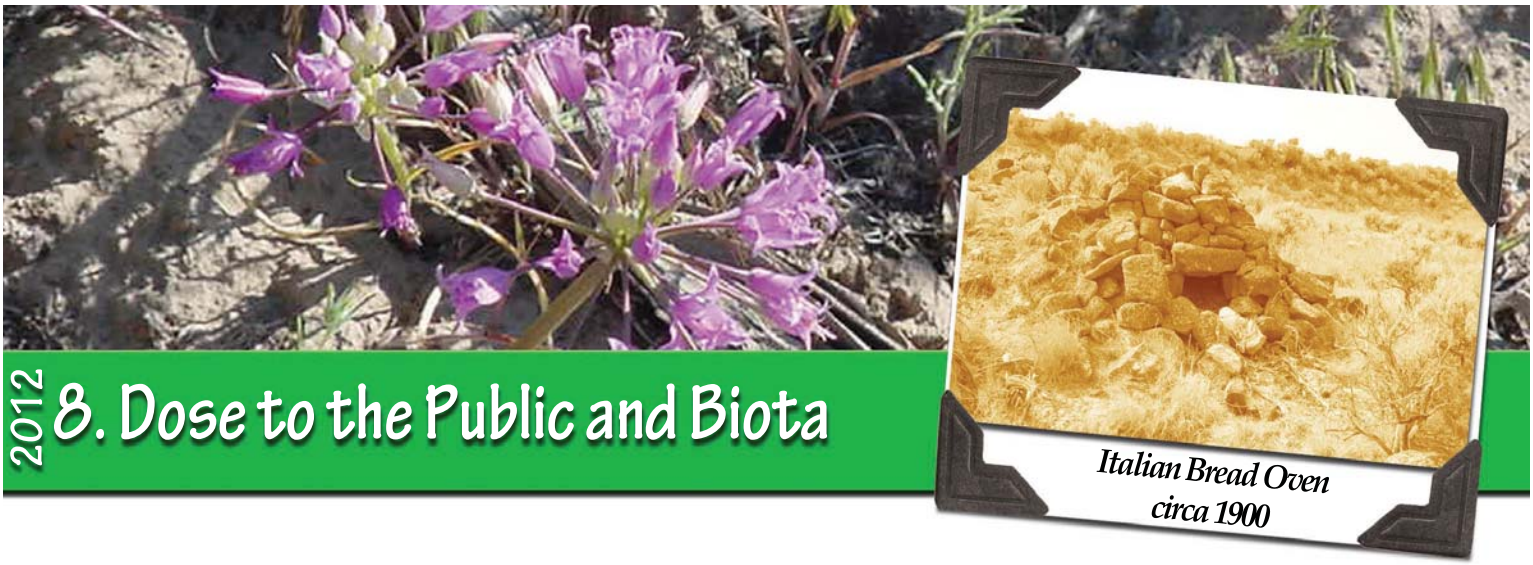
Remnants of late 1800s Powell Stage Station



2012

8. Dose to the Public and Biota

Italian Bread Oven
circa 1900

Chapter 8 Highlights

The potential radiological dose to the public from Idaho National Laboratory (INL) Site operations was evaluated to determine compliance with pertinent regulations and limits. The Clean Air Act Assessment Package 88-PC computer program is required by the U.S. Environmental Protection Agency to demonstrate compliance with the Clean Air Act. The dose to the hypothetical, maximally exposed individual in 2012, as determined by this program, was 0.036 mrem (0.36 μSv), well below the applicable standard of 10 mrem (100 mSv) per year.

The maximum potential population dose to the approximately 309,730 people residing within an 80-km (50-mi) radius of any INL Site facility was also evaluated. The population dose was calculated using reported releases, an air dispersion model developed by the National Oceanic and Atmospheric Administration Air Resources Laboratory-Field Research Division, and methodology recommended by the Nuclear Regulatory Commission. For 2012, the estimated potential population dose was 0.199 person-rem (1.99×10^{-3} person-Sv). This dose is about 0.0001 percent of that expected from exposure to natural background radiation of 120,795 person-rem (1,208 person-Sv).

Using the maximum radionuclide concentrations in collected waterfowl and large game animals, a maximum potential dose from ingestion was calculated. The maximum potential dose to an individual was calculated to be 0.009 mrem (0.09 mSv) for ingestion of waterfowl. Because no humanmade radionuclides were detected in 2012 in large game animals, no dose was calculated for ingestion of game animals.

The potential doses to aquatic and terrestrial biota from contaminated soil and water were evaluated using a graded approach. Initially, the potential doses were screened using maximum concentrations of radionuclides detected in soil and effluents at the INL Site. Results of the screening calculations indicate that contaminants released from INL Site activities do not have an adverse impact on plants or animal populations. In addition, maximum concentrations of radionuclides measured in waterfowl accessing INL Site ponds were used to estimate internal doses to the waterfowl. These calculations indicate that the potential doses to waterfowl do not exceed the Department of Energy limits for biota.

No unplanned releases occurred from the INL Site in 2012, and, therefore, no doses were associated with unplanned releases.

8. DOSE TO THE PUBLIC AND BIOTA

It is the policy of the U.S. Department of Energy (DOE), "To implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by DOE operations and by which DOE cost-effectively meets or exceeds compliance with applicable environmental, public health, and resource protection laws, regulations, and DOE requirements" (DOE Order 436.1). DOE Order 458.1 further states, "It is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable..." This chapter describes the potential dose to members of the public and biota from operations at the Idaho National Laboratory (INL) Site, based on 2012 environmental monitoring measurements.

8.1 Possible Exposure Pathways to the Public

Air, soil, groundwater, agricultural products, and biota are routinely sampled to document the amount of radioactivity in these media and to determine if radioactive materials have been transported off the INL Site. The air pathway is the primary way people living beyond the INL Site boundary could be exposed to releases from INL Site operations (Figure 8-1). Airborne radioactive materials are rapidly carried from the source and dispersed by winds. The concentrations from routine releases are too small to measure at locations around the INL Site,

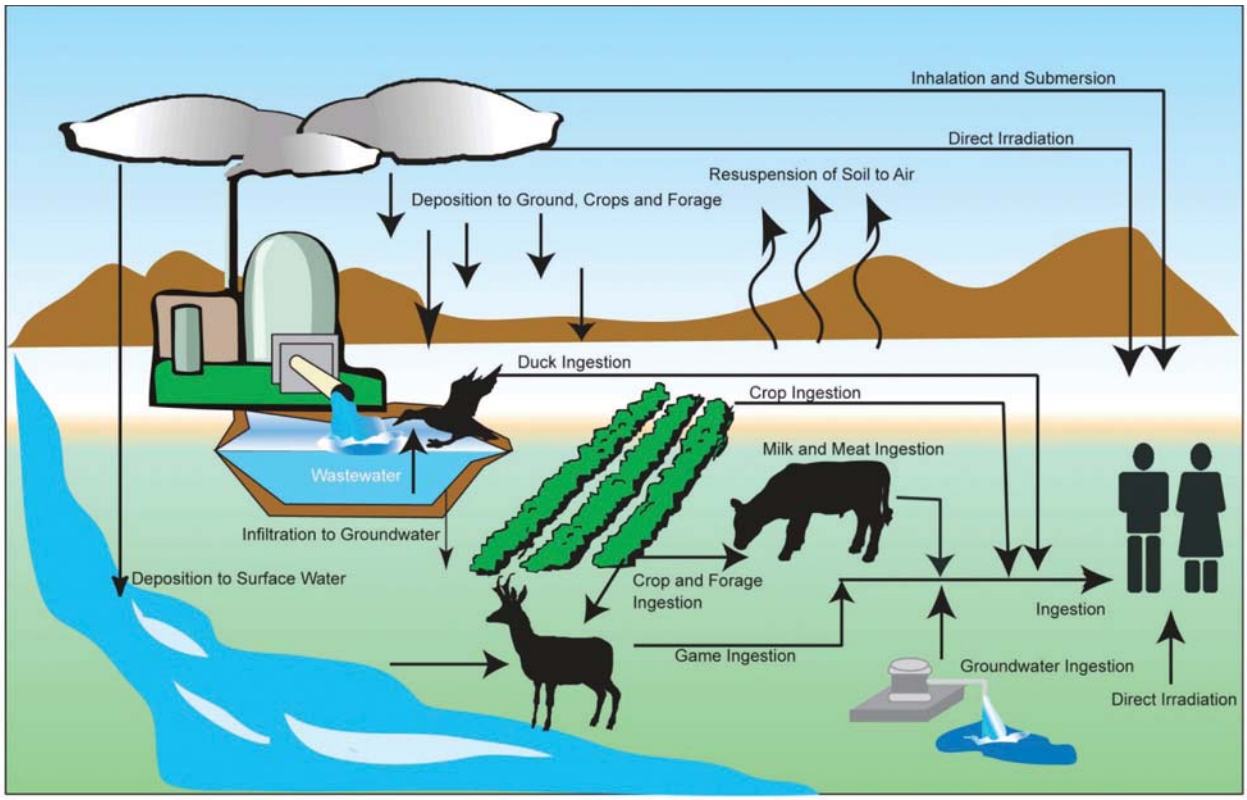


Figure 8-1. Potential Exposure Pathways to Humans from the INL Site.

so atmospheric dispersion models were used to estimate the downwind concentration of air pollutants and the potential doses from these projected offsite concentrations. Conservative doses were also calculated from ingestion of meat from wild game animals and waterfowl that access the INL Site. Ingestion doses were calculated from concentrations of radionuclides measured in game animals killed by vehicles on roads at the INL Site and in waterfowl harvested from ponds on the INL Site if animals sampled had detectable levels of human-made radionuclides. External exposure to radiation in the environment (primarily from naturally-occurring radionuclides) was measured directly using thermoluminescent dosimeters and optically stimulated luminescence dosimeters.

Water pathways were not considered major contributors to dose because no surface water flows off the INL Site and no radionuclides associated with INL Site releases have been measured in public drinking water wells.

8.2 Dose to the Public from INL Site Air Emissions

The potential doses from INL Site air emissions were estimated using the amounts reported to be released by the facilities. During 2012, doses were calculated for the radionuclides and data presented in Table 4-2 and summarized in Table 8-1. Although noble gases were the radionuclides released in the largest quantities, they contributed very little to the cumulative dose (affecting immersion only) largely because of their short half-lives and the fact that they are not incorporated into the food supply. The radionuclides which contributed the most to the overall estimated dose (strontium-90 [^{90}Sr], iodine-129, cesium-137 [^{137}Cs], americium-241, and plutonium isotopes) are typically associated with airborne particulates and were a very small fraction of the total amount of radionuclides reported.

Two kinds of dose estimates were made using the release data:

- **The effective dose to the hypothetical maximally exposed individual**, as defined by the National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations. The Clean Air Act Assessment Package (CAP) 88-PC computer code (EPA 2007) was used to predict the maximum downwind concentration at the nearest offsite receptor location and estimate the dose to the maximally exposed individual.
- **The collective effective dose (population dose) for the population within 80 km (50 mi) of any INL Site facility.** For this calculation the mesoscale diffusion (MDIFF) model (Sagendorf et al. 2001) was used to model air transport and dispersion. The population dose was estimated using dispersion values from the model projections to comply with DOE Order 458.1.

The dose estimates considered 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 (Figure 8-1.) The CAP88-PC computer code uses dose and risk tables developed by the U.S. Environmental Protection Agency (EPA). Population dose calculations were made using the MDIFF air dispersion model in combination with Nuclear Regulatory Commission (NRC) dose calculation methods (NRC 1977), DOE effective dose coefficients for inhaled radionuclides (DOE 2011), EPA dose conversion factors for ingested

Table 8-1. Summary of Radionuclide Composition of Idaho National Laboratory Site Airborne Effluents (2012).

	Curies[a] Released										
Facility[b]	Tritium	^{85}Kr	Noble Gases[c] ($T_{1/2}$ < 40 days)	Short-lived Fission and Activation Products[d] ($T_{1/2}$ < 3 hours)	Fission and Activation Products[e] ($T_{1/2}$ > 3 hours)	Total Radioiodine[f]	Total Radiostrontium[g]	Total Uranium[h] Ci/(g)	Plutonium[i]	Other Actinides[j]	Other[k]
ATR Complex	381	0	831	6.04E-01	3.59E-02	2.17E-02	3.75E-02	1.72E-09/ (5.50E-03)	2.68E-05	1.48E-04	1.35E-02
CFA	0.79	0	0	0	5.14E-09	2.30E-08	4.02E-12	7.56E-08/ (2.63E-04)	1.12E-10	1.81E-08	8.10E-10
INTEC	175	1203	0	0	1.37E-02	2.70E-02	1.13E-02	5.80E-07/ (3.14E-01)	5.81E-03	7.33E-08	1.92E-03
MFC	1.76	0	0	6.00E-12	0	3.51E-06	1.73E-05	6.90E-06/ (1.26E-03)	2.93E-07	4.03E-07	9.16E-04
RWMC	338	2.53E-10	0	7.65E-09	0	0	1.57E-08	1.45e-09/ (7.82E-04)	3.11E-04	4.43E-04	1.12E-01
TAN	3.26E-02	0	0	0	0	0	1.02E-06	2.22E-10/ (5.56E-04)	0	0	0
Total	896	1203	831	6.04E-01	4.93E-02	4.87E-02	4.88E-02	7.55E-06/ (3.22E-01)	6.15E-03	5.92E-04	1.29E-01

a. One curie (Ci)= 3.7 x 10^{10} becquerels (Bq).

b. CFA = Central Facilities Area; INTEC = Idaho Nuclear Technology and Engineering Center; MFC = Materials and Fuels Complex; ATR Complex = Advanced Test Reactor Complex; RWMC = Radioactive Waste Management Complex (including AMWTP = Advanced Mixed Waste Treatment Project); TAN = Test Area North (including SMC = Specific Manufacturing Capability).

c. Noble gases with half-lives less than 40 days released from the INL Site are: ^{39}Ar, ^{41}Ar, ^{85m}Kr, ^{87}Kr, ^{88}Kr, ^{127}Xe, ^{129m}Xe, ^{131m}Xe, ^{133}Xe, ^{133m}Xe, ^{135}Xe, ^{135m}Xe, and ^{138}Xe. (Ar = argon, Kr = krypton, and Xe = xenon.)

d. Fission products and activation products ($T_{1/2}$<3 hours) = ^{136m}Ba, ^{137m}Ba, ^{139}Ba, ^{141}Ba, ^{212}Bi, ^{83}Br, ^{60m}Co, ^{138}Cs, ^{67}Cu, ^{179m}Hf, ^{114}In, ^{142}La, ^{56}Mn, ^{93}Mo, ^{99}Mo, ^{97}Nb, ^{212}Po, ^{216}Po, ^{144}Pr, ^{144m}Pr, ^{88}Rb, ^{89}Rb, ^{103m}Rh, ^{106m}Rh, ^{219}Rn, ^{126m}Sb, ^{129}Te, ^{208}Tl, ^{187}W, ^{90}Y, ^{91m}Y, ^{92}Y, etc. See Table HI-1 for more information.

e. Fission products and activation products ($T_{1/2}$>3 hours) = ^{144}Ce, ^{58}Co, ^{51}Cr, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{55}Fe, ^{175}Hf, ^{181}Hf, ^{203}Hg, ^{22}Na, ^{24}Na, ^{95}Nb, ^{63}Ni, ^{147}Pm, ^{224}Ra, ^{188}Re, ^{103}Ru, ^{106}Ru, ^{124}Sb, ^{125}Sb, ^{127}Sb, ^{46}Sc, ^{151}Sm, ^{182}Ta, ^{99}Tc, ^{99m}Tc, ^{65}Zn, ^{95}Zr, etc. See Table HI-1 for more information.

f. Total radioiodine = ^{125}I, ^{128}I, ^{129}I, ^{131}I, ^{132}I, ^{133}I, ^{134}I, and ^{135}I.

g. Total radiostrontium = ^{85}Sr, ^{89}Sr, ^{90}Sr, ^{91}Sr, and ^{92}Sr.

h. Total uranium = ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{237}U, and ^{238}U. Grams of uranium released calculated using the specific activity (Ci/g) for each uranium nuclide and then summing the results.

i. Total plutonium = ^{236}Pu, ^{237}Pu, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu.

j. Other actinides = ^{227}Ac, ^{241}Am, ^{243}Am, ^{249}Cf, ^{242}Cm, ^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm, ^{248}Cm, ^{237}Np, ^{239}Np, ^{231}Pa, ^{234}Pa, ^{227}Th, ^{228}Th, ^{229}Th, ^{230}Th, ^{231}Th, ^{232}Th, and ^{234}Th. See Table HI-1 for more information.

k. Other = radioisotopes of other elements that are not noble gases, activation or fission products or actinides.

radionuclides (EPA 2002), and EPA dose conversion factors for external exposure to radionuclides in the air and deposited on the ground surface (EPA 2002).

8.2.1 Maximally Exposed Individual Dose

The EPA NESHAPs regulation requires demonstrating that radionuclides other than radon released to air from any DOE nuclear facility do not result in a dose to the public of greater than 10 mrem/yr (40 Code of Federal Regulations [CFR] 61, Subpart H). This includes releases from stacks and diffuse sources such as resuspension of contaminated soil particles. EPA requires the use of an approved computer code such as CAP88-PC to demonstrate compliance with 40 CFR 61. CAP88-PC uses a modified Gaussian plume model to estimate the average dispersion of radionuclides released from up to six sources. It uses an average annual wind file, based on multiple-year meteorological data collected at the INL Site by NOAA. Assessments are done for a circular grid of distances and directions from each source with a radius of 80 kilometers (50 miles) around the facility. The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food and intake rates to people from ingestion of food produced in the assessment area. Estimates of the radionuclide concentrations in produce, leafy vegetables, milk and meat consumed by humans are made by coupling the output of the atmospheric transport models with the U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 terrestrial food chain models.

The dose from INL Site airborne releases of radionuclides was calculated to the maximally exposed individual to demonstrate compliance with NESHAPs and is published in the *National Emissions Standards for Hazardous Air Pollutants – Calendar Year 2012 INL Report for Radionuclides* (DOE-ID 2013). In order to identify the maximally exposed individual, the doses at 63 locations were calculated and then screened for the maximum potential dose to an individual who might live at one of these locations. The highest potential dose was screened to be to a hypothetical person living at Frenchman's Cabin, located at the southern boundary of the INL Site (see Figure 4-2). This location is inhabited only during portions of the year, but it must be considered as a potential maximally exposed individual location according to NESHAPs. An effective dose of 0.0357 mrem (0.357 µSv) was calculated for a hypothetical person living at Frenchman's Cabin during 2012.

Who is the maximally exposed individual?

The maximally exposed individual is a hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation from a given event or process. This individual lives outside the INL Site at the location where the highest concentration of radionuclides in air have been modeled using reported effluent releases. In 2012, this hypothetical person lived at Frenchman's Cabin, just south of the INL Site boundary (Figure 4-2).

Figure 8-2 compares the maximum individual doses calculated for 2003 through 2012. All of the doses are well below the whole body dose limit of 10 mrem (100 µSv) for airborne releases of radionuclides established by 40 CFR 61. The highest dose was estimated in 2008 and was attributable primarily to plutonium-241 which was reported to be released during the dismantling of facilities at Test Area North.

Although noble gases were the radionuclides released in the largest quantities, they contributed relatively little to the cumulative dose from all pathways (affecting immersion only) largely because of their short half-lives and the fact that they are not incorporated into the food supply. Many of the radionuclides that contributed the most to the overall dose (americium-241, ^{137}Cs, ^{90}Sr, plutonium-238 and -239, and iodine-129) are typically associated with airborne particulates and were a very small fraction of the total amount of radionuclides reported (Figure 8-3). Tritium and argon-41, which are not associated with particulates, contributed about 69 percent of the calculated dose in 2012.

8.2.2 Eighty Kilometer (50 Mile) Population Dose

The National Oceanic and Atmospheric Administration Air Resources Laboratory – Field Research Division (NOAA ARL-FRD) developed an air transport and dispersion model called MDIFF in the 1990s (Sagendorf et al. 2001). It is based on an earlier model called MESODIF and was developed by the NOAA ARL-FRD from field experiments in arid environments (e.g., the INL Site and the Hanford Site in eastern Washington). The model was used in the population dose calculations. A detailed description of the model and its capabilities may be found at http://www.noaa.inel.gov/capabilities/modeling/T&D.htm.

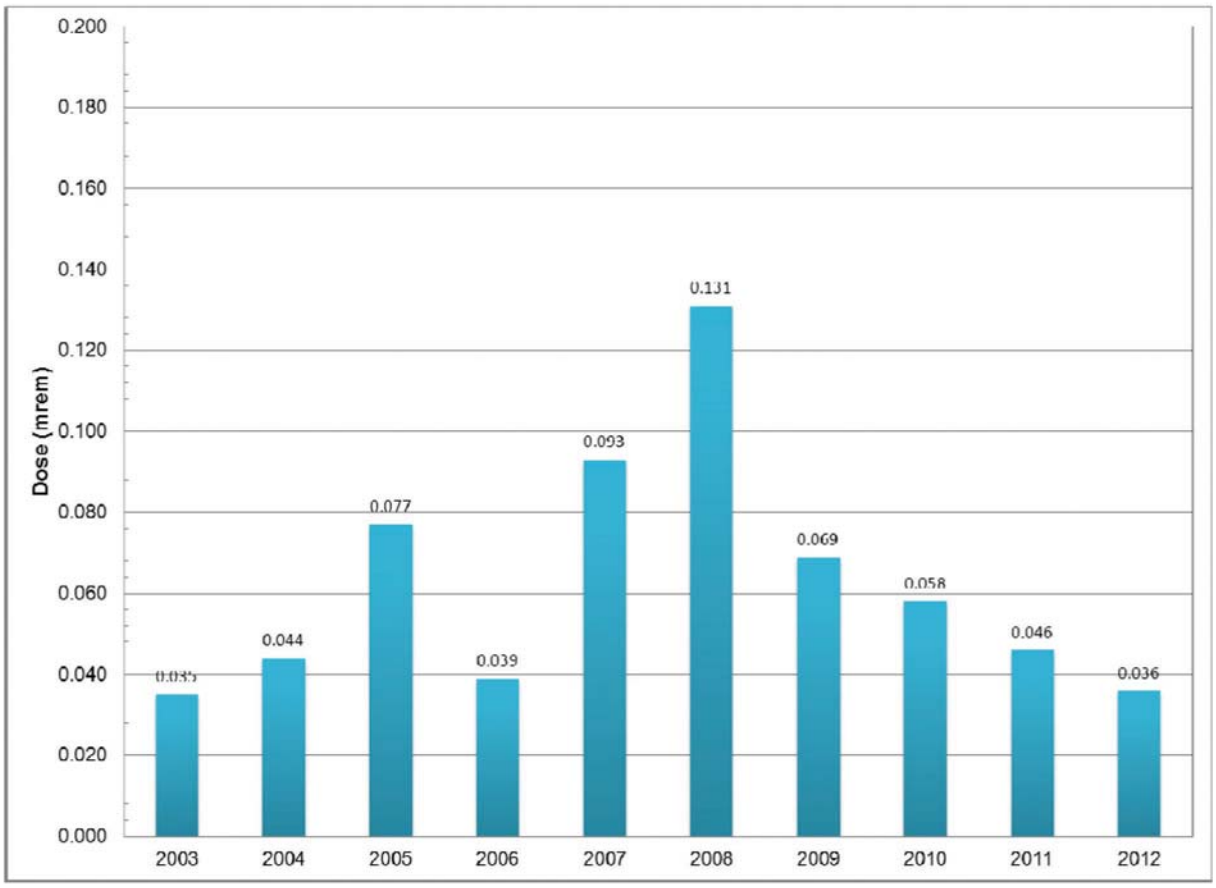


Figure 8-2. Maximum Individual Doses from INL Site Airborne Releases Estimated for 2003 – 2012.

The NOAA ARL-FRD gathered meteorological data continuously at 35 meteorological stations during 2012 on and around the INL Site (see *Meteorological Monitoring*, a supplement to this Annual Site Environmental Report). The transport and dispersion of contaminants by winds was projected by the MDIFF using wind speeds and directions from the 1-hr Mesonet database for 2012. The model predicted average annual air concentrations, resulting from INL Site airborne effluent releases, at each of over 10,000 grid points on and around the INL Site (Figure 8-4).

The results were used to prepare a contour map showing calculated annual air concentrations called time integrated concentrations (Figure 8-5). The higher numbers on the map represent higher annual average concentrations. So, for example, the annual air concentration resulting from INL Site releases were estimated to be about four times higher at Terreton than at Dubois. This map was used to identify where an individual might be exposed to the highest air concentration during the year, and what that annual air concentration was. This concentration was then used to calculate the 80-km population dose. In 2012 this individual was projected by MDIFF to live at Frenchman's Cabin at the southern boundary of the INL Site. This location is the same as the location of the maximally exposed individual used by CAP88-PC.

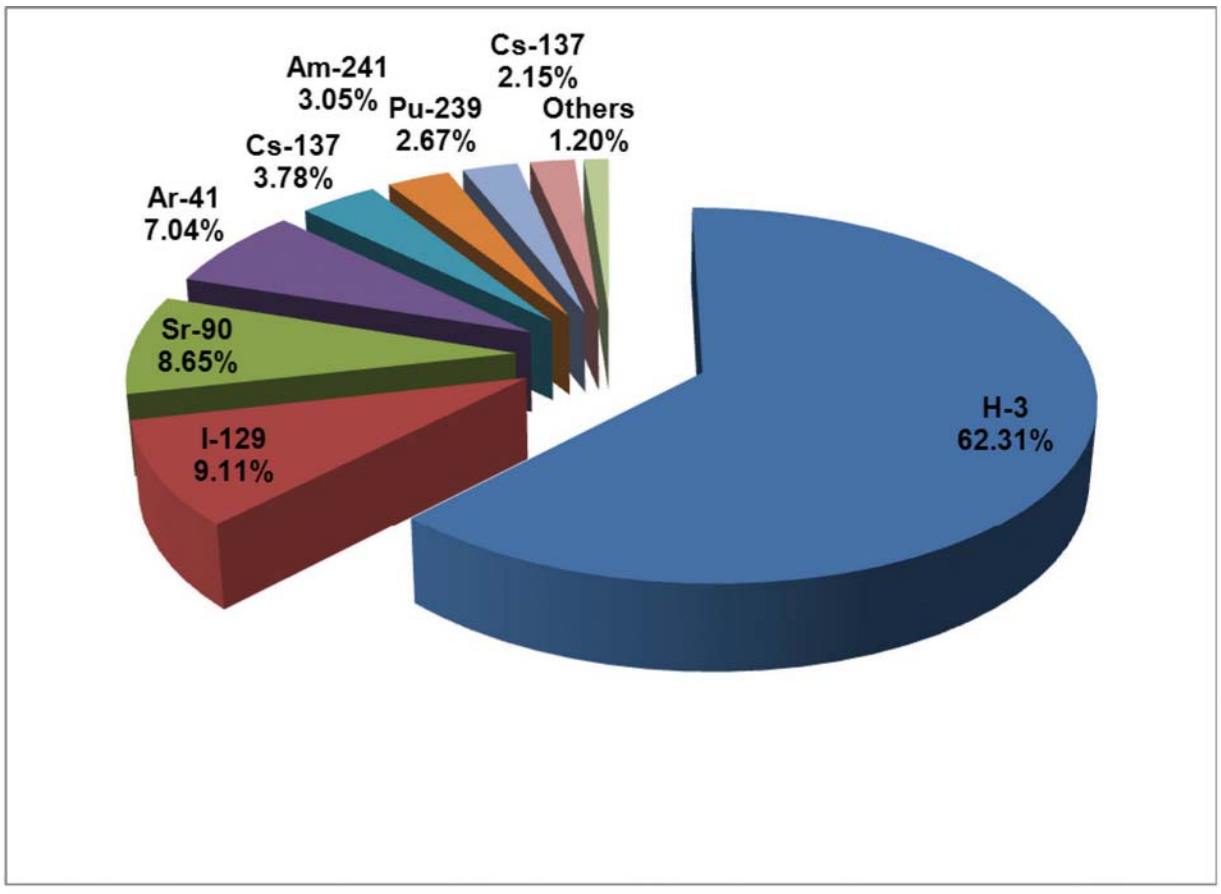


Figure 8-3. Radionuclides Contributing to Dose to Maximally Exposed Individual from INL Site Airborne Effluents as Calculated Using the CAP88-PC Model (2012).

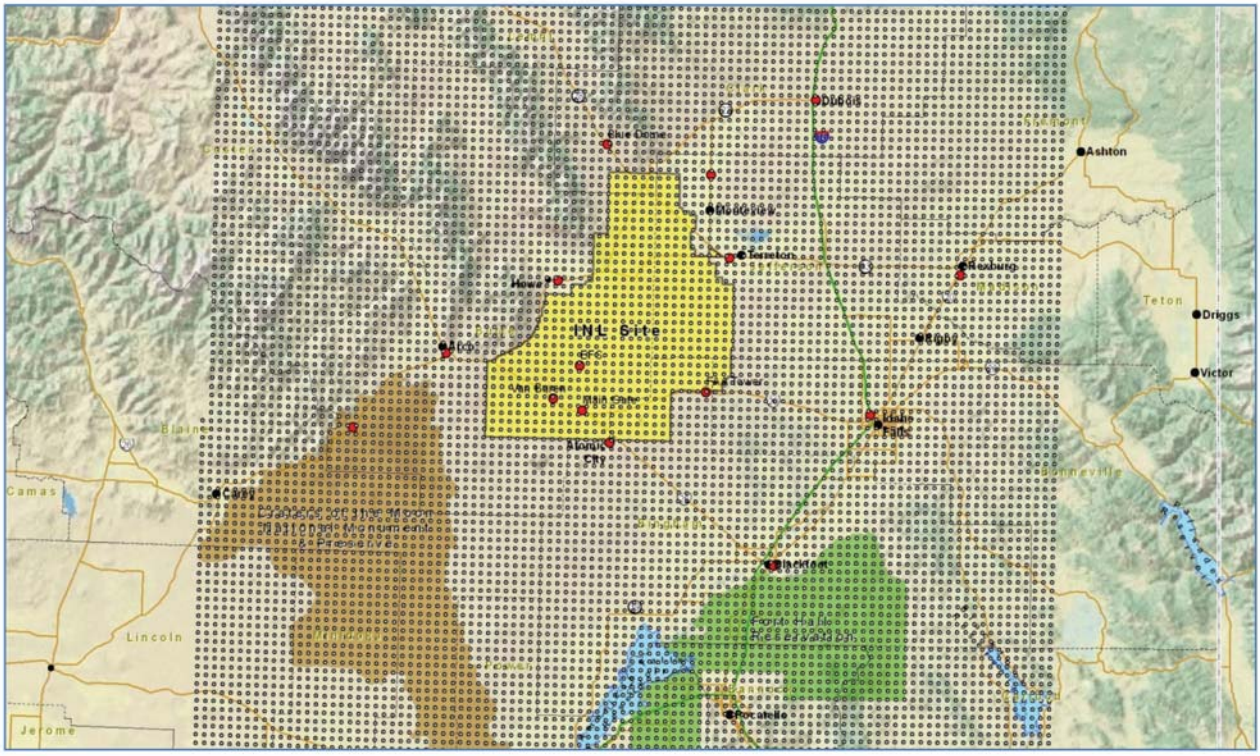


Figure 8-4. INL Site Mesoscale Grid Currently Used in MDIFF Simulations of INL Site Air Dispersion Annual TICs. Red Circles Represent Current ESER Air Monitoring Locations.

The average modeled air concentration from each INL Site facility at the Frenchman's Cabin location was then input into a spreadsheet used to estimate doses with Nuclear Regulatory Commission methods and EPA dose conversion factors.

The population of each census division was updated with data from the 2010 census. The doses received by people living in each census division were calculated by multiplying the following four variables together:

- The release rate for each radionuclide (summarized in Table 8-1)
- The MDIFF air concentration calculated for each location (a county census division)
- The population in each census division within that county division
- The dose calculated to be received by the individual exposed to the highest MDIFF-projected air concentration.

The estimated dose at each census division was then summed over all census divisions to result in the 50-mi (80-km) population dose (Table 8-2). The estimated potential population dose was 0.199 person-rem (1.99×10^{-3} person-Sv) to a population of approximately 309,730. When compared with the approximate population dose of 120,795 person-rem (1,208 person-Sv) estimated to be received from natural background radiation, this represents an increase of

about 0.0001 percent. The largest collective doses are in the Idaho Falls and Pocatello census divisions due to their greater populations.

The largest contributors to the population dose were americium-241 contributing about 20 percent of the total population dose, iodine-129 and ^{90}Sr contributing about 18 percent each, and plutonium-239 contributing about 16 percent (Figure 8-6).These were followed by Argon-41 (about 8 percent), and ^{137}Cs and plutonium-240 (about 5 percent each). All other isotopes contributed less than 5 percent each.

For 2012, the Idaho Nuclear Technology and Engineering Center contributed nearly 41 percent of the total dose. The Radioactive Waste Management Complex contributed nearly 33 percent and the Advanced Test Reactor (ATR) Complex accounted for just over 26 percent. All other facilities contributed a total of less than 0.1 percent.

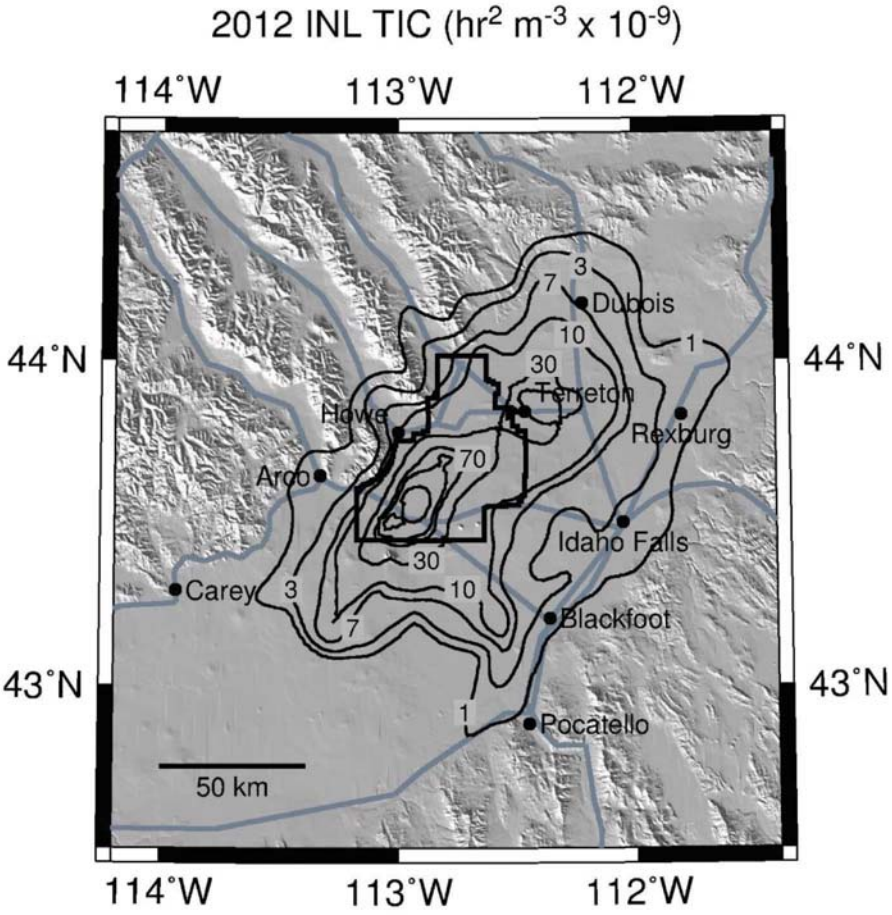


Figure 8-5. INL Site Time Integrated Concentrations (2012).

Table 8-2. Dose to Population within 80 Kilometers (50 miles) of INL Site Facilities (2012).

Census Division[a,b]	Population[c]	Population Dose	
		Person-rem	Person-Sv
Aberdeen	3331	4.24×10^{-4}	4.24×10^{-6}
Alridge	575	2.90×10^{-5}	2.90×10^{-7}
American Falls	6853	3.77×10^{-4}	3.77×10^{-6}
Arbon (part)	29	6.91×10^{-6}	6.91×10^{-8}
Arco	2564	1.43×10^{-2}	1.43×10^{-4}
Atomic City (division)	2682	8.44×10^{-3}	8.44×10^{-5}
Blackfoot	15,004	6.15×10^{-3}	6.15×10^{-5}
Carey (part)	1024	4.20×10^{-4}	4.20×10^{-6}
East Clark	79	6.32×10^{-5}	6.32×10^{-7}
East Madison (part)	262	4.70×10^{-5}	4.70×10^{-7}
Firth	3265	1.19×10^{-3}	1.19×10^{-5}
Fort Hall (part)	4357	1.18×10^{-3}	1.18×10^{-5}
Hailey-Bellevue (part)	5	1.92×10^{-11}	1.92×10^{-13}
Hamer	2344	2.18×10^{-2}	2.18×10^{-4}
Howe	366	4.98×10^{-3}	4.98×10^{-5}
Idaho Falls	99,068	5.16×10^{-2}	5.16×10^{-4}
Idaho Falls, west	1725	2.88×10^{-3}	2.88×10^{-5}
Inkom (part)	625	8.16×10^{-5}	8.16×10^{-7}
Island Park (part)	92	6.13×10^{-5}	6.13×10^{-7}
Leadore (part)	6	5.48×10^{-8}	5.48×10^{-10}
Lewisville-Menan	4165	7.10×10^{-3}	7.10×10^{-5}
Mackay (part)	1223	2.23×10^{-6}	2.23×10^{-8}
Moreland	10,302	1.70×10^{-2}	1.70×10^{-4}
Pocatello	71,015	2.47×10^{-2}	2.47×10^{-4}
Rexburg	26,420	1.37×10^{-2}	1.37×10^{-4}
Rigby	17,486	1.34×10^{-2}	1.34×10^{-4}
Ririe	1853	1.79×10^{-4}	1.79×10^{-6}
Roberts	1652	4.65×10^{-3}	4.65×10^{-5}
Shelley	8419	4.83×10^{-3}	4.83×10^{-5}
South Bannock (part)	317	8.76×10^{-5}	8.76×10^{-7}
St. Anthony (part)	2522	1.50×10^{-3}	1.50×10^{-5}
Sugar City	6722	6.04×10^{-3}	6.04×10^{-5}
Swan Valley (part)	6193	1.92×10^{-4}	1.92×10^{-6}
Ucon	6295	5.01×10^{-3}	5.01×10^{-5}
West Clark	889	8.65×10^{-4}	8.65×10^{-6}
Total	**309,730**	**0.199**	**1.99×10^{-3}**

a. The U.S. Census Bureau divides the country into four census regions and nine census divisions. The bureau also divides counties (or county equivalents) into census county divisions.

b. (Part) means only a part of the county census division lies within the 80-km (50-mi) radius of a major INL Site facility.

c. Population extrapolated to estimated 2012 values based on 2010 Census Report for Idaho.

8.3 Dose to the Public from Ingestion of Wild Game from the INL Site

The potential dose an individual may receive from occasionally ingesting meat from game animals continues to be studied at the INL Site. These studies estimate the potential dose to individuals who may eat waterfowl that briefly reside at wastewater disposal ponds at the ATR Complex and Materials and Fuels Complex, and game animals that may reside on or migrate across the INL Site.

8.3.1 Waterfowl

Nine ducks were collected during 2012: three each from the ATR Complex wastewater ponds, the MFC wastewater ponds, and a control location near American Falls Reservoir. The maximum potential dose from eating 225 g (8 oz) of duck meat collected in 2012 is presented in Table 8-3. Radionuclide concentrations used to determine these doses are reported in Figure 7-5. Doses from consuming waterfowl are conservatively based on the assumption that ducks are eaten immediately after leaving the pond and no radioactive decay occurs.

The maximum potential dose of 0.009 mrem (0.09 μSv) from these waterfowl samples is substantially below the 0.89 mrem (8.9 μSv) dose estimated from the most contaminated

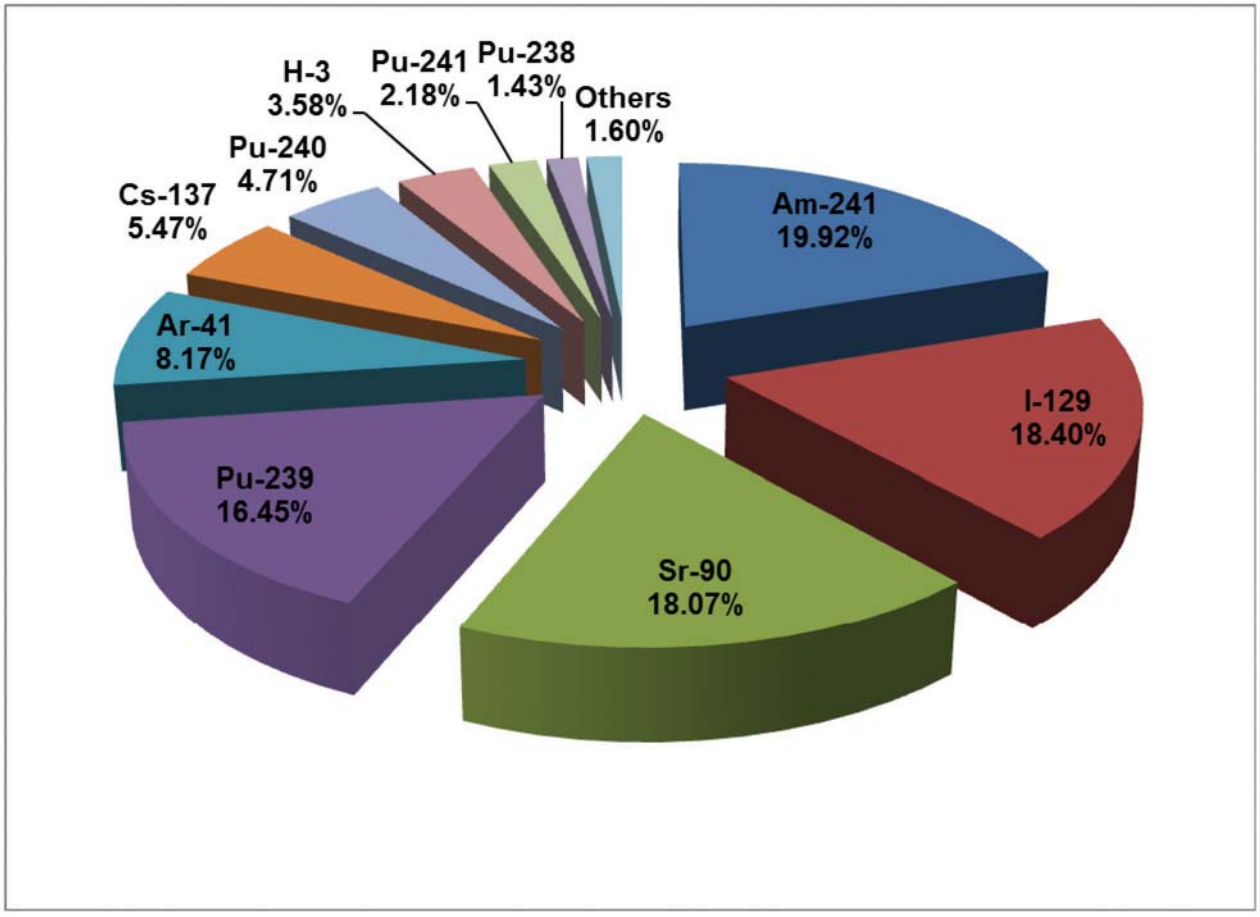


Figure 8-6. Radionuclides Contributing to Dose to Population Dose from INL Site Airborne Effluents as Calculated Using the MDIFF Air Dispersion Model (2012).

Table 8-3. Maximum Annual Potential Dose from Ingestion of Edible Waterfowl Tissue Using INL Site Wastewater Disposal Ponds in 2012.[a]

Radionuclide	ATR Complex Maximum Dose (mrem/yr)	MFC Maximum Dose[b] (mrem/yr)	Control Sample Maximum Dose[b] (mrem/yr)
Cobalt-60	1.37×10^{-4}	0	0
Cesium-137	8.81×10^{-3}	0	0
Total Dose	**8.95×10^{-3}**	**0**	**0**

a. Effective dose from consuming 225 g (8 oz) of edible (muscle) waterfowl tissue. Dose conversion factors are from Federal Guidance Report No. 13 (EPA 2002).

ducks taken from the evaporation ponds between 1993 and 1998 (Warren et al. 2001). These evaporation ponds have been remediated and are no longer available to waterfowl. The ducks were not collected directly from the wastewater disposal ponds at the ATR Complex but from sewage lagoons adjacent to them. However, they probably resided at all the ponds while they were in the area.

8.3.2 Big Game Animals

A study on the INL Site from 1976 to 1986 conservatively estimated the potential whole-body dose that could be received from an individual eating the entire muscle (27,000 g [952 oz]) and liver mass (500 g [17.6 oz]) of an antelope with the highest levels of radioactivity found in these animals was 2.7 mrem (27 µSv) (Markham et al. 1982). Game animals collected at the INL Site during the past few years have generally shown much lower concentrations of radionuclides. In 2012, no game animals had a detectable concentration of ^{137}Cs or other human-made gamma-emitting radionuclides. Therefore no dose was calculated for consuming game animal meat in 2012.

The contribution of game animal consumption to the population dose has not been calculated because only a limited percentage of the population hunts game, few of the animals killed have spent time on the INL Site, and most of the animals that do migrate from the INL Site would have reduced concentrations of radionuclides in their tissues by the time they were harvested (Halford et al. 1983). The total population dose contribution from these pathways would, realistically, be less than the sum of the population doses from inhalation of air, submersion in air, ingestion of vegetables, and deposition on soil.

8.4 Dose to the Public from Drinking Contaminated Groundwater from the INL Site

Tritium has previously been detected in two U.S. Geological Survey monitoring wells located along the southern boundary of the INL Site. These wells, located in an uninhabited area, have shown a historical downward trend in tritium detections. The maximum concentration (<1,150 pCi/L) is considerably less than the maximum contaminant level established by EPA for drinking

water (20,000 pCi/L). The maximum contaminant level corresponds to a dose from the drinking water ingestion pathway of 4 mrem per year. An individual drinking water from these wells would hypothetically receive a dose of less than 0.2 mrem (2.0 µSv) in one year. Because no one uses these wells for drinking water, this is an unrealistic scenario and the groundwater ingestion pathway is not included in the total dose estimate to a maximally exposed individual.

8.5 Dose to the Public from Direct Radiation Exposure along INL Site Borders

The direct radiation exposure pathway from gamma radiation to the public is monitored annually using thermoluminescent dosimeters and optically stimulated luminescence dosimeters (Figure 7-8). In 2012, the external radiation measured along the INL Site boundary was statistically equivalent to that of background radiation and, therefore, does not represent a dose resulting from INL Site operations.

8.6 Dose to the Public from All Pathways

DOE Order 458.1 establishes a radiation dose limit to a member of the general public from all possible pathways as a result of DOE facility operations. This limit is 100 mrem/yr (1 mSv/yr) above the dose from background radiation and includes the air transport, ingestion, and direct exposure pathways. For 2012, the only probable pathways from INL Site activities to a realistic maximally exposed individual include the air transport pathway and ingestion of game animals.

The hypothetical individual, assumed to live on the southern INL Site boundary at Frenchman's Cabin (Figure 4-2), would receive the highest calculated dose from INL Site airborne releases reported for 2012 (Section 8.2.1). For this analysis, we also assumed that the same hypothetical individual would kill and eat a duck with the maximum radionuclide concentrations detected in 2012 (Figure 7-5). For this scenario, the duck would be killed at the nearby Mud Lake Wildlife Management Area. The duck would be killed soon after it left the INL Site. It was also assumed that the individual would not receive a dose from eating a big game animal since no human-made radionuclides were detected in road-killed animals sampled in 2012.

The dose estimate for an offsite maximally exposed individual from the air and game animal pathways is presented in Table 8-4. The total dose was conservatively estimated to be 0.045 mrem (0.45 µSv) for 2012. For comparison, the total dose received by the maximally exposed individual in 2011 was calculated to be 0.07 mrem (0.7 µSv).

The total dose calculated to be received by the hypothetical maximally exposed individual for 2012 (0.045 mrem [0.45 µSv]) represents about 0.01 percent of the dose expected to be received from background radiation (390 mrem [3.9 µSv], as shown in Table 7.4) and is well below the 100 mrem/yr (1 µSv/yr) limit above background established by DOE. As discussed in the Helpful Information section of this report, the 100 mrem limit is far below the exposure levels that cause acute health effects.

The dose received by the entire population within 80 km (50 mi) of INL Site facilities was calculated to be 0.199 person-rem. This is approximately 0.0001 percent of the dose (120,795 person-rem) expected from exposure to natural background radiation in the region.

Table 8-4. Contribution to Estimated Dose to a Maximally Exposed Individual by Pathway (2012).

Pathway	Dose to Maximally Exposed Individual (mrem)	Dose to Maximally Exposed Individual (mSv)	Percent of Dose Limit[a]	Estimated Population Dose (person-rem)	Estimated Population Dose (person-Sv)	Population within 80 km	Estimated Background Radiation Population Dose (person-rem)[b]
Air	3.57×10^{-2}	3.57×10^{-4}	3.57×10^{-1}	0.199	0.00199	309,730	120,795
Waterfowl ingestion	8.95×10^{-3}	8.95×10^{-5}	NA[c]	NA	NA	NA	NA
Big game animals	NC[d]	NC	NA	NA	NA	NA	NA
Total pathways	4.47×10^{-2}	4.47×10^{-4}	4.47×10^{-2}	NA	NA	NA	NA

a. The EPA regulatory standard for the air pathway is 10 mrem/yr effective dose equivalent. The DOE limit for all pathways is 100 mrem/yr total effective dose equivalent.

b. The individual dose from background was estimated to be 390 mrem (3.9 mSv) in 2012 (Table 7-4).

c. NA = Not applicable

d. NC = Not calculated. No human-made radionuclides were detected in the samples analyzed this year.

8.7 Dose to Biota

8.7.1 Introduction

The impact of environmental radioactivity at the INL Site on nonhuman biota was assessed using *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002) and the associated software, RESRAD-Biota (DOE 2004). The graded approach includes a screening method and three more detailed levels of analysis for demonstrating compliance with standards for protection of biota. The threshold of protection is assumed at the following absorbed doses: 1 rad/d (10 mGy/d) for aquatic animals, 0.1 rad/d (1 mGy/d) for terrestrial animals, and 1 rad/d (10 mGy/d) for terrestrial plants.

The graded approach begins the evaluation using conservative default assumptions and maximum values for all currently available data. This general screening level (Level 1 in RESRAD-Biota) provides generic limiting concentrations of radionuclides in environmental media termed “Biota Concentration Guides.” Each Biota Concentration Guide is the environmental concentration of a given radionuclide in soil or water that, under the assumptions of the model, would result in a dose rate less than 1 rad/d (10 mGy/d) to aquatic animals or terrestrial plants or 0.1 rad/d (1 mGy/d) to terrestrial animals. If the sum of the measured maximum environmental concentrations divided by the biota concentration guides (the combined sum of fractions) is less than one, no negative impact to plant or animal populations is expected. No doses are calculated unless the screening process indicates a more detailed analysis is necessary. Failure at this initial screening step does not necessarily imply harm to organism populations. Instead, it is an indication that more realistic model assumptions may be necessary.

If the screening process indicates the need for a more site-specific analysis, an analysis is performed using site-representative parameters (e.g., distribution coefficients, bioconcentration factors) instead of the more conservative default parameters. This is Level 2 in RESRAD-Biota.

The next step in the graded approach methodology involves a site-specific analysis employing a kinetic modeling tool provided in RESRAD-Biota (Level 3). Multiple parameters which represent contributions to the organism internal dose (e.g., body mass, consumption rate of food/soil, inhalation rate, lifespan, biological elimination rates) can be modified to represent site- and organism-specific characteristics. The kinetic model employs equations relating body mass to internal dose parameters. At Level 3, bioaccumulation (the process by which biota concentrate contaminants from the surrounding environment) can be modeled to estimate the dose to a plant or animal. Alternatively, concentrations of radionuclides measured in the tissue of an organism can be input into RESRAD-Biota to estimate the dose to the organism.

The final step in the graded approach involves an actual site-specific biota dose assessment, which would involve a problem formulation, analysis, and risk characterization protocol similar to that recommended by EPA (1998). RESRAD-Biota cannot perform these calculations.

8.7.2 Terrestrial Evaluation

Of particular importance for the terrestrial evaluation portion of the 2012 biota dose assessment is the division of the INL Site into evaluation areas based on potential soil contamination and habitat types. For the INL Site, it is appropriate to consider specific areas that have been historically contaminated above background levels. Most of these areas have been

monitored for radionuclides in soil since the early 1970s (Jessmore et al. 1994). In some of these areas, structures have been removed and areas cleaned to a prescribed, safe contamination level, but the soil may still have residual, measurable concentrations of radionuclides. These areas are associated with facilities shown in Figure 1-3 and include:

- Auxiliary Reactor Area
- ATR Complex
- Critical Infrastructure Test Range Complex
- Large Grid, a 24-mile radius around the Idaho Nuclear Technology and Engineering Center
- Materials and Fuels Complex
- Naval Reactors Facility
- Radioactive Waste Management Complex
- Test Area North.

For the initial terrestrial evaluation, the most recently measured maximum concentrations of radionuclides in soil were used (Table 8-5.) The table includes laboratory analyses of soil samples collected in 2005, 2006, and 2012 by the INL and Idaho Cleanup Project contractors. The INL contractor currently uses in situ gamma spectroscopy to determine levels of ^{137}Cs and other gamma-emitting radionuclides in surface soils. The results of these surveys (Table 7-2) are also included in Table 8-5.

Using the maximum radionuclide concentrations for all locations in Table 8-6, a screening level analysis was made of the potential terrestrial biota dose. The soil concentrations are conservative because background concentrations (see Table 7-2) were not subtracted. The analysis also assumed that animals have access to water in facility effluents and ponds. The maximum radionuclide concentrations reported in Appendix C were used to represent surface water concentrations. The combined sum of fractions was less than one for both terrestrial animals (0.176) and plants (0.00203) and passed the general screening test (Table 8-6).

Based on the results of the graded approach, there is no evidence that INL Site-related radioactivity in soil is harming terrestrial plant or animal populations.

8.7.3 Aquatic Evaluation

For the aquatic evaluation, maximum effluent or pond radionuclide concentrations are typically used. The maximum concentration for each radionuclide reported in any pond or effluent in Appendix C was used. When “uranium-233/234” was reported, it was conservatively assumed that each radionuclide was present in equal concentrations.

The results shown in Table 8-7 indicate that INL Site-related radioactivity in ponds and liquid effluents is not harming aquatic biota. The combined sum of fractions was less than one for both aquatic animals (0.0146) and riparian animals (0.00431)

Tissue data from waterfowl collected on the ATR Complex ponds in 2012 were also available (Figure 7-5). Concentrations of radionuclides in tissue can be input into the RESRAD-Biota code

Table 8-5. Concentrations of Radionuclides in INL Site Soils, by Area.

Location[a]	Radionuclide	Detected Concentration (pCi/g)[b] Minimum	Maximum
ARA	Cesium-134	5.00×10^{-2}	8.00×10^{-2}
	Cesium-137	9.00×10^{-2}	1.62
	Uranium-238	-----[c]	5.47
	Strontium-90	2.10×10^{-1}	3.70×10^{-1}
	Plutonium-238	------	3.90×10^{-3}
	Plutonium-239/240	1.30×10^{-2}	1.80×10^{-2}
	Americium-241	5.50×10^{-3}	8.50×10^{-3}
ATR Complex	Cobalt-60	3.00×10^{-2}	1.10×10^{-1}
	Cesium-134	2.00×10^{-2}	1.00×10^{-1}
	Cesium-137	8.00×10^{-2}	8.30×10^{-1}
	Europium-152	------	7.80×10^{-1}
	Americium-241	------	4.00×10^{-2}
	Strontium-90	------	5.82×10^{-2}
	Plutonium-238	5.90×10^{-3}	4.30×10^{-2}
	Plutonium-239/240	1.70×10^{-2}	2.18×10^{-2}
CITRC	Cesium-134	5.80×10^{-2}	8.00×10^{-2}
	Cesium-137	1.60×10^{-1}	1.70×10^{-1}
MFC	Cobalt-60	-----	2.00×10^{-1}
	Cesium-134	5.00×10^{-2}	7.00×10^{-2}
	Cesium-137	1.00×10^{-1}	2.20×10^{-1}
	Uranium-238	-----	2.58
	Plutonium-239/240	1.50×10^{-2}	2.90×10^{-2}
	Americium-241	4.30×10^{-3}	1.20×10^{-2}
INTEC	Cobalt-60	-----	3.30×10^{-2}
	Cesium-134	5.00×10^{-2}	8.00×10^{-2}
	Cesium-137	5.30×10^{-1}	2.72
	Uranium-238	4.20	5.56
	Strontium-90	4.90×10^{-1}	7.10×10^{-1}
	Plutonium-238	2.50×10^{-2}	4.30×10^{-2}
	Plutonium-239/240	1.10×10^{-2}	2.90×10^{-2}
	Americium-241	6.10×10^{-3}	8.10×10^{-3}
Large Grid	Cesium-134	6.00×10^{-2}	6.30×10^{-2}
	Cesium-137	1.30×10^{-1}	2.40×10^{-1}
	Strontium-90	------	1.10×10^{-1}
	Plutonium-238	3.30×10^{-3}	4.00×10^{-3}
	Plutonium-239/240	1.00×10^{-2}	2.50×10^{-2}
	Americium-241	5.50×10^{-3}	8.50×10^{-3}
NRF	Cesium-134	3.00×10^{-2}	8.00×10^{-2}
	Cesium-137	1.4×10^{-1}	1.60×10^{-1}
	Uranium-238	3.96	4.31
	Plutonium-239/240	5.70×10^{-3}	1.60×10^{-2}
	Americium-241	4.30×10^{-3}	9.70×10^{-3}
RWMC	Cesium-134	6.00×10^{-2}	8.00×10^{-2}
	Cesium-137	8.00×10^{-2}	2.10
	Sr-90	1.23×10^{-2}	1.78×10^{-1}
	Americium-241[d]	2.02×10^{-2}	4.63×10^{-1}
	Plutonium-238	2.19×10^{-3}	1.51×10^{-2}
	Plutonium-239/240	3.6×10^{-2}	5.25×10^{-1}
TAN/SMC	Cesium-134	4.00×10^{-2}	6.00×10^{-2}
	Cesium-137	1.10×10^{-1}	3.7×10^{-1}
	Uranium-238	------	4.33
	Plutonium-239/240	1.25×10^{-2}	1.74×10^{-2}
	Americium-241	3.20×10^{-3}	5.70×10^{-3}
ALL	Cobalt-60	3.00×10^{-2}	2.00×10^{-1}
	Cesium-134	2.00×10^{-2}	1.00×10^{-1}

Table 8-5. Concentrations of Radionuclides in INL Site Soils, by Area. (cont.)

Location[a]	Radionuclide	Detected Concentration (pCi/g)[b] Minimum	Maximum
	Cesium-137	8.00×10^{-2}	2.72
	Europium-152	------	7.80×10^{-1}
	Strontium-90	1.23×10^{-2}	7.10×10^{-1}
	Uranium-238	3.96	5.56
	Plutonium-238	2.19×10^{-3}	4.30×10^{-2}
	Plutonium-239/240	5.70×10^{-3}	5.25×10^{-1}
	Americium-241[d]	4.30×10^{-3}	4.63×10^{-1}

a. ARA = Auxiliary Reactor Area; ATR = Advanced Test Reactor Complex; CITRC = Critical Infrastructure Test Range Complex; Large Grid = A 24- mile radius around INTEC; 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.

b. Legend:
- Results measured in 2012 using in situ gamma spectroscopy (see Table 7-2.)
- Results measured by laboratory analyses of soil samples collected in 2005
- Results measured by laboratory analyses of soil samples collected in 2006
- Results measured by laboratory analyses of soil samples collected in 2012.

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

d. The data shown for Am-241 were the results of laboratory analysis of soil samples collected by the ICP contractor. In situ surveillance of the area also detected Am-241, with results ranging from 0.72 to 3.83 pCi/g. However, these results were probably due to shine from material containing americium-241, which is stored near where the measurements were taken. In situ results most likely do not represent true measurements of Am-241 activity in soil outside the RWMC. For this reason, the laboratory results were selected for this table.

at the Level 3 step to calculate the internal dose to biota. To confirm that doses to waterfowl from exposure to radionuclides in the vicinity of the ATR Complex are not harmful, a Level 3 analysis was performed using the maximum tissue concentrations shown in Figure 7-5. The waterfowl were assumed in the model to be riparian animals, accessing both aquatic and terrestrial environments in the area. External dose was calculated using the maximum radionuclide concentrations measured in soils around the ATR Complex.

Results of the dose evaluation to waterfowl using radionuclide concentrations measured in tissue are shown in Table 8-8. The estimated dose to waterfowl was calculated by RESRAD-Biota 1.5 to be 4.78E-04 rad/d (4.78×10^{-3} mGy/d) (DOE 2004). This dose is less than the standard of 1 rad/d (10 mGy/d). Based on these results, there is no evidence that impounded water at the INL Site is harming aquatic biota.

8.8 Doses from Unplanned Releases

No unplanned radioactive releases from the INL site were reported in 2012. As such, there are no doses associated with unplanned releases during 2012.

Table 8-6. RESRAD Biota 1.5 Biota Dose Assessment (Screening Level) of Terrestrial Ecosystems on the INL Site (2012).

Terrestrial Animal						
	Water			Soil		
Nuclide	Concentration (pCi/L)	BCG[a] (pCi/L)	Ratio	Concentration (pCi/g)	BCG (pCi/g)	Ratio
Am-241	0	2.02E+05	0.00E+00	0.463	3.89E+03	1.19E-04
Co-60	0	1.19E+06	0.00E+00	0.2	6.92E+02	2.89E-04
Cs-134	0	3.26E+05	0.00E+00	0.1	1.13E+01	8.85E-03
Cs-137	0	5.99E+05	0.00E+00	2.72	2.08E+01	1.31E-01
Eu-152	0	2.55E+06	0.00E+00	0.78	1.52E+03	5.12E-04
Pu-238	0	1.89E+05	0.00E+00	0.043	5.27E+03	8.16E-06
Pu-239	0	2.00E+05	0.00E+00	0.525	6.11E+03	8.59E-05
Sr-90	0	5.45E+04	0.00E+00	0.71	2.25E+01	3.16E-02
U-233	1.21	4.01E+05	3.02E-06	0	4.83E+03	0.00E+00
U-234	1.21	4.04E+05	2.99E-06	0	5.13E+03	0.00E+00
U-238	0.562	4.06E+05	1.38E-06	5.56	1.58E+03	3.52E-03
Summed	-	-	**7.4E-06**	-	-	**1.76E-01**
Terrestrial Plant						
	Water			Soil		
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Concentration (pCi/g)	BCG (pCi/g)	Ratio
Am-241	0	7.04E+08	0.00E+00	0.463	2.15E+04	2.15E-05
Co-60	0	1.49E+07	0.00E+00	0.2	6.13E+03	3.26E-05
Cs-134	0	2.28E+07	0.00E+00	0.1	1.09E+03	9.21E-05
Cs-137	0	4.93E+07	0.00E+00	2.72	2.21E+03	1.23E-03
Eu-152	0	3.06E+07	0.00E+00	0.78	1.47E+04	5.30E-05
Pu-238	0	3.95E+09	0.00E+00	0.71	1.75E+04	2.46E-06
Pu-239	0	7.04E+09	0.00E+00	0	1.27E+04	4.14E-05
Sr-90	0	3.52E+07	0.00E+00	0	3.58E+03	1.98E-04
U-233	1.21	1.06E+10	1.14E-10	5.56	5.23E+04	0.00E+00
U-234	1.21	3.08E+09	3.93E-10	0.463	5.16E+04	0.00E+00
U-238	0.562	4.28E+07	1.31E-08	0.2	1.57E+04	3.54E-04
Summed	-	-	**1.36-08**	-	-	**2.03E-03**

a. BCG = Biota Concentration Guide. Each radionuclide-specific BCG represents the limiting radionuclide concentration in an environmental medium which would not result in recommended dose standards for biota to be exceeded.

Table 8-7. RESRAD Biota 1.5 Assessment (Screening Level) of Aquatic Ecosystems on the INL Site (2012).

Aquatic Animal						
	Water			Sediment		
Nuclide	Concentration (pCi/L)	BCG[a] (pCi/L)	Ratio	Concentration (pCi/g)	BCG (pCi/g)	Ratio
U-233	1.21	2.00E+02	6.06E-03	0.0605	1.06E+07	5.71E-09
U-234	1.21	2.02E+02	6.00E-03	0.0605	3.08E+06	1.96E-08
U-238	0.562	2.23E+02	2.53E-03	0.0281	4.28E+04	6.56E-07
Summed	-	-	**1.46E-02**	-	-	**6.81E-07**
Riparian Animal						
	Water			Sediment		
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Concentration (pCi/g)	BCG (pCi/g)	Ratio
U-233	1.21	6.76E+02	1.79E-03	0.0605	5.28E+03	1.15E-05
U-234	1.21	6.83E+02	1.77E-03	0.0605	5.27E+03	1.15E-05
U-238	0.562	7.56E+02	7.43E-04	0.0281	2.49E+03	1.13E-05
Summed	-	-	**4.31E-03**	-	-	**3.42E-05**

a. BCG = Biota Concentration Guide. Each radionuclide-specific BCG represents the limiting radionuclide concentration in an environmental medium which would not result in recommended dose standards for biota to be exceeded.

Table 8-8. RESRAD Biota 1.5 Assessment (Level 3 Analysis) of Aquatic Ecosystems on the INL Site Using Measured Waterfowl Tissue Data (2012).

	Waterfowl Dose (rad/d)				
Nuclide	Water[a]	Soil[b]	Sediment	Tissue[c]	Summed
Am-241	0.00E+00	8.15E-08	0.00E+00	0.00E+00	8.15E-08
Co-60	0.00E+00	4.97E-06	0.00E+00	1.61E-06	6.58E-06
Cs-134	0.00E+00	1.49E-06	0.00E+00	0.00E+00	1.49E-06
Cs-137	0.00E+00	1.47E-05	0.00E+00	1.54E-06	3.02E-05
Eu-152	0.00E+00	8.76E-06	0.00E+00	0.00E+00	8.76E-06
Pu-238	0.00E+00	4.41E-11	0.00E+00	0.00E+00	4.41E-11
Pu-239	0.00E+00	2.69E-10	0.00E+00	0.00E+00	2.69E-10
Sr-90	0.00E+00	1.28E-07	0.00E+00	0.00E+00	1.28E-07
U-233	1.79E-04	0.00E+00	0.00E+00	5.05E-06	1.79E-04
U-234	1.77E-04	0.00E+00	0.00E+00	0.00E+00	1.77E-04
U-238	7.30E-05	2.11E-06	0.00E+00	0.00E+00	7.51E-05
Total	**4.29E-04**	**3.22E-05**	**0.00E+00**	**8.20E-06**	**4.78E-04**

a. None of these radionuclides were measured in the ATR Complex Cold Waste Pond. Hence, there were no doses calculated for water and sediment.
b. External doses to waterfowl were calculated using soil concentrations. Maximum concentrations ofradionuclides measured in soil at the ATR Complex were used (Table 8-5).
c. Internal doses to waterfowl were calculated using maximum concentrations in edible tissue shown in Figure 7-5.

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Remnants of the circa 1880s Birch Creek Stage Station

2012

9. Monitoring Wildlife Populations

Sheepherders' Tea Kettle

Chapter 9 Highlights

Field data are routinely collected on several key groups of wildlife at the Idaho National Laboratory (INL) Site for information that can be used to prepare National Environmental Policy Act documents and to enable the U.S. Department of Energy (DOE) to make informed decisions, based on species use of the INL Site and historical trends, for planning projects and complying with environmental policies and executive orders related to protection of wildlife. During 2012, midwinter eagle, big game, sage-grouse, breeding bird, and bat surveys were conducted on the INL Site and are highlighted as follows:

The midwinter eagle survey has been conducted every January, as part of the national Midwinter Bald Eagle Survey, since 1983. Along with identifying and documenting bald eagles, researchers also identify all raptors, golden eagles, ravens, and other selected bird species. One bald eagle and seven golden eagles were observed in 2012.

Surveys to estimate the herd sizes of pronghorn and elk have been conducted for 30 years on the INL Site. The historical methods used included visual observation on biannual aerial surveys. This year 17 radio-transmitting collars were placed on elk, in conjunction with a study through Idaho State University, to provide information on the year-round movements and use of the INL Site by elk.

Sage-grouse research has been conducted on the INL Site for over 30 years. When sage-grouse were petitioned for listing under the Endangered Species Act in 2004, DOE recognized the need to reduce impacts to existing and future mission activities and to enter into a Candidate Conservation Agreement with the U.S. Fish and Wildlife Service to identify threats to the species and its habitat and develop conservation measures and objectives to avoid or minimize threats to sage-grouse. Since 2010, Environmental Surveillance, Education, and Research (ESER) biologists have conducted surveys of sage-grouse leks along routes established by the Idaho Department of Fish and Game in the mid-1990s, as well as at historic leks on the INL Site.

The North American Breeding Bird Survey (BBS) was developed in the 1960s by the U.S. Fish and Wildlife Service along with the Canadian Wildlife Service to document trends in bird populations. The U.S. Geological Survey manages the program in North America, which currently consists of over 4,100 routes with approximately 3,000 of these sampled annually. The INL Site has five permanent official BBS routes, established in 1985, and eight additional routes which border INL Site facilities. Approximately 2,612 birds from 47 species were documented in 2012 along these routes.

Bats have been monitored on the INL Site periodically for the past several decades. Bat populations are of concern because of their important roles in insect control, plant pollination, and seed dissemination and because of their recent declines due to white-nose syndrome, wind-energy development, climate change, and human destruction of hibernacula. There are 14 known species of bats in Idaho and nine of those species have been documented to occupy the INL Site during some part of the year. Currently, bats occupy at least 17 of 23 caves known to exist on the INL Site. During 2012 ESER established permanent bat-monitoring stations at eight facilities and the three largest known hibernacula on the INL Site.

9. MONITORING WILDLIFE POPULATIONS

The Environmental Surveillance, Education, and Research (ESER) Program has historically collected data on several key groups of wildlife that occupy the Idaho National Laboratory (INL) Site, including raptors, ungulates, sage-grouse (*Centrocercus urophasianus*), breeding birds, and bats. These surveys provide U.S. Department of Energy (DOE) with an understanding of how these species use the INL Site, as well as historical trends of these species. This information is often used in National Environmental Policy Act (NEPA 1970) documents and enables DOE officials to make informed decisions for project planning, as well as maintaining up-to-date information on potentially sensitive species on the INL Site. These surveys also support DOE's compliance with several policies and executive orders including:

- Migratory Bird Treaty Act (1918)
- Bald and Golden Eagle Protection Act (1940)
- Endangered Species Act (1973)
- Executive Order 11514 (1970) - Protection and Enhancement of Environmental Quality: In furtherance of the purpose and policy of NEPA, directs federal agencies to monitor, evaluate, and control on a continuing basis their activities to protect and enhance the quality of the environment
- Idaho National Laboratory Comprehensive Land Use and Environmental Stewardship Report (2011).

Herein we summarize results from wildlife surveys conducted by the ESER Program on the INL Site during 2012. The results and population trends reported in this document were based on field observations and do not necessarily represent comprehensive information about population status or occurrence of species on the INL Site.

9.1 Midwinter Eagle Survey

Each January, hundreds of individuals throughout the United States count eagles along standardized, non-overlapping survey routes as part of the Midwinter Bald Eagle Survey (Steenhof et al. 2008). These surveys were coordinated from 1979 to 1992 by the National Wildlife Federation. After that time, the Bureau of Land Management's Raptor Research and Technical Assistance Center assumed responsibility for overseeing these surveys. That

responsibility, however, shifted to the National Biological Survey (1993-1996) and later to the U.S. Geological Survey (USGS). In April 2007, the USGS established a partnership with the U.S. Army Corps of Engineers to maintain the long-term, national coordination of Midwinter Bald Eagle survey data analysis and reporting (Steenhof et al. 2008).

The Midwinter Bald Eagle Surveys were originally established to provide an index of the total number of wintering bald eagles (*Haliaeetus leucocephalus*) in the lower 48 states, as well as to determine bald eagle distribution during a standardized survey period and to identify previously unrecognized areas of important winter habitat (Steenhof et al. 2008). Beginning in 1984, the National Wildlife Federation asked participants in each state to count bald eagles along standard routes. Doing this provided data regarding trends of wintering bald eagles. Survey routes were standardized as clearly described areas where bald eagles had been observed in the past. Observers conduct surveys during the first two weeks of January each year, usually on one of two target days (Steenhof et al. 2008). Each state has a coordinator that is responsible for organizing local counts, enlisting survey participants, and compiling data. The size of survey routes vary from single fixed points to 241 km (150 mi.) in length. Approximately 44 percent of the surveys are conducted from vehicles, 18 percent are conducted from fixed-wing aircraft, 8 percent are collected from boats, and 7 percent are conducted by helicopter (Steenhof et al. 2008). The number of states participating in the Midwinter Bald Eagle Survey each year has ranged from 25 to 41, and the number of standard survey routes per state ranges from 1 to 84 (Steenhof et al. 2008).

On the INL Site, Midwinter Bald Eagle Surveys have taken place since 1983. During those years, two teams surveyed two established routes across the north and south of the INL Site in January covering about 122 miles along roads (Figure 9-1). Along with identifying and documenting bald eagles, researchers on the INL Site also scan the landscape with binoculars and spotting scopes and identify all raptors, as well as golden eagles (*Aquila chrysaetos*), ravens (*Corvus corax*), northern (*Lanius excubitor*) and loggerhead (*L. ludovicianus*) shrikes and black-billed magpies (*Pica hudsonia*) along each route (Figure 9-2). Global Positioning System (GPS) coordinates are collected for each observation, and all data are submitted to the regional coordinator of the USGS Biological Resource Division to be added to the nationwide database.

On 13 January 2012, two teams surveyed the two established routes on the INL Site (Figure 9-1). During those surveys, 101 birds were counted, which was lower than the number of individuals observed in 2011 and lower than the average count of 220 birds since 2002. This decrease in number birds observed in 2012 may be due to natural variability in weather patterns on the day of the survey. The raven was the most abundant species observed (62 sightings), and the rough-legged hawk (*Buteo lagopus*) was the second most abundant species recorded (22 sightings). One bald eagle and seven golden eagles were observed. No rare or unusual species were documented during those surveys.

9.2 Big game

Surveys for big game on the INL Site have been conducted for at least 30 years. Many of those surveys occurred in different areas across the Site using different methods. In the late-1990s, standardized-survey methods were initiated to try to estimate the number of pronghorn (*Antilocapra americana*) and elk (*Cervus elaphus*) using this area, especially individuals that

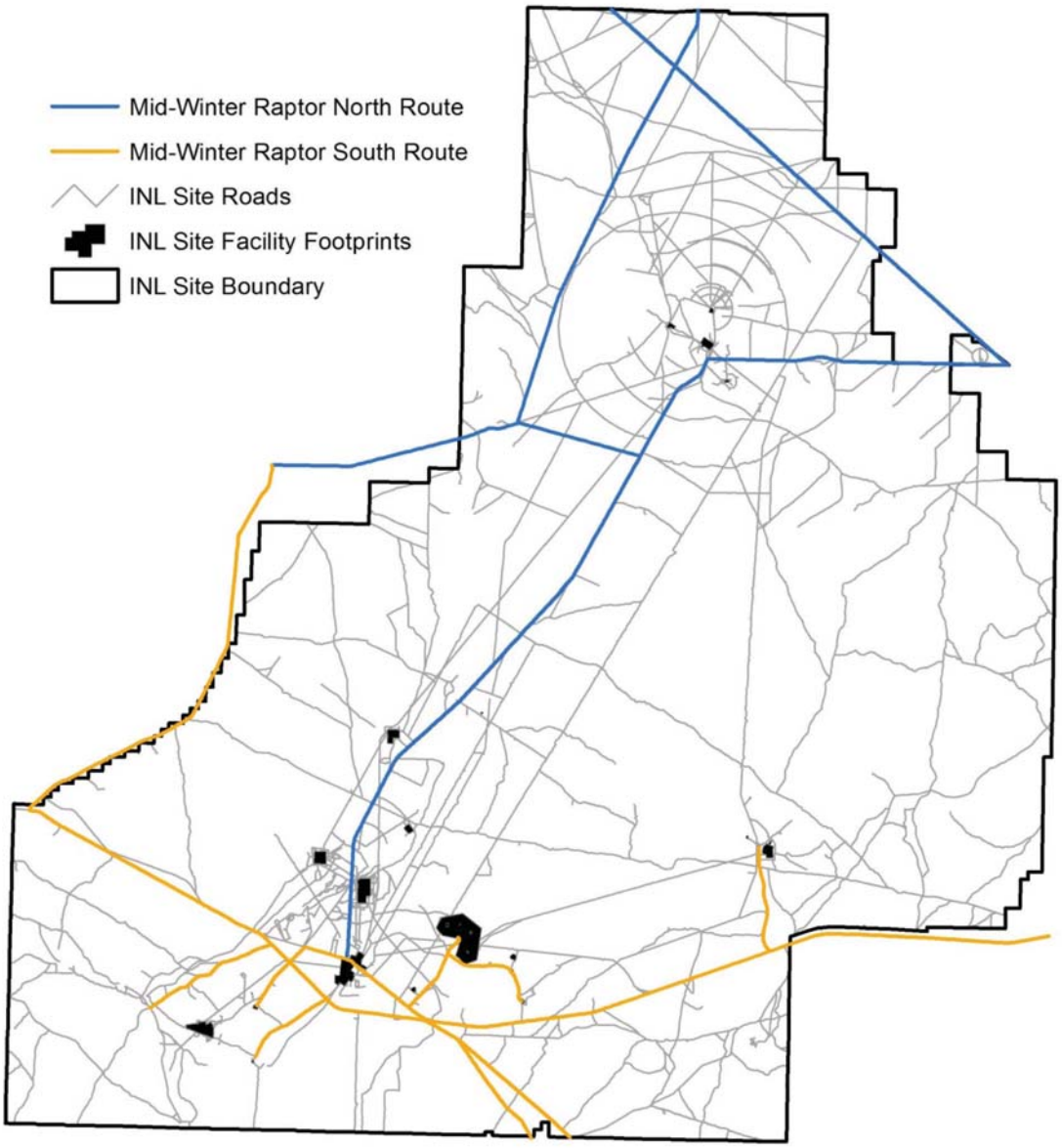

Figure 9-1. Routes for the Midwinter Bald Eagle Surveys on the INL Site.

were potentially depredating agricultural fields adjacent to the Site. Those methods included collecting data by visual observations using an aerial survey that covered about 65-70 percent of the INL Site. Those flights were usually conducted for three consecutive days once in the winter (January to March) and once in the summer (July to August). After an elk hunt was initiated on the INL Site, most of the complaints from landowners subsided regarding ungulate depredation on agricultural lands adjacent to the Site.

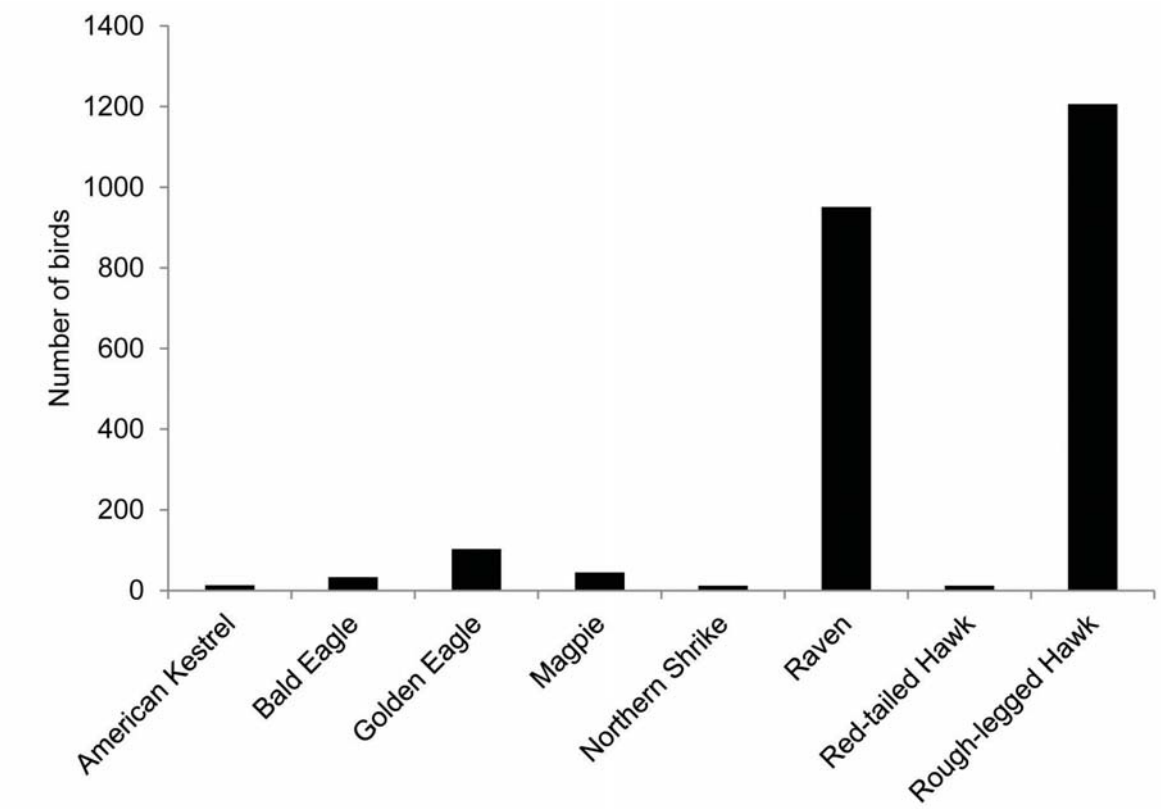

Figure 9-2. Number of birds observed during Midwinter Bald Eagle Surveys on the INL Site from 2002 to 2012. Only birds that were observed on > 5 occasions during that time were included in this figure.

Survey flights provided a limited understanding of the distribution of elk and pronghorn on the Site during certain days in winter and summer. That information was useful as a snapshot of ungulate activity during a few days each year and did not have long-term applicability. Those data provided basic, but not strongly defensible, information for use in documents related to the National Environmental Policy Act. Therefore, those surveys were not conducted in 2012. Recent advances using GPS collars are much more effective for tracking animal movements and distribution. ESER deployed 17 radio-transmitting collars on elk in conjunction with a study through Idaho State University (Figure 9-3). Data gathered from that study will help provide more reliable and defensible information regarding the movements and use of the INL Site by elk year-round. Study results will be reported in the 2013 report.

9.3 Sage-grouse

Populations of sage-grouse have declined in the last 50 years (Connelly et al. 2004, Garton et al. 2011), and the distribution of this species has been reduced to nearly half of its historic extent across western North America (Schroeder et al. 2004, Connelly et al. 2011a). Although the rate of decline of this species has slowed over the past several decades (Connelly et al. 2004,

Figure 9-3. Researchers deployed 17 radio-transmitting collars on elk during late winter (February to March) to document how these animals use the INL Site.

Garton et al. 2011), concern exists for populations of sage-grouse because of the reliance of this species on sagebrush (*Artemisia* spp.) habitat. Indeed, sagebrush-steppe ecosystems have been greatly altered during the past 150 years, and these areas are currently at risk from multiple threats, such as wildfires, mechanical treatments, agriculture, mining, oil and gas development, livestock grazing, and urbanization (Knick et al. 2003, Connelly et al. 2004). Healthy stands of sagebrush are necessary for sage-grouse to survive. Additionally, sage-grouse require a diverse understory of native forbs and grasses that provide protection from predators, and also provide chicks with high-protein insects necessary for growth (Connelly et al. 2011b).

U.S. Department of Energy-Idaho Operations Office (DOE-ID) has funded some important sage-grouse research on the INL Site (Figure 9-4). Those studies covered diverse topics such as seasonal movements (Connelly and Ball 1982, Connelly et al. 1988), habitat use (Connelly and Ball 1982, Connelly 1982), and food habits of this species (Connelly and Ball 1987). Other research has documented the response of sage-grouse to different land-management practices (Connelly et al. 1981, Connelly 1982), identified leks in areas that were recently disturbed (Connelly and Ball 1979, Connelly et al. 1981), tracked potential movements of radionuclides off-Site by these birds (Connelly and Markham 1983), and documented the location of active leks on the INL Site (Connelly 1982).

When sage-grouse were petitioned for listing under the Endangered Species Act (Connelly et al. 2004), DOE-ID recognized that to reduce impacts to existing and future mission activities on the INL Site they needed to enter into a Candidate Conservation Agreement (CCA) with the U.S.

Fish and Wildlife Service (FWS). A CCA is a voluntary agreement between the FWS and another federal agency, in which both partners identify threats to a species under consideration for listing and its key habitat, and develop conservation measures and objectives to avoid or minimize those threats. Since 2004, DOE-ID has been working with the FWS to develop a CCA for sage-grouse on the INL Site (DOE-ID and FWS 2012). DOE-ID assigned the task of developing the CCA to the ESER Program, which subcontracted the Wildlife Conservation Society to lead that effort (DOE-ID and FWS 2012). Subsequently, a field study was designed and implemented by Wildlife Conservation Society, and substantial data were collected concerning sage-grouse that occupy the INL Site (DOE-ID and FWS 2012). The draft CCA for sage-grouse is currently under review by the FWS.

Three lek routes (Lower Birch Creek, Tractor Flats, and Radioactive Waste Management Complex [RWMC]) were established by the Idaho Department of Fish and Game (IDFG) in the mid-1990s and have been monitored annually since that time using a protocol developed by the IDFG (Figure 9-5). Since 1999, the number of leks monitored across those routes has increased from 12 to 23. Employees of the IDFG surveyed the Lower Birch Creek Route until 2010; thereafter, biologists from the ESER Program conducted these surveys.

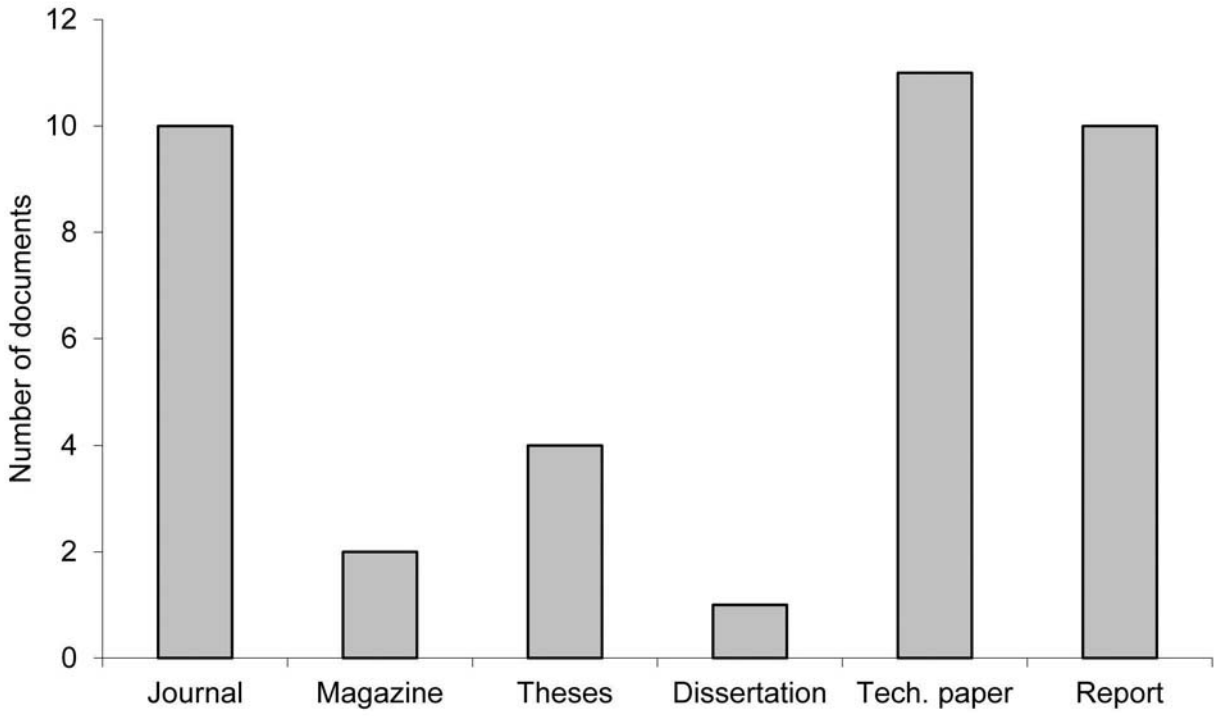

Figure 9-4. Numbers and types of publications regarding sage-grouse research conducted on the INL Site from 1976 to 2011.

Sage-grouse lek surveys began in late March and extended into the first week of May 2012. ESER conducted at least four surveys on the Tractor Flats, RWMC, and Lower Birch Creek Routes (Figure 9-5). The number of sage-grouse observed on the Tractor Flats Route peaked on March 27 with 63 males. The number of birds observed on the RWMC Route peaked on March 23 with 107 males; whereas the number of sage-grouse observed on the Lower Birch Creek Route peaked at 52 males on March 29. Peak attendance by males was the same in 2012 as in 2011 on the Tractor Flats Route, when we observed 63 birds. The number of males on the RWMC Route decreased compared with 132 birds observed in 2011, and the number of males

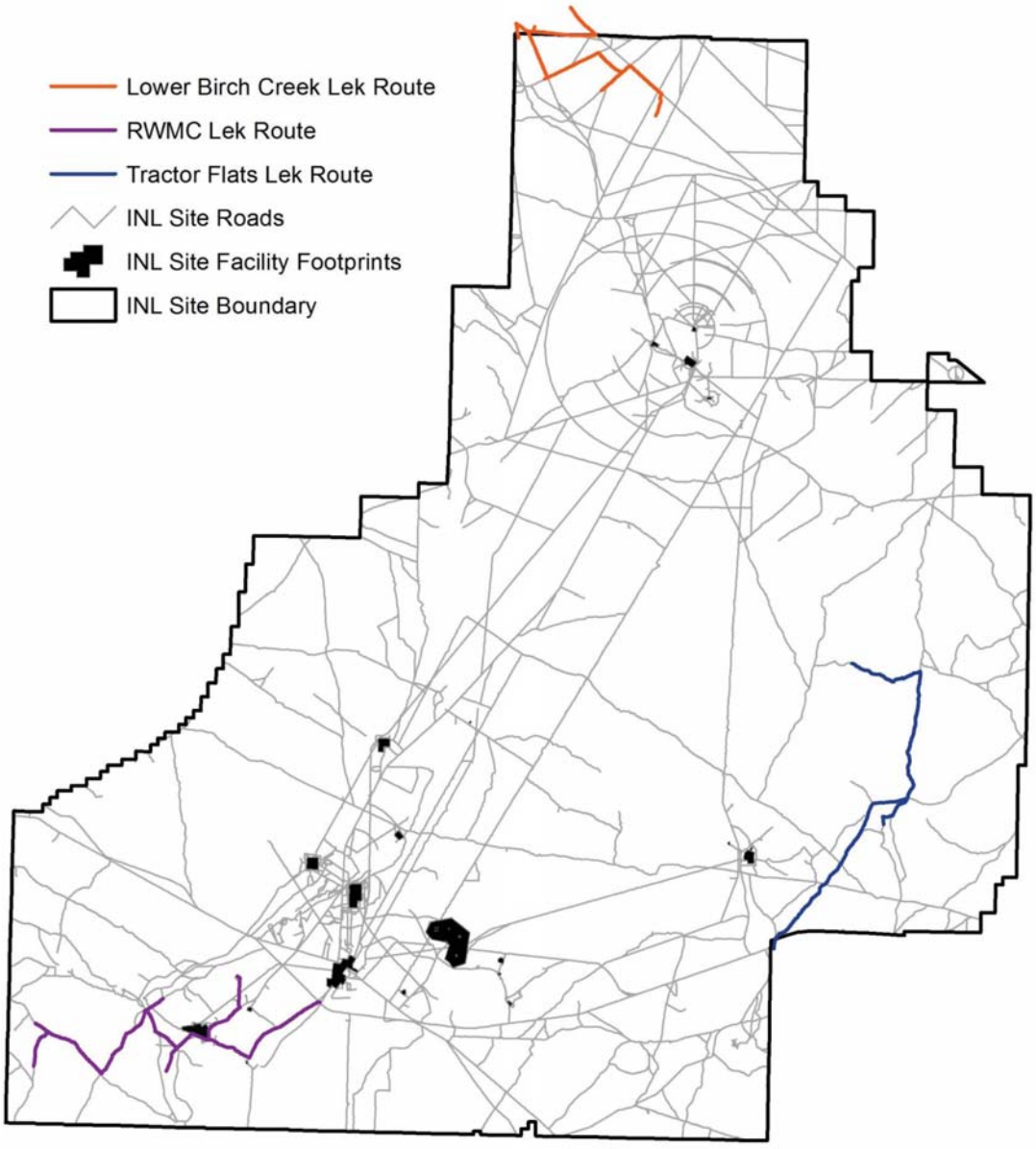

Figure 9-5. Location of lek routes for sage-grouse on the INL Site.

on the Lower Birch Creek Route increased compared with 50 birds observed in 2011. Combining data from all routes, the average number of male sage-grouse on the INL Site has remained steady the last few years (Figure 9-6). We provided the IDFG with survey data from lek routes on the INL Site. IDFG combined those data with historic data to help members of the local sage-grouse working groups decide on hunting seasons for sage-grouse in eastern Idaho.

9.4 Breeding Bird Surveys

The North American Breeding Bird Survey (BBS) was developed by the FWS along with the Canadian Wildlife Service to document trends in bird populations. Pilot surveys began in 1965 and immediately expanded to cover the U.S. east of the Mississippi and Canada and by 1968 included all of North America (Sauer and Link 2011). The BBS program in North America is managed by the USGS and currently consists of over 4,100 routes, with approximately 3,000 of these being sampled each year. BBS data provide long-term species abundance and distribution trends across a broad-geographic scale. These data have been used to estimate population changes for hundreds of bird species, and they are the primary source for regional conservation programs and modeling efforts (Sauer and Link 2011). The BBS provides a wealth of information

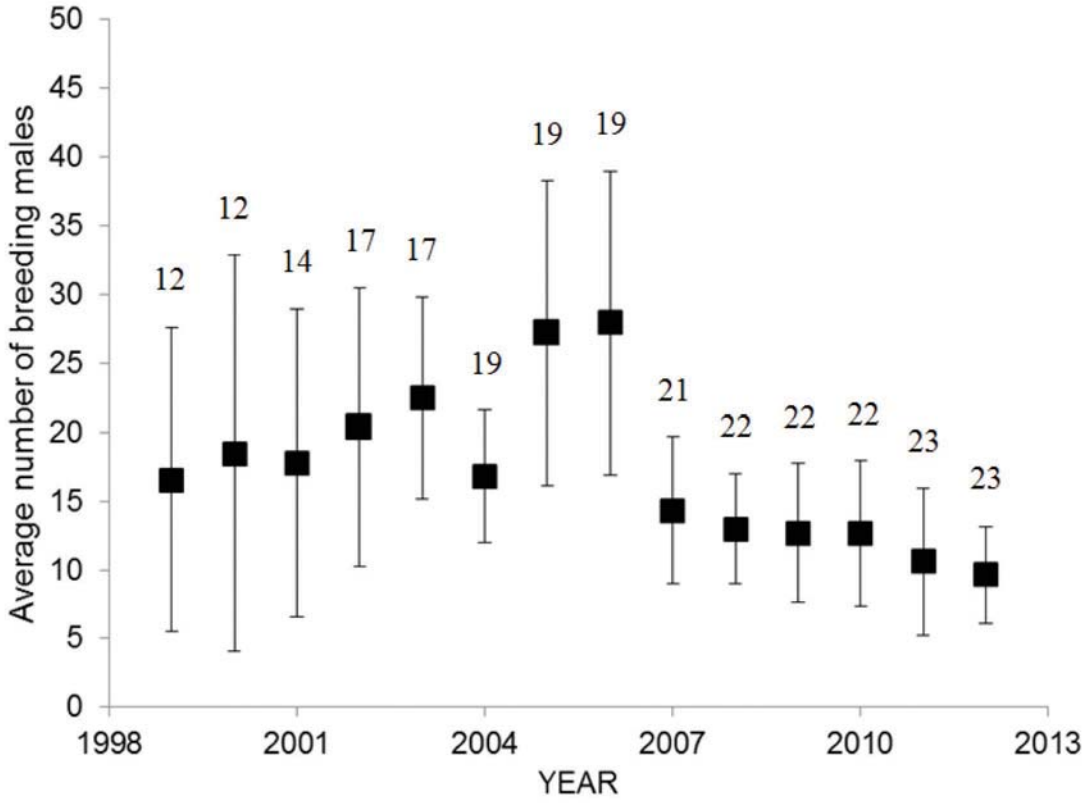

Figure 9-6. Average (± SD) number of male sage-grouse on the three lek routes (Lower Birch Creek, Tractor Flats, and RWMC) on the INL Site. The number of leks sampled in each year is above the bars.

about population trends of birds in North America, and is the foundation for broad conservation assessments extending beyond local jurisdictional boundaries.

The INL Site has five permanent, official BBS routes originally established in 1985 (remote routes) and eight additional survey routes near INL Site facilities (facility routes; Figure 9-7). Facility routes were developed to monitor avifauna populations in proximity to anthropogenic activities and disturbances. The annual BBS provides land managers with information regarding the population trends of breeding birds relative to activities conducted on the INL Site.

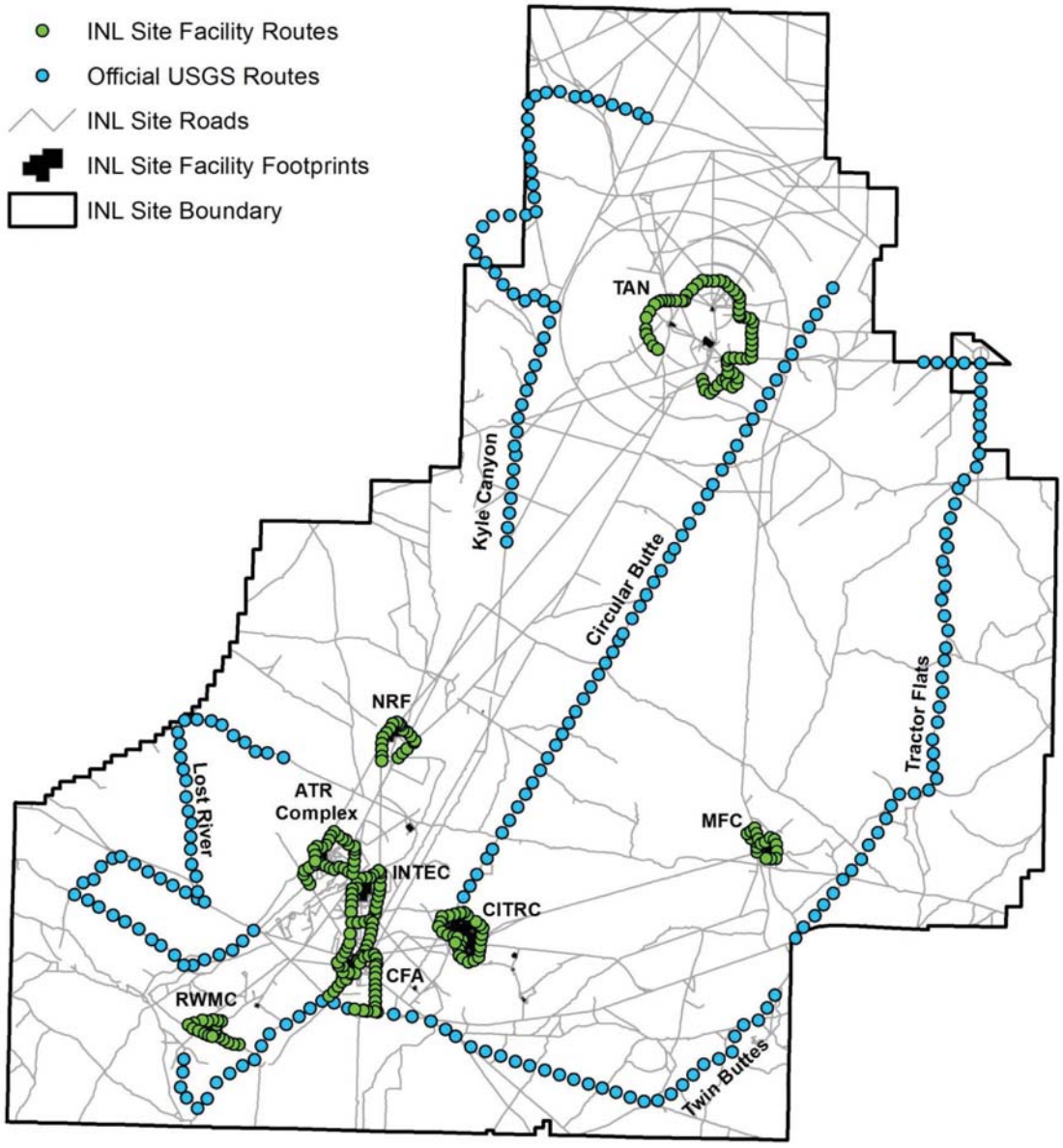

Figure 9-7. Location of Breeding Bird Survey routes on the INL Site.

In 2012, ESER conducted surveys from June 4 to July 3 along 13 established routes, five of which are part of a nationwide survey administered by the USGS and eight of which border INL Site facilities. We documented 2,612 birds from 47 species during these surveys (Figure 9-8). Bird abundance was less than the 1985-2011 average of 4,970 birds, and the number of species (i.e., species richness) was lower than the 25-year average of 58. Recent fires on the INL Site have reduced the amount of sagebrush habitat. Such reduction in habitat may have affected the total abundance of birds. Furthermore, other factors (i.e., observer or spring weather patterns) could influence bird abundance; therefore, additional years of data will be needed to compare 2012 results with those of previous surveys.

Compared with past surveys, we observed similar patterns of bird abundance among those species that are typically the most numerous. In 2012, the five species that were documented in greatest abundance were horned lark (*Eremophila alpestris, n* = 897), western meadowlark (*Sturnella neglecta, n* = 621), sage thrasher (*Oreoscoptes montanus, n* = 298), Brewer's sparrow (*Spizella breweri, n* = 172), and sage sparrow (*Amphispiza belli, n* = 161). During 26 years of breeding bird surveys on the INL Site these species have been the five most abundant 19 times, and in the remaining seven years they were among the six most abundant species.

Species observed during the 2012 BBS that are considered species of conservation concern in Idaho included the Franklin's gull (*Larus pipixcan, n* = 15), burrowing owl (*Athene cunicularia, n* = 1), ferruginous hawk (*Buteo regalis, n* = 7), and greater sage-grouse (*n* = 4). Data from the BBS were submitted to the USGS Patuxent Wildlife Research Center.

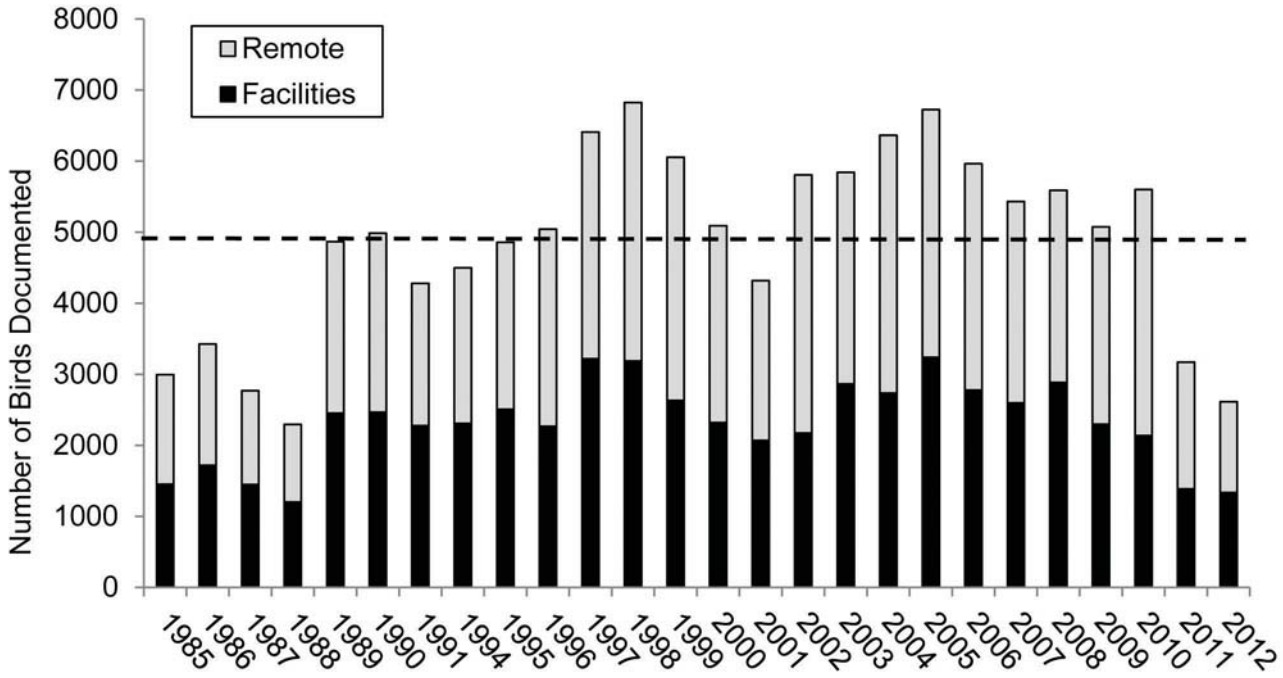

Figure 9-8. Number of birds observed during the Breeding Bird Survey on the INL Site. The dashed black line indicates the mean number of birds observed from 1985 to 2012. No Breeding Bird Surveys were conducted on the INL Site in 1992 or 1993.

9.5 Bats

Many bat species have important roles in ecosystem functions (i.e., insect control, plant pollination, and seed dissemination), and these mammals provide important ecosystem services (Kunz and Reichard 2010, Cryan 2011). For example, insectivorous bats are very effective at suppressing populations of nocturnal insects, and some authors estimate the value of bats to the agricultural industry at roughly $22.9 billion each year (Boyles et al. 2011). Moreover, insectivorous bats are effective top-down predators of forest insects (Boyles et al. 2011). Potential declines in populations of bats could have far-reaching consequences across ecosystems and biological communities (Miller 2001, Adams 2003, Blehert et al. 2009).

White-nose syndrome (WNS), wind-energy development, climate change, as well as human destruction and modification of hibernacula have impacted populations of bats. WNS has been identified as a recent major threat to many bats that hibernate in caves (Blehert et al. 2009; Foley et al. 2011; Kunz and Reichard 2010), and this disease has killed at least 5.5 to 6.7 million bats in seven species (Blehert et al. 2009; Foley et al. 2011). WNS has been considered as one of the greatest wildlife crises of the past century (Kunz and Reichard 2010), and many species of bats could be at risk of significant declines or extinction due to this disease (Kunz and Reichard 2010). Wind-energy development is expanding rapidly across the western USA, and unprecedented mortality rates of bats have occurred recently at these facilities (Arnett et al. 2008; Cryan 2011; Cryan and Barclay 2009). Additionally, the loss, modification, and disturbance of hibernacula by humans are also concerns for bat populations (Adams 2003).

Research and monitoring of bats have been conducted on the INL Site by contractors of DOE-ID periodically over the past several decades. During that time four theses, three reports, and one publication have been produced by contractors, university researchers, and graduate students. The majority of that research and monitoring, however, occurred in the late 1980s and early 1990s. Of the 14 known species of bats that occur in Idaho, nine of those species are documented to occupy the INL Site during some part of the year (Table 9-1). Six of those species are likely migratory and use the Site seasonally; whereas, three are considered residents (Table 9-1). Many of these species are considered for different levels of protection by the FWS, U.S. Bureau of Land Management, Western Bat Working Group, and other conservation organizations.

Currently, at least 17 out of 23 caves that are known to exist on the INL Site are used by several species of bats for winter hibernacula, as well as for summer day and night roosts. Lava caves are also essential habitat during most of the year for three resident species. Indeed, much of the information concerning bats on the INL Site comes from research that has centered on counting and trapping individuals at caves (Genter 1984, Wackenhut 1990, Bosworth 1994, Doering 1996). In addition to being used as roost and hibernation areas, caves also provide habitat for concentrated patches of insect prey for these mammals. Additionally, preliminary surveys indicate that caves may be used as stop-over habitat during fall migrations by previously undocumented forest bats, such as the hoary bat (*Lasiurus cinereus*) and possibly the western (*L. blossevillii*) or eastern red bat (*L. borealis*). Very little is known about the use of caves by migrating forest bats (Cryan 2011), and these areas may provide vital resources as bats traverse atypical habitats.

Table 9-1. Bat species and the seasons and areas they occupy on the INL Site, as well as protection status and threats to these mammals.

Common and Scientific Name	Distribution, Habitat, and Seasonal Occurrence	Affected by WNS[a]	Affected by Wind Energy
Big Brown Bat (*Eptesicus fuscus*)[b]	Sitewide; buildings, caves, and lava tubes; year round	Yes	Yes
Hoary Bat (*Lasiurus cinereus*)[c]	Patchy; riparian and junipers; summer and autumn	No	Yes
Little Brown Myotis (*Myotis lucifugus*)[c]	Sitewide; roosts in buildings; summer and autumn	Yes	Yes
Pallid Bat (*Antrozous pallidus*)[c]	Patchy; shrub lands; autumn	No	No
Red Bat (*Lasiurus blossevillii* or *L. borealis*)[c]	Patchy; caves; autumn	No	Yes
Silver-haired Bat (*Lasionycteris noctivagans*)[c]	Patchy; riparian and junipers; summer and autumn	No	Yes
Townsend's Big-eared Bat (*Corynorhinus townsendii*)[b]	Sitewide; caves and lava tubes; year round	Potentially	Potentially
Western Long-eared Myotis (*Myotis evotis*)[c]	Southeast and northwest INL Site; caves and junipers; summer and autumn	Yes	Potentially
Western Small-footed Myotis (*Myotis ciliolabrum*)[b]	Sitewide; buildings, caves, and lava tubes; year round	Yes	Potentially

a = White Nose Syndrome
b = Resident Species
c = Migratory Species

Anthropogenic structures are also used as habitat by bats on the INL Site. Currently, there are at least 16 facilities on the INL Site, and many activities occur at these facilities—i.e., nuclear testing, research and development, and government defense programs. These areas, and their associated lands, occupy about 0.38 percent of the INL Site. Some of these facilities were constructed in the 1950s, and are surrounded by mature trees and wastewater ponds, which provide bats with vertical-structure habitat, water, and foraging areas. Indeed, during summer all resident and one migratory bat species use anthropogenic structures around facilities and near roads for roost sites (Keller et al. 1993, Haymond and Rogers 1997).

During winter 2012, ESER established permanent bat-monitoring stations at the eight facilities and at the three largest known hibernacula (Middle Butte, Aviator, and Rattlesnake Caves; Figure 9-9). AnaBat Detectors were set to record a least one half of one hour before sunset to one half of one hour after sunrise. During summer 2012, ESER randomly deployed the remaining 12 AnaBat Detectors at the 20 caves to determine if, and to what extent, these areas are utilized by bats across summer, autumn, and winter. Each detector remained at a cave for about two weeks. ESER and its subcontractors have started to analyze recorded bat calls using Analook zero-crossing software, which can distinguish among the call sequences of species (Figure 9-10). The number of passes/the number of days the detector was set will be quantified and then an activity index for all bats and by species will be produced from the acoustical data (Miller 2001, Britzke et al. 2011). Those data will be used to compare bat activity at caves, facilities, and other important areas during certain seasons across the INL Site. ESER is in the process of producing filters to identify calls recorded by the acoustical equipment. The results of this monitoring program will provide critical information regarding bat ecology on the INL Site.

Figure 9-9. A passive-acoustical monitoring station for bats with a microphone mounted at the top. These devices record the echolocation calls of bats.

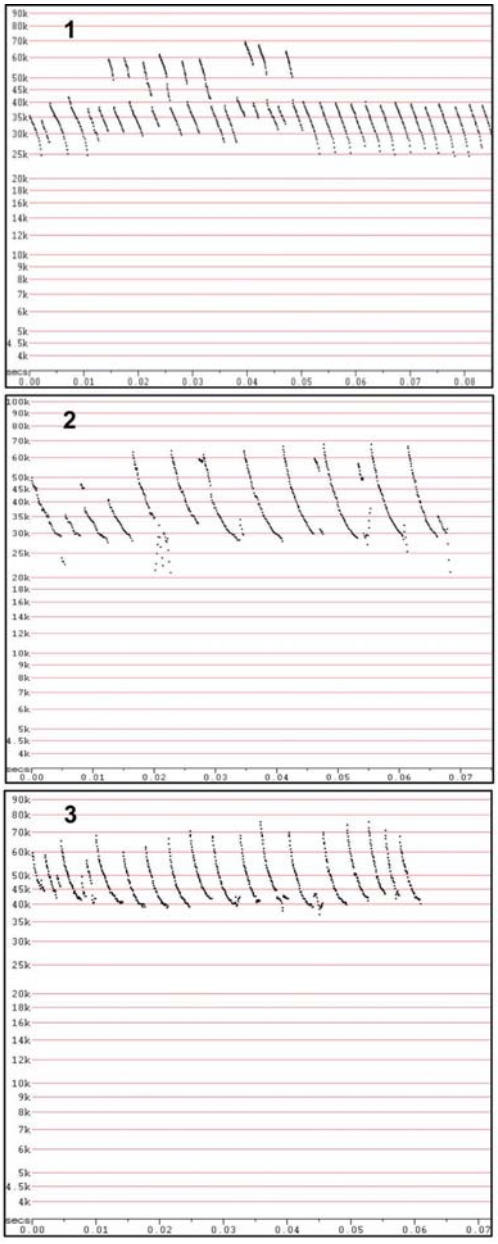

Figure 9-10. Echolocation calls recorded by AnaBat Detectors of three species of bats (1 = Townsend's big-eared bat, 2 = big brown bat, 3 = western small-footed myotis) from caves on the INL Site.

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10. Environmental Research at the Idaho National Laboratory Site

2012

Late 1800s Powell Stage Station
Photo courtesy of H. Powell Family

Chapter 10 Highlights

The Idaho National Laboratory Site was designated as a National Environmental Research Park in 1975. The National Environmental Research Park program was established in response to recommendations from citizens, scientists, and members of Congress to set aside land for ecosystem preservation and study. In many cases, these protected lands became the last remaining refuges of what were once extensive natural ecosystems. The National Environmental Research Parks provide rich environments for training researchers and introducing the public to ecological sciences. NERPs have been used to educate grade school and high school students and the general public about ecosystem interactions at U.S. Department of Energy (DOE) sites; train graduate and undergraduate students in research related to site-specific, regional, national, and global issues; and promote collaboration and coordination among local, regional, and national public organizations, schools, universities, and federal and state agencies.

During 2012, six ecological research projects were conducted on the Idaho National Environmental Research Park:

- *Long-term Vegetation Transects*
- *Surveying, Monitoring and Predicting the Occurrence and Spread of Native and Non-Native Plant Species at the Idaho National Laboratory Site*
- *Studies of Ants and Ant Guests at the Idaho National Laboratory Site*
- *Post-wildfire Wind Erosion In and Around the Idaho National Laboratory Site*
- *The Influence of Precipitation, Vegetation and Soil Properties on the Ecohydrology of Sagebrush Steppe Rangelands on the Idaho National Laboratory Site*
- *Distribution, Movements, and Space Use by Elk on the Idaho National Laboratory Site*

The United States Geological Survey (USGS) has been studying the hydrology and geology of the eastern Snake River Plain and eastern Snake River Plain aquifer since 1949. The USGS INL Project Office collects data from research and monitoring wells to create and refine hydrologic and geologic models of the aquifer, to track contaminant plumes in the aquifer and improve understanding of the complex relationships between the rocks, sediments and water that compose the aquifer. Six reports were published in 2012 by the Idaho National Laboratory Project Office:

- *Construction diagrams, geophysical logs, and lithologic descriptions for boreholes USGS 103, 105, 108, 131, 135, NRF-15, and NRF-16, Idaho National Laboratory, Idaho*

- *A comparison of U.S. Geological Survey three-dimensional model estimates of groundwater source areas and velocities to independently derived estimates, Idaho National Laboratory and vicinity, Idaho*
- *Water-quality characteristics and trends for selected sites at and near the Idaho National Laboratory, Idaho, 1949–2009*
- *Completion summary for borehole USGS 136 near the Advanced Test Reactor Complex, Idaho National Laboratory, Idaho*
- *Multilevel groundwater monitoring of hydraulic head and temperature in the eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, 2009–10*
- *Evaluation of quality-control data collected by the U.S. Geological Survey for routine water-quality activities at the Idaho National Laboratory, Idaho*

10. ENVIRONMENTAL RESEARCH AT THE IDAHO NATIONAL LABORATORY SITE

This chapter summarizes ecological research performed at the Idaho National Environmental Research Park (Section 9.1) and research conducted on the eastern Snake River Plain and eastern Snake River Plain aquifer by the United States Geological Survey (Section 9.2) during 2012.

10.1 Ecological Research at the Idaho National Environmental Research Park

The Idaho National Laboratory (INL) Site was designated as a National Environmental Research Park in 1975. The National Environmental Research Park Program was established in response to recommendations from citizens, scientists, and members of Congress to set aside land for ecosystem preservation and study. This has been one of the few formal efforts to reserve land on a national scale for ecological research and education. In many cases, these protected lands became the last remnants of what were once extensive natural ecosystems.

Five basic objectives guide activities on National Environmental Research Parks:

- Develop methods for assessing and documenting environmental consequences of human actions related to energy development
- Develop methods for predicting environmental consequences of ongoing and proposed energy development
- Explore methods for eliminating or minimizing predicted adverse effects from various energy development activities on the environment
- Train people in ecological and environmental sciences
- Educate the public on environmental and ecological issues.

National Environmental Research Parks provide rich environments for training researchers and introducing the public to the ecological sciences. They have been used to educate grade

school and high school students and the general public about ecosystem interactions at Department of Energy (DOE) sites; train graduate and undergraduate students in research related to site-specific, regional, national, and global issues; and promote collaboration and coordination among local, regional, and national public organizations, schools, universities and federal and state agencies. Ecological research on National Environmental Research Parks is leading to better land-use planning, identifying sensitive areas on DOE sites so that restoration and other activities are compatible with ecosystem protection and management, and increased contributions to ecological science in general.

Ecological research was conducted at federal laboratories long before National Environmental Research Parks were established. For example, at the INL Site, ecological research began in 1950 with the establishment of the long-term vegetation transect study. This is perhaps DOE's oldest ecological data set and one of the most intensive data sets for sagebrush steppe. In addition, in 1989, a long-term reptile monitoring study was initiated, which is the longest continuous study of its kind in the world. Also, in 1993, a protective cap biobarrier experiment was initiated, which evaluated the long-term performance of evapotranspiration caps and biological intrusion barriers. Those long-term plots are now being used to test hypotheses on the potential effects of climate change.

The Idaho National Environmental Research Park provides coordination of ecological research and information exchange at the INL Site. It facilitates ecological research on the INL Site by attracting new researchers to use the area, providing background data for new research projects, and assisting researchers to obtain access to the INL Site. The Idaho National Environmental Research Park provides infrastructure support to ecological researchers through the Experimental Field Station and reference specimen collections. The Idaho National Environmental Research Park tries to foster cooperation and research integration by encouraging researchers to collaborate, developing interdisciplinary teams to address more complex problems, encouraging data sharing, and leveraging funding across projects to provide more efficient use of resources. It also integrates research results from many projects and disciplines and provides analysis of ecosystem-level responses. The Idaho National Environmental Research Park has developed a centralized ecological data repository to provide an archive for ecological data and to facilitate data retrieval for new research projects and land management decision making. It also provides interpretation of research results to land and facility managers to support compliance with natural resource laws including the National Environmental Policy Act, Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act.

A total of 33 graduate students, post-doctoral students, faculty, and agency and contractor scientists participated in six research projects on the Idaho National Environmental Research Park in 2012. Several undergraduate students and technicians also gained valuable experience through participation in these research activities. The six projects include six graduate student research projects, with students and faculty from Idaho State University, Boise State University, the College of Idaho, and Montana State University. Other researchers represented the Environmental Surveillance, Education, and Research Program, U.S. Geological Survey, U.S. Department of Agriculture – Forest Service Rocky Mountain Research Station, and the Idaho National Laboratory.

Three of the graduate students received at least part of their research funding from the Department of Energy, Idaho Operations Office (DOE-ID) through the Environmental Surveillance, Education, and Research Program. Three of the six projects received funding in whole or part from DOE-ID through the Environmental Surveillance, Education, and Research Program. Other funding sources included the National Science Foundation, Bureau of Land Management, Idaho State University, U.S. Environmental Protection Agency, U.S. Department of Agriculture – Forest Service Rocky Mountain Research Station, U.S. Department of Defense, U.S. Geological Survey – Forest and Rangeland Ecosystem Science Center, U.S. Geological Survey – Northwest Climate Science Center, The Berryman Institute, and The Rocky Mountain Elk Foundation.

Most of the DOE-ID-funded research and much of the research funded by other agencies addresses land management issues applicable to the INL Site. These issues include preparing for potential Endangered Species Act listings, understanding wildland fire effects, minimizing invasive species impacts, and understanding long-term trends in plant community composition, sagebrush health, and potential effects of climate change. The results of these projects will be used to support the preparation of a Conservation Management Plan.

10.1.1 Long-Term Vegetation Transects

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- Jackie R. Hafla, Natural Resource Specialist, Environmental Surveillance, Education, and Research Program, Gonzales-Stoller Surveillance, Idaho Falls, ID.

Funding Source

- U. S. Department of Energy-Idaho Operations Office

Background

Abiotic and biotic conditions across the entire region have been characterized by rapid change over the past decade. These changes include shifts in land cover, land use, and climate. Several large wildland fires have removed sagebrush from a large portion of the Upper Snake River Plain over the past ten to twenty years. INL Site specifically, nearly 60,000 ha have burned in the past five years alone. Soil disturbance associated with fighting wildland fires and soil disturbance associated with general increases in the use of remote backcountry areas are notable at the INL Site and throughout the Intermountain West. Finally, some of the hottest and driest years during the 60-year weather record occurred during the past decade. All of these factors contribute to increasing stress on native plant communities and potentially set the stage for a period of dramatic change in vegetation composition across the region.

The Long-Term Vegetation (LTV) Transects and associated permanent vegetation plots were

established on what is now the INL Site in 1950. Vegetation abundance data, including density and cover, have been collected periodically once every two to ten years from plots located along two macro-transects, which are perpendicular to one another and intersect near the center of the INL Site (Figure 10-1). In 2011, 89 plots were sampled, which represents the twelfth LTV sample period. Eleven plots were sampled again in 2012 because they burned just a few weeks subsequent to sampling in 2011. Fourteen ancillary plots were also established to better address mechanisms affecting trends in sagebrush cover. Results from those analyses are included with the current LTV effort as well. LTV data are generally used to monitor vegetation condition and change in sagebrush steppe communities across the INL Site, while specific uses range from support for NEPA to conservation management planning. They are also uniquely suited to characterize native vegetation response to climate, land cover, and land use change.

Objectives

The current LTV technical report, which integrates data from the most recent sampling effort, is organized into four chapters, each with specific objectives. Chapter 1 provides a brief overview of the LTV project and summarizes changes since the previous LTV sample period. Recent land cover change from wildland fire and changes in the amount and timing of precipitation are discussed, along with the potential for those factors to affect native vegetation. A summary of vegetation monitoring and research outside the scope of the LTV, but which inform our interpretation of the LTV data, were included in Chapter 1 as well.

The second chapter is an update of long-term trend analyses for major vegetation functional groups across the INL Site. It includes information about native shrub, grass, and perennial forb abundance, as well as distribution and abundance patterns of non-native species. The results of analyses presented in this chapter provide an indication of general vegetation condition on the INL Site.

The T-17 fire burned 11 LTV plots just a few weeks after data collection had been completed in 2011, providing a unique opportunity to monitor post-fire recovery on well-characterized sites. We resampled the 11 burned plots in 2012, and Chapter 3 compares vegetation abundance and composition immediately pre- and post-fire. Eventually, these data will be used to develop a better understanding of how pre-fire condition affects post-fire recovery and to help identify indicators of potential post-fire recovery issues in the first few years after a wildland fire.

Chapter 4 includes INL-specific data and discussion about big sagebrush (Artemisia tridentata) population biology and its effects on sagebrush steppe plant communities. In the late 1990s and early 2000s it became evident in the LTV data that big sagebrush was undergoing a dramatic and prolonged period of decline. The nature of big sagebrush decline on the INL Site coupled with increasing conservation pressures for sagebrush-obligate species, made obvious the need for an investigation into big sagebrush ecology. Fourteen plots were established in the center of the INL Site (Figure 10-1) for the purposes of characterizing big sagebrush population dynamics. Results of the big sagebrush population study, as well as the implications of these results on conservation measures and land management strategies at the INL Site are also included in this chapter.

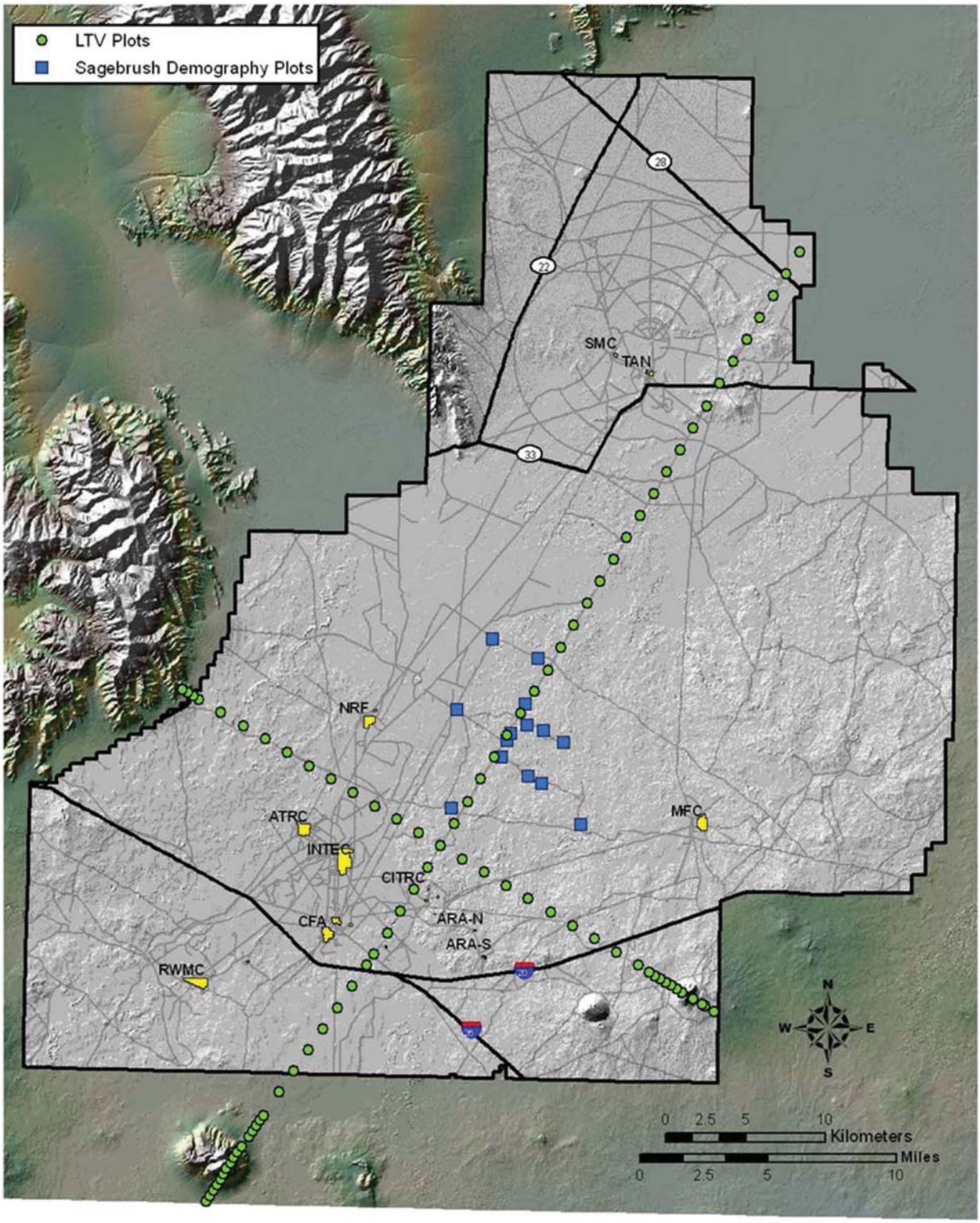

Figure 10-1. Map of the INL Site with plot locations for the LTV permanent plots and the ancillary Sagebrush Demography study plots.

Accomplishments through 2012

During the 2012 growing season, a full suite of abundance and distribution data were collected on the 11 plots that burned in the T-17 Fire in late August of 2011. Those data, along with data from the 2011 project database were integrated into the primary LTV database after undergoing final QA/QC and data verification/validation processes. The final, comprehensive project database was archived on the ESER server. Data analyses were finished and a draft of the LTV technical report, as described above, was completed by the end of 2012. The report was finalized shortly thereafter.

Results

Some of the more important vegetation composition patterns resulting from incorporation of the 2011 LTV data into the long-term trend analyses were related to the abundance and distribution of non-native species. Crested wheatgrass (*Agropyron cristatum*) abundance has continued to increase linearly since about 1990 (Figure 10-2) and is of particular concern because it has invaded the plots were it is found, it continues to increase in the plots it occupies, and where present, it occurs with much greater mean abundance than comparable native, perennial bunchgrass species. Cheatgrass (*Bromus tectorum*) distribution increased between

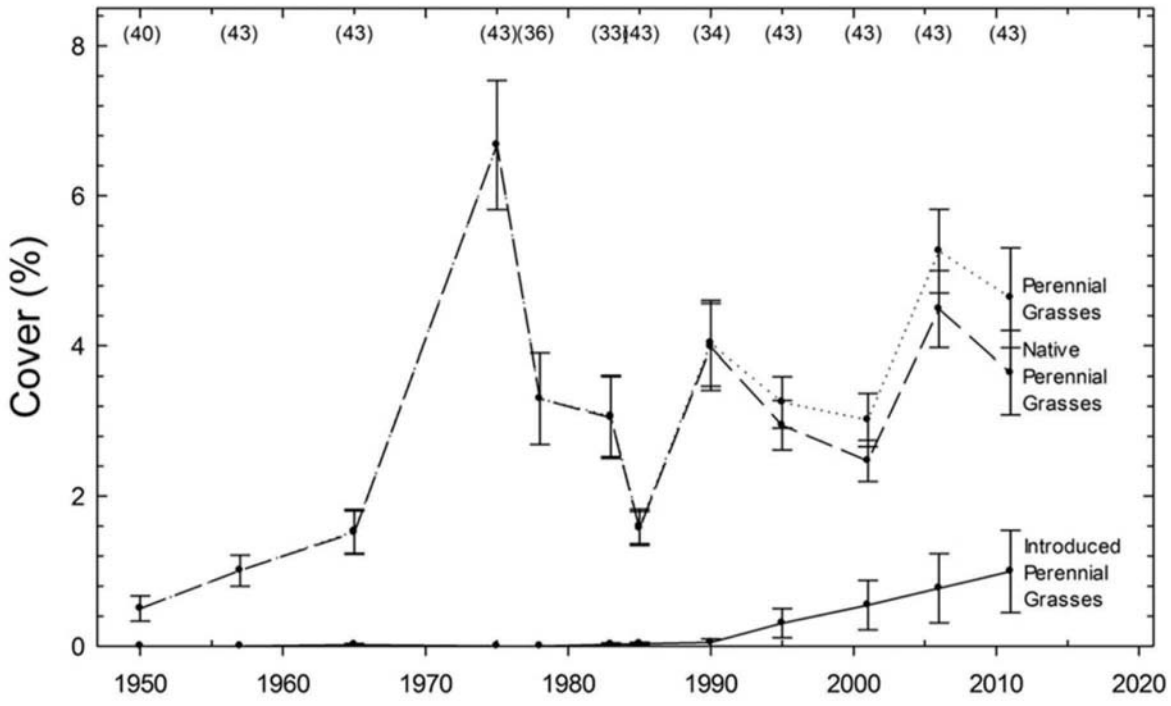

Figure 10-2. Trends in total perennial grass cover, native perennial grass cover, and introduced perennial grass (crested wheatgrass) cover from 1950 to 2011 for the core subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Data were collected using line-interception methods and are represented here as means ± 1 SE. Numbers in parentheses at the top of the frame indicate the number of plots for which data were available in each sample year.

the 2006 and 2011 sample periods, and cheatgrass abundance, which historically fluctuates, increased significantly over the past five years (Figure 10-3). Introduced annual forbs, primarily desert alyssum (*Alyssum desertorum*), continued along a trajectory of exponential increase which began in the mid-1990s. It doesn't appear as though increases in non-native species were at the expense of the native herbaceous understory, but these trends do mark a departure from ranges of historical herbaceous composition.

The 2011 LTV surveys provided an opportunity to assess the relationship between pre-and post-fire vegetation condition when the T-17 Fire burned 11 of the LTV plots only a few weeks after they were sampled. Despite the extremely dry conditions during the first growing season following the T-17 Fire, recovery of native perennial grasses, was notable and was consistent with results reported from earlier studies at the INL Site (Table 10-1). Results from this limited data set, indicate a striking post-fire decline in introduced annual species such as cheatgrass. These results suggest a different post-fire response of introduced annuals than may be otherwise expected.

Previous reports from the LTV data have demonstrated a decline in big sagebrush cover that is not associated with loss due to fire. Between 1975 and 2006 average big sagebrush cover on the unburned, core LTV plots declined from more than 20 percent to less than 10 percent. In order to better understand the losses of big sagebrush cover and the declines in stand condition at the INL Site, we completed the sagebrush demography study. Big sagebrush was generally

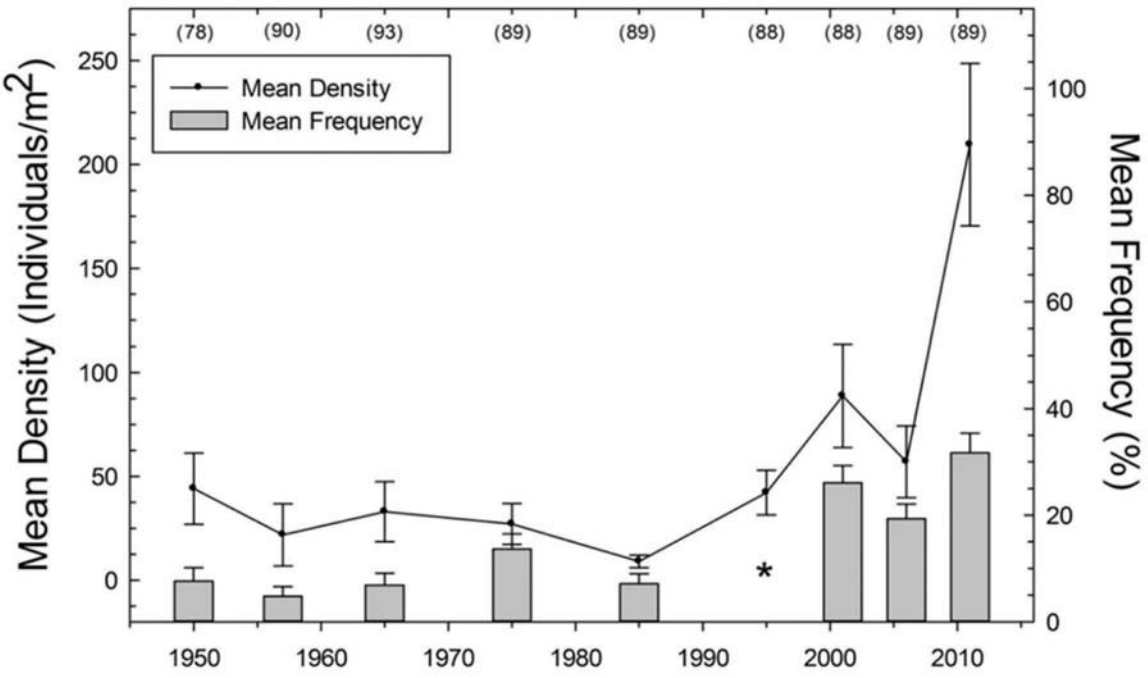

Figure 10-3. Density and frequency trends for *Bromus tectorum* on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site from 1950 to 2011. Data are means ± 1 SE.
***Frequency data are missing from the 1995 data archives.**

Table 10-1. Mean absolute cover by functional group and one-way repeated measures ANOVA[a] results comparing pre- and post-fire vegetation on 11 Long-Term Vegetation Transect plots at the Idaho National Laboratory Site.

	2011	2012	Significant
Native Shrubs	18.04	0.48	Yes
Native Perennial Graminoids	7.81	5.98	No
Native Perennial Forbs	1.60	0.74	Yes
Native Succulents	0.16	0.03	Yes
Native Annuals and Biennials	0.23	0.09	No
Introduced Annuals and Biennials	11.96	0.55	Yes

a. ANOVA = Analysis of Variance.

much younger than we had anticipated (Figure 10-4). Based on our results, mechanisms controlling big sagebrush stand replacement appear to be related to a combination of general precipitation patterns and fine-scale microsite conditions. Across the study site, annual recruitment patterns are cyclic and patterns in annual age class size reflect patterns in annual precipitation, but recruitment in some stands appears to be more affected by annual precipitation than in others. Our results suggest that disturbance is not required for stand replacement. In fact, all stands sampled for this project had a mean age of living individuals of less than 25 years and a mean age of individuals at death of less than 50 years, indicating that natural rates of turnover at the INL Site are much higher than expected.

Plans for Continuation

The 2011 sample effort, along with the database updates and technical report are complete. The LTV plots are scheduled to be sampled again in their entirety in 2016.

Publications, Theses, Reports

Forman, A. D., J. R. Hafla , R. D. Blew. 2013. The Idaho National Laboratory Site Long-term Vegetation Transects: Understanding Change in Sagebrush Steppe. GSS-ESER-163, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

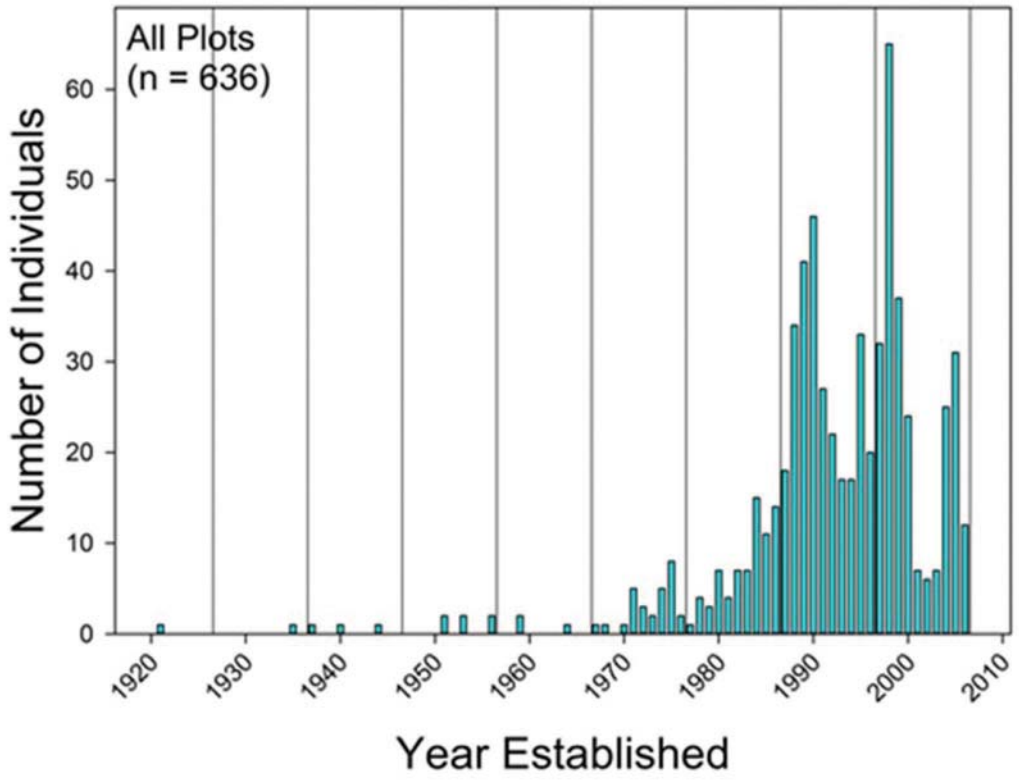

Figure 10-4. Annual age class distributions for 636 big sagebrush plants sampled on the INL Site. Data are pooled from 14 sample locations.

10.1.2 Survey, Monitoring and Predicting the Occurrence and Spread of Native and Non-Native Plant Species at Idaho National Laboratories

Investigators and Affiliations

- Lisa Rew, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana
- Bruce Maxwell, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana
- Matt Lavin, Department of Plant Sciences and Plant Pathology, Montana State University, Bozeman, Montana
- Tyler Brummer, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana
- Kimberley Taylor, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana

Funding Sources

- U.S. Department of Energy, Idaho Operations Office

Background

Management of both non-indigenous plant species (NIS) and rare plant species (RPS) is a high priority in many managed forests, wildlands and rangeland areas. However, rarely do either public or private agencies have sufficient resources to manage all NIS or conserve all RPS. Neither do agencies have sufficient information on the potential impacts of future anthropogenic development. Therefore, a better understanding of the temporal and spatial processes which drive both NIS and RPS population distributions and dynamics is required to improve management effectiveness and efficiency. The difficulty in increasing our knowledge of NIS and RPS population dynamics in the sagebrush-steppe plant community is that they occur with low frequency on the landscape and can be difficult to detect because they are similar in morphology to the co-occurring species. By using knowledge of probable routes of introduction for the NIS, and particular habitat requirements for the RPS, appropriate survey methods can be developed. Repeated sampling can then help to elucidate the spatiotemporal dynamics of select populations. From such data, predictive occurrence maps can be generated for the current landscape, but also for a range of future scenarios including anthropogenic development. Incorporating the information into a decision support management prioritization framework can help resource managers prioritize populations to manage and help evaluate the potential impacts of different disturbance scenarios to minimize the negative (RPS) or positive (NIS) impacts on plant population dynamics.

Objectives

The goal of this study was to determine the current distribution of NIS and RPS on the INL Site and predict the potential spatial and temporal metapopulation dynamics of these species to help inform management and future development decisions.

Accomplishments through 2012

Survey detection error and metapopulation dynamics: A total of 33 ten-meter-wide belt transects that originated on roads or facility margins and traveled two km away from the road or facility were selected for survey in 2012, to evaluate extinction and colonization rates. Transects were repeats from previous years and selected according to stratification on fire chronology and proximity to facilities. Presence and absence of eight targeted NIS were recorded along these transects in two 200 m sections. The 200 m sections were randomly located, one within 0-1000 m and the other 1001-2000 m from the road.

To assess the role of fire on the availability of seed for colonization we collected soil samples at approximately 40 locations along the fire chronology. The soil samples were potted in a glass house and individuals are being counted and identified as they germinate.

Results

Survey detection error and metapopulation dynamics: We now have three seasons of extinction/colonization data (2009-2010, 2010-2011, 2011-2012). Data analysis and model summarization of these rates are being completed for the eight targeted NIS – *Agropyron cristatum*, *Alyssum desertorum*, *Bromus tectorum*, *Carduus nutans*, *Descurainia sophia*, *Halogeton glomeratus*, *Lepidium perfoliatum*, and *Sisymbrium altissimum*. We are aiming to define the relative importance of propagule pressure/isolation, habitat quality, disturbance

(wildfire) and inter-annual climate variability on colonization and extinction dynamics of these species.

Seedlings germinating from the seed bank samples are still being assessed.

Plans for Continuation

Data analysis, interpretation and finalization and revision of manuscripts is on-going.

Publications, Theses, Reports

Publications:

Brummer, T. J. (2012) *Non-native species distributions in space and time: integrating ecological theory and predictive modeling*. Master's thesis, Montana State University.

Lavin, M., T. Brummer, T. Seipel, B. Maxwell, and L. Rew. (in press) *The intermountain flora sets the stage for a community phylogenetic analysis of plant biodiversity in the sagebrush steppe of western North America*. Brittonia. (Accepted Dec. 2012)

Brummer, T., B. Maxwell, M. Higgs, and L. Rew. (in press) *Surveying non-native species occurrence and modeling realized distributions at local and landscape scales*. Diversity and Distributions. (Accepted Jan 2013).

Lavin, M., T. Brummer T, R. Quire, B. Maxwell, and L. Rew. *Physical disturbance shapes vascular plant diversity more profoundly that fire in the sagebrush steppe of southeastern Idaho, USA*. Ecology and Evolution. (Submitted Feb 2013)

Brummer, T., B. Maxwell, S. Lele, and L. Rew. *Detection error in plant surveys: to correct or not to correct*. Under substantial revision – will be resubmitted late winter 2013.

Taylor, K., T. Brummer, B. Maxwell, M. Lavin, and L. Rew. *Assessing the effect of fire sequence on Bromus tectorum abundance*. In Preparation.

Brummer, T., Maxwell, B., M. Lavin, and L. Rew. *Regional population dynamics of non-native plant species*. Early preparation and analysis not yet complete.

Presentations:

Rew, L., P. Lawrence, B. Maxwell, T. Brummer, and F. Pollnac. 2013. *Prioritizing weed populations for management using your own data*. Montana Weed Control Association, January 16-17th 2013, Great Falls, MT. [Invited]

Rew, L. 2012. *Mapping, surveying and prioritizing weed management*. Noxious Weed Management Certification Workshop. October 2-4th 2012, Bozeman, Montana. [Invited]

Rew, L. 2012. *Mapping, surveying and prioritizing weed management*. Noxious Weed Management Certification Workshop. April 3-5th 2012, Bozeman, Montana. [Invited]

Rew, L. 2012. P*redictive weed maps*. South Dakota Weed and Pest Conference. February 23-24th, 2012 Rapid City, South Dakota. ~210 [Invited]

10.1.3 Studies of Ants and Ant Guests at the Idaho National Laboratory Site

Investigators and Affiliations

- William H. Clark, Orma J. Smith Museum of Natural History, The College of Idaho, Caldwell, Idaho

Funding Sources

- Funding is by the principal investigator with some assistance from and collaboration with the Orma J. Smith Museum of Natural History.

Background

Clark and Blom (2007) reported the first comprehensive annotated checklist of ants at the INL Site. This publication gives a starting point for additional research relating to ants, their natural history and ecology, and ant guests at INL Site. Ant guests (*myrmecophiles*) are organisms that live in close association with ants. These are generally mutualistic associations, but may also be commensal or parasitic.

Objectives

Immediate objectives are to locate living larvae of the ant guest beetle (*Gonasida elata*) (*Coleoptera: Tenebrionidae*) within nests of the harvester ant (*Pogonomyrmex salinus*) (*Hymenoptera: Formicidae*). These beetles have been documented from the harvester ant nests here in the past by Clark and Blom (unpublished data), but the larvae have not been previously described. Fresh larvae are needed for scanning electron microscopy (SEM) to provide for a proper description of these organisms. The overall objective will be to document the interaction of this beetle with the ants.

Other observations on additional ant guests will be made as they are encountered. Information relating to the ants of INL Site will be documented as possible.

Accomplishments through 2012

During the fall of 2011, 100 nests of the harvester ant (*Pogonomyrmex salinus*) were selected and marked along Road T-17 near Circular Butte (Figure 10-5). These nests were then surveyed by INL archaeologists for cultural resources and approval was given for excavation of nests as needed. A total of 10 percent of the nests were excavated during late 2011 and no *Gonasida elata* were found. Additional nests were excavated during the fall of 2012 and again no *Gonasida elata* were found. Searches will continue, perhaps during other seasons of the year.

Results

Two ant guest taxa; an ant beetle (*Coleoptera: Tenebrionidae: Araeoschizus* sp.) (Figure 10-6) and a Jerusalem cricket (*Orthoptera: Stenopelmatidae, Stenopelmatus*) were found at the INL Site. The Stenopelmatus is likely also a species that has not been previously described. Both taxa will require more study during future visits to the INL Site.

Plans for Continuation

Field research will continue into the foreseeable future.

Figure 10-5. Nest of *Pogonomyrmex salinus* (*Hymenoptera: Formicidae*) marked for future study. Nest near Circular Butte, November 2011, W.H. Clark photo. Ant mound is approximately 0.75 m diameter.

Figure 10-6. *Araeoschizus* (*Coleoptera: Tenebrionidae*) found in a *Pogonomyrmex salinus* nest. Nest near Circular Butte, November 2011, W.H. Clark photo. Beetle is approximately 4 mm in length.

Publications, Theses, Reports

The project is still in the field data collection phase and no publications have been prepared.

10.1.4 Post-wildfire Wind Erosion In and Around the Idaho National Laboratory Site

Investigators and Affiliations

- Matthew J. Germino, Ph.D., Research Ecologist, United States Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise Idaho

Collaborators

- Nancy F. Glenn, Ph.D., Professor, Geosciences Department, Idaho State University, Boise, Idaho
- Joel Sankey, Ph.D., Research Scientist, United States Geological Survey, Flagstaff, Arizona
- Amber N. Hoover, Technician, Idaho National Laboratory, Idaho Falls, Idaho
- Jeremy P. Shive, GIS/Remote Sensing Analyst, Environmental Surveillance, Education, and Research Program, S.M. Stoller Corporation, Idaho Falls, ID
- Mike Griffel, student, Idaho State University, Idaho Falls, ID
- Natalie Wagenbrenner, Engineer, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Moscow, Idaho
- Brian Lamb, Ph.D., Washington State University, Laboratory for Atmospheric Research, Pullman, Washington
- Peter Robichaud, Ph.D., U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Moscow, Idaho

Funding Sources

- U.S. Department of Defense
- Bureau of Land Management
- US Geological Survey
- USDA Forest Service Rocky Mountain Research Station

Background

Wind erosion following large wildfires on and around the INL Site is a recurrent threat to human health and safety, DOE operations and trafficability, and ecological and hydrological condition of the INL Site and down-wind landscapes. Causes and consequences of wind erosion are mainly known from warm deserts (e.g., Southwest U.S.), dunefields, and croplands, and some but not all findings are transferable to the cold desert environments such as where the INL Site lies.

Objectives

This is a large and multifaceted research program with the overall goal being to determine and describe wildland fire effects on wind erosion in rangelands on and around the INL Site. The specific objectives include the following:

- To quantify the role of wind erosion and dust emissions in post-fire environments as well as the associated potential impacts on site fertility, invasibility by exotic grasses, micro-scale geomorphology, and regional air quality.
- To determine if the aerodynamic parameters friction velocity, roughness length, and displacement height change through time following wildland fire, and to identify how these parameters relate to vegetation recovery after fire.
- To determine the effects of repeat burning on levels of wind erosion, for sites that reburn a few years following prior fires.
- To determine how surface-soil moisture variations relate to (i.e., control) erodibility over the months when vegetation has yet to recover on the site.
- To link monitoring of near-soil saltation activity to dust emission and model regional dust plumes culminating from INL Site fires, using a combination of ground-level, air quality, and remotely sensed approaches.

Accomplishments through 2012

In 2012, we continued to evaluate the large and complex array of remotely sensed and ground-based data we collected from 2010 through 2011 on the very high levels of wind erosion on the 2010 Jefferson Fire, and on the 2010 Middle Butte Fire. These analyses will help guide development of standardized protocols for monitoring erosion, which is increasingly a need on the Snake River Plain.

Results

Jefferson Fire, example of preliminary results:

Adding to analyses conducted in prior years, we made evaluations of different time frames and calculation methods for assessing the amount of erosion occurring after the Jefferson wildfire, and the critical threshold windspeed. Our preliminary results suggest different threshold windspeed and duration of soil movement events for PM_{10} dust well above ground (2-5 m) compared to saltation of larger particles near ground (Table 10-2). Threshold windspeeds appear to have increased substantially over time since burning.

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.

Plans for Continuation

In 2013, we do not plan to collect more field data unless new fire and erosion conditions arise. Our efforts will continue to focus on using existing data for modeling, analysis, and publication.

Table 10-2. Comparison of different methods for evaluating threshold windspeeds for erosion (windspeed required to move soil) and erosion events, in the first few months after July wildfire (2010 Jefferson Fire, 108K acres; Aug to mid-Nov 2010), and after the first winter but prior to the first bit of vegetation recovery (Apr through Jun 2011). Erosion was measured as saltation (bouncing soil particles within a few cm of the soil surface) by a "Sensit" instrument along with windspeeds with cup anemometers, and PM_{10} was measured with a Met-One (E-sampler) PM_{10} (particles < 10 micron) detector, and friction velocity (U*) with sonic anemometers and eddy covariance calculations. The Gausian method relates saltation or PM_{10} activity to a frequency distribution of windspeeds within 5-min periods, whereas the "instantaneous" method is simply finding the windspeed at which saltation or PM_{10} emissions occur. ***(Unpublished data of MJ Germino, in preparation for publication.)***

Average Event Thresholds Compared Annually	**2010 (m/s)**	**2011 (m/s)**
Beginning of Moderate to Large Erosion Events		
Sensit Windspeed Threshold Gaussian Method	8.57	11.29
Sensit Windspeed Threshold Instantaneous Method	8.65	11.95
Sensit U* Threshold	0.23	0.45
PM10 Windspeed Threshold	5.25	9.2
PM10 U* Threshold	0.26	0.47
During Moderate to Large Erosion Events		
Sensit Windspeed Threshold Gaussian Method	8.86	11.15
Sensit Windspeed Threshold Instantaneous Method	8.66	11.9
Sensit U* Threshold	Not Applicable	Not Applicable
PM10 Windspeed Threshold	Not Applicable	Not Applicable
PM10 U* Threshold	Not Applicable	Not Applicable
Ending of Moderate to Large Erosion Events		
Sensit Windspeed Threshold Gaussian Method	8.94	11.34
Sensit Windspeed Threshold Instantaneous Method	8.72	10.93
Sensit U* Threshold	0.23	0.56
PM10 Windspeed Threshold	8.96	12.1
PM10 U* Threshold	0.43	0.68
Sensit Event Durations	**2010 (hours)**	**2011 (hours)**
Average Event	8.32	8.37
Longest Event	20.42	23.75
Shortest Event	2	0.58
PM10 Event Durations	**2010 (hours)**	**2011 (hours)**
Average Event	3.32	3.93
Longest Event	9.25	9.08
Shortest Event	0.42	1.42

Publications, Theses, Reports

Publications:

Wagenbrenne, N., M. Germino, B. Lamb, P. Robichaud, R. Foltz. 2013. *Wind erosion from a sagebrush steppe burned by wildfire: Measurements of PM10 and horizontal sediment flux*. Aeolian Research. http://dx.doi.org/10.1016/j.aeolia.2012.10.003.

Sankey, J., M. Germino, T. Sankey, A. Hoover. 2012. *Fire effects on the spatial patterning of soil properties in sagebrush steppe, USA: Meta-analysis*. International Journal of Wildland Fire 21:545 – 556.

Sankey, J., M. Germino, N. Glenn, S. Benner. 2012. *Bioavailable nutrients transported by wind in an eroding cold desert*. Aeolian Research 17-27.

Sankey, J., M. Germino, N. Glenn. 2012. *Dust supply varies with sagebrush microsites and time since burning in experimental erosion events*. Journal of Geophysical Research-Biogeosciences 117:1-13.

Hoover, A, M. Germino. 2012. *Post-fire, Resource-Island Effects on Bromus tectorum and Pseudoroegneria spicata: Evidence From a Common-Garden Study*. Rangeland Ecology and Management 65:160-170.

Presentations:

Germino, M. 2013. *Post-fire wind erosion and air quality.* EPA Region 10, Air Quality Conference, Ellensburg WA, March 13

Germino, M. 2013. *Post-fire wind erosion: risks and resilience*. National Fire Emergency Stabilization and Rehabilitation Program, Boise, ID, Feb 26

Germino, M. 2013. *Dust, an emerging problem in the Great Basin: insights from 2012*. Great Basin Consortium, 2nd annual meeting, Boise, ID, January 14

Germino, M. 2012. *Weather and post-fire wind erosion Climate Forum, Great Basin*. Desert Research Institute, Reno NV, October 17

Germino, M. 2012. *Post-fire wind erosion*. JFSP SageSTEP/Great Basin Soc. Ecological Restoration Field Day, Roberts, ID, June 7

Germino, M., N. Glenn, J. Sankey. *Ecological biogeomorphology: meta-analysis of post-fire wind erosion in sagebrush steppe*. Ecological Society of America Annual Meeting, Portland, Aug 5.

10.1.5 The Influence of Precipitation, Vegetation and Soil Properties on the Ecohydrology of Sagebrush Steppe Rangelands on the INL Site

Investigators and Affiliations

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Collaborators

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- Kevin Feris, Ph.D., Assistant Professor, Boise State University, Boise, Idaho
- Kathleen Lohse, Ph.D., Assistant Professor, Idaho State University, Pocatello, Idaho
- Marie-Anne deGraff, Ph.D., Assistant Professor, Boise State University, Boise, Idaho
- David Huber, Ph.D. candidate, Idaho State University, Pocatello, Idaho
- Patrick Sorenson, M.S., Boise State University, Boise, Idaho
- Patricia Xochi Campos, M.S. candidate, Boise State University, Boise Idaho
- Carrier Jilek, B.S. candidate, Boise State University, Boise, Idaho
- Cassandra Gause, B.S./M.S. candidate, Idaho State University, Pocatello, Idaho
- Jennifer Forbey Ph.D., Assistant Professor, Boise State University, Boise, Idaho
- Lisa Lam, B.S. candidate, Boise State University, Boise, Idaho

Funding Sources

- Idaho Experimental Program to Stimulate Competitive Research (EPSCoR), National Science Foundation.
- US Geological Survey, Forest and Rangeland Ecosystem Science Center
- US Geological Survey, Northwest Climate Science Center

In-kind facilities and infrastructure support from DOE-ID, logistics support through Gonzales Stoller Surveillance LLC.

Background

The INL Site and other landscapes having sagebrush steppe vegetation are experiencing a simultaneous change in climate and floristics that result from increases in exotic species. Determining the separate and combined/interactive effects of climate and vegetation change is important for assessing future changes on the landscape and for hydrologic processes.

This research uses the 72 experimental plots established and initially maintained for many years as the “Protective Cap Biobarrier Experiment” by Dr. Jay Anderson and the Stoller ESER program, and the experiment is also now referred to as the “INL Site Ecohydrology Study.” We are evaluating long-term impacts of different plant communities commonly found throughout Idaho subject to different precipitation regimes and to different soil depths. Treatments of amount and timing of precipitation (irrigation), soil depth, and either native/perennial or exotic grass

vegetation allow researchers to investigate how vegetation, precipitation and soil interact to influence soil hydrology and ecosystem biogeochemistry. This information will be used to improve a variety of models, as well as provide data for these models.

Objectives

The goal of this study is to assess the interactive and reciprocal effects of hydroclimate shifts and plant community composition on ecohydrological and biogeochemical processes, with the specific objectives to:

- Determine response of vegetation to timing of irrigation and soil depth, and conversely the influence of plant communities and vegetation type on deep soil water infiltration
- Investigate microbial communities and soil microbial enzymatic activity and soil aggregation/ porosity, to assess whether fundamental ecosystem changes to treatments are occurring and could feed back on water flow patterns
- Investigate changes in plant and soil nutrient pools and fluxes due to vegetation and precipitation differences.

Accomplishments through 2012

In 2012 we inserted an additional set of Time Domain Reflectometry (TDR) water content sensors in an effort to reduce our reliance on manual neutron-probe measurements, an effort that will continue. In 2011 we inserted Decagon Echo probes at 3 depths in shrub interspaces in about 1/3 of the plots, and in 2012 we inserted Campbell 616 probes into all 72 plots, with one sensor spanning 0-30 cm depth in interspace microsites. We installed litter traps to begin a formal evaluation of plant litter inputs, dug soil pits and analyzed the stratigraphy and pedogenesis of the soils, analyzed soil respiration, and made a number of soil biogeochemical measurements. We finished an extensive analysis of point-intercept data on vegetation cover of all plots, comparing the sampling method used from 1993 to 2006 with a revised method that will focus on aerial cover and leaf-area indices. We began a newly funded project on sagebrush demographic responses to the treatments, including detailed sampling of sagebrush responses. As part of this, we tested several approaches for measuring sagebrush growth, including marking stems and measuring stem elongation in the field compared to clipping stems to measure stem lengths along annual growth increments revealed by buds and the number of annual xylem (vascular) rings in the wood.

Results

Preliminary results from soil pits reveal a surprisingly large amount of pegogenic activity since 1993 that has caused the soil profiles of experimental plots to resemble soil structure in the surrounding and natural sagebrush steppe. Features including the formation of calcic pedogenic minerals, silt layers that suggest vertical transport of fine soil particles, and these all vary by treatment. In a preliminary round of soil respiration, we did not detect appreciable differences among treatments, but did reveal strong differences between shrub and interspace microsites. Very large differences in sagebrush growth and seedling establishment are evident among the treatments, with winter irrigation continuing to promote greater sagebrush presence than other treatments. Preliminary data suggest large differences in growth estimated by measuring stem

elongation in the field compared to clipping stems to measure stem lengths along annual growth increments revealed by buds and the number of annual xylem (vascular) rings in the wood (Figure 10-7). Sagebrush growth is an important variable to measure for assessing ecosystem change and function (e.g., for carbon storage, grazing impacts, hydrology, etc), and these data show much greater sensitivity of lab-based measurements, but also raise questions about sources of error in the field, assuming the laboratory measurement is more reliable.

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.

Plans for Continuation

We will continue making the same types of measurements as in the past year, generating multiple-years of data to substantiate our findings. New additions will continue to include 1) assessments of soil solution biogeochemistry done through installation of lysimeters via cores from the surface, 2) measurements of net primary productivity, 3) assessment of litter inputs and decomposition processes, along with root growth assessed by root-ingrowth tubes, 4) sagebrush demography.

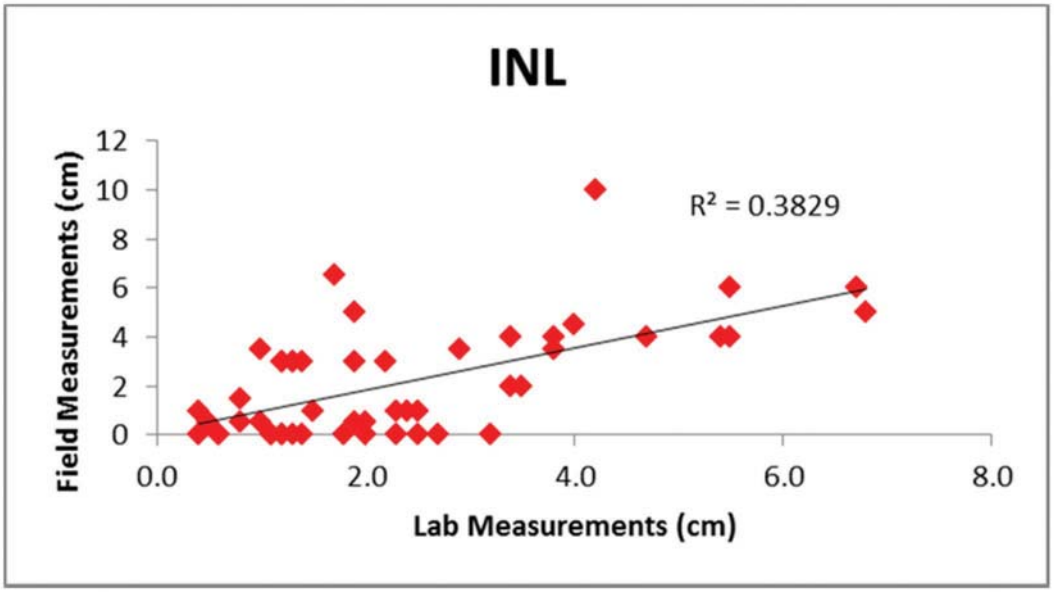

Figure 10-7. Difference in annual stem growth estimated by marking stems and repeatedly measuring growth along them in the field, compared to clipping stems and measuring annual growth increments in the laboratory. Each datum is a plant, from all plots with native vegetation and 2 m deep soil.

Publications, Theses, Reports

Germino, M., and K. Reinhardt. 2013. *Experimental evidence for sagebrush responses to climate*. Great Basin Consortium, 2nd annual meeting, Boise, ID, January 14, 2012.

Germino, M. 2012. *Fire, wind, and water: landscape change and its relationship to development*. Mountain West Water Institute Meeting, Idaho Falls, ID, May 15, 2012.

Joy S., D. Huber, A. Kathleen, K. Lohse, M. Germino, M. de Graaff, and K. Feris. 2012. *Shifts in Timing and Magnitude of Precipitation Modulate Soil Carbon Pools in Semi-Arid Ecosystems*. American Geophysical Union Annual Meeting, San Francisco, CA, December 10, 2012.

Germino, M., L. Svenson, and K. Reinhardt. 2012. *Climate and Upland Ecosystems: Points of sensitivity and adaptation variability in sagebrush steppe viewed from a single species.* 3rd Annual Pacific Northwest Climate Science Conference, Boise, Idaho, ID, October 1-2, 2012.

Germino, M. and B. Crosby. 2012. *Plenary: The Changing Landscape of Science and Management of Land and Water: New Collaborative Initiatives and their Relevance*. Tri-State (ID-NV-NM) NSF EPSCoR annual meeting, Sun Valley, ID, April 4, 2012.

Huber D., S. Hardenbrook, K. Lohse, M. Germino, K. Reinhardt. 2012. *Effects of Climate Shifts and Plant-Community Transformations on Carbon and Nitrogen Cycling in Semi-Arid Rangelands*. Tri-State (ID-NV-NM) NSF EPSCoR annual meeting, Sun Valley, ID, April 4, 2012.

Jilek C., K. Feris, and M. Germino. 2012. *Influence of Precipitation Regime on Microbial Decomposition Patterns in Semi-Arid Ecosystems*. Tri-State (ID-NV-NM) NSF EPSCoR annual meeting, Sun Valley, ID, April 4, 2012.

Reinhardt, K. and M. Germino. 2012. *Effects of long-term experimental changes in precipitation seasonality on cover, ecophysiology, foliar crown properties, and carbon pools in big sagebrush*. Northwest Science Association Annual Meeting, Boise, ID, March 29, 2012

de Graff, M., J. Vanderveen, and M. Germino. 2012. *Changes in soil aggregate dynamics and carbon storage following 18 years of experimental increased precipitation in a cold-desert ecosystem*. Northwest Science Association Annual Meeting, Boise, ID, March 29, 2012.

10.1.6 Distribution, Movements, and Space Use by Elk on the Idaho National Laboratory Site

Investigators and Affiliations

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Funding Sources

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- U. S. Environmental Protection Agency
- The Berryman Institute
- The Rocky Mountain Elk Foundation
- Idaho State University

Background

Large mammals play important functional roles in many ecosystems, including sagebrush-steppe. Indeed, large herbivores often act as keystone species, and thus understanding the causes and consequences of their patterns of behavior can provide important insights into a variety of ecosystem processes. In addition, detailed data on movements of large mammals can provide land managers with critical information on ecological interactions between those animals and their environment. Such information is necessary for understanding past effects of anthropogenic disturbance on mammals and for predicting effects of future development, as well as for minimizing the negative effects of development on mammals. Such data may also provide important clues about the potential transport of nutrients and environmental contaminants by large mammals across landscapes. Nevertheless, the detailed data necessary to understand large-scale patterns of movement and resource selection by large mammals on the INL Site have never been obtained.

Previous research on large herbivores at the INL Site has focused primarily on documenting presence-absence or general locations of those animals through aerial surveys, with some notable exceptions. For example, Strohmeyer and Peek (1996), Strohmeyer et al. (1999), and Comer (2000) reported that elk (*Cervus elaphus*) on the INL Site foraged primarily in burned areas and agricultural fields at night, but strongly selected sagebrush habitat on lava located far from foraging areas during the day. Even in those studies, however, locations of individual elk were collected infrequently via very high frequency (VHF) radio-collars, and consequently a large number of important questions remain unanswered. For example: 1) To what extent do elk on the INL Site utilize surrounding agricultural lands, and how does that use vary seasonally?

2) What proportion of the elk population on the INL Site is resident (i.e., remains on the Site all year) versus migratory (i.e., leaves the Site for some portion of the year)? 3) How do elk on the INL Site respond to anthropogenic factors already in place, such as roads and Site facilities? 4) How do general patterns of movement and space use by elk on the INL Site change seasonally? These and similar questions can be addressed using high-frequency location data, and answers to these questions will allow biologists and land managers to minimize the negative effects of future development on populations of elk and other large herbivores on the INL Site, and will also provide information useful for managers desiring to minimize depredation of crops surrounding the INL Site by large herbivores. In addition, detailed movement data for elk will provide insights into the potential role of this species in distributing environmental contaminants both on and off of the INL Site.

Objectives

The overall goal of our project was to document landscape-scale patterns of movement and space use by elk at the INL Site. Results of our study will be integrated into the Conservation Management Plan for the INL Site, and will provide the U. S. Department of Energy with important information for environmental planning purposes. In addition, our results will provide information useful for managers desiring to minimize depredation of crops surrounding the INL Site by large herbivores, and will provide insights into the potential role of large mammals in distributing environmental contaminants both on and off of the study site.

- Capture 20 elk per during 2010-2012 on the INL Site in order to collect data on body condition, morphology, disease, and pregnancy status, and to fit each of those animals with a GPS collar programmed to collect hourly locations between March and December.
- Determine the extent to which critical habitat (e.g., calving grounds) for elk occurs within the Development Zone.
- Determine when, where, and to what extent elk move between the INL Site and surrounding agricultural lands to aid in quantifying potential depredation problems and potential transport of contaminants off of the INL Site by elk.

Accomplishments through 2012

- A total of 58 female elk were captured and fit with GPS collars in the winters of 2010, 2011 and 2012 by net-gun from a helicopter or by drive-netting. During the capture, data on body condition, morphology, and blood parameters were collected.
- We plotted all locations obtained from GPS-collared elk in ArcGIS 10 and calculated the proportion of locations occurring in agricultural fields (based on 2011 NAIP imagery) on a seasonal basis.
- We used the “near” tool in ArcGIS to calculate the distance from each elk location on the INL Site to the nearest Site facility, as well as to the nearest primary road. We then calculated the percentage of elk locations that occurred within 1 km of either INL Site facilities or primary roads on the Site.

Results

We captured a total of 58 adult female elk on the INL Site during winters of 2010-2012. After accounting for post capture mortality and equipment failure (primarily during 2010), we obtained usable GPS data from 35 of those animals (Figure 10-8). A total of 55,998 hourly GPS locations were obtained for elk during spring (April-June; Figure 10-9), 39,907 locations were obtained during summer (July-September; Figure 10-10), and 35,671 locations were obtained during autumn (October-November; Figure 10-11). The proportion of elk locations occurring on the INL Site was 27 percent, 23 percent, and 63 percent during spring, summer, and autumn, respectively.

Overall, elk spent very little time in agricultural fields surrounding the INL Site during spring through autumn, or within 1 km of Site facilities or primary roads (Table 10-3). The amount of time spent in close proximity to each of these areas (agricultural fields, facilities, and roads) increased, however, between spring and autumn (Table 10-3). A maximum of 9 percent of elk locations occurred in agricultural fields, 1 percent within 1 km of a Site facility, and 10 percent within 1 km of a primary road on the Site during autumn (Table 10-3). The majority of elk locations occurring within 1 km of a primary road on the INL Site were in the southwestern portion of the Site along U.S. highway 26/20 (Figure 10-12).

Our results indicate that use of the INL Site by many elk during spring-autumn is largely transient. Indeed, only a small proportion of our study animals remained on the INL Site

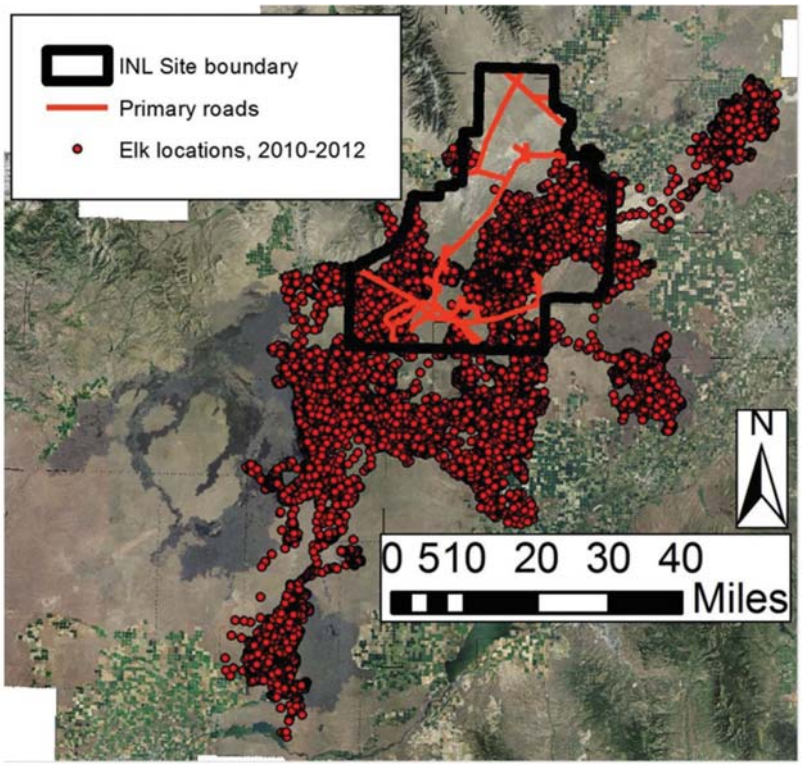

Figure 10-8. 131,576 hourly GPS locations obtained from 35 collared female elk (*Cervus elaphus*) on the INL Site from April-November, 2010-2012.

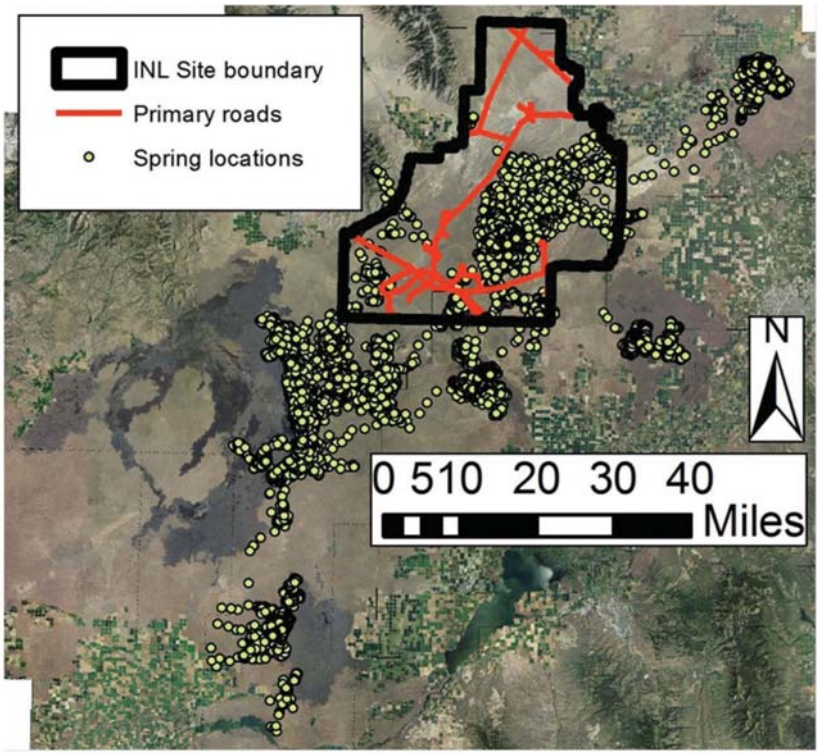

Figure 10-9. 55,998 hourly GPS locations obtained from 35 collared female elk (*Cervus elaphus*) on the INL Site during spring (April-June), 2010-2012.

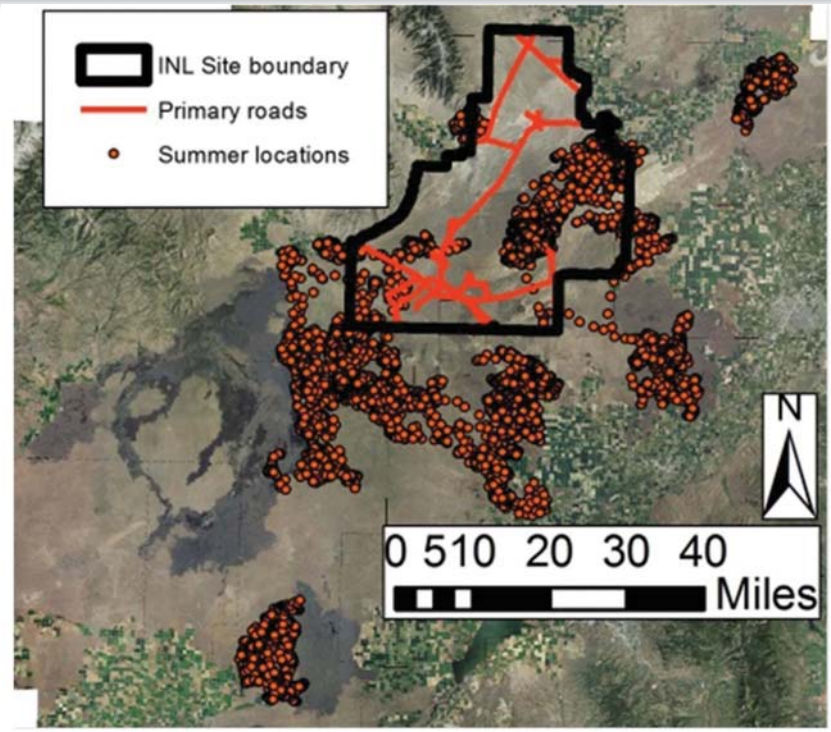

Figure 10-10. 39,907 hourly GPS locations obtained from 35 collared female elk (*Cervus elaphus*) on the INL Site during summer (July-September), 2010-2012.

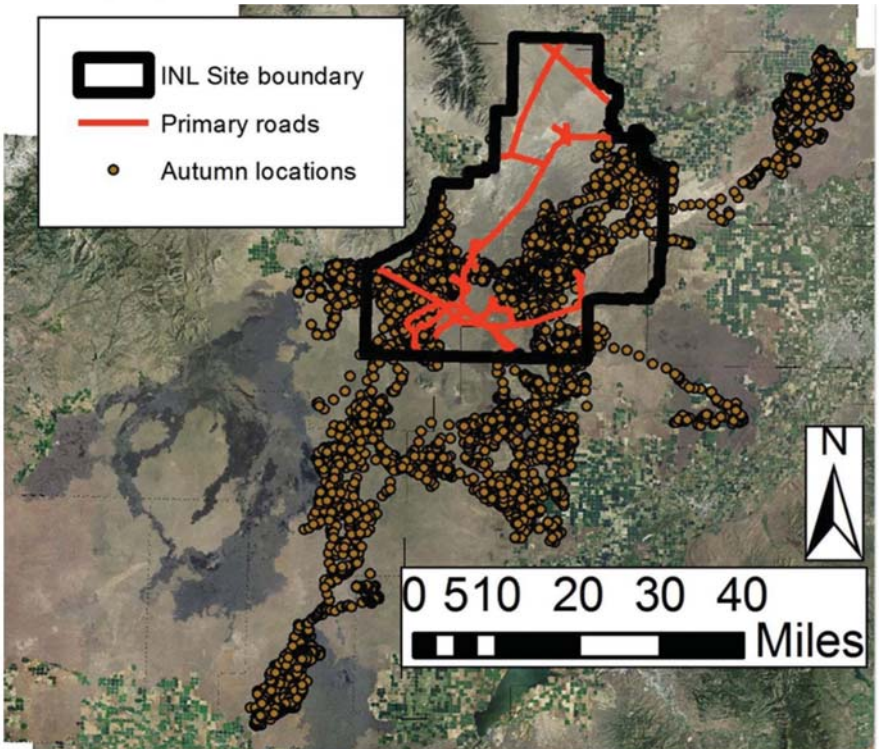

Figure 10-11. 35,671 hourly GPS locations obtained from 35 collared female elk (*Cervus elaphus*) on the INL Site during autumn (October-November), 2010-2012.

Table 10-3: Proportion of hourly GPS locations obtained from collared female elk (*Cervus elaphus*) on the INL Site that were in agricultural fields, or within 1 km of an INL Site facility or primary road, during spring (April-June), summer (July-September), and autumn (October-November), 2010-2012.

	Proportion of elk locations		
	Spring	Summer	Autumn
Agricultural fields	0.01	0.06	0.09
INL Site facilities	0.00	0.00	0.01
Paved roads	0.03	0.05	0.10

throughout the entire year. Most elk that were captured and fit with GPS collars during late winter dispersed long distances during early spring, and home ranges of collared animals covered hundreds of square miles of the Big Desert. Nearly all of those animals, however, returned to the INL Site during winter, and many of them returned during autumn. One of the most likely explanations for the substantial increase in the proportion of elk locations occurring within the boundaries of the INL Site during autumn is that the Site provides a refugium from hunters. Most hunting seasons in units surrounding the INL Site occur during autumn and early winter, and it is likely that elk respond rapidly to hunting pressure by shifting their distribution, as well as the timing of various behaviors, such as foraging (Naylor et al. 2009).

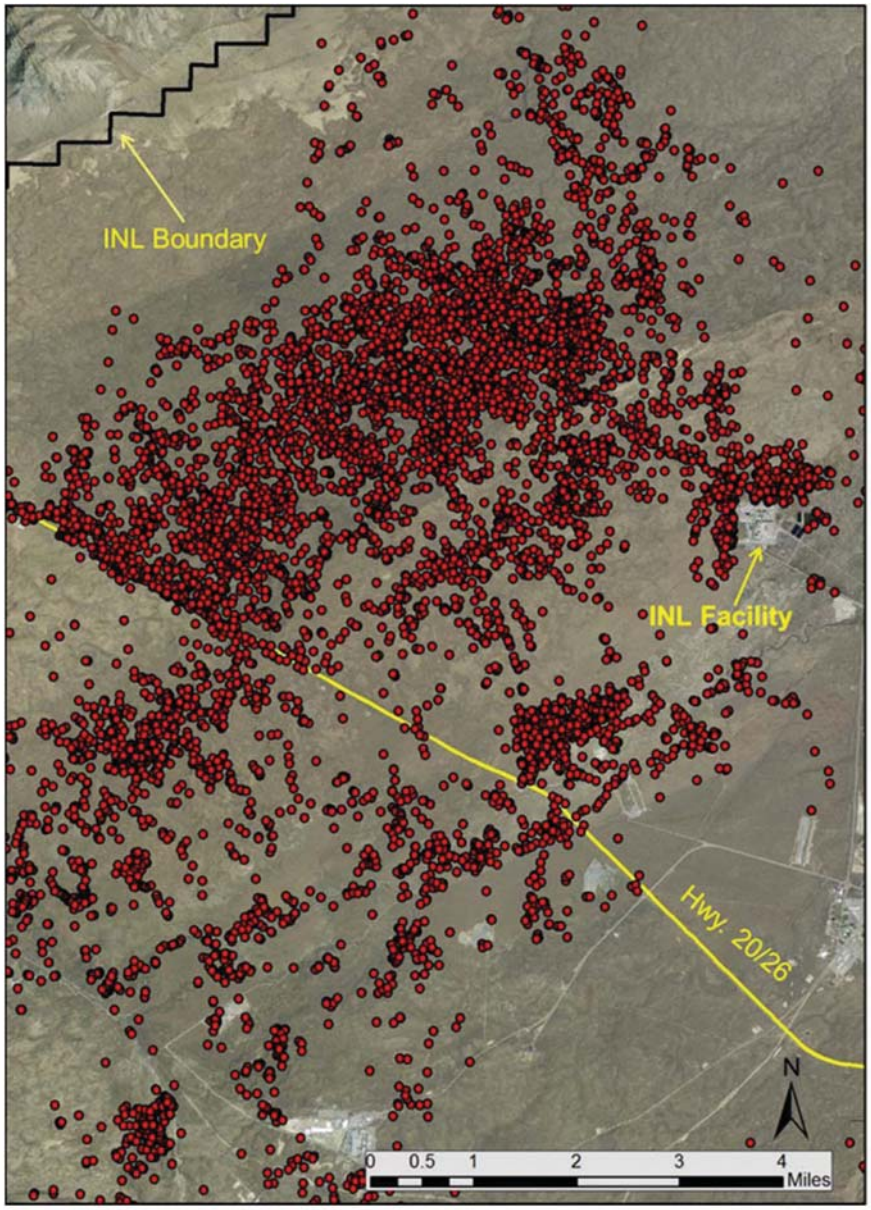

Figure 10-12. Hourly GPS locations obtained from collared female elk (*Cervus elaphus*) during 2010-2012 showing some use by elk of areas near major highways and INL Site facilities.

Our results do not support the hypothesis that elk have been successful in occupying the Big Desert ecosystem largely as a result of the high quality forage provided by agricultural fields. Although agricultural fields did appear to provide an increasingly import source of forage for elk as quality of native forages presumably declined between spring and autumn, elk still spent only a small amount of time utilizing those fields, and many elk never used agricultural fields at all. Consequently, we conclude that the combination of burned habitat and native sagebrush-steppe in the Big Desert provided forage of sufficient quality and abundance to support a substantial number of elk during spring through autumn, even in the absence of agriculture. This conclusion

is also supported by results of other studies of elk conducted in similar sagebrush-steppe ecosystems (e.g., McCorquodale 1991).

It is not clear from our study how elk in the Big Desert obtain the water necessary for their survival. Although we did document some use of guzzlers by elk, many collared animals never utilized a known water source throughout the duration of our study. This included waste water ponds associated with many INL Site facilities. Collared elk in our study were almost never found within 1 km of a Site facility, and only a small number of GPS locations occurred near waste water ponds. As a result, we conclude that the probability of elk transporting environmental contaminants off of the INL Site as a result of drinking contaminated water is likely very low.

Numerous studies of elk and other large herbivores have documented strong avoidance of primary roads and other forms of human disturbance (e.g., Rowland et al. 2000, Naylor et al. 2009). Our results are consistent with the hypothesis that elk generally try to avoid areas with substantial disturbance (this included both roads and INL Site facilities in our study). Nevertheless, because 10 percent of the GPS locations we obtained from elk that were on the INL Site during autumn were located within 1 km of a primary road, the potential for vehicle collisions with elk does indeed exist. Our results indicate that the highest potential for a vehicle collision with elk exists in the southwestern corner of the INL Site along highway 26/20, and this potential is greatest during October-November. Consequently, we recommend that any efforts made by the Department of Energy to reduce dangerous interactions between humans and elk be focused along that stretch of highway. Such efforts could include the placement of warning signs along the highway to indicate that elk frequently cross in that area. In addition, during the hunting season, it may be useful to place temporary electronic signs along that stretch of highway to draw further attention among motorists to the potential for a collision with elk crossing the highway.

Data collected during the course of this project were useful for quantifying the seasonal distribution of elk on the INL Site, as well as how that distribution was influenced by agriculture, roads, and INL Site facilities. Like many large mammals, however, the distribution of elk is highly fluid, and can vary with seasonal and annual changes in factors such as habitat, anthropogenic disturbance, or risk of predation. For example, during the course of this study several large wildfires on and around the INL Site resulted in a substantial change in the abundance and distribution of sagebrush and grassland habitat. This change affected the distribution of elk on the INL Site almost immediately, and in 2012 many collared elk never left the boundaries of the Jefferson Fire during the entire spring-autumn period. Consequently, we recommend that high frequency (e.g. hourly) location data be collected for at least 30 elk on the INL Site every 3-5 years in order to keep track of changes in the distribution of elk that may influence potential conflicts with humans near roads, agriculture, or INL Site facilities. Such data could also be of great importance if wolves take up residence on the INL Site in the near future. Recent confirmed sightings of wolves on the INL Site highlight the potential for such a shift in distribution of these predators, and if such a shift occurs, it will undoubtedly influence the movement and distribution of elk on the INL Site. Indeed, some researchers have reported that elk select areas that are closer to human disturbance when in the presence of wolves, because it reduces the risk of predation. If this occurred on the INL Site, then conflicts with elk near roads or Site facilities could increase dramatically. In addition, it would be useful to collect similar data for other species

of large mammal on the INL Site (e.g., pronghorn and mule deer) in order to determine how those species interact both with the environment on the INL Site, as well as with each other.

Plans for Continuation

The field work for the project has been completed and is in the data analysis and writing phase.

Publications, Reports, and Theses

This project is ongoing (i.e., field data are still being collected), and thus no publications have been completed at this time. Several peer-reviewed publications and a Ph.D. dissertation will be forthcoming when the project is completed in 2013.

10.2 U.S. Geological Survey 2012 Publication Abstracts

In 1949, the United States Geological Survey (USGS) was asked to characterize water resources prior to the building of nuclear-reactor testing facilities at the INL Site. Since that time, USGS hydrologists and geologists have been studying the hydrology and geology of the eastern Snake River Plain and the eastern Snake River Plain aquifer.

At the INL Site and in the surrounding area, the USGS INL Project Office:

- Monitors and maintains a network of existing wells
- Drills new research and monitoring wells, providing information about subsurface water, rock and sediment
- Performs geophysical and video logging of new and existing wells
- Maintains the Lithologic Core Storage Library (CSL).

Data gathered from these activities is used to create and refine hydrologic and geologic models of the aquifer, to track contaminant plumes in the aquifer and improve understanding of the complex relationships between the rocks, sediments and water that compose the aquifer. The USGS INL Project Office publishes reports about their studies, available through the USGS Publications Warehouse (http://id.water.usgs.gov/projects/INL/pubs.html.)

Six reports were published by the USGS INL Project Office in 2012. The abstracts of these studies and the publication information associated with each study are presented below.

10.2.1 Construction diagrams, geophysical logs, and lithologic descriptions for boreholes USGS 103, 105, 108, 131, 135, NRF-15, and NRF-16, Idaho National Laboratory, Idaho (Mary K.V. Hodges, Stephanie M. Orr, Katherine E. Potter, and Tynan LaMaitre)

This report, prepared in cooperation with the DOE-ID, summarizes construction, geophysical, and lithologic data collected from about 4,509 feet of core from seven boreholes deepened or drilled by the U.S. Geological Survey (USGS), Idaho National Laboratory (INL) Project Office, from 2006 to 2009 at the INL. USGS 103, 105, 108, and 131 were deepened and cored from 759 to 1,307 feet, 800 to 1,409 feet, 760 to 1,218 feet, and 808 to 1,239 feet, respectively. Boreholes USGS 135, NRF-15, and NRF-16 were drilled and continuously cored from land surface to

1,198, 759, and 425 feet, respectively. Cores were photographed and digitally logged by using commercially available software. Borehole descriptions summarize location, completion date, and amount and type of core recovered.

10.2.2 A comparison of U.S. Geological Survey three-dimensional model estimates of groundwater source areas and velocities to independently derived estimates, Idaho National Laboratory and vicinity, Idaho (Jason C. Fisher, Joseph P. Rousseau, Roy C. Bartholomay, and Gordon W. Rattray)

The USGS, in cooperation with the DOE-ID, evaluated a three-dimensional model of groundwater flow in the fractured basalts and interbedded sediments of the eastern Snake River Plain aquifer at and near the Idaho National Laboratory to determine if model-derived estimates of groundwater movement are consistent with (1) results from previous studies on water chemistry type, (2) the geochemical mixing at an example well, and (3) independently derived estimates of the average linear groundwater velocity. Simulated steady-state flow fields were analyzed using backward particle-tracking simulations that were based on a modified version of the particle tracking program MODPATH. Model results were compared to the 5-microgram-per-liter lithium contour interpreted to represent the transition from a water type that is primarily composed of tributary valley underflow and streamflow-infiltration recharge to a water type primarily composed of regional aquifer water. This comparison indicates several shortcomings in the way the model represents flow in the aquifer. The eastward movement of tributary valley underflow and streamflow-infiltration recharge is overestimated in the north-central part of the model area and underestimated in the central part of the model area. Model inconsistencies can be attributed to large contrasts in hydraulic conductivity between hydrogeologic zones.

Sources of water at well NPR-W01 were identified using backward particle tracking, and they were compared to the relative percentages of source water chemistry determined using geochemical mass balance and mixing models. The particle tracking results compare reasonably well with the chemistry results for groundwater derived from surface-water sources (–28 percent error), but overpredict the proportion of groundwater derived from regional aquifer water (108 percent error) and underpredict the proportion of groundwater derived from tributary valley underflow from the Little Lost River valley (–74 percent error). These large discrepancies may be attributed to large contrasts in hydraulic conductivity between hydrogeologic zones and (or) a short-circuiting of underflow from the Little Lost River valley to an area of high hydraulic conductivity.

Independently derived estimates of the average groundwater velocity at 12 well locations within the upper 100 feet of the aquifer were compared to model-derived estimates. Agreement between velocity estimates was good at wells with travel paths located in areas of sediment-rich rock (root-mean-square error [RMSE] = 5.2 feet per day [ft/d]) and poor in areas of sediment-poor rock (RMSE = 26.2 ft/d); simulated velocities in sediment-poor rock were 2.5 to 4.5 times larger than independently derived estimates at wells USGS 1 (less than 14 ft/d) and USGS 100 (less than 21 ft/d). The models overprediction of groundwater velocities in sediment-poor rock may be attributed to large contrasts in hydraulic conductivity and a very large, model-wide estimate of vertical anisotropy (14,800).

10.2.3 Water-quality characteristics and trends for selected sites at and near the Idaho National Laboratory, Idaho, 1949–2009 (Roy C. Bartholomay, Linda C. Davis, Jason, C. Fisher, Betty J. Tucker, and Flint A. Raben)

The USGS, in cooperation with the DOE-ID, analyzed water-quality data collected from 67 aquifer wells and 7 surface-water sites at the INL from 1949 through 2009. The data analyzed included major cations, anions, nutrients, trace elements, and total organic carbon. The analyses were performed to examine water-quality trends that might inform future management decisions about the number of wells to sample at the INL and the type of constituents to monitor. Water-quality trends were determined using (1) the nonparametric Kendall's tau correlation coefficient, p-value, Theil-Sen slope estimator, and summary statistics for uncensored data; and (2) the Kaplan-Meier method for calculating summary statistics, Kendall's tau correlation coefficient, p-value, and Akritas-Theil-Sen slope estimator for robust linear regression for censored data.

Statistical analyses for chloride concentrations indicate that groundwater influenced by Big Lost River seepage has decreasing chloride trends or, in some cases, has variable chloride concentration changes that correlate with above-average and below-average periods of recharge. Analyses of trends for chloride in water samples from four sites located along the Big Lost River indicate a decreasing trend or no trend for chloride, and chloride concentrations generally are much lower at these four sites than those in the aquifer. Above-average and below-average periods of recharge also affect concentration trends for sodium, sulfate, nitrate, and a few trace elements in several wells. Analyses of trends for constituents in water from several of the wells that is mostly regionally derived groundwater generally indicate increasing trends for chloride, sodium, sulfate, and nitrate concentrations. These increases are attributed to agricultural or other anthropogenic influences on the aquifer upgradient of the INL.

Statistical trends of chemical constituents from several wells near the Naval Reactors Facility may be influenced by wastewater disposal at the facility or by anthropogenic influence from the Little Lost River basin. Groundwater samples from three wells downgradient of the Power Burst Facility area show increasing trends for chloride, nitrate, sodium, and sulfate concentrations. The increases could be caused by wastewater disposal in the Power Burst Facility area.

Some groundwater samples in the southwestern part of the INL and southwest of the INL show concentration trends for chloride and sodium that may be influenced by wastewater disposal. Some of the groundwater samples have decreasing trends that could be attributed to the decreasing concentrations in the wastewater from the late 1970s to 2009. The young fraction of groundwater in many of the wells is more than 20 years old, so samples collected in the early 1990s are more representative of groundwater discharged in the 1960s and 1970s, when concentrations in wastewater were much higher. Groundwater sampled in 2009 would be representative of the lower concentrations of chloride and sodium in wastewater discharged in the late 1980s. Analyses of trends for sodium in several groundwater samples from the central and southern part of the eastern Snake River aquifer show increasing trends. In most cases, however, the sodium concentrations are less than background concentrations measured in the aquifer. Many of the wells are open to larger mixed sections of the aquifer, and the increasing trends may indicate that the long history of wastewater disposal in the central part of the INL is increasing sodium concentrations in the groundwater.

10.2.4 Completion summary for borehole USGS 136 near the Advanced Test Reactor Complex, Idaho National Laboratory, Idaho (Brian V. Twining, Roy C. Bartholomay, and Mary K.V. Hodges)

In 2011, the USGS, in cooperation with the DOE-ID, cored and completed borehole USGS 136 for stratigraphic framework analyses and long-term groundwater monitoring of the eastern Snake River Plain aquifer at the Idaho National Laboratory. The borehole was initially cored to a depth of 1,048 feet (ft) below land surface (BLS) to collect core, open-borehole water samples, and geophysical data. After these data were collected, borehole USGS 136 was cemented and backfilled between 560 and 1,048 ft BLS. The final construction of borehole USGS 136 required that the borehole be reamed to allow for installation of 6-inch (in.) diameter carbon-steel casing and 5-in. diameter stainless-steel screen; the screened monitoring interval was completed between 500 and 551 ft BLS. A dedicated pump and water-level access line were placed to allow for aquifer testing, for collecting periodic water samples, and for measuring water levels.

Geophysical and borehole video logs were collected after coring and after the completion of the monitor well. Geophysical logs were examined in conjunction with the borehole core to describe borehole lithology and to identify primary flow paths for groundwater, which occur in intervals of fractured and vesicular basalt.

A single-well aquifer test was used to define hydraulic characteristics for borehole USGS 136 in the eastern Snake River Plain aquifer. Specific-capacity, transmissivity, and hydraulic conductivity from the aquifer test were at least 975 gallons per minute per foot, 1.4 × 105 feet squared per day (ft^2/d), and 254 feet per day, respectively. The amount of measureable drawdown during the aquifer test was about 0.02 ft. The transmissivity for borehole USGS 136 was in the range of values determined from previous aquifer tests conducted in other wells near the Advanced Test Reactor Complex: 9.5 × 103 to 1.9 × 105 ft^2/d.

Water samples were analyzed for cations, anions, metals, nutrients, total organic carbon, volatile organic compounds, stable isotopes, and radionuclides. Water samples from borehole USGS 136 indicated that concentrations of tritium, sulfate, and chromium were affected by wastewater disposal practices at the Advanced Test Reactor Complex. Depth-discrete groundwater samples were collected in the open borehole USGS 136 near 965, 710, and 573 ft BLS using a thief sampler; on the basis of selected constituents, deeper groundwater samples showed no influence from wastewater disposal at the Advanced Test Reactor Complex.

10.2.5 Multilevel groundwater monitoring of hydraulic head and temperature in the eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, 2009–10 (Brian V. Twining and Jason C. Fisher)

During 2009 and 2010, the USGS's INL Project Office, in cooperation with the DOE-ID, collected quarterly, depth-discrete measurements of fluid pressure and temperature in nine boreholes located in the eastern Snake River Plain aquifer. Each borehole was instrumented with a multilevel monitoring system consisting of a series of valved measurement ports, packer bladders, casing segments, and couplers. Multilevel monitoring at the INL has been ongoing since 2006. This report summarizes data collected from three multilevel monitoring wells installed during 2009 and 2010 and presents updates to six multilevel monitoring wells. Hydraulic heads

(heads) and groundwater temperatures were monitored from 9 multilevel monitoring wells, including 120 hydraulically isolated depth intervals from 448.0 to 1,377.6 feet below land surface.

Quarterly head and temperature profiles reveal unique patterns for vertical examination of the aquifer's complex basalt and sediment stratigraphy, proximity to aquifer recharge and discharge, and groundwater flow. These features contribute to some of the localized variability even though the general profile shape remained consistent over the period of record. Major inflections in the head profiles almost always coincided with low-permeability sediment layers and occasionally thick sequences of dense basalt. However, the presence of a sediment layer or dense basalt layer was insufficient for identifying the location of a major head change within a borehole without knowing the true areal extent and relative transmissivity of the lithologic unit. Temperature profiles for boreholes completed within the Big Lost Trough indicate linear conductive trends; whereas, temperature profiles for boreholes completed within the axial volcanic high indicate mostly convective heat transfer resulting from the vertical movement of groundwater. Additionally, temperature profiles provide evidence for stratification and mixing of water types along the southern boundary of the Idaho National Laboratory.

Vertical head and temperature change were quantified for each of the nine multilevel monitoring systems. The vertical head gradients were defined for the major inflections in the head profiles and were as high as 2.1 feet per foot. Low vertical head gradients indicated potential vertical connectivity and flow, and large gradient inflections indicated zones of relatively low vertical connectivity. Generally, zones that primarily are composed of fractured basalt displayed relatively small vertical head differences. Large head differences were attributed to poor vertical connectivity between fracture units because of sediment layering and/or dense basalt. Groundwater temperatures in all boreholes ranged from 10.2 to 16.3˚C.

Normalized mean hydraulic head values were analyzed for all nine multilevel monitoring wells for the period of record (2007–10). The mean head values suggest a moderately positive correlation among all boreholes, which reflects regional fluctuations in water levels in response to seasonality. However, the temporal trend is slightly different when the location is considered; wells located along the southern boundary, within the axial volcanic high, show a strongly positive correlation.

10.2.6 Evaluation of quality-control data collected by the U.S. Geological Survey for routine water-quality activities at the Idaho National Laboratory, Idaho, 1996–2001 (Gordon W. Rattray)

The USGS, in cooperation with the DOE-ID, collects surface water and groundwater samples at and near the INL Site as part of a routine, site-wide, water-quality monitoring program. Quality-control samples are collected as part of the program to ensure and document the quality of environmental data. From 1996 to 2001, quality-control samples consisting of 204 replicates and 27 blanks were collected at sampling sites. Paired measurements from replicates were used to calculate variability (as reproducibility and reliability) from sample collection and analysis of radiochemical, chemical, and organic constituents. Measurements from field and equipment blanks were used to estimate the potential contamination bias of constituents.

The reproducibility of measurements of constituents was calculated from paired measurements as the normalized absolute difference (NAD) or the relative standard deviation

(RSD). The NADs and RSDs, as well as paired measurements with censored or estimated concentrations for which NADs and RSDs were not calculated, were compared to specified criteria to determine if the paired measurements had acceptable reproducibility. If the percentage of paired measurements with acceptable reproducibility for a constituent was greater than or equal to 90 percent, then the reproducibility for that constituent was considered acceptable. The percentage of paired measurements with acceptable reproducibility was greater than or equal to 90 percent for all constituents except orthophosphate (89 percent), zinc (80 percent), hexavalent chromium (53 percent), and total organic carbon (TOC; 38 percent). The low reproducibility for orthophosphate and zinc was attributed to calculation of RSDs for replicates with low concentrations of these constituents. The low reproducibility for hexavalent chromium and TOC was attributed to the inability to preserve hexavalent chromium in water samples and high variability with the analytical method for TOC.

The reliability of measurements of constituents was estimated from pooled RSDs that were calculated for discrete concentration ranges for each constituent. Pooled RSDs of 15 to 33 percent were calculated for low concentrations of gross-beta radioactivity, strontium-90, ammonia, nitrite, orthophosphate, nickel, selenium, zinc, tetrachloroethene, and toluene. Lower pooled RSDs of 0 to 12 percent were calculated for all other concentration ranges of these constituents, and for all other constituents, except for one concentration range for gross-beta radioactivity, chloride, and nitrate + nitrite; two concentration ranges for hexavalent chromium; and TOC. Pooled RSDs for the 50 to 60 picocuries per liter concentration range of gross-beta radioactivity (reported as cesium-137) and the 10 to 60 milligrams per liter (mg/L) concentration range of nitrate + nitrite (reported as nitrogen [N]) were 17 percent. Chloride had a pooled RSD of 14 percent for the 20 to less than 60 mg/L concentration range. High pooled RSDs of 40 and 51 percent were calculated for two concentration ranges for hexavalent chromium and of 60 percent for TOC.

Measurements from (1) field blanks were used to estimate the potential bias associated with environmental samples from sample collection and analysis, (2) equipment blanks were used to estimate the potential bias from cross contamination of samples collected from wells where portable sampling equipment was used, and (3) a source-solution blank was used to verify that the deionized water source-solution was free of the constituents of interest. If more than one measurement was available, the bias was estimated using order statistics and the binomial probability distribution. The source-solution blank had a detectable concentration of hexavalent chromium of 2 micrograms per liter. If this bias was from a source other than the source solution, then about 84 percent of the 117 hexavalent chromium measurements from environmental samples could have a bias of 10 percent or more. Of the 14 field blanks that were collected, only chloride (0.2 milligrams per liter) and ammonia (0.03 milligrams per liter as nitrogen), in one blank each, had detectable concentrations. With an estimated confidence level of 95 percent, at least 80 percent of the 1,987 chloride concentrations measured from all environmental samples had a potential bias of less than 8 percent. The ammonia bias, which may have occurred at the analytical laboratory, could produce a potential bias of 5–100 percent in eight potentially affected ammonia measurements. Of the 11 equipment blanks that were collected, chloride was detected in 4 of these blanks, sodium in 3 blanks, and sulfate and hexavalent chromium were each detected in 1 blank. The concentration of hexavalent chromium in the equipment blank was the same concentration as in the source-solution blank collected on the same day, which indicates

that the hexavalent chromium in the equipment blank is probably from a source other than the portable sampling equipment, such as the sample bottles or the source-solution water itself. The potential bias for chloride, sodium, and sulfate measurements was estimated for environmental samples that were collected using portable sampling equipment. For chloride, it was estimated with 93 percent confidence that at least 80 percent of the measurements had a bias of less than 18 percent. For sodium and sulfate, it was estimated with 91 percent confidence that at least 70 percent of the measurements had a bias of less than 12 and 5 percent, respectively.

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Solarized Early 20th Century Bottle
Exposed after Middle Butte Fire

11. Quality Assurance

11. QUALITY ASSURANCE

Quality assurance (QA) consists of the planned and systematic activities necessary to provide adequate confidence that the product or service will meet requirements. An effective QA program is essential to collect quality data. QA procedures are designed to ensure sample integrity, precision, and accuracy in the analytical results and to ensure that the environmental data are representative and complete. This chapter presents information on specific measures taken by the effluent monitoring and environmental monitoring programs in 2012 to ensure the quality of data collected and presented in this annual report.

11.1 Quality Assurance Policy and Requirements

The primary policy, requirements, and responsibilities for establishing and maintaining plans and actions that ensure QA in U.S. Department of Energy (DOE) activities are provided in DOE Order 414.1D, "Quality Assurance," 10 Code of Federal Regulations (CFR) 830, Subpart A, "Quality Assurance Requirements," and American Society of Mechanical Engineers (ASME) NQA-1-2012, "Quality Assurance Requirement for Nuclear Facility Applications." The ASME NQA-1-2012 is the preferred standard for activities at nuclear facilities. Additional QA program requirements in 40 CFR 61, Appendix B must be met for all radiological air emission sources continuously monitored for compliance with 40 CFR 61, Subpart H.

The ten criteria established in 10 CFR 830, Subpart A and DOE Order 414.1D that are required as part of a quality program are shown in the box on the right. Each Idaho National Laboratory (INL) Site environmental monitoring organization incorporates the requirements into its QA program documentation for environmental monitoring.

Quality Assurance Criteria Established by the U.S. Department of Energy

- Quality assurance program
- Personnel training and qualification
- Quality improvement process
- Documents and records
- Established work processes
- Established standards for design and verification
- Established procurement requirements
- Inspection and acceptance testing
- Management assessment
- Independent assessment

11.2 Environmental Monitoring Program Documentation

Strict adherence to program procedures is an implicit foundation of QA. In 2012, samples were collected and analyzed according to documented

program procedures. Samples were collected by personnel trained to conduct sampling and properly process samples. Sample integrity was maintained through a system of sample custody records. Analytical data quality was verified by a continuing program of quality control (QC) detailed in program QA documents. Results were evaluated and input into databases using data management, validation, and reporting procedures. An overview of the Idaho Cleanup Project (ICP) contractor, INL contractor, and Environmental Surveillance, Education, and Research (ESER) contractor environmental monitoring program documentation is presented in Table 11-1, Figure 11-1 and Figure 11-2, respectively.

11.3 Environmental Monitoring Program Quality Assurance Program Documentation

Implementation of QA elements for sample collection and data assessment activities were documented using the approach recommended by the Environmental Protection Agency (EPA). The EPA policy on QA plans is based on the national consensus standard ANSI/ASQC E4-1994, "Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs." The EPA approach to data quality centers on the data quality objective process. Data quality objectives are project dependent and are determined on the basis of the data users' needs and the purpose for which data are generated. Quality elements applicable to environmental monitoring and decision-making are specifically addressed in *EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5)* (EPA 2001). These elements are categorized as follows:

- Project management
- Data generation and acquisition
- Assessment and oversight
- Data validation and usability.

A Quality Assurance Project Plan documents the planning, implementation, and assessment procedures for a particular project, as well as any specific QA and QC activities. It integrates all the technical and quality aspects of the project in order to provide a "blueprint" for obtaining the type and quality of environmental data and information needed for a specific decision or use.

The following sections summarize how each monitoring organization at the INL Site implements QA requirements.

11.3.1 Idaho National Laboratory Contractor

The INL contractor integrates applicable requirements from *Manual 13A—Quality Assurance Laboratory Requirements Documents* (INL 2012) into the implementing monitoring program plans and procedures for non-CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) monitoring activities. The program plans address the QA elements as stated in *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5) (EPA 2001) to ensure that the required standards of data quality are met.

In addition, the INL contractor uses a documented approach for collecting, assessing, and reporting environmental data. Environmental and effluent monitoring are conducted in

Table 11-1. Idaho Cleanup Project Environmental Program Procedures.

Document/Media Type	Document No.[a] and Title
Requirements Documents	PRD-5030, Environmental Requirements for Facilities, Processes, Materials, and Equipment MCP-3480, Environmental Instructions for Facilities, Processes, Materials, and Equipment
Data and Validation Documents	PLN-491, Laboratory Performance Evaluation Program Plan PLN-1401, Transferring Integrated Environmental Data Management System Revised Data to the Environmental Data Warehouse MCP-9236, Analytical Data Verification GDE-201, Inorganic Analyses Data Validation for Sample and Analysis Management GDE-204, Guide to Assessment of Radionuclide Analysis of Performance Evaluation Samples GDE-205, Radioanalytical Data Validation GDE-206, Obtaining Laboratory Services for Sample Analysis GDE-234, Generating Sampling and Analysis Plan Tables for Environmental Sampling Activities GDE-239, Validation of Volatile Organic Compounds Data Analyzed Using Gas Chromatography/Mass Spectrometry GDE-240, Validation of Gas and Liquid Chromatographic Organic Data GDE-241, Validation of Semivolatile Organic Compounds Data Analyzed Using Gas Chromatography/Mass Spectrometry GDE-7003, Levels of Analytical Method Data Validation MCP-1298, Sample and Analytical Data Management Process for the Sample and Analysis Management Program MCP-9229, Validating, Verifying and Controlling EM Data
Sampling Documents	MCP-9439, Environmental Sampling Activities at the INL
Groundwater Documents	PLN-1305, Wastewater Reuse Permit Groundwater Program Plan SPR-162, Measuring Groundwater Levels and Sampling Groundwater TPR-6539, Calibrating and Using the Hydrolab Quanta Water Quality Multiprobe TPR-7582, Well Inspection/Logging Using Down-Hole Cameras
Liquid Effluent Documents	PLN-729, Idaho Cleanup Project Liquid Effluent Monitoring Program Plan GDE-142, Quality Control Sample Submission SPR-101, Liquid Effluent Sampling TPR-6539, Calibrating and Using the Hydrolab Quanta Water Quality Multiprobe
Drinking Water Documents	PLN-730, Idaho Cleanup Project Drinking Water Program Plan SPR-188, Collecting Water Samples for Radiological Analysis SPR-189, Routine Collection of Samples for Coliform Bacteriological Analysis SPR-190, Sampling of Public Water Systems TPR-6555, Cross Connection Inspections and Backflow Prevention Assembly Testing
Surveillance Documents	PLN-720, Environmental Surveillance Program Plan
Biota Documents	SPR-106, Biotic Monitoring
Air Documents	SPR-107, Waste Management Low-Volume Suspended Particulate Air Monitoring SPR-193, Ambient Air Sampling for NESHAP Compliance at Accelerated Retrieval Project MCP-1264, Ambient Air Surveillance Instrumentation Calibration

Table 11-1. Idaho Cleanup Project Environmental Program Procedures. (cont.)

Document/Media Type	Document No.[a] and Title
Soil Documents	SPR-110, Surface Soil Sampling
Surface Water Documents	SPR-213, Surface Water Sampling at Radioactive Waste Management Complex
Surface Radiation Documents	TPR-6525, Surface Radiation Surveys Using the Global Positioning Radiometric Scanner
In Situ Documents	TPR-6526, In Situ Soil Radiation Measurements TPR-6863, In Situ Gamma Radiation Measurement of Radionuclides in Containers TPR-7485, Filling Gamma Detector with Liquid Nitrogen TPR-7859, Shipping Screen Gamma Scan TPR-7860, Germanium Detector Calibration and Performance Testing Using Gamma Vision-32
Documentation Documents	MCP-9227, Environmental and Regulatory Services Logkeeping Practices MCP-9235, Reporting Requirements of the Liquid Effluent Monitoring and Wastewater Land Application Permit Groundwater Monitoring Programs
Sample Management Documents	MCP-9228, Managing Nonhazardous Samples MCP-1394, Managing Hazardous Samples

a. GDE = Guide
MCP = Management Control Procedure
PLN = Plan
PRD = Program Requirements Document
SPR = Sampling Procedure
TPR = Technical Procedure.

accordance with PLN-8510, "Planning and Management of Environmental Support and Services Monitoring Services Activities," PLN-8515, "Data Management Plan for the INL Environmental Support and Services Monitoring Services Program," and PLN-8550, "Environmental Support and Services Monitoring Services Surveillance Plan" in order to ensure that analytical work for environmental and effluent monitoring supports data quality objectives.

11.3.2 Idaho Cleanup Project Contractor

All CERCLA monitoring activities at the INL Site are conducted in accordance with the *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10 and Removal Actions* (DOE-ID 2009). The Quality Assurance Project Plan was written in accordance with "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988). In addition, the ICP contractor uses:

- PLN-720, "Environmental Surveillance Program Plan"
- PLN-729, "Idaho Cleanup Project Liquid Effluent Monitoring Program Plan"

Figure 11-1. Idaho National Laboratory Environmental Support and Services Program Documentation.

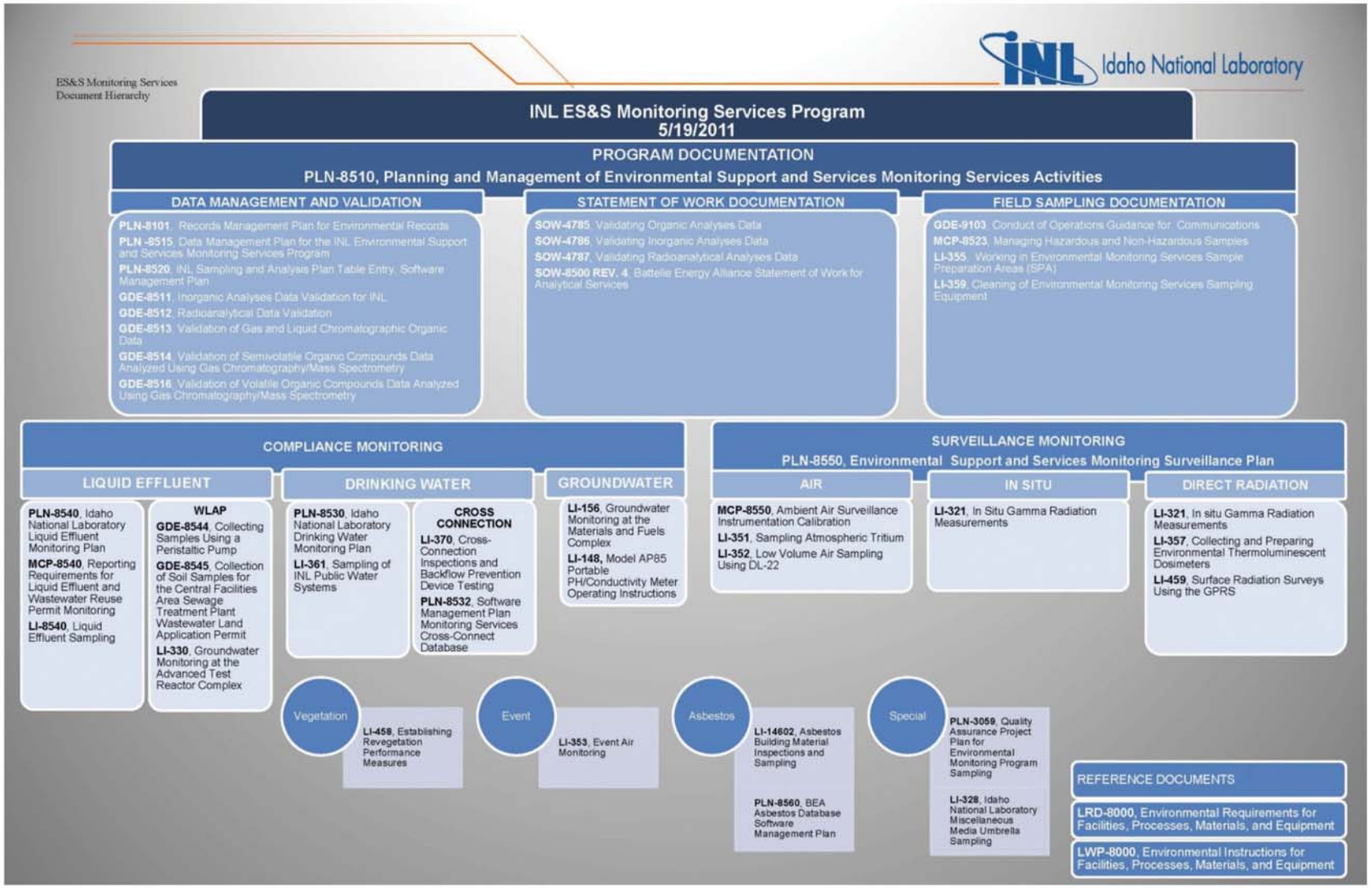
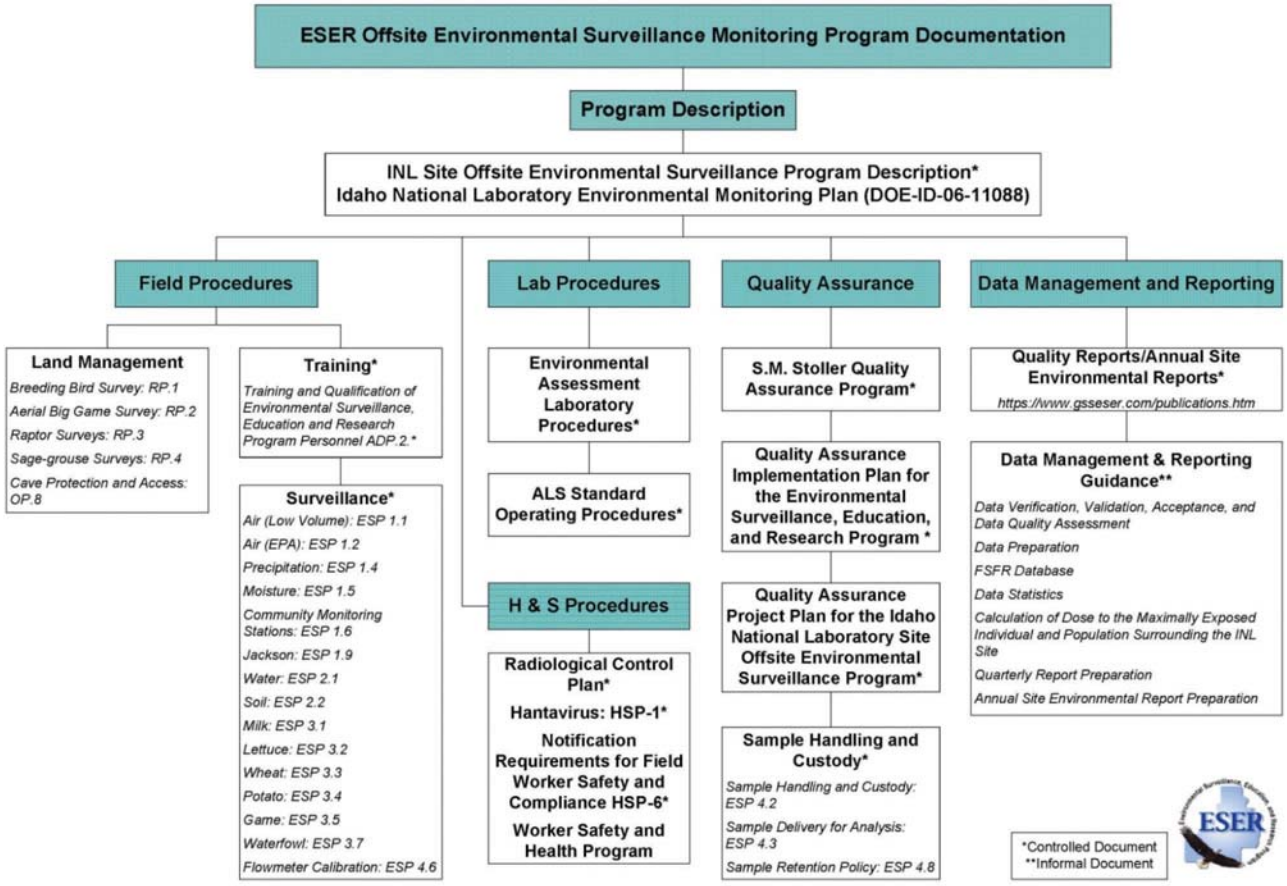


Figure 11-2. Environmental Surveillance, Education and Research Program Offsite Environmental Surveillance Documentation.



- PLN-730, “Idaho Cleanup Project Drinking Water Program Plan”
- PLN-1305, “Wastewater Reuse Permit Groundwater Monitoring Program Plan.”

11.3.3 Advanced Mixed Waste Treatment Project

The Advanced Mixed Waste Treatment Project maintains a QA program in accordance with 40 CFR 61, Appendix B, as required of all radiological air emission sources continuously monitored for compliance with 40 CFR 61, Subpart H. The QA requirements are documented in AMWTP-PD-EC&P-02, *Quality Assurance Project Plan for the WMF 676 NESHAPs Stack Monitoring System*.

11.3.4 Environmental Surveillance, Education, and Research Program

The ESER Program maintains a QA program consistent with the requirements of 10 CFR 830, Subpart A, and DOE Order 414.1D that is implemented through the *ESER Quality Management Plan for the Environmental Surveillance, Education and Research Program*.

Additional QA requirements for monitoring activities are provided in the *ESER Quality Assurance Project Plan for the INL Offsite Environmental Surveillance Program*. Analytical laboratories used by the ESER Program maintain their own QA programs consistent with DOE requirements.

11.3.5 U.S. Geological Survey

Field Methods and Quality-Assurance Plan for Quality-of-Water Activities, U.S. Geological Survey, Idaho National Laboratory, Idaho (Knobel et al. 2008) defines procedures and tasks performed by project-office personnel that ensure the reliability of water quality data. The plan addresses all elements needed to ensure:

- Reliability of the water-quality data
- Compatibility of the data with data collected by other organizations at the INL Site
- That data meet the programmatic needs of DOE and its contractors and the scientific and regulatory communities.

The U.S. Geological Survey (USGS) conducts performance audits on field personnel collecting samples and of the analytical laboratories that analyze their environmental monitoring samples. In addition, the USGS routinely evaluates its QC data and publishes analyses in USGS reports.

11.3.6 National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration *Quality Program Plan, NOAA Air Resources Laboratory Field Research Division* (NOAA-ARLFRD 1993) addresses the requirements of DOE Order 414.1D, and is consistent with ASME. Implementing procedures include regular independent system and performance audits, written procedures and checklists, follow-up actions, and continuous automated and visual data checks to ensure representativeness and accuracy. The plan and implementing procedures provide the framework to ensure that the INL Meteorological Monitoring Network meets the elements of “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance” (DOE/EH-0173T).

All the meteorological sensors in the Air Resources Laboratory Field Research Division tower network are inspected, serviced, and calibrated semiannually as recommended by American Nuclear Society guidelines of ANSI/ANS 3.11 2005. Unscheduled service also is performed promptly whenever a sensor malfunctions.

11.4 Analytical Laboratories

Analytical laboratories used to analyze environmental samples collected on and off the INL Site are presented in Table 11-2.

Radiological analytical laboratories used for routine analyses of radionuclides in environmental media were selected by each environmental monitoring program based on each laboratory’s capabilities and past results in performance evaluation programs, such as the Mixed Analyte Performance Evaluation Program (MAPEP) described in Section 10.6.1. Continued acceptable performance in programs such as MAPEP is required to remain as the contracted laboratory.

Table 11-2. Analytical Laboratories Used by INL Site Contractors and U.S. Geological Survey Environmental Monitoring Programs.

Contractor and Program	Laboratory	Type of Analysis
ICP Drinking Water Program	GEL Laboratories, LLC	Radiological
	Intermountain Analytical Service – EnviroChem	Microbiological
	UL LLC	Inorganic and organic
ICP Environmental Program	ALS Laboratory Group – Fort Collins	Radiological
ICP Effluent Monitoring Program	ICP Wastewater Laboratory	Microbiological
	GEL Laboratories, LLC	Radiological
	Southwest Research Institute	Inorganic
ICP Groundwater Monitoring Program	GEL Laboratories, LLC	Microbiological
	Southwest Research Institute	Inorganic and radiological
INL Drinking Water Program	General Engineering Laboratories	Radiological
	Intermountain Analytical Service – EnviroChem	Inorganic
	Teton Microbiology Laboratory of Idaho Falls	Bacterial
	UL LLC	Organic
INL Liquid Effluent and Groundwater Programs	General Engineering Laboratories	Radiological
	Southwest Research Institute	Inorganic, nonradiological
INL Environmental Surveillance Program	ALS Laboratory Group – Fort Collins	Radiological
	Environmental Services In Situ Gamma Laboratory	I-131
	Landauer Inc.	Penetrating Radiation (OSL dosimeters)
Environmental Surveillance, Education and Research Program	Environmental Assessments Laboratory at Idaho State University	Gross radionuclide analyses (e.g., gross alpha and gross beta), OSL dosimetry, liquid scintillation counting (tritium), and gamma spectrometry

Table 11-2. Analytical Laboratories Used by INL Site Contractors and U.S. Geological Survey Environmental Monitoring Programs. (cont.)

Contractor and Program	Laboratory	Type of Analysis
	ALS Laboratory Group – Fort Collins	Specific radionuclide (e.g., strontium-90, americium-241, plutonium-238 and plutonium-239/240)
U.S. Geological Survey	DOE's Radiological and Environmental Sciences Laboratory	Radiological
	USGS National Water Quality Laboratory	Nonradiological and low-level tritium and stable isotopes
	Purdue Rare Isotope Measurement Laboratory	Low-level iodine-129
	TestAmerica Laboratories	Radiological and nonradiological for the USGS Naval Reactors Facility sample program
	Brigham Young University Laboratory of Isotope Geochemistry	Low-level tritium for the USGS Naval Reactors Facility sample program

Each laboratory's adherence to laboratory and QA procedures is checked through audits by representatives of the contracting environmental monitoring program. Subcontract laboratories used by the INL and ICP contractors also are audited by the DOE Consolidated Audit Program (DOECAP). This program uses trained and certified personnel to perform in-depth audits of subcontract laboratories to review:

- Personnel training and qualification
- Detailed analytical procedures
- Calibration of instrumentation
- Participation in an inter-comparison program
- Use of blind controls
- Analysis of calibration standards.

Audit results are maintained by the DOECAP. Laboratories are required to provide corrective action plans for audit findings.

Laboratory data quality is verified by a continuing program of internal laboratory QC, participation in inter-laboratory crosschecks, replicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories. These quality checks are described in the following sections.

11.5 Quality Assurance/Quality Control Results for 2012

Results of the QA measurements for 2012 are summarized in the following sections.

11.5.1 Liquid Effluent Program Quality Assurance/Quality Control

Idaho National Laboratory Contractor – The INL contractor Liquid Effluent Monitoring and Groundwater Monitoring Programs have specific QA/QC objectives for analytical data. Goals are established for accuracy, precision, and completeness. The program submits field duplicates to provide information on variability caused by sample heterogeneity and collection methods. In 2012, field duplicates were collected at the Advanced Test Reactor Complex Cold Waste Pond, USGS-065, Materials and Fuels Complex Industrial Waste Pipeline and the Industrial Waste Pond, and well ANL-MON-A-014 at the Material and Fuels Complex.

For nonradiological analytes, if the reported concentration in the first sample and the duplicate exceeded the detection limit by a factor of five or more, the laboratory precision was evaluated by calculating the relative percent difference (RPD) using Equation 1:

$$\mathbf{RPD} = \frac{|\mathbf{R_1} - \mathbf{R_2}|}{(\mathbf{R_1} + \mathbf{R_2})/2} \times \mathbf{100} \qquad (1)$$

Where

R_1 = concentration of analyte in the first sample

R_2 = concentration of analyte in the duplicate sample.

The precision of the radiological results were considered acceptable if the RPD was less than or equal to 35 percent or if the following condition was met:

$$|\mathbf{R_1} - \mathbf{R_2}| \leq 3\left(\mathbf{s_1^2} + \mathbf{s_2^2}\right)^{1/2} \qquad (2)$$

Where

R_1 = concentration of analyte in the first sample

R_2 = concentration of analyte in the duplicate sample

s_1 = uncertainty (one standard deviation) associated with the laboratory measurement of the first sample

s_2 = uncertainty (one standard deviation) associated with the laboratory measurement of the duplicate sample.

The INL contractor Liquid Effluent Monitoring and Groundwater Program requires that the RPD from field duplicates be less than or equal to 35 for 90 percent of the analyses. Over 90 percent of the results for the duplicate samples were comparable to the original samples.

The goal for completeness is to collect 100 percent of all required compliance samples. This goal was met in 2012.

Kinds of Quality Control Samples

Blind Spike — Used to assess the accuracy of the analytical laboratories. Contractors obtain samples spiked with known amounts of radionuclides or nonradioactive substances from suppliers whose spiking materials are traceable to National Institute of Standards and Technology (NIST). These samples are then submitted to the laboratories with regular field samples using the same labeling and sample numbering system. The analytical results are expected to compare to the known value within a set of performance limits. Generally used to establish intra-laboratory or analyst-specific precision and accuracy or to assess the performance of all or a portion of the measurement system. A double blind spike is a sample submitted to evaluate performance with concentration and identity unknown to both the submitter and the analyst.

Performance Evaluation Sample — A type of blind sample. The composition of performance evaluation samples is unknown to the analyst. Performance evaluation samples are provided to evaluate the ability of the analyst or laboratory to produce analytical results within specified limits. Performance evaluation samples (submitted as double blind spikes) are required to assess analytical data accuracy.

Field Replicates (duplicates or collocated samples) — Two samples collected from a single location at the same time. Two separate samples are taken from the same source, stored in separate containers, and analyzed independently. In the case of air sampling, two air samplers are placed side by side and each filter is analyzed separately. Duplicates are useful in documenting the precision of the sampling process. Field duplicates provide information on analytical variability caused by sample heterogeneity, collection methods and laboratory procedures.

Split Sample — A sample collected and later divided into two portions that are analyzed separately. The samples are taken from the same container and analyzed independently. Split samples are used to assess analytical variability and comparability.

Trip Blank — A sample of analyte-free media taken from the sample preparation area to the sampling site and returned to the analytical laboratory unopened. A trip blank is used to document contamination attributable to shipping and field handling procedures. This type of blank is useful in documenting contamination of volatile organics samples.

Field Blank — A clean analyte-free sample that is carried to the sampling site and then exposed to sampling conditions, returned to the laboratory, and treated as an environmental sample. Collected to assess the potential introduction of contaminants during sampling. This blank is used to provide information about contaminants that may be introduced during sample collection, storage, and transport.

Accuracy was assessed using the results of the laboratory's control samples, initial and continuing calibration samples, and matrix spikes. As an additional check on accuracy, four performance evaluation samples (prepared by MAPEP personnel at the Radiological and Environmental Sciences Laboratory as described in Section 11.6.1) were submitted to the laboratory and analyzed for radiological constituents. The results for the spiked constituents were in agreement with the known spiked concentrations.

Idaho Cleanup Project Contractor – The ICP contractor Liquid Effluent Monitoring Program has specific QA/QC objectives for analytical data. All effluent sample results were usable in 2012 except some sample results that were rejected during data validation because of laboratory QC issues.

Goals are established for accuracy, precision, and completeness, and all analytical results are validated following standard EPA protocols. The ICP contractor Liquid Effluent Monitoring Program submits three types of QC samples: performance evaluation samples, field duplicate samples, and equipment rinsate samples.

Performance evaluation samples consist of standards with known concentrations that are submitted to the analytical laboratory as a regular sample. The performance evaluation sample is used to assess laboratory accuracy; results should be within the performance acceptance limits specified on the QC standards certification.

At a minimum, performance evaluation samples are required quarterly. During 2012, performance evaluation samples were submitted to the laboratory with routine monitoring samples on February 22, 2012, May 16, 2012, September 12, 2012, and December 13, 2012. Ninety percent of the results were within the QC performance acceptance limits, indicating acceptable accuracy. The laboratory was notified of the results outside the performance acceptance limits, and the laboratory implemented corrective action, as necessary.

To quantify measurement uncertainty from field activities, a field duplicate sample is collected annually at each sample location. The RPD determined from nonradiological field duplicate samples should be 35 percent or less for 90 percent of the analyses and is calculated using Equation 3:

$$\mathbf{RPD} = \frac{|R_1 - R_2|}{(R_1 + R_2)/2} \times 100 \quad (3)$$

Where

R_1 = concentration of analyte in the first sample

R_2 = concentration of analyte in the duplicate sample.

Nonradiological field duplicate samples were collected at CPP-769, CPP-773, and CPP-797 on June 13, 2012, and at CPP-797 on July 11, 2012. For 2012, 95 percent of results (with two detectable quantities) were within the program goal of less than or equal to 35 percent.

The mean difference (MD) determined from the radiological field duplicate should be less than or equal to 3 and is calculated using Equation 4:

$$MD = \frac{|S - D|}{\sqrt{(\sigma_S^2 + \sigma_D^2)}} \quad (4)$$

Where

MD = mean difference of the duplicate results

S = original sample result

D = duplicate sample result

σ^2_S = associated combined propagated 1σ uncertainty of the original result (as a standard deviation)

σ^2_D = associated combined propagated 1σ uncertainty of the duplicate result (as a standard deviation).

If one of the results is not statistically positive, the MD is calculated by using one-half the required detection level (RDL) value for the nonpositive radionuclide result, as shown in Equation 5:

$$MD = \frac{|Positive\ \ Result - \tfrac{1}{2}\ RDL|}{\sqrt{(\sigma^2_{POS} + \tfrac{1}{2}\ RDL^2)}} \quad (5)$$

Where

MD = mean difference of the duplicate results

Positive Result = positive sample result

½RDL = one-half of the appropriate RDL.

σ^2_{POS} = associated combined propagated 1σ uncertainty of the positive result (as a standard deviation)

$½RDL^2$ = ½RDL value is the assumed uncertainty.

The MD for the radiological field duplicate sample collected at CPP-773 on October 25, 2012, was less than 3.

Equipment rinsates are collected annually and are used to evaluate the effectiveness of equipment decontamination. They are collected after completion of decontamination and prior to sampling. Equipment rinsates should be less than five times the method detection limit. Rinsate samples were collected at CPP-773 on April 18, 2012. The analytical results for the rinsate samples indicate that decontamination procedures are adequate.

The goal for completeness is to collect 100 percent of all required compliance samples. During 2012, this goal was met.

11.5.2 Idaho Cleanup Project Contractor Wastewater Reuse Permit Groundwater Monitoring Quality Assurance/Quality Control

Groundwater sampling for Wastewater Reuse Permit compliance follows established procedures and analytical methodologies.

During 2012, groundwater samples were collected from all of the Idaho Nuclear Technology and Engineering Center New Percolation Ponds permitted wells that had sufficient water. Samples were not collected from perched water Well ICPP-MON-V-191 in September/October 2012 because the well was dry. All other permit-required samples were collected. All groundwater sample results were usable.

Field QC samples were collected or prepared during sampling in addition to regular groundwater samples. Laboratories qualified by the ICP Sample and Analysis Management organization performed all ICP groundwater analyses during 2012.

Duplicate samples are collected to assess natural variability and precision of analyses. One duplicate groundwater sample was collected for every 20 samples collected or, at a minimum, 5 percent of the total number of samples collected. Duplicate samples were collected using the same sampling techniques and preservation as regular groundwater samples. Duplicate samples were collected on April 4, 2012, September 4, 2012, and September 11, 2012. Ninety-three percent of nonradiological duplicate sample results (with two detectable quantities) were within the program goal for RPD of less than or equal to 35 percent (see Equation 3 for the RPD calculation in Section 10.5.1). The MD determined from the radiological field duplicate (see Equation 4 or Equation 5 for the calculation in Section 11.5.1) should be less than or equal to 3. The samples collected on April 3, 2012, and September 4, 2012, were within the goal of less than 3.

Field blanks are collected to assess the potential introduction of contaminants during sampling activities. One field blank was collected for every 20 samples collected or, at a minimum, 5 percent of the total number of samples collected. Field blank samples were collected on April 4, 2012, and September 5, 2012. All analytical results were below the detection/reporting limit. Results from the field blanks did not indicate field contamination.

Equipment blanks (rinsates) were collected to assess the potential introduction of contaminants from incomplete decontamination activities. They were collected by pouring analyte-free water through the sample port manifold after decontamination and before subsequent use. Rinsate samples were collected on April 4, 2012, and September 5, 2012. Ninety-seven percent of the results were below the detection/reporting limit. Results from the equipment blanks indicate proper decontamination procedures.

Results from the duplicate, field blank, and equipment blank (rinsate) samples indicate that laboratory procedures, field sampling procedures, and decontamination procedures effectively produced high quality data.

Performance evaluation standards are prepared by an independent laboratory and sent “blind” to the analytical laboratory for analysis. Performance evaluation standards consist of specified parameter type and concentration prepared in the independent laboratory. The performance evaluation standard is used to assess laboratory accuracy, and the results should be within the performance acceptance limits specified on the performance standard’s certification.

Performance evaluation samples were submitted to the laboratory with routine monitoring samples on April 3, 2012, and September 5, 2012. Ninety-five percent of the results were within the QC performance acceptance limits.

During the April 2012 groundwater sampling event, performance evaluation samples were analyzed for fecal and total coliforms, inorganics, and metals. The performance evaluation sample result for mercury was outside the performance acceptance limits, and the laboratory was notified so they could evaluate whether corrective action was necessary.

During the September 2012 groundwater sampling event, performance evaluation samples were analyzed for fecal and total coliforms, inorganics, and metals. The fluoride result was outside the performance acceptance limits, and the laboratory was notified so they could evaluate whether corrective action was necessary.

11.5.3 Drinking Water Program Quality Assurance/Quality Control

Idaho National Laboratory Contractor – The INL contractor Drinking Water Program has specific QA/QC objectives for analytical data. Drinking Water Program goals are established for precision of less than or equal to 35 percent for 90 percent of the analyses and 100 percent completeness. All Drinking Water Program analytical results, except bacteria, are validated following standard EPA protocols. The Drinking Water Program submits field duplicates to provide information on analytical variability caused by sample heterogeneity, collection methods, and laboratory procedures.

For nonradiological analytes, if the reported concentration in the first sample and the duplicate exceeded the detection limit by a factor of five or more, the laboratory precision was evaluated by calculating the relative RPD using Equation 1 (see Section 11.5.1).

The precision of the radiological results were considered acceptable if the RPD was less than or equal to 35 percent or if the condition of Equation 2 was met.

RPD was not calculated if either the sample or its duplicate was reported as nondetect. For 2012, the Drinking Water Program had six sets of radiological data with detectable quantities. Using the above criteria, 100 percent of the radiological data is comparable, meeting the RPD goal of less than or equal to 35 percent for 90 percent of the analyses.

Blind spike samples are used to determine the accuracy of laboratory analyses for concentrations of parameters in drinking water. Within each calendar year, the program lead determines the percentage of the samples collected (excluding bacteria samples) that are QA/QC samples, which include blind spikes. All blind spike percent recoveries must fall within the standards range.

Representativeness is ensured through use of established sampling locations, schedules, and procedures for field sample collections, preservation, and handling.

The data quality objectives address completeness for laboratory and field operations. The criterion for completeness by laboratories is that at least 90 percent of the surveillance and 100 percent of the compliance samples submitted annually must be successfully analyzed and reported according to specified procedures. Similarly, the criterion for field data collection under the INL Environmental Support and Services Monitoring Services is that at least 90 percent of the surveillance and 100 percent of the compliance samples must be successfully collected on an annual basis and reported according to the specified procedures. If a completeness criterion is not met, the problem will be evaluated, and it will be determined whether the quality of the

remaining data is suspect and whether a corrective action is needed either in the field collection or laboratory analysis.

Comparability is ensured through the use of (1) laboratory instructions for sample collection, preparation, and handling, (2) approved analytical methods for laboratory analyses, and (3) consistency in reporting procedures.

Idaho Cleanup Project Contractor – The ICP contractor Drinking Water Program completeness goal is to collect, analyze, and verify 100 percent of all compliance samples. This goal was met during 2012.

The ICP contractor Drinking Water Program requires that 10 percent of the samples (excluding microbiological) collected be QA/QC samples to include duplicates, trip blanks, blind spikes, and field blanks. This goal was met in 2012 for all parameters.

The RPD calculation (see Equation 3 in Section 11.5.1) is used for nonradiological field duplicate samples, and an MD calculation (see Equation 4 or Equation 5 in Section 10.5.1) is used for radiological field duplicate samples to assess data precision. The RPD must be within 35 percent or less for 90 percent of the field duplicates that have positive results greater than five times the method detection limit. Nonradiological field duplicate samples were collected on January 25, 2012, April 26, 2012, June 20, 2012, July 18, 2012, and November 12, 2012. For 2012, 100 percent of results were within the program goal of less than or equal to 35 percent. The MD for radiological field duplicate samples should be less than or equal to 3. Samples collected on May 17, 2012, and December 10, 2012, were less than 3.

Trip blank samples were collected on January 25, 2012, April 26, 2012, July 18, 2012, and November 12, 2012. All analytical results were below the detection/reporting limit.

During 2012, performance evaluation samples were submitted to the laboratory with routine monitoring samples on January 25, 2012, April 26, 2012, June 20, 2012, July 18, 2012, and November 12, 2012. Ninety-seven percent of the results were within the QC performance acceptance limits, indicating acceptable accuracy. The laboratory was notified of the results outside the performance acceptance limits, and the laboratory implemented corrective action, as necessary.

Field blank samples were collected on April 26, 2012, July 18, 2012, and November 12, 2012. All analytical results were below the detection/reporting limit. Results from the field blanks did not indicate field contamination.

11.5.4 Environmental Surveillance, Education, and Research Program Quality Assurance/ Quality Control

Goals are established for completeness, accuracy, and precision, and all analytical results are validated by the laboratories. The ESER Program submitted four types of QC samples to the laboratories in 2012 – blank samples, field duplicate samples, laboratory split samples, and performance evaluation samples (i.e., double blind spike samples).

The ESER contractor met its completeness goals of greater than 98 percent in 2012. Twelve air samples were considered invalid because insufficient volumes were collected due to power

interruptions. A few milk samples were not collected in 2012, because they were not available for collection. All other samples were collected as planned.

Field blank samples were submitted with each set of samples to test for the introduction of contamination during the process of field collection, laboratory preparation, and laboratory analysis. Ideally, blank results should be within two standard deviations of zero and preferably within one standard deviation. In 2012, the majority of blanks were within one to two standard deviations of zero.

Field duplicate samples were collected for air, milk, lettuce, potatoes, and grain to help assess data precision and sampling bias. Most duplicate data were associated with the air sampling program. Duplicate air samplers were operated at two locations (Arco and Monteview) adjacent to regular air samples. The objective was to have data close enough to conclude that there was minor sampling bias between the samplers and acceptable laboratory precision. The ESER QA program establishes that sample results should agree within three standard deviations (Equation 2). Any variation outside the predetermined criterion could be due to one of the samplers not operating correctly (e.g., a leak in one sampling system) or not operating within the same operating parameters (e.g., flow rate, sampling time). In addition, any variation outside the predetermined criterion could be attributed to inhomogeneous distribution of a contaminant in the sample medium so that true replication is not possible. The sample and duplicate results agreed with each in approximately 95 percent of all environmental samples collected during 2012, indicating acceptable precision.

The analytical laboratories split and analyzed a number of agriculture product, precipitation, and atmospheric moisture samples to assess agreement within the 20 percent or the 3σ criterion. The latter criterion was applied in nearly all cases. All but one split sample analyses (potassium-40 in the third quarter milk) met acceptance criteria in 2012, indicating acceptable precision.

The Idaho State University Environmental Assessment Laboratory (ISU-EAL) recounts a number of samples of each media type as another measure of precision. The lab tests each recount using both the 20 percent criterion and the 3σ criterion. All recounts were within acceptable limits.

Accuracy is measured through the successful analysis of samples spiked with a known standard traceable to the National Institute for Standards and Technology (NIST). Each analytical laboratory conducted an internal spike sample program using NIST standards to confirm analytical results.

Each laboratory also participated in the MAPEP by analyzing performance evaluation samples provided by that program, as discussed in Section 10.6.1. The MAPEP Series 26 (March 2012) and MAPEP Series 27 (August 2012) Flag Results for ISU-EAL are summarized below:

- MAPEP Series 26
  - “N” (Not Acceptable) for Gamma Spectrometry Soil Sample on Co-60 (Sensitivity Evaluation)
  - “N” for Tritium (H-3) Water Sample (Not Reporting Previously Reported Analyte)
  - “N” for Gross Alpha Air Filter Sample

- MAPEP Series 27

  - "W" (Acceptable with Warning) for Gamma Spec Soil Sample on Cs-134

  - "N" for Gross Alpha Water Sample.

While none of the above findings invalidate any of the measurements reported to the ESER in 2012, one matter prompted MAPEP personnel to issue a Letter of Concern (dated July 26, 2012) to the ISU-EAL laboratory. The issue was numerous "L" Uncertainty Flags (laboratory reporting unreasonably "low" uncertainties) on the MAPEP Sensitivity Evaluations in MAPEP Series 25 (performed in 2011) and MAPEP 26. The ISU-EAL had a visit from the MAPEP Program personnel to help evaluate this potential quality concern. From this visit, the ISU-EAL made an administrative decision to adjust the way that they calculate and report gamma spec uncertainties to the ESER Surveillance Program and also the MAPEP Program. This became effective November 2012.

The MAPEP Series 26 (March 2012) and MAPEP Series 27 (August 2012) Flag Results for ALS-FC are summarized below:

- MAPEP Series 26

  - No Flags

- MAPEP Series 27

  - "N" for stronium-90 (^{90}Sr) Vegetation Sample (False Positive).

None of the above results resulted in a letter of concern and do not indicate a potential quality concern.

As an additional check on accuracy, the ESER contractor provided blind spiked samples [prepared by MAPEP personnel at the Radiological and Environmental Sciences Laboratory (RESL) as described in Section 11.6.1] for soil, wheat, air particulate filter, milk, and water samples. All results for milk spikes were "Acceptable," except for Co-60 and Zn-65, which were "Acceptable with Warning" and ^{90}Sr, which was "Not Acceptable". Milk is particularly hard to analyze because of the tendency for it to separate into solids and liquid. It is thus difficult to obtain a homogeneous sample for analysis. ESER personnel are working with the laboratory to resolve this issue.

All results for soil spikes were "Acceptable" except for Co-60 (which has never been detected in environmental soil samples), which was "Not Acceptable" and ^{90}Sr, which was "Acceptable with Warning". All results for wheat spikes were "Acceptable" except for cesium-134 (^{134}Cs), which was "Acceptable with Warning". Analysis could not be completed on the water sample due to an extremely high particulate concentration on the counting planchet, which interfered with the counting of the sample. The ISU-EAL has modified their procedure to deal with high particulate samples when analyzing for gross alpha and gross beta in water samples.

11.5.5 INL Environmental Surveillance Program Quality Assurance/Quality Control

The INL contractor analytical laboratories analyzed all Surveillance Monitoring Program samples as specified in the statements of work. These laboratories participate in a variety of intercomparison QA programs, which verify all the methods used to analyze environmental

samples. The programs include the DOE MAPEP and the EPA National Center for Environmental Research Quality Assurance Program. The Surveillance Monitoring Program met its completeness and precision goals. Samples were collected and analyzed as planned from all available media. The Environmental Surveillance Program submitted duplicate, blank, and QC samples with routine samples for analyses as required. Results concluded the laboratories met the performance objectives specified by MAPEP and the National Center for Environmental Research.

11.5.6 ICP Waste Management Surveillance Quality Assurance/Quality Control

ALS Laboratory Group of Fort Collins, Colorado, performs a wide range of chemical and radiochemical measurements on a variety of environmental media, including air particulates, fiber media, water, soils, vegetation, tissue, and wastes. ALS Laboratory Group was contracted to analyze samples for the ICP Waste Management Surveillance Program in 2012.

ALS Laboratory Group participated in a variety of intercomparison QA programs, which verify all the methods used to analyze environmental samples. The programs include the DOE MAPEP and the EPA National Center for Environmental Research Quality Assurance Program. The laboratory met the performance objectives specified by MAPEP and the National Center for Environmental Research.

All blind performance evaluation samples submitted to ALS Laboratory Group for analysis in 2012 by the Waste Management Surveillance Program showed satisfactory agreement except the following:

Soil samples—The ^{134}Cs result was evaluated as not acceptable because a statistically positive result was reported for a sample that was a blank for that radionuclide. As a result, some of the 134Cs results in soil samples potentially may be biased high.

Water samples— Americium-241 (^{241}Am) results were evaluated as not acceptable because a statistically positive result was reported for a sample that was a blank for that radionuclide. As a result, some ^{241}Am results in water samples potentially may be biased high.

These results were provided to the DOECAP, and they were addressed during the audit. The most recent DOECAP audit report (DOECAP 2012) showed no major findings, and the corrective action plan was acceptable. ALS Laboratory Group has the instrumentation, procedures, and laboratory systems in place to produce data of documented quality for environmental and waste samples.

The ICP Waste Management Surveillance Program met its completeness and precision goals. The ICP Waste Management Surveillance Program submitted duplicate and blank samples to ALS Laboratory Group with routine samples for analyses per PLN-720. For 2012, the results for the analyzed samples, with the exception of the samples discussed in the previous paragraph, were within the acceptable range.

11.5.7 U.S. Geological Survey Water Sampling Quality Control/Quality Assurance

Water samples are collected in accordance with a QA plan for quality-of-water activities by personnel assigned to the USGS INL project office; the plan was revised in 2008 (Knobel et al. 2008). Additional QA is assessed with QA/QC duplicates, blind replicates, replicates, source

solution blanks, equipment blanks, field blanks, splits, trip blanks, and spikes (Knobel et al. 2008). Evaluations of QA/QC data collected by USGS can be found in Wegner (1989), Williams (1996), Williams (1997), Williams et al. (1998); Bartholomay and Twining (2010), and Rattray (2012). During 2012, the USGS collected 17 blind replicate samples, four equipment blank samples, five field blank samples, three source solution blank samples, two spike samples, and one trip blank sample. Evaluation of results will be summarized in a future USGS report.

11.5.8 In Situ Gamma Spectroscopy Quality Control

High purity Germanium detectors used for in situ gamma spectroscopy measurements are calibrated yearly using NIST traceable radioactive sources in a laboratory setting. These calibrations are performed using a fixed geometry, long count time procedure. Collected calibration spectra are stored and then analyzed using a standard peak search peak fit algorithm. Energy calibration is performed to establish a linear relationship between peak positions and spectrum channels. The same calibration spectrum is then used to establish a relationship between the peak widths and peak energies. Finally, the detector efficiency is established, and a mathematical fit of efficiency versus gamma ray energy is established. The peak energy, peak width, and efficiency parameters for each detector are stored and used for all subsequent daily QC checks.

Prior to daily field use, each detector undergoes a QC check. This is performed using the same NIST traceable source as above. The overall activity of the measured source is compared to the certified (NIST) value.

During field measurements, the position of the naturally occurring potassium-40 gamma ray peak is checked to make certain that energy drift has not occurred during field spectrum acquisition. In addition, approximately 10 percent of field measurements are repeated with a different detector so that the two measurements can be compared. Finally, very long time acquisitions are performed at selected field locations in order to assure stability in the measurements. Results from these measurements are also compared to regular count time results at those locations. Software analysis of field spectra is addressed in several publications, including HASL-300 (www.orau.org/ptp/PTP%20library/library/DOE/EML/hasl300/HASL300/TOC.htm) and ICRU Report No. 53 (ICRU 1994).

11.6 Performance Evaluation Programs

11.6.1 Mixed Analyte Performance Evaluation Program

The MAPEP is administered by DOE's Radiological and Environmental Sciences Laboratory. DOE has mandated since 1994 that all laboratories performing analyses in support of the Office of Environmental Management shall participate in MAPEP. MAPEP distributes samples of air filter, water, vegetation, and soil for analysis during the first and third quarters. Series 26 was distributed in March 2012, and Series 27 was distributed in August 2012.

Both radiological and nonradiological constituents are included in MAPEP. Results can be found at http://www.id.energy.gov/resl/mapep/mapepreports.html (DOE 2012).

Laboratories that participate in MAPEP sometimes have results with a flag. MAPEP laboratory results may include the following flags:

- A = Result acceptable, bias ≤20 percent
- W = Result acceptable with warning, 20 percent < bias <30 percent
- N = Result not acceptable, bias >30 percent
- L = Uncertainty potentially too low (for information purposes only)
- H = Uncertainty potentially too high (for information purposes only)
- QL = Quantitation limit
- RW = Report warning
- NR = Not reported.

MAPEP issues a letter of concern to a participating laboratory for sequential unresolved failures. This is to help participants identify, investigate, and resolve potential quality issues (http://www.id.energy.gov/resl/mapep/handbookv13.pdf). A letter of concern is issued to any participating laboratory that demonstrates:

- "Not Acceptable" performance for a targeted analyte in a given sample matrix for the two most recent test sessions (e.g., plutonium-238 [^{238}Pu] in soil test 13 "+N" [+36% bias], ^{238}Pu in soil test 14 "-N" [-43% bias]);
- "Not Acceptable" performance for a targeted analyte in two or more sample matrices for the current test session (e.g., cesium-137 [^{137}Cs] in water test 14 "+N" [+38%], ^{137}Cs in soil test 14 "+N" [+45%]);
- Consistent bias, either positive or negative, at the "Warning" level (greater than +/-20% bias) for a targeted analyte in a given sample matrix for the two most recent test sessions (e.g., ^{90}Sr in air filter test 13 "+W" [+26%], ^{90}Sr in air filter test 14 "+W" [+28%]);
- Quality issues (flags other than "Acceptable") that weren't identified by the above criteria for a targeted analyte in a given sample matrix over the last three test sessions (e.g., americum-241 [^{241}Am] in soil test 12 "-N" [-47%], ^{241}Am in soil test 13 "+W" [+24%], ^{241}Am in soil test 14 "-N" [-38%]);
- Any other performance indicator and/or historical trending that demonstrate an obvious quality concern (e.g., consistent "false positive" results for ^{238}Pu in all tested matrices over the last three test sessions).

A more detailed explanation on MAPEP's quality concerns criteria can be found at http://www.inl.gov/resl/mapep/mapep_loc_final_2_.pdf.

11.6.2 National Institute of Standards and Technology

The DOE RESL participates in a Radiological Traceability Program administered through NIST. The Radiological and Environmental Sciences Laboratory prepares requested samples for analysis by NIST to confirm their ability to adequately prepare sample material to be classified as NIST traceable. NIST also prepares several alpha-, beta-, and gamma-emitting standards in all matrix types for analysis by the Radiological and Environmental Sciences Laboratory to confirm their analytical capabilities. The Radiological and Environmental Sciences Laboratory maintained

NIST certifications in both preparation and analysis in 2012. For further information on the RESL RTP go to: http://www.id.energy.gov/resl/rtp/rtp.html

11.6.3 Dosimetry

The INL contractor Operational Dosimetry Unit QA-tests environmental thermoluminescent dosimeters (TLD) during monthly, quarterly, and semi-annual processing periods. The QA test dosimeters are prepared by a program administrator. The delivered irradiation levels are blind to the processing technician. The results for each of the QA tests have remained within the 30-percent acceptance criteria (Relative Bias) during each testing period.

Landauer InLight dosimeters are designed to meet ANSI N545 Standard and HPS Draft Standard N13.29. The Neutrak CR-39 is Department of Energy Laboratory Accreditation Program accredited.

11.6.4 Other Programs

INL Site contractors participate in additional performance evaluation programs, including those administered by the International Atomic Energy Agency, EPA, and the American Society for Testing and Materials. Contractors are required by law to use laboratories certified by the state of Idaho or certified by another state whose certification is recognized by the state of Idaho for drinking water analyses. The Idaho Department of Environmental Quality oversees the certification program and maintains a list of approved laboratories. Where possible (i.e., the laboratory can perform the requested analysis), the contractors use state-approved laboratories for all environmental monitoring analyses.

11.7 Independent Assessment of INL Site Environmental Monitoring Programs

In 2010, the DOE Headquarters Office of Independent Oversight within the Office of Health, Safety, and Security reviewed QA in conjunction with an independent assessment of the INL Site environmental monitoring programs (see Section 3.1.2). The full Assessment Report entitled “Independent Oversight Assessment of Environmental Monitoring at the Idaho National Laboratory,” is available at http://www.hss.doe.gov/indepoversight/reports/eshevals.html. The report stated that “Quality Assurance laboratory analyses and data reporting is adequate but could be improved further with enhanced laboratory oversight and accountability.” The independent assessment found that all laboratories used by INL Site contractors participate in the MAPEP proficiency testing (PT) program. Their conclusions are documented in the following statements:

> *However, because PT is only conducted semiannually for certain analytes within particulate matrices (i.e., soil, water, vegetation, and air filters), it cannot be completely relied upon to ensure the validity and reliability of environmental data… While some contractors are using double blind samples to provide for continuing quality assurance of laboratory data, the approach is inconsistent and is not implemented by all contractors.*

To correct this, the independent assessment team recommended that minimum standards be established in the technical basis document development that include double blind sampling by all contractors to complement the MAPEP process in the overall QA program for environmental

monitoring. This will be addressed in the technical basis development that is being conducted by the INL, ICP, and ESER contractors (see Section 3.1.2).

11.8 Duplicate Sampling between Organizations

The ESER contractor, the INL contractor, and the state of Idaho's Department of Environmental Quality (DEQ) INL Oversight Program (OP) collected air monitoring data throughout 2012 at four common sampling locations: the distant locations of Craters of the Moon National Monument and Idaho Falls, and on the INL Site at the Experimental Field Station and Van Buren Boulevard Gate. While some differences exist in precise values due to variances in sampling methods, collection dates, and analytical methods, data from these sampling locations show similar patterns over the year. The INL OP Annual Report for 2011 is available at: http://www.deq.idaho.gov/media/935500-inl_oversight_program_annual_report_2011.pdf.

DEQ-INL OP also uses a network of passive electret ionization chambers (EICs) on and around the INL to cumulatively measure radiation exposure. These measurements are then used to calculate an average exposure rate for the quarterly monitoring period. Radiation monitoring results obtained by DEQ-INL OP are compared with radiation monitoring results reported by the DOE and its INL contractors for these same locations to determine whether the data are comparable. DEQ-INL OP has placed several EICs at locations monitored by DOE contractors, using thermoluminescent dosimetry (TLD). Ambient penetrating radiation measurements during 2011 showed 100 percent of Battelle Energy Alliance's and 100 percent of ESER Gonzales-Stoller Surveillance, LLC's TLD measurements satisfied the "3 sigma" test when compared with co-located DEQ-INL OP EIC measurements

The DEQ-INL OP also collects surface water and drinking water samples at select downgradient locations in conjunction with the ESER Contractor. Samples are collected at the same place and time, using similar methods. Sample-by-sample comparisons showed that results were generally in very good agreement, with all compared analyses achieving the goal of 80 percent of results meeting comparison criteria.

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Appendix A. Environmental Statutes and Regulations

The following environmental statutes and regulations apply, in whole or in part, to the Idaho National Laboratory (INL) or at the INL Site boundary:

- 36 CFR 79, 2012, “Curation of Federally-Owned and Administered Archeological Collections,” U.S. Department of the Interior, National Park Service, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 50, 2012, “National Primary and Secondary Ambient Air Quality Standards,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 61, 2012, “National Emission Standards for Hazardous Air Pollutants,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 112, 2012, “Oil Pollution Prevention,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 122, 2012, “EPA Administered Permit Programs: the National Pollutant Discharge Elimination System,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 141, 2012, “National Primary Drinking Water Regulations,” U.S. Environmental Protection Agency, Code of Federal Regulations, Office of the Federal Register
- 40 CFR 260, 2012, “Hazardous Waste Management System: General,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 261, 2012, “Identification and Listing of Hazardous Waste,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 262, 2012, “Standards Applicable to Generators of Hazardous Waste,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 263, 2012, “Standards Applicable to Transporters of Hazardous Waste,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 264, 2012, “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 265, 2012, “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register
- 40 CFR 267, 2012, “Standards for Owners and Operators of Hazardous Waste Facilities Operating under a Standardized Permit,” U.S. Environmental Protection Agency, *Code of Federal Regulations*, Office of the Federal Register

- 43 CFR 7, 2012, “Protection of Archeological Resources,” U.S. Department of the Interior, National Park Service, *Code of Federal Regulations*, Office of the Federal Register
- 50 CFR 17, 2012, “Endangered and Threatened Wildlife and Plants,” U.S. Department of the Interior, Fish and Wildlife Service, *Code of Federal Regulations*, Office of the Federal Register
- 50 CFR 226, 2012, “Designated Critical Habitat,” U.S. Department of Commerce, National Marine Fisheries Service, *Code of Federal Regulations*, Office of the Federal Register
- 50 CFR 402, 2012, “Interagency Cooperation – Endangered Species Act of 1973, as Amended,” U.S. Department of the Interior, Fish and Wildlife Service, *Code of Federal Regulations*, Office of the Federal Register
- 50 CFR 424, 2012, “Listing Endangered and Threatened Species and Designating Critical Habitat,” U.S. Department of the Interior, Fish and Wildlife Service, *Code of Federal Regulations*, Office of the Federal Register
- 50 CFR 450–453, 2012, “Endangered Species Exemption Process,” U.S. Department of the Interior, Fish and Wildlife Service, *Code of Federal Regulations*, Office of the Federal Register
- DOE Order 231.1B, 2011, “Environment, Safety, and Health Reporting,” Change 1, U.S. Department of Energy
- DOE Order 435.1, 2001, “Radioactive Waste Management,” Change 1, U.S. Department of Energy
- DOE Order 436.1, 2011, “Departmental Sustainability,” U.S. Department of Energy
- DOE Order 458.1, 2011, “Radiation Protection of the Public and the Environment,” U.S. Department of Energy
- DOE Standard 1196-2011, 2011, “Derived Concentration Technical standard,” U.S. Department of Energy
- Executive Order 11514, 1970, “Protection and Enhancement of Environmental Quality”
- Executive Order 11988, 1977, “Floodplain Management”
- Executive Order 11990, 1977, “Protection of Wetlands”
- Executive Order 12580, 1987, “Superfund Implementation”
- Executive Order 12856, 1993, “Federal Compliance With Right-to-Know Laws and Pollution Prevention Requirements”
- Executive Order 12873, 1993, “Federal Acquisition, Recycling, and Waste Prevention”
- Executive Order 13101, 1998, “Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition”
- Executive Order 13514, 2009, “Federal Leadership in Environmental, Energy, and Economic Performance”

- IDAPA 58.01.01, 2012, “Rules for the Control of Air Pollution in Idaho,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.02, 2012, “Water Quality Standards,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.03, 2012, “Individual/Subsurface Sewage Disposal Rules,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.05, 2012, “Rules and Standards for Hazardous Waste,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.06, 2012, “Solid Waste Management Rules,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.08, 2012, “Idaho Rules for Public Drinking Water Systems,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.11, 2012, “Ground Water Quality Rule,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.15, 2012, “Rules Governing the Cleaning of Septic Tanks,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality
- IDAPA 58.01.17, 2012, “Recycled Waste Rules,” Idaho Administrative Procedures Act, Idaho Department of Environmental Quality

U.S. Department of Energy (DOE) Order 458.1 provides the principal requirements for protection of the public and environment at the INL Site. The DOE public dose limit is shown in Table A-1, along with the Environmental Protection Agency statute for protection of the public, for the airborne pathway only.

Derived Concentration Standards are established to support DOE Order 458.1 in DOE Standard 1196-2011 (DOESTD-1196-2011), “Derived Concentration Technical Standard.” These quantities represent the concentration of a given radionuclide in either water or air that results in a member of the public receiving 100 mrem (1mSv) effective dose following continuous exposure for one year for each of the following pathways: ingestion of water, submersion in air, and inhalation. The Derived Concentration Standards used the environmental surveillance programs at the INL Site are shown in Table A-2. The most restrictive Derived Concentration Standard is listed when the soluble and insoluble chemical forms differ. The Derived Concentration Standards consider only inhalation of air, ingestion of water, and submersion in air.

Ambient air quality standards are shown in Table A-3.

Water quality standards are dependent on the type of drinking water system sampled. Tables A-4 through A-7 list maximum contaminant levels set by the Environmental Protection

Table A-1. Radiation Standards for Protection of the Public in the Vicinity of DOE Facilities.

Radiation Standard	Effective Dose Equivalent (mrem/yr)	Effective Dose Equivalent (mSv/yr)
DOE standard for routine DOE activities (all pathways)	100[a]	1
EPA standard for site operations (airborne pathway only)	10	0.1

a. The effective dose equivalent for any member of the public from all routine DOE operations, including remedial activities, and release of naturally occurring radionuclides shall not exceed this value. Routine operations refer to normal, planned operations and do not include accidental or unplanned releases.

Agency for public drinking water systems in 40 Code of Federal Regulations 141 (2012) and the Idaho groundwater quality values from IDAPA 58.01.11 (2012).

Table A-2. Derived Concentration Standards for Radiation Protection.

Derived Concentration Standard[a]					
Radionuclide	In Air (µCi/ml)	In Water (µCi/ml)	Radionuclide	In Air (µCi/ml)	In Water (µCi/ml)
Gross Alpha[b]	4×10^{-14}	1.7×10^{-7}	Antimony-125	3.1×10^{-10}	2.7×10^{-5}
Gross Beta[c]	2.4×10^{-13}	2.5×10^{-8}	Iodine-129[f]	3.8×10^{-10}	3.3×10^{-7}
Tritium (tritiated water)	2.1×10^{-7}	1.9×10^{-3}	Iodine-131[f]	2.3×10^{-9}	1.3×10^{-6}
Carbon-14	6.6×10^{-10}	6.2×10^{-5}	Iodine-132[f]	3.0×10^{-8}	9.8×10^{-5}
Sodium-24	4.1×10^{-9}	7.0×10^{-9}	Iodine-133[f]	7.2×10^{-9}	6.0×10^{-6}
Argon-41[d]	1.4×10^{-8}	__	Iodine-135[f]	1.6×10^{-8}	3.0×10^{-5}
Chromium-51	9.4×10^{-8}	7.9×10^{-4}	Xenon-131m[d]	2.4×10^{-6}	__
Manganese-54	1.1×10^{-9}	4.4×10^{-5}	Xenon-133[d]	6.3×10^{-7}	__
Cobalt-58	1.7×10^{-9}	3.9×10^{-5}	Xenon-133m[d]	6.6×10^{-7}	__
Cobalt-60	1.2×10^{-10}	7.2×10^{-6}	Xenon-135[d]	7.8×10^{-8}	__
Zinc-65	1.6×10^{-9}	8.3×10^{-6}	Xenon-135m[d]	4.5×10^{-8}	__
Krypton-85[d]	3.6×10^{-6}	__	Xenon-138[d]	1.6×10^{-8}	__
Krypton-85m[d,e]	1.3×10^{-7}	__	Cesium-134	1.8×10^{-10}	2.1×10^{-6}
Krypton-87[d]	2.2×10^{-8}	__	Cesium-137	3.9×10^{-10}	3.0×10^{-6}
Krypton-88[d]	8.8×10^{-9}	__	Cesium-138	7.5×10^{-8}	3.1×10^{-4}
Rubidium-88[d]	2.5×10^{-8}	8×10^{-4}	Barium-139	5.8×10^{-8}	2.4×10^{-4}
Rubidium-89[d]	7.9×10^{-9}	2×10^{-3}	Barium-140	6.2×10^{-10}	1.1×10^{-5}
Strontium-89	4.6×10^{-10}	1.1×10^{-5}	Cerium-141	9.9×10^{-10}	4×10^{-5}
Strontium-90	2.5×10^{-11}	1.1×10^{-6}	Cerium-144	7.1×10^{-11}	5.5×10^{-6}
Yttrium-91m	3.1×10^{-7}	2.7×10^{-3}	Plutonium-238	3.7×10^{-14}	1.5×10^{-7}
Zirconium-95	6.3×10^{-10}	3.1×10^{-5}	Plutonium-239	3.4×10^{-14}	1.4×10^{-7}
Technetium-99m	1.7×10^{-7}	1.4×10^{-3}	Plutonium-240	3.4×10^{-14}	1.4×10^{-7}
Ruthenium-103	1.3×10^{-9}	4.2×10^{-5}	Plutonium-241	1.8×10^{-12}	7.6×10^{-6}
Ruthenium-106	5.6×10^{-11}	4.1×10^{-6}	Americium-241	4.1×10^{-14}	1.7×10^{-7}

a. Derived concentration standards are from DOE-STD-1196-2011 (*Derived Concentration Technical Standard)* and support the implementation of DOE Order 458.1. They are based on a committed effective dose equivalent of 100 mrem/yr (1 mSv) for ingestion or inhalation of a radionuclide during one year. Inhalation values shown represent the most restrictive lung retention class.

b. Based on the most restrictive alpha emitter (^{241}Am).

c. Based on the most restrictive beta emitter (^{228}Ra).

d. The DCS for air immersion is used because there is no inhaled air DCS established for the radionuclide.

e. An "m" after the number refers to a metastable form of the radionuclide.

f. Particulate aerosol form in air.

Table A-3. Environmental Protection Agency Ambient Air Quality Standards.

Pollutant	Type of Standard[a]	Sampling Period	EPA[b] (mg/m^3)
Sulfur dioxide	Secondary	3-hour average	1,300
	Primary	24-hour average	365
	Primary	Annual average	80
Nitrogen dioxide	Primary and secondary	Annual average	100
	Secondary	24-hour average	150
Total particulates[c]	Primary and secondary	Annual average	50

a. National primary ambient air quality standards define levels of air quality to protect the public health. Secondary ambient air quality standards define levels of air quality to protect the public welfare from any known or anticipated adverse effects of a pollutant.

b. The state of Idaho has adopted these ambient air quality standards.

c. The primary and secondary standard to the annual average applies only to "particulates with aerodynamic diameter less than or equal to a nominal 10 micrometers."

Table A-4. Environmental Protection Agency Maximum Contaminant Levels for Public Drinking Water Systems and State of Idaho Groundwater Quality Standards for Radionuclides and Inorganic Contaminants.

Constituent	Maximum Contaminant Levels	Groundwater Quality Standards
Gross alpha (pCi/L)	15	15
Gross beta (mrem/yr)	4	4
Beta/gamma emitters	Concentrations resulting in 4 mrem total body or organ dose equivalent	4 mrem/yr effective dose equivalent
Radium-226 plus -228 (pCi/L)	5	5
Strontium-90 (pCi/L)	8	8
Tritium (pCi/L)	20,000	20,000
Uranium (µg/L)	30	30
Arsenic (mg/L)	0.01	0.05
Antimony (mg/L)	0.006	0.006
Asbestos (fibers/L)	7 million	7 million
Barium (mg/L)	2	2
Beryllium (mg/L)	0.004	0.004
Cadmium (mg/L)	0.005	0.005
Chromium (mg/L)	0.1	0.1
Copper[b] (mg/L)	1.3	1.3
Cyanide (mg/L)	0.2	0.2
Fluoride (mg/L)	4	4
Lead (mg/L)	0.015	0.015
Mercury (mg/L)	0.002	0.002
Nitrate (as N) (mg/L)	10	10
Nitrite (as N) (mg/L)	1	1
Nitrate and Nitrite (both as N) (mg/L)	--[b]	10
Selenium (mg/L)	0.05	0.05
Thallium (mg/L)	0.002	0.002

a. Treatment technique action level, the concentration of a contaminant which, if exceeded, triggers treatment or other requirements that a water system must follow.
b. No maximum contaminant level for this constituent.

Table A-5. Environmental Protection Agency Maximum Contaminant Levels for Public Drinking Water Systems and State of Idaho Groundwater Quality Standards for Organic Contaminants.

Constituent	Maximum Contaminant Levels (mg/L)	Groundwater Quality Standards (mg/L)
Benzene	0.005	0.005
Carbon tetrachloride	0.005	0.005
m-Dichlorobenzene	—	0.6
o-Dichlorobenzene	0.6	0.6
p-Dichlorobenzene	0.075	0.075
1,2-Dichloroethane	0.005	0.005
1,1-Dichloroethylene	0.007	0.007
cis-1,2-Dichloroethylene	0.07	0.07
trans-1,2-Dichloroethylene	0.1	0.1
Dichloromethane	0.005	0.005
1,2-Dichloropropane	0.005	0.005
Ethylbenzene	0.7	0.7
Monochlorobenzene	0.1	0.1
Styrene	0.1	0.1
Tetrachloroethylene	0.005	0.005
Toluene	1.0	1.0
1,2,4-Trichlorobenzene	0.07	0.07
1,1,1-Trichloroethane	0.2	0.2
1,1,2-Trichloroethane	0.005	0.005
Trichloroethylene	0.005	0.005
Vinyl chloride	0.002	0.002
Xylenes (total)	10.0	10.0
Bromate	0.01	—
Bromodichloromethane	—	0.1
Bromoform	—	0.1
Chlorodibromomethane	—	0.1
Chloroform	—	0.002
Chlorite	1.0	—
Haloacetic acids (HAA5)	0.06	—
Total Trihalomethanes (TTHMs)	0.08	0.1

Table A-6. Environmental Protection Agency Maximum Contaminant Levels for Public Drinking Water Systems and State of Idaho Groundwater Quality Standards for Synthetic Organic Contaminants.

Constituent	Maximum Contaminant Levels (mg/L)	Groundwater Quality Standards (mg/L)
Alachlor	0.002	0.002
Atrazine	0.003	0.003
Carbofuran	0.04	0.04
Chlordane	0.002	0.002
Dibromochloropropane	0.0002	0.0002
2,4-D	0.07	0.07
Ethylene dibromide	0.00005	0.00005
Heptachlor	0.0004	0.0004
Heptachlor epoxide	0.0002	0.0002
Lindane	0.0002	0.0002
Methoxychlor	0.04	0.04
Polychlorinated biphenyls	0.0005	0.0005
Pentachlorophenol	0.001	0.001
Toxaphene	0.003	0.003
2,4,5-TP (silvex)	0.05	0.05
Benzo(a)pyrene	0.0002	0.0002
Dalapon	0.2	0.2
Di(2-ethylhexyl) adipate	0.4	0.4
Di(2-ethylhexyl) phthalate	0.006	0.006
Dinoseb	0.007	0.007
Diquat	0.02	0.02
Endothall	0.1	0.1
Endrin	0.002	0.002
Glyphosate	0.7	0.7
Hexachlorobenzene	0.001	0.001
Hexachlorocyclopentadiene	0.05	0.05
Oxamyl (vydate)	0.2	0.2
Picloram	0.5	0.5
Simazine	0.004	0.004
2,3,7,8-TCDD (dioxin)	3×10^{-8}	3×10^{-8}

Table A-7. Environmental Protection Agency National Secondary Drinking Water Regulations and State of Idaho Groundwater Quality Standards for Secondary Contaminants.

Constituent	Secondary Standards[a]	Groundwater Quality Standards
Aluminum (mg/L)	0.05 to 0.2	0.2
Chloride (mg/L)	250	250
Color (color units)	15	15
Foaming agents (mg/L)	0.5	0.5
Iron (mg/L)	0.3	0.3
Manganese (mg/L)	0.05	0.05
Odor (threshold odor number)	3 threshold odor number	3
pH	6.5 to 8.5	6.5 to 8.5
Silver (mg/L)	0.1	0.1
Sulfate (mg/L)	250	250
Total dissolved solids (mg/L)	500	500
Zinc (mg/L)	5	5

a. The Environmental Protection Agency (EPA) has not established National Primary Drinking Water Regulations that set mandatory water quality standards (maximum contaminant levels) for these constituents because these contaminants are not considered a risk to human health. EPA has established National Secondary Drinking Water Regulations that set secondary maximal contaminant levels as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor.

REFERENCES

40 CFR 141, 2012, "National Primary Drinking Water Regulations," U.S. Environmental Protection Agency, Code of Federal Regulations, Office of the Federal Register.

DOE Order 458.1, 2011, "Radiation Protection of the Public and the Environment," U.S. Department of Energy.

DOE, 1988a, Internal Dose Conversion Factors for Calculation of Dose to the Public, DOE/EH-0071, U.S. Department of Energy.

DOE, 1988b, External Dose-Rate Conversion Factors for Calculation of Dose to the Public, DOE/EH-0070, U.S. Department of Energy.

IDAPA 58.01.11, 2012, "Ground Water Quality Rule," Idaho Administrative Procedures Act, Idaho Department of Environmental Quality.

Appendix B. Optically Stimulated Luminescence Dosimeter Studies

Thermoluminescent dosimeters (TLDs) have been used historically by the Idaho National Laboratory (INL) and Environmental Surveillance, Education, and Research (ESER) environmental surveillance programs to measure ionizing radiation exposures at onsite and offsite locations near the INL Site. The TLDs measure ionizing radiation exposures from all sources, including natural radioactivity, cosmic radiation, fallout from nuclear weapons testing, radioactivity from fossil fuel burning, and airborne radioactive effluents from INL Site operations and other industrial processes. Direct penetrating gamma radiation cannot be collected by filters or chemically trapped in any media, but is directly measured using TLDs. The principle of TLD technology is that when certain crystals are exposed to penetrating gamma radiation, impurities are excited to high energy states and remain in these states at normal ambient temperature. When the TLDs are heated, electrons are released and the crystal returns to the lower state of energy. The released electrons are in the form of photon energy, which is measured with a photomultiplier tube; the light intensity is proportional to the absorbed dose of radiation.

A new technology, the optically stimulated luminescence dosimeter (OSLD), has been developed to measure 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, in which these electrons are released by the exposure to heat, the trapped electrons in the OSLD are released by exposure to green light from a laser. The advantages to this new technology are:

- Faster processing time
- Not dependent on normal variation of temperature and humidity
- Empties only a small fraction of trapped electrons, so it can be reread.
- High degree of environmental stability
- High level of sensitivity
- Wide range of dose measuring capabilities.

The primary advantage of the OSLD technology compared to the traditional TLD is that the nondestructive reading of the OSLD allows for dose verification (i.e. the dosimeter can be read multiple times without destruction of the accumulated signal inside the aluminum oxide chips).

OSLD technology was tested in the laboratory and field for environmental radiation surveillance application by Idaho State University (ISU), in conjunction with the ESER program. The environmental performance of the OSLDs were tested and verified in the laboratory at ISU using American National Standard (ANSI), Landauer OSLD technical specifications, and International Electrotechnical Commission (IEC) performance standards. In the field, OSLDs and TLDs were co-deployed by ESER personnel at locations on the INL Site, the INL Site perimeter and at more distant locations for at least one year. The data from the OSLDs and TLDs were then compared statistically. The results of the laboratory and field tests are presented in Sections B.1 and B.2.

B.1 Laboratory Verification of Environmental Performance of OSLDs

B.1.1 Introduction

InLight® OSLDs manufactured by Landauer Inc. were selected for environmental dosimetry applications due to their proprietary OSLD technology. The key performance characteristics of the InLight® OSLD in personal and environmental dosimetry applications includes: the ability for rapid readout; environmental stability; and enhanced sensitivity. There have been, however, merely a handful of validations of the dosimeter for environmental applications. Thus, the objective of the laboratory study was to confirm the environmental performance of the InLight® OSLD based upon ANSI N13.29 1995 draft test criteria (ANSI 1995), Landauer technical specifications, and IEC 62387-1 performance standards (IEC 2007).

The research was conducted by Jinho Jung for a Master of Science degree with the Department of Nuclear Engineering and Health Physics at ISU (Jung 2012). Dr. Richard Brey, chair of the ISU Department of Nuclear Engineering and Health Physics, was his advisor for this study. Dr. Craig Yoder, Sr. Vice President of Global Technology for Landauer, was a committee member. Dr. Yoder led the development of the InLight® family of products for Landauer.

B.1.2 Laboratory Methodology

The InLight® OSLD are designed for environmental monitoring of beta, gamma, and x-ray radiation. Each dosimeter consists of a waterproof plastic envelope, and a case containing both copper and plastic filters enclosing four aluminum oxide (Al_2O_3:C) detector elements (Figure B-1). The detectors are embedded in a slide which is inserted into the case before placement into the plastic envelope.

Figure B-1. Environmental Dosimeter Assembly.

The dosimeters were exposed in the laboratory to specific reference radiation levels, defined by test requirements. The dosimeters were then read with a MicroStar® reader consisting of a light emitting diode (LED) Stimulation array, photo-counting system, and associated fixtures. The read out process uses an LED array to stimulate the detectors, and the light emitted by the optically stimulated luminescence (OSL) material is detected and measured by a photomultiplier tube using a high sensitivity photon counting system. The amount of light released during optical stimulation is directly proportional to the radiation dose and the intensity of stimulation light. A dose calculation algorithm was then applied to the measurement to determine exposure results.

Verification of the OSLD in Accordance with ANSI N 13.29 Category I, II, and III tests – American National Standards Institute Draft N13.29 describes performance tests for environmental radiation dosimetry providers. The tests involve exposing dosimeters to laboratory photon, beta, and X-ray sources at routine and accident dose levels (Table B-1).

National Institute of Standards and Technology (NIST) traceable ISU cesium-137 irradiators with the current source strength of 11 Ci (4.07×10^{11} Bq) and 1 Ci (3.7×10^{10} Bq) were used as

Table B-1. Categories of Performance Tests in ANSI N13.29

Category	Sub category	Quantity	Dose selecting range
I	Photon accident	D(10)[a]	0.01~0.5Gy
	Beta accident	D(0.07)[b]	0.01~0.5Gy
II	Photon routine	H*(10)[c]	0.2~10mSv
	Beta routine	H'(0.07)[d]	0.2~10mSv
III	H40 (effective energy <38 keV)	H*(10)	0.2~10mSv
	NS100 (effective energy 80 keV)	H*(10)	0.2~10mSv

a. D(10) = deep absorbed dose (at 10 mm) in tissue. Absorbed dose is defined as the statistical average of the energy imparted per unit mass at a point. The unit of absorbed dose is the gray (Gy) and1 Gy is equal to 100 rad.

b. D (0.07) = shallow absorbed dose (at 0.07 mm) in tissue. Absorbed dose is defined as the statistical average of the energy imparted per unit mass at a point. The unit of absorbed dose is the gray (Gy) and 1 Gy is equal to 100 rad.

c. H*(10) = ambient dose equivalent. H*(10) is an operational quantity for area monitoring and is designed for monitoring strongly penetrating radiation (i.e., photons above about 12 keV) and neutrons. The ambient dose equivalent is the dose equivalent at a point in a radiation field that would be produced by the corresponding expanded and aligned field in a 30-cm diameter sphere of unit density tissue (ICRU sphere) at a depth of 10 mm on the radius vector opposing the direction of the aligned field. The unit of ambient dose equivalent is the milliSievert (mSv) and 1 mSv is equal to 100 mrem.
H'(0.07) = directional dose equivalent. H'(0.07) is an operational quantity for determination of equivalent dose to skin, lens of the eye, etc., and is also for beta radiation and low-energy photons. The directional dose equivalent at the point of interest in the actual radiation field is the dose equivalent which would be generated in the associated radiation field at a depth of *d* mm on the ICRU-sphere which is oriented in a fixed direction. If the dose equivalent in skin is to be determined, the depth of 0.07 mm is used. The unit of directional dose equivalent is the milliSievert (mSv) and 1 mSv is equal to 100 mrem.

sources for the photon sub category tests of Categories I and II. The beta irradiation of OSLDs for the Categories I and II beta accident and beta routine sub categories was performed in Glenwood, Illinois, by Landauer using a NIST traceable stontium-90/yttrium-90 source. The beam codes H40 and NS100 from Landauer were utilized for the low energy X-ray response analyses for Category III of the laboratory testing.

For each sub category, five randomly selected dosimeters were exposed to a specific experimental radiation field. Then the irradiated dosimeters were read. The standard deviation (S) and bias (B) for each performance quotient (P_i) in each sub category were computed. In order to pass the conditions of draft ANSI N13.29, the following performance criteria must be met:

$$|B| \leq 0.35,\ S \leq 0.35,\ |B| + S \leq 0.50 \quad \text{(Eqn. 1)}$$

where

$$B\ (bias) \equiv \overline{P} = \sum_{i=1}^{n=5} \frac{P_i}{n}$$

$$S\ (standard\ deviation) \equiv \sqrt{\frac{\sum_{i=1}^{n} (P_i - B)^2}{(n-1)}}$$

$$P\ (performance\ quotient) \equiv \frac{H_i' - H_i}{H_i} \quad (\text{of the } i^{th} \text{ of } n = 5 \text{ dosimeters})$$

$$H_i = dose\ delivered$$

$$H_i' = dose\ measured.$$

The sample size of five was selected because it is used in ANSI (1995) and because a statistical analysis conducted as part this study determined that this size would have enough statistical power to meet the objective of the ANSI standard.

Evaluation of OSLD Technical Specifications – Three types of the Landauer technical specifications were tested: uncertainty, the linearity of the reported dose range, and the dose measuring capability in that range and the range of dosimeter responses relevant to energy. Two additional categories were also investigated: low dose resolution ability; and low dose rate for the accuracy and reproducibility of the InLight® OSL dosimeters.

Uncertainty. Uncertainty was defined in this study to be accuracy and reproducibility. The accuracy was computed as the average percent difference between delivered dose and measured dose in five arbitrarily chosen dosimeters. The reproducibility was considered as the standard deviation of measured dose equivalent of the five dosimeters. The treatment levels of 50, 75, and 100 mrem (0.5, 0.75, and 1 mSv) were designated with each level consisting of five dosimeters.

Linearity. The linear relationship between the measured dose and delivered dose was examined within the range of 5 to 50,000 mrem (0.05 to 500 mSv) using twelve treatment groups (Table B-2). Each treatment group consisted of five arbitrarily selected dosimeters. IEC 62387-1 (IEC 2007) specified the incremental dose levels for the twelve treatment group. The ideal linearity between the dose equivalent measured and the dose equivalent delivered is defined as the slope of the best line fit. In the linearity test, two methodologies, the Lack-of-Fit test (Dielman 2005) and the Non-linearity test (IEC 2007) were used.

Low Energy Response. The relative response of the InLight® OSLDs irradiated with a low energy X-ray was tested. Eighty dosimeters (16 categories × five dosimeters per category) were used in the experimental design shown in Table B-3.

Low Dose Resolution. Quarterly environmental radiation dose is generally small. A low dose resolution experiment was designated to scrutinize whether or not the InLight® OSLDs have the capability to detect small changes in the environmental radiation dose. The dose levels from 5 mrem (0.05 mSv) to 50 mrem (0.5 mSv) with 5 mrem (0.05 mSv) intervals were selected to observe the resolution ability of the InLight® OSLDs.

Dose Rate Independence. Ideally, the total dose measured by a dosimeter, which is an integrating system, should be independent of the rate at which at which the dose was delivered.

Table B-2 . Experimental Layout of the Linearity Tests.

Groups	Incremental dose levels in mrem[a]								
	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9
5 ~ 50,000 treatments	10	30	100	300	1,000	3,000	10,000	30,000	50,000
Replications	10	10	10	5	5	5	5	5	5

a. 1 mrem = 0.01 mSv

Table B-3. Low Energy Response Experimental Layout.

Beam code	H40	NS100	H200	H300
Effective energy (keV)	<38	80	166	252
Dose level (mrem)[a]	20, 50, 75, 100			
Replication	Five for each category			

a. 1 mrem = 0.01 mSv.

The dose rate independence of the InLight® OSLDs was examined by irradiating OSLDs at relatively low dose rates, 0.028 and 0.405 R/hr, in comparison with the irradiation rate of 0.800 R/hr, previously used in the uncertainty assessments. Two treatment levels of about 50 and 75 mrem were applied to each dose rate group, with each treatment group consisting of five dosimeters.

Verification of Environmental Performance in Accordance with IEC 62387-1 – Environmental performance requirements according to the international standard IEC 62387-1 (IEC 2007) with the InLight® OSLDs were explored. The environmental performance requirements for dosimeters include:

1. Measuring fading factors under several conditions
   a. Extreme temperature conditions
   b. After drops
   c. After light exposure
2. Dose build-up fading
3. Fading, self-irradiation
4. Response to natural radiation
5. Reader stability factors

Fading Factors. Dosimeters can lose signal in a process known as fading. Fading is the loss or change in the observed response to that anticipated if no fading occurred.

Ambient temperature dependence was tested by first subjecting three groups of dosimeters (n=6) to three temperature treatments: room temperature (15 – 25°C); -20°C; and 50°C. Dosimeters in each group were pretreated to an exposure equivalent to 300 mrem (3 mSv). The different temperature treatments were conducted for a seven-day duration.

A drop test was performed to observe if there was any loss of dose information in an OSLD after dropping it. The dosimeters were first irradiated with an average measured dose equivalent of 35 mrem (0.035 mSv). One group of six dosimeters was subjected to drops from a height of 1 m onto a flat surface of concrete – one drop on each of six faces of the dosimeter. A second group of six dosimeters served as a reference group (i.e., they were not dropped.)

The possibility of dosimeter fading after light exposure was investigated. Two groups, each group consisting of six dosimeters, were first irradiated to provide a measured dose equivalent of 300 mrem (3 mSv). One group was stored in normal daylight, the second in a shadow under daylight conditions for seven days.

Dose Build-up, Fading, Self-irradiation and Response to Natural Radiation. Authenticating fading factors over a variety of determinants are included in the IEC document, which specifies the environmental performance requirements for dosimeters (IEC 2007). Among the requirements are: dose build-up; fading; self-irradiation; and response to natural radiation. Table B-4 shows the treatments on each group of dosimeters tested. Groups 1, 2, and 3, consisting of twenty four dosimeters each, were irradiated at 0.35 mSv. Groups 1 and 3 address

Table B-4. Treatment on Dose Build up, Self-Irradiation, Response to Natural Radiation (IEC 2007)

Group	Treatment (time periods of readouts post irradiation)
G_1	1 hour after the irradiation
G_2 (reference group)	1 week after the irradiation
G_3	4 weeks after the irradiation
G_4 and G_5	Stored for 4 weeks in a bag

dose build-up, fading, and self-irradiation. Group 2, read after one week, was considered the reference group for Groups 1 and 3. Group 4, consisting of twenty five dosimeters, was irradiated at 0.05 mSv. Group 5, consisting of twenty five dosimeters, was not irradiated. Groups 4 and 5 were read and compared to test response to natural radiation.

Reader Stability. Reader stability was investigated using two methods, Method A and Method B. Method A utilized three different groups of dosimeters, each group consisting of six dosimeters, per IEC standard procedure (Table B-5). Method B involved reading the same dosimeters used to obtain Group 1 data two and four weeks after the initial reading thus taking advantage of the OSLDs' re-reading capability. Both Method A and Method B used the same interpretation described in IEC 62387-1 with the relative responses of Groups 1 and 3 compared to the reference Group 2.

Additional Tests. In addition to the five tests outlined in IEC 62387-1 (IEC 2007), two other tests, multiple readouts on the same dosimeters and time dependence, were conducted at ISU to help authenticate the fading factors of the OSLDs. The re-reading option of the OSLD is one of its outstanding features over TLDs. The multiple readout experiment involved initially irradiating three groups of dosimeters, each group consisted of five dosimeters, to three different dose levels (low, medium, and high). The initial readouts were 48, 114, and 150 mrem (0.48. 1.14, and 1.50 mSv), respectively. The next step was to read each dosimeter nineteen times consecutively.

The time dependence on dose fading of dosimeters involved four groups, each group consisting of three to six dosimeters with initial mean readouts ranging from 37 to 122 mrem

Table B-5. Treatments to Test Reader Stability Using Method A (IEC 2007).

Group	Treatments: the time of the readout
G_1	Irradiated dosimeter to produce a measured dose equivalent of 300 mrem at the beginning of the test and then one week later
G_2	Irradiated to the same dose as Group 1 after 2 weeks and then read one week later
G_3	Irradiated to the same dose as Group 1 after 4 weeks and then read one week later

(0.37 to 1.22 mSv). The dosimeters were read in two, four, and five week periods post initial readout.

B.1.3 Results

Verification of the OSLD in Accordance with ANSI N 13.29 Category I, II, and III tests – The following data were obtained during the ANSI N 13.29 high and low dose uncertainty examination and the low energy response of the InLight® OSLDs. The values B, S, and the tolerance level, |B|+S obtained from the category tests were compared to the boundary values of the performance criteria in each category. The InLight® OSLD met the requirements of Category I, II, and III tests. The results are summarized in Tables B-6 and B-7.

Table B-6. Results of ANSI N 13.29 Category I and II Tests.

Category	Subcategory	Dose delivered (mrem)[a]	Dose measured (mrem)	B[b]	S[c]	|B|+S	Performance
Category I	Photon Accident	40,000	40,882	0.014	0.03	0.044	Pass
		29,000	29,207				
		24,000	24,042				
		35,000	37,089				
		48,000	47,013				
	Beta Accident	15,000	14,287	0.002	0.036	0.038	Pass
		35,000	34,417				
		24,000	25,216				
		25,000	25,171				
		26,000	25,909				
Category II	Photon Routine	920	984	0.023	0.048	0.071	Pass
		400	395				
		79	193				
		63	61				
		155	157				
	Beta Routine	275	277	0.0019	0.017	0.019	Pass
		361	364				
		51	52				
		272	265				
		883	883				

1 mrem = 0.01 mSv.
B = bias (see Equation 1 on page B-4).
S = standard deviation (see Equation 1 on page B-4).

Table B-7. Results of ANSI N 13.29 Category III Tests.

Beam code (effective energy)	Dose delivered (mrem)[a]	Dose measured (mrem)	B[b]	S[c]	|B|+S	Performance
H40 (<38 keV)	806	757	-0.052	0.077	0.13	Pass
	65	56				
	925	992				
	602	558				
	360	338				
NS100 (80 keV)	162	165	-0.046	0.095	0.14	Pass
	109	116				
	542	465				
	358	305				
	286	279				

a. 1 mrem = 0.01 mSv.
b. B = bias.
c. S = standard deviation.

Evaluation of OSLD Technical Specifications – The results of tests to verify Landauer technical specifications are shown in Tables B-8 through B-12.

Uncertainty. Three treatment levels of 50, 75, and 100 mrem (0.5, 0.75, 1 mSv) were used to test the accuracy and the reproducibility of the InLight® dosimeters. The goal of this effort was to evaluate whether the dosimeters meet Landauer's technical specifications of ±15 percent accuracy and ±5 percent reproducibility. The results presented in Table B-8 demonstrate that the InLight® dosimeters performed well within these specifications.

Table B-8. Averaged Accuracy and Reproducibility Response on Multiple OSL dosimeters.

Delivered dose (mrem)[a]	50	75	100
Dose measured on individual dosimeters (mrem)	49	80	105
	52	83	105
	52	78	108
	54	77	108
	51	83	113
Averaged Accuracy	3.2%	6.9%	7.8%
Reproducibility	3.6%	3.7%	3.3%

a. 1 mrem = 0.01 mSv.

Table B-9. Measured Dose Data for Non-Linearity Test of IEC 62387-1.

Dose Delivered (mrem)[a]	Group	$\bar{G}_i$[b]	s_i[c]	Lower bound[d]	Upper bound[e]
10	G_1	11	1.33	0.92	1.16
30	G_2	31	2.38	0.89	1.07
100	G_3	105	4.02	0.91	1.07
300	G_4	317	19.94	0.89	1.11
1,000	G_5	1,066	24.66	0.93	1.09
3,000	G_6	3,169	133.15	0.91	1.09
10,000	G_7	10,402	363.77	0.90	1.07
30,000	G_8	29,875	875.81	0.86	1.02
50,000	G_9	51,164	1,286.59	0.89	1.05

a. 1 mrem = 0.01 mSv.

b. $\bar{G}_i$ = Mean measured dose equivalent (mrem) for i*th* irradiated group.

c. s_i = Standard deviation of the mean measured dose (mrem) for the i*th* irradiated group.

d. Lower bound = $\left(\frac{\bar{G}_i}{\bar{G}_{r,0}} - U_{com}\right) \cdot \frac{C_{r,0}}{C_i}$.

e. Upper bound = $\left(\frac{\bar{G}_i}{\bar{G}_{r,0}} + U_{com}\right) \cdot \frac{C_{r,0}}{C_i}$.

Table B-10. Determination of the Linearity Requirement of IEC 62387-1.

Group	$U_{C,com}$	0.91 - $U_{C,com}$	1.11 + $U_{C,com}$	Linearity requirement
G_1	0.07	0.84	1.18	Pass
G_2	0.07	0.84	1.18	Pass
G_3	0.07	0.88	1.12	Pass
G_4	0.07	0.88	1.12	Pass
G_5	0.07	0.88	1.12	Pass
G_6	0.07	0.84	1.18	Pass
G_7	0.07	0.84	1.18	Pass
G_8	0.07	0.84	1.18	Pass
G_9	0.07	0.84	1.18	Pass

Table B-11. Summary of Low Energy X-ray Response Data.

Energy levels	H40 (<38 keV)			NS100 (80 keV)			H200 (160 keV)			H300 (262 keV)		
Dose delivered (mrem)[a]	50	78	100	49	75	102	49	75	102	50	76	102
Accuracy (%)	-4.8	-9.5	-1.2	12.7	5.3	2.8	8.9	4.8	3.3	7.2	5.3	0.6
Reproducibility (%)	5.0	5.5	3.8	4.2	5.9	5.3	3.1	6	4.4	6.1	3.1	2.1

a. 1 mrem = 0.01 mSv.

Table B-12. Lack-of-fit Test Summary.

Energy levels	H 40	NS 100	H 200	H 300
p-value	0.015	0.907	0.129	0.124
Conclusion	Possible non-linearity y = 4.8 + 1.01x	No evidence of lack of fit	No evidence of lack of fit	No evidence of lack of fit

Linearity. The linearity test of the anticipated dose measuring range of the OSLD was performed with two evaluation techniques; the lack-of-fit test and the non-linearity test of IEC 62387-1. The lack-of-fit test is intended to assess the assumption that the relationship between two parameters is linear. The non-linearity test is a testing method recommended in Section 11.3 of IEC 62387-1 that examines each relative response of a group *i* with respect to the reference group with the consideration of the expanded uncertainty of the combined quantity to be within the IEC recommended upper and lower limits.

The statistical software, Minitab1 (http://www.minitab.com/en-US/default.aspx) was used for the lack-of-fit test, including the model adequacy check. The lack-of-fit test gave no evidence on non-linearity (p-value = 0.316). Figure B-2 visually demonstrates the linearity of the data and the overlap with the ideal linear fit.

The non-linearity test of IEC 62387-1 specifies that when the following inequality holds for the dose range data, then the linearity characteristic of the dosimeter is acceptable:

$$0.91 - U_{C.com} \leq \left(\frac{\bar{G}_i}{\bar{G}_{r,0}} \pm U_{com}\right) \cdot \frac{C_{r,0}}{C_i} \leq 1.11 + U_{C.com}, \quad \text{(Eqn. 2)}$$

where

U_{com} = Expanded uncertainty of a combined quantity,

$U_{C.com}$ = Expanded uncertainty of combined quantity of conventional true values,

C_i = Conventional true dose value of irradiated group *i*,

$C_{r,0}$ = Conventional true value of delivered reference dose equivalent,

$G_{r,0}$ = Indicated value of a dosimeter irradiated with $C_{r,0}$.

$\bar{G}_i$ = Average value of irradiated group *i* (IEC 62387-1, 2007).

The values of the relative expanded uncertainty, $U_{C,com}$ were determined using Guidance on Uncertainty Measurements as stated in IEC 62387-1. Guidance on Uncertainty Measurements is available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf.

The overall requirement for the non-linearity test was met according to the section 11.3 of IEC 62387-1, as shown in Tables B-9 and B-10. Although the two test methods used different approaches, the Lack-of-fit test and the non-linearity test demonstrated the linear response over the dose measuring range of the dosimeters.

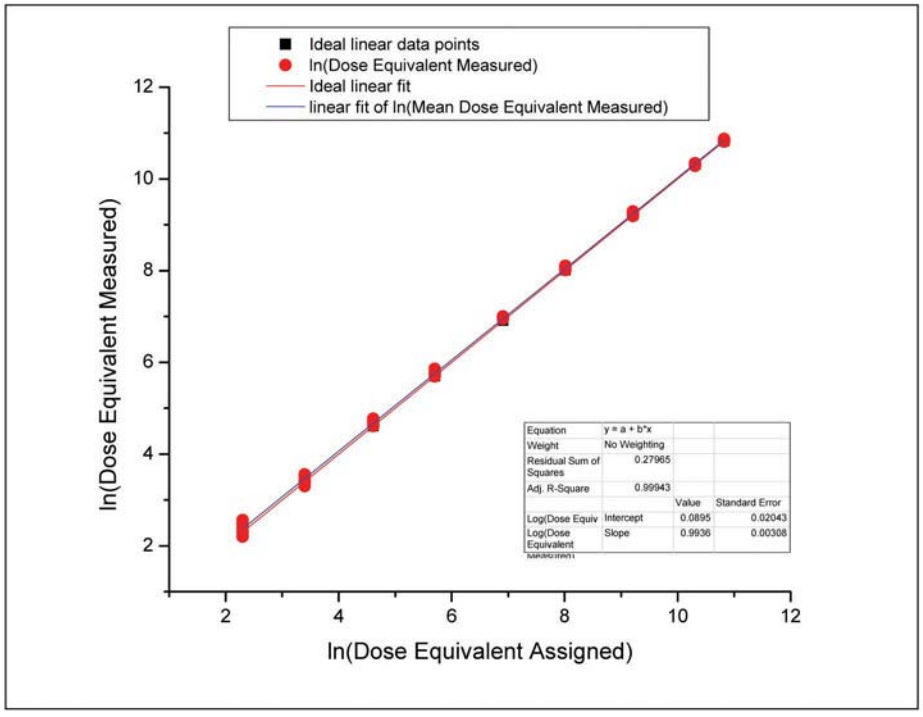

Figure B-2. Ideal Linear Fit and Measured Linear Relationship of Delivered and Measured Doses. The red line is the ideal linear fit line, and the blue line is the actual data fit. On this log-log coordinate system the measured data may be fit by a linear equation: y=0.089+0.994x. The adjusted R^2 value describing this fit is 0.99943, which indicates that the measured data closely estimates the ideal fit. Note the line is nearly 45 degrees with a slope near one and an intercept near zero.

Low Energy Response. Low energy response of the InLight® OSL dosimeter was observed using four X-ray energies: H 40 (<38 keV), NS 100 (80 keV); H 200 (160 keV), and H 300 (262 keV). The methods used to evaluate the response were: uncertainty inspection, Lack-of-fit test, and two-factor factorial experimental design. These methodologies assess accuracy and reproducibility; linearity; and effects by two factors – energy level and environmental doses.

Table B-11 summarizes the uncertainty (accuracy and reproducibility) due to low energy X-rays. Accuracy was within 15 percent in all categories. Reproducibility ranged between 2.1 to 6.1 percent.

Table B-12 presents the results of the lack-of-fit test. The InLight® dosimeter responded with excellent linearity to effective beam energies of 80, 160, and 252 keV, respectively. On the other hand, the p-value (0.015) associated with the beam H 40 (<38 keV) showed evidence of a nonlinear response. However, the regression line equation (y = 4.8 +1.01x) supports a certain degree of linear response to the H 40 beam.

The result of analysis of the two-factor factorial design with two factors (dose levels and energy level) shows that there is no evidence of interaction effect between the two factors (p = 0.244). However, there is evidence that the different energy levels caused a difference in response ($p < 0.0005$). Figure B-3 shows this difference graphically. The mean response of the dosimeters at beam code H 40 (<38 keV) was lower than the other three beam energies. This was explored further by testing various dose levels delivered by all four beams. The delivered doses examined were ~50 mrem (0.50 mSv), ~75 mrem (0.75 mSv), and 100 mrem (1 mSv). An under response of the H 40 beam was obvious at the 50 mrem (0.5 mSv) and 75 mrem (0.75 mSv) levels. The responses to the other three energies (80 keV, 160 keV, and 262 keV) overlap each other at all delivered doses.

Low Dose Resolution. To test the low dose resolution ability of the dosimeters, seven groups, each group consisting of five dosimeters, were exposed to the following ambient dose equivalents: 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 mrem (0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, and 0.50 mSv). Table B-13 presents the experimental results. A one-way analysis of variance (ANOVA) was used to test the null hypothesis H_0: $\mu_i=\mu_j$ for all i,j and the alternative hypothesis H_a: at least one μ_i is different from the rest. The overall F-test showed that the means were not all equal (p-value < 0.0005).

To examine the differences further, pair-wise comparisons were made to assess low dose resolution between close dosages. Fisher's Least Significant Difference (LSD) method was used to perform a t-test for each pair of averages. Table B-14 presents the results of the comparisons. The low p-values of the LSD paired comparison tests clearly declare a significant difference of any pair of means and thus the dose resolution capability of the dosimeters.

Dose Rate Independence. Three experimental treatments differing by radiation dose rates were used to evaluate the dose rate independence over the anticipated field conditions. Table B-15 summarizes the experimental results. The data are consistent with the accuracy and reproducibility reported by Landauer's technical specifications of this product.

Figure B-4 is a plot of the dose rates versus the dose levels reported in Table B-11. The figure helps to demonstrate that the dose equivalent measured with the InLight® OSLDs is

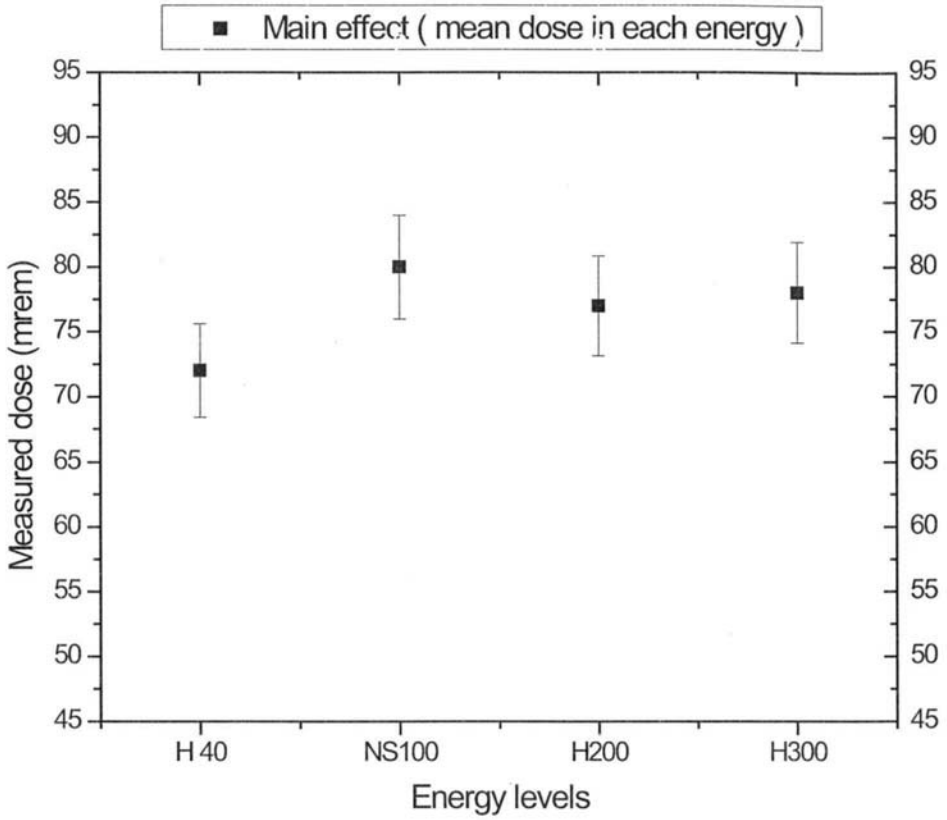

Figure B-3. The Mean Effect Due to Different Energies of the Beam.

Table B-13. Data for Low Dose Resolution with Five Replications at Each Dose Level.

Dose delivered (mrem)[a]	5	10	15	20	25	30	35	40	0.45	0.50
Measured	0.04	0.09	0.15	0.19	0.24	0.33	0.38	0.39	0.46	0.49
dose equivalent (mrem)	0.05	0.11	0.16	0.18	0.25	0.34	0.34	0.41	0.48	0.52
from	0.05	0.10	0.14	0.21	0.23	0.27	0.33	0.42	0.42	0.52
five random	0.04	0.11	0.15	0.21	0.26	0.31	0.38	0.40	0.5	0.54
dosimeters	0.06	0.11	0.17	0.21	0.27	0.31	0.37	0.42	0.47	0.51

a. 1 mrem = 0.01 mSv.

Table B-14. Pair Wise Comparison of the Interest with Fisher LSD Test.

Doses compared (mrem[a])	20 vs. 25	25 vs.30	30 vs. 35	35 vs. 40	40 vs. 45	45 vs. 50
L[b]	5	5	5	5	5	5
p-value	0.001	0.004	0.049	0.003	0.01	0.018

a. 1 mrem = 0.01 mSv.

b. $L = \left|\overline{y}_i - \overline{y}_j\right|$ (the paired mean difference).

Table B-15. Accuracy and Reproducibility using Low Dose Rate Irradiations.

Dose rate	0.0276 R/hr		0.405 R/hr		0.800 R/Hr	
Delivered dose (mrem)[a]	50	75	50	75	50	75
Groups	G3	G4	G1	G2	G5	G6
Dose equivalent delivered to individual dosimeters	50	73	51	77	49	80
	51	78	52	74	52	83
	52	72	53	80	52	78
	52	74	53	76	54	77
	52	75	51	79	51	83
Average	51	74	52	77	52	80
Average Accuracy (%)	2.8	0.8	4.0	3.5	4.3	4.2
Reproducibility (%)	1.7	3.1	1.9	3.1	3.5	4.3

a. 1 mrem = 0.01 mSv.

negligibly affected by the three discrete dose rates used. That is, the dosimeter measurements are independent of dose rate.

Verification of Environmental Performance in Accordance with IEC 62387-1 –

Fading Factors. Extreme temperatures were used to test the effect of temperature on dosimeter fading. The dosimeters showed no fading effect at room temperature, -20 °C, and 50°C and therefore met the IEC requirement.

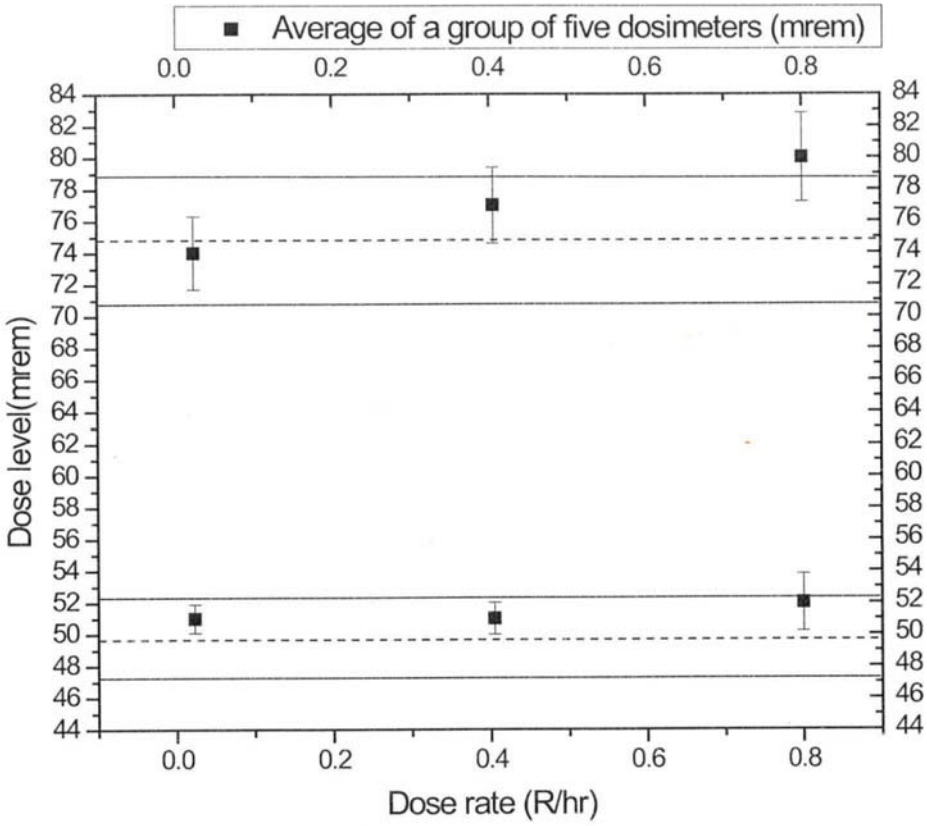

Figure B-4. Dose Rate Versus Two Dose Levels of 50 and 75 mrem (0.5 and 0.75 mSv). The dashed line is the dose equivalent delivered. The solid lines above and below each dashed line represents ± 5% of the dose equivalent delivered. The average dose equivalent measured in each group of five dosimeters is shown as a square with an error bar representing one standard deviation.

The drop test results demonstrated that drops do not affect fading of the InLight® OSLDs.

Response to light exposure by the OSLDs was found to be acceptable within IEC recommendations.

Dose Build-up, Fading, Self-irradiation and Response to Natural Radiation. When considering the issues of dose build-up, fading, self-irradiation, and response to natural radiation, IEC 62387-1 recommends an irradiation of four groups using 24 replicates for groups 1, 2, and 3, 25 replicates for group 5 at the minimum reported sensitivity of the device. The minimum reported sensitivity of the InLight® OSLD is conservatively taken to be 5 mrem (0.05 mSv). Under this criterion, one was to consider the magnitude of the average response to the known response of a reference dosimeter added to the expanded uncertainty of the average response. This ratio was to be greater than or equal to 0.91 but less than or equal to 1.11.

However, because of the low sensitivity of the InLight® OSLD, the criteria established were rescinded by IEC as too restrictive. The absolute quantity of the standard deviation at this

dosimeters minimum sensitivity, and that of any comparable technology, would be too large to ever meet this requirement. The IEC working group had re-evaluated this requirement and agreed that an acceptable test at this characteristic could be conducted at a 35 mrem (0.35 mSv) reference dose equivalent instead of at the minimum sensitivity of the dosimeter. For every group, the mean indicated value $\bar{G}_i$ and the standard deviation s_i will be determined, and from every indicated value of Group 4, $G_{j,4}$ the value $\bar{G}_5$ will be subtracted: $G_4' = \{G_{j,4} - \bar{G}_5\}$, $j = 1,\ldots,25$. From this new group four prime, $\bar{G}_4'$ and s_4' will be determined. Group 1 and Group 3 address the dose build-up, fading and self-irradiation, whereas Group 4 and Group 5 deal with the response to natural radiation. The combined examination was chosen by the IEC because the physical effects occur simultaneously.[1]

With this variation in the test protocol, the test criteria are given as:

$$\text{If } 0.91 \leq \left(\frac{\bar{G}_1}{\bar{G}_2} \pm U_{com}\right) \leq 1.11 \text{ holds, and } -5 \leq \bar{G}_5 \pm U_m \leq +5 \text{ holds,}$$

where

$\bar{G}_i$ = Average value of the group i,

$\bar{G}_2$ = Average value of group 2 (reference group),

U_{com} = Expanded uncertainty of a combined quantity

U_m = Expanded uncertainty of a mean value,

then the requirements are met. Table B-16 provides the data generated during the phase of this investigation.

The relative response of Group 1 and 3 with respect to the reference group 2 and with the consideration of expanded uncertainty of a combined quantity met the IEC requirement for the dose build-up test. The evaluation on Group 4 and 5 also satisfied the IEC recommendation.

Reader Stability. Reader stability was investigated using the same data generated in the previous experiment. The data shown in Table B-17 demonstrate the reader's stability. Two methods were used. Method A used the protocol of IEC 62387-1 and Method B (approved with the IEC working group via email) used the data of group 1, 2, and 3 of the previous evaluation (Table B-16) but considered only one set of six dosimeters.

Additional Tests

- ***Multiple readings on same dosimeters.*** The purpose of this experimental design, a two factor factorial design, was to evaluate the re-readability characteristic of the InLight® OSLD using the three environmental dose levels. The three groups, each group consisting of five dosimeters, were irradiated to three different dose levels. The first group of five dosimeters was irradiated. The mean value of the initial readouts of this group was 48 mrem (0.48 mSv). The mean initial readout values post irradiations for the second and third group were 114 and 150 mrem (1.14 and 1.50 mSv) respectively. The three groups of dosimeters were labeled as low, medium, and high dose level according to the initial group

[1] The clarification of the combined examinations on the test groups was given from IEC.

Table B-16. Results of Evaluation of Dose Build-up, Self-irradiation, and Response to Natural Radiation.

	$\bar{G}_i$ (mrem)[a]	s_i (mrem)	Evaluation	Requirement
G_1	36	2.46	$\frac{\bar{G}_1}{\bar{G}_2} \pm U_{com} = (0.98, 1.07)$	Met
G_2	35	2.47	Reference	-
G_3	35	2.85	$\frac{\bar{G}_3}{\bar{G}_2} \pm U_{com} = (0.97, 1.04)$	Met
G_4	34	2.47	$\frac{\bar{G}_4'}{\bar{G}_2} \pm U_{com} = (0.93, 1.01)$	Met
G_5	19	-	$\bar{G}_5 \pm U_m = (1.52, 2.24)$	Met

a. 1 mrem = 0.01 mSv

mean readouts. The next step of the data generation was to read each dosimeter nineteen times consecutively.

The hypotheses that were examined were:

a. There is no fading effect versus there is fading effect due to the multiple readouts

b. Any fading is the same rate for all dose levels.

Main effects are experienced when there are consistent differences in response as the level of the factor changes. The first hypothesis tests whether or not there exists the main effect due to the multiple readouts and an interaction effect exists when the difference in response as the level changes on one factor depends on the level of the other factor. In this case interaction would occur if fading occurred at different rates, over multiple readings, for different dose levels. Lack of interaction means fading occurs at the same rate for all different dose levels.

Statistical analysis of the data showed that there is no evidence of interaction. In other words, the rates of change in dose drop over multiple readouts were nearly equal over these dose levels. Both main effects were significant (p-value < 0.0005). There is a dependence of fading of dosimeters due to repeated readouts. Table B-18 summarizes the mean dose level with the multiple readouts. The relative regression line fit equation of the two parameters, mean dose versus multiple readouts was $y = -0.39x + 103$ with $R^2 = 0.89$ (Figure B-5). The estimated dose fading between the first and the last readout was 0.07 mSv or 6.8 percent of the initial readout. However, the dose diminishing trend was negligible between the consecutive readouts.

Further statistical analysis of the data demonstrates that the decreasing trend in multiple readouts is a function of the magnitude of the measured value. The results show that dose

Table B-17. Results of Evaluation of Reader Stability.

		G_1	G_2	G_3	Evaluation	Requirements
Method A	Measured values (mrem[a])	324	312	302	$\frac{\bar{G}_1}{\bar{G}_2} \pm U_{com} = (1.00, 1.07)$ $\frac{\bar{G}_3}{\bar{G}_2} \pm U_{com} = (0.95, 1.04)$	Met
		315	307	311		
		336	318	328		
		309	315	304		
		322	305	321		
		330	314	298		
	s_i	9.79	4.96	11.72		
	$\bar{G}_i$	323	312	311		
Method B	Measured values (mrem)	324	315	313	$\frac{\bar{G}_1}{\bar{G}_2} \pm U_{com} = (0.99, 1.08)$ $\frac{\bar{G}_3}{\bar{G}_2} \pm U_{com} = (0.95, 1.04)$	Met
		315	303	311		
		336	328	319		
		309	304	302		
		322	309	297		
		330	314	315		
	s_i	9.79	9.20	8.30		
	$\bar{G}_i$	323	312	310		

a. 1 mrem = 0.01 mSv

Table B-18. Mean Dose Measurements and the Consecutive Readouts.

Order of readouts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Mean dose (mrem)	104	102	104	101	100	100	100	100	98	99	99	97	97	98	97	98	97	96	96
Mean dose (mSv)	1.04	1.02	1.04	1.01	1.00	1.00	1.00	1.00	0.98	0.99	0.99	0.97	0.97	0.98	0.97	0.98	0.97	0.96	0.96

levels are the stronger predictor of decreasing response. The InLight® OSLDs exposed to a high dose tend to lose more dose information in multiple readouts than dosimeters that have received a low dose. Figure B-6 shows this trend graphically.

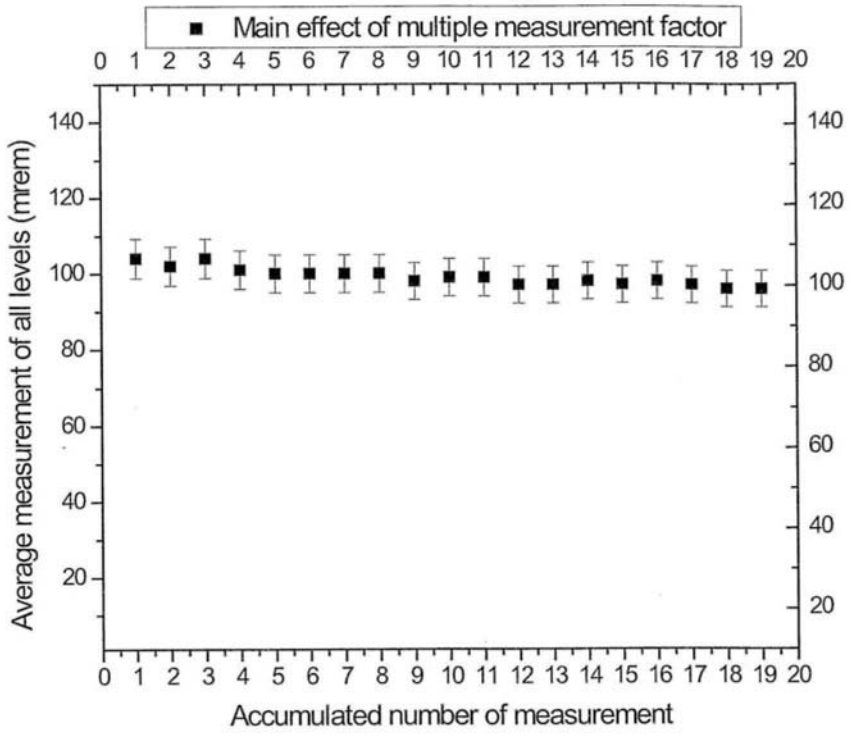

Figure B-5. The Main Effect of Multiple Measurements Showing the Average Dose Slightly Decreasing as the Number of Measurements Increases.

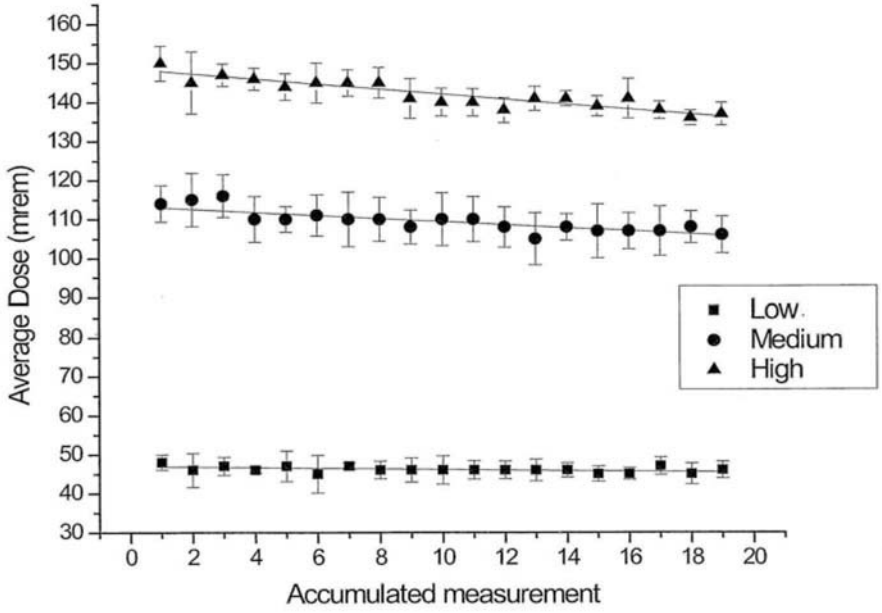

Figure B-6. Decreases in Low, Medium, and High Doses as a Function of the Number of Measurements.

- ***Time dependence.*** The objective of the investigation was to see whether or not there was a mean difference in response due to time periods between readouts. Four groups of dosimeters were irradiated to provide the average initial readouts of 0.37, 0.41, 0.98, and 1.22 mSv for Group 1, 2, 3, and 4 respectively. The second, third and fourth readouts were repeated in two, four, and five weeks period post initial readouts. The dosimeters were stored in the lead storage of the laboratory where there was minimum interference by natural radiation when they were not in use.

  The hypotheses that were examined were:

  - H_o: The means are equal in all groups versus
  - H_a: At least one mean of a group is not equal from the rest, due the treatments.

  Table B-19 is a summary of the statistics associated with these data groups. The large P-values (between 0.171 and 0.589) indicate the data are consistent with the null hypothesis that the mean readings did not change over time. The small R^2 values in the ANOVA analysis further confirm that changes in means were small or nonexistent over time.

  Considering environmental dosimeter applications, it is apparent that fading characteristics over lengthy periods of time becomes a crucial issue. Based upon the data generated for this portion of the investigation, the InLight® OSLDs did not appear to suffer from the loss of the initially received dose information over the five week time periods.

B.1.4 Conclusions of Laboratory Validation Study

The InLight® OSLDs exceeded Category I, II, and III test criteria of the laboratory phase in ANSI N13.29. In all values of bias (B), standard deviation of the performance quotient (S), and the tolerance level (|B|+S), the InLight® OSLDs showed an order of magnitude superior performance. The uncertainty assessment on the InLight® OSLD revealed the accuracy within ± 15 percent and the reproducibility within ± 5 percent with the environmental dose levels of 5, 75, and 100 mrem (0.50, 0.75, and 1 mSv). Both the lack-of-fit test using regression analysis principle and non-linearity test of IEC standard on dose measuring range of the InLight® OSLD justified the linearity. Also the low dose resolution ability was validated in the dose ranging from 0.2 to 0.5 mSv with 0.05 mSv interval using Fisher's LSD paired comparison method. Dose rate independence was justified with three different dose rates irradiating the InLight® OSLDs with

Table B-19. Data Summary of Statistical Evaluation of the Time Dependence Post Exposure of the Measured Value.

Groups	F statistic	P-value	R^2(adj)
G_1	1.98	0.171	16.37%
G_2	0.66	0.589	0.00%
G_3	H=3.32	0.344	-
G_4	1.63	0.234	11.22%

about 5 and 75 mrem (0.5 and 0.75 mSv). The characteristics of the InLight® OSLDs complied with the technical specification reported by Landauer Inc. Dose build-up, fading, self-irradiation and response to natural radiation were examined according to the IEC international standard for authenticating fading factors of the dosimeters. The requirements were met. Two additional tests using experimental design principle were performed: Multiple readouts on same dosimeters and Time dependence. The statistical analysis revealed that there is no significant fading due to re-reading of the dosimeters and also time is not a factor of fading. Throughout this study using two standard documents, ANSI N13.29 and IEC 62387-1 and the Landauer technical specification report of the InLight® OSLD, the observed performance indicates that the InLight® OSLD is a promising technology for environmental radiation monitoring and surveillance.

B.2 ESER Environmental Surveillance Program Field Study

B.2.1 Introduction

ISU operates the Environmental Assessment Laboratory (EAL) that provides radiological analyses for various environmental surveillance organizations and educational opportunities for students. EAL personnel are also involved with various independent environmental research projects. The EAL serves as a state resource for performing and assisting in environmental research. Students learn environmental research techniques, analytical skills, and rules of compliance related to monitoring.

The EAL in cooperation with the Gonzales-Stoller Surveillance, LLC, who is the ESER contractor, is actively involved in environmental surveillance and research activities concerned with the INL Site. Presently, the role of the EAL is the “blind” analysis of environmental surveillance samples collected by ESER personnel. “Blind” in this context indicates that EAL personnel have no knowledge of the sampling location.

This section provides the results of analyses of the OSLDs collected 4/30/12, 5/1/12, 5/2/12, 11/1/12, 11/6/12, and 11/7/12. It is based on a report authored by Dr. Richard Brey, Chair of the ISU Department of Nuclear Engineering and Health Physics, ISU (Brey 2013). Instrument performance checks and internal quality assurance samples were used during the study to insure quality assurance and are documented in Brey (2013).

B.2.2 Data Reporting Conventions

Analytical results are reported in units of dose (mrem). Uncertainty is reported at one and two standard deviations. Several dosimeters resulted in an error which was due to certain regions of the dosimeter covered by foil elements having a dose which was lower than anticipated. This lower dose was associated with sensitivity to ultraviolet light from the sun. Landauer personnel suggested calculating a “corrected” value using the following formula:

$$\frac{\left(\frac{(E_3 + E_4)}{2}\right)}{0.87}$$

where: E3 = the reading for copper covered element 3

E4 = the reading for copper covered element 4.

This error was unanticipated but once identified easily fixed by supplementing the environmental dosimeter holder with an additional internal opaque envelope developed at the suggestion of Landauer. Landauer has a commercially available envelope but is technically unhappy with its performance as it has, in their experience, left a slight residue on the chips. The very trivial envelope developed by ISU under the suggestion of Landauer leaves no such residue.

Comparison TLD data was provided by ESER personnel. To inter-compare these data sets, values reported in the exposure units of Roentgen (R) were converted to units of dose equivalent rem. To accomplish this, the exposure values were multiplied by a value of 0.87 to convert exposure into the measured absorbed dose in air, and these values were multiplied by a quality factor of 1.0 assuming all exposures were associated exclusively with low linear-energy-transfer (LET) radiation.

B.2.3 Results

The results of the analyses of the OSLDs and the TLD values obtained by ESER personnel during concurrent field measurements are presented in Tables B-20 and B-21.

B.2.4 Analysis

The following analyses were conducted by Dr. Rich Brey and Dr. DeWayne Derryberry, as well as by Mr. Mark Williams. A plot of the concurrently located and irradiated TLD versus OSLD measured values is provided in Figure B-7.

This plot shows very good agreement between OSLDs and the TLDs. It is evident that these two devices for practical purposes are measurements of the same field magnitude and these two sets of data show excellent correlation. This is the first and most important conclusion.

It must be understood that these data represent two different kinds of measurements albeit using similar but by no means identical technology. OSLDs clearly provides a greater value of precision, and has other technical advantages. Calibrations for both the TLDs and OSLDs were accomplished using NIST traceable calibration sources. Calibrations were performed on different NIST traceable sources. This too has the potential for introducing slight differences in the group response of these two sets of instruments.

Noting and understanding the similarities, these two devices, when considering this relatively large data set demonstrate minute and understandable differences. Statistically, these are slightly different measurement sets. The OSLD and TLD values are different statistically but the relative error is small.

Evaluation of the data as a whole – These data were first considered as a single set and evaluated. Consider the results of the paired T-test (two-tailed test), presented in Table B-22. The hypotheses tested were:

Table B-20. Results of Analyses of ESER Program OSLDs and TLDs from November 1, 2011, to April 30, 2012.

	OSLD		TLD	
Location	mrem	1σ	mrem[a]	1 σ
Aberdeen	49.4	3.5	58.2	5.7
Arco	54.8	3.9	56.6	5.6
Atomic City	52.4	3.7	59.2	5.8
Blackfoot	51.1	3.6	54.1	5.3
Blue Dome	41.5	2.9	48.8	4.8
Craters of Moon	45.0	3.2	54.2	5.3
Dubois	42.0	3.0	48.7	4.8
Howe	54.1	3.9	56.4	5.5
Idaho Falls	50.0	3.5	56.7	5.6
Jackson	39.5	2.8	47.8	4.7
Minidoka	44.0	3.1	52.2	5.1
Monteview	45.5	3.2	55.1	5.4
Mountain View	47.2	3.3	52.3	5.1
Mud Lake	56.2	4.0	63.3	6.2
Reno Ranch	44.0	3.1	51.7	5.1
Rexburg	59.9	4.3	66.8	6.6
Roberts	60.8	4.3	62.7	6.1

a. Converted from exposure (R) to dose equivalent (mrem).

Null Hypothesis (H_o): Mean difference = 0

Alternate Hypothesis (H_a): Mean difference ≠ 0

There is strong evidence that the OSLDs and TLDs are producing different readings (p-value = 0.002). A small p-value indicates overwhelming evidence of a difference, but does not necessarily mean the differences are themselves large.

A histogram of these differences within the data set as a whole is provided in Figure B-8, and a boxplot is provided in Figure B-9. The histogram and the boxplots below indicate the OSLD data reads a lower value than TLD values approximately 60 percent of the time with a

Table B-21. Results of Analyses of ESER Program OSLDs and TLDs from May 1, 2012, to October 31, 2012.

	OSLD		TLD	
Location	mrem	1 σ	mrem[a]	1 σ
Aberdeen	57.1	4.1	53.5	5.3
Arco	54.6	3.9	53.1	5.2
Atomic City	58.3	4.1	55.7	5.5
Blackfoot	53.0	3.8	50.4	5.0
Blue Dome	45.5	3.2	43.9	4.3
Craters of Moon	54.3	3.8	52.0	5.1
Dubois	46.5	3.3	44.6	4.4
Howe	50.2	3.6	49.2	4.8
Idaho Falls	57.9	4.1	53.8	5.3
Jackson	39.2	2.8	41.0	4.0
Minidoka	47.1	3.3	47.6	4.6
Monteview	56.9	4.0	51.1	5.0
Mountain View	46.3	3.3	45.4	4.5
Mud Lake	56.5	4.0	56.8	5.6
Reno Ranch	52.6	3.7	46.7	4.6
Rexburg	65.9	4.7	63.2	6.2
Roberts	64.7	4.6	58.0	5.7

a. Converted from exposure (R) to dose equivalent (mrem).

mean difference of -1.86 mrem, but this value, although statistically significant, is of little practical significance considering the measurement uncertainty. (The histograms and boxplots also show that the differences are approximately normal.)

The data were then evaluated separately according to the two observation periods.

Evaluation of November to April Data – Using the same Hypothesis as stated previously, the paired T-test analysis still produced a marginal result, with weak evidence of a difference (p-value = 0.055). However the evidence is much weaker than in the previous analysis (Table B-23).

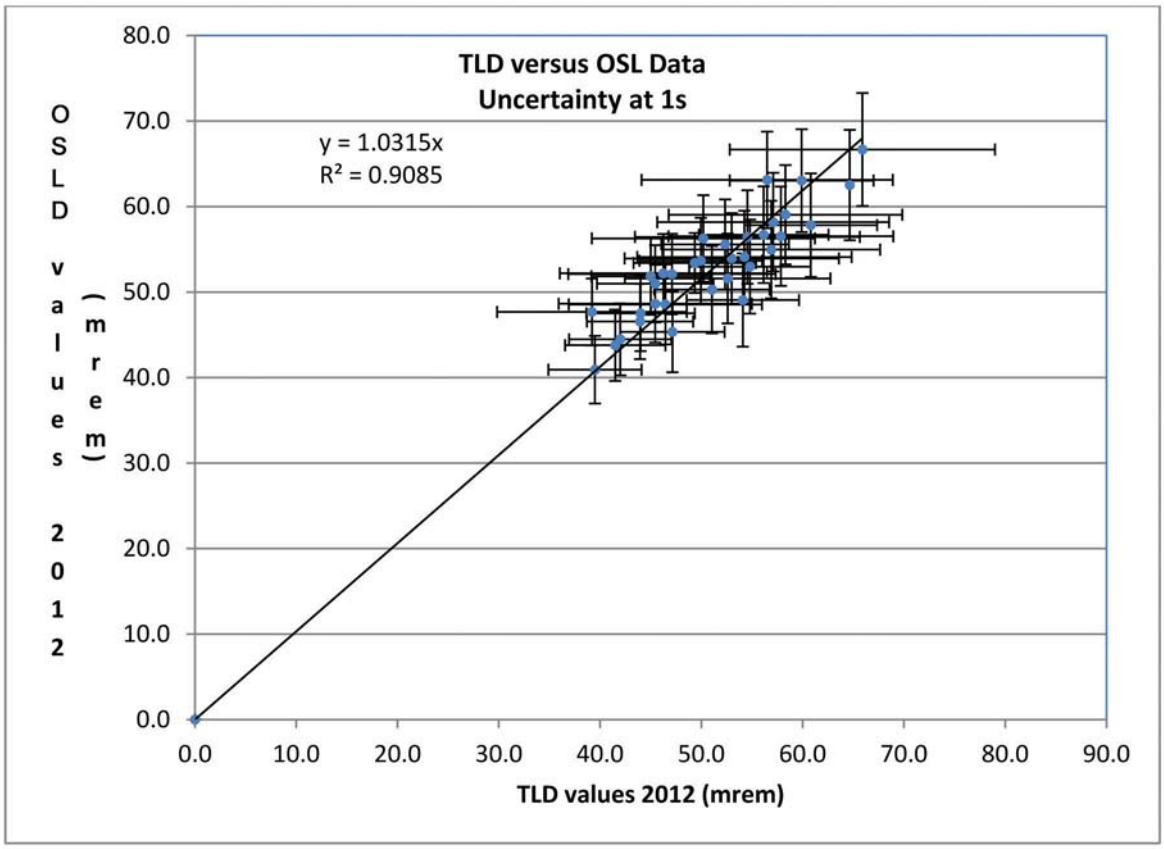

Figure B-7. Plot of OSLD versus TLD results.

Table B-22. Results of Paired T-test of Difference between OSLD and TLD Measurements.

	N	Mean	Std. Dev	Std. Error Mean
OSLD	34	51.27	6.92	1.19
TLD	34	53.13	5.93	1.02
Difference	34	-1.860	3.162	0.542
95% CI[a] for mean difference	(-2.963, -0.757)			
Results of T-test	T-test of mean difference = 0 (vs. not = 0); T-value = -3.43; P-value = 0.002			

a. CI = confidence interval

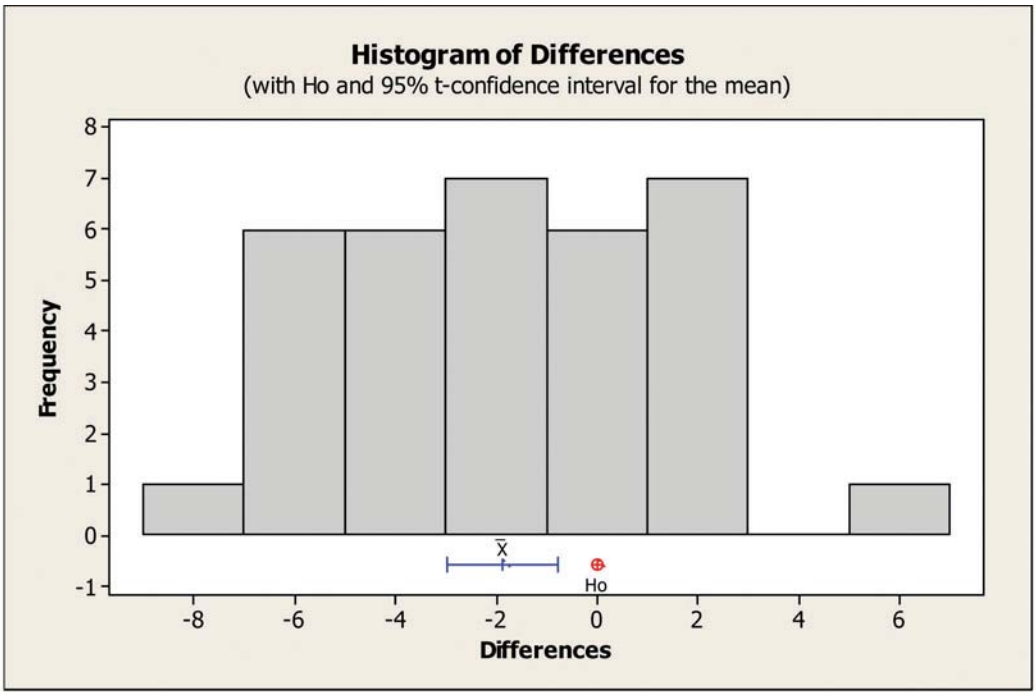

Figure B-8. Histogram of Differences between OSLD and TLD Measurements.

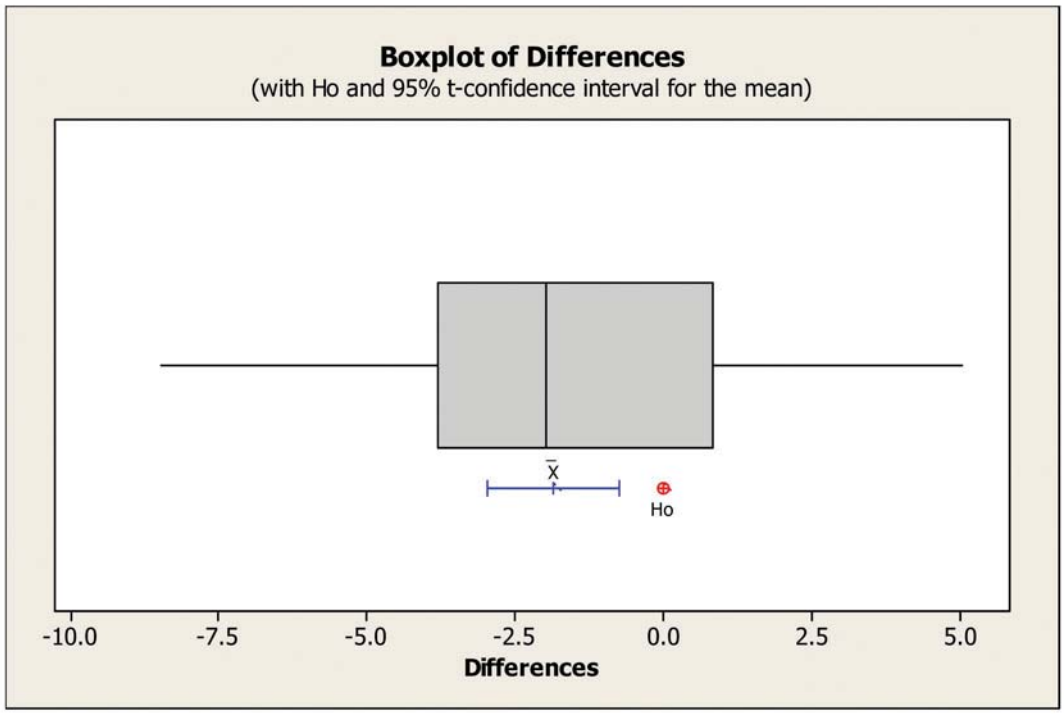

Figure B-9. Boxplot of Differences between OSLD and TLD Measurements.

When considering the November to April data set, a histogram of the consistency or lack differences is provided in Figure B-10 and a boxplot is provided in Figure B-11.

Evaluation of May to October Data – Using the same Hypothesis as before, the paired T-test analysis provides moderate evidence the dosimeters are producing different readings (p-value = 0.015). Again, a similar result was observed (Table B-24). The differences that are statistically significant are not large.

Table B-23. Results of Paired T-test of Difference between OSLD and TLD Measurements from November 1, 2011, to April 30, 2012.

	N	Mean	Std. Dev	Std. Error Mean
OSLD	17	49.24	6.43	1.56
TLD	17	50.82	5.73	1.39
Difference	17	-1.586	3.155	0.765
95% CI[a] for mean difference	(-3.208, -0.036)			
Results of T-test	T-test of mean difference = 0 (vs. not = 0); T-value = -2.07; P-value = 0.055			

a. CI = confidence interval

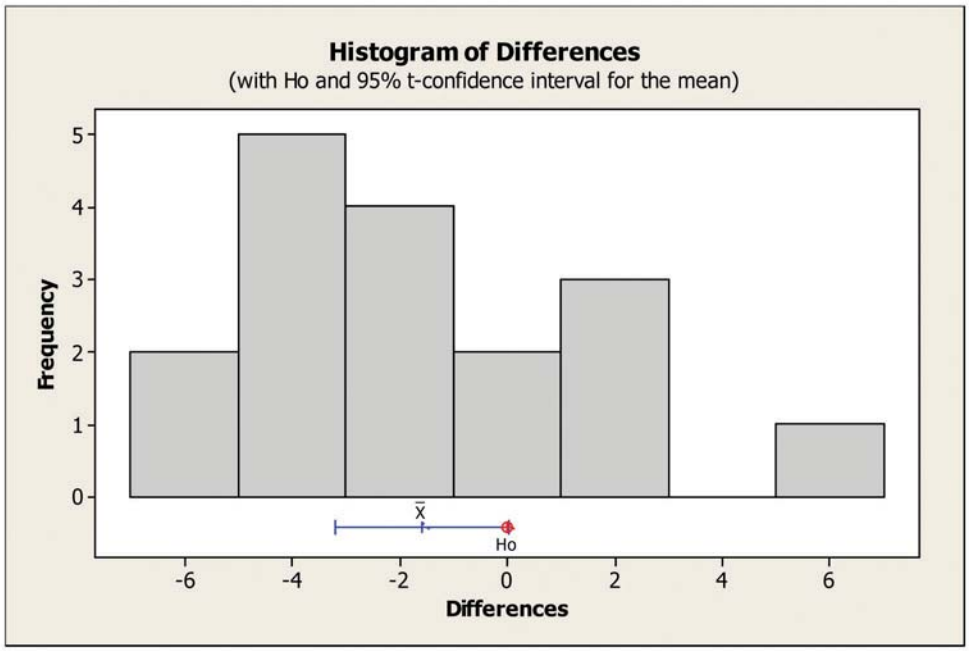

Figure B-10. Histogram of Differences between OSLD and TLD Measurements Obtained from November 1, 2011, to April 30, 2012.

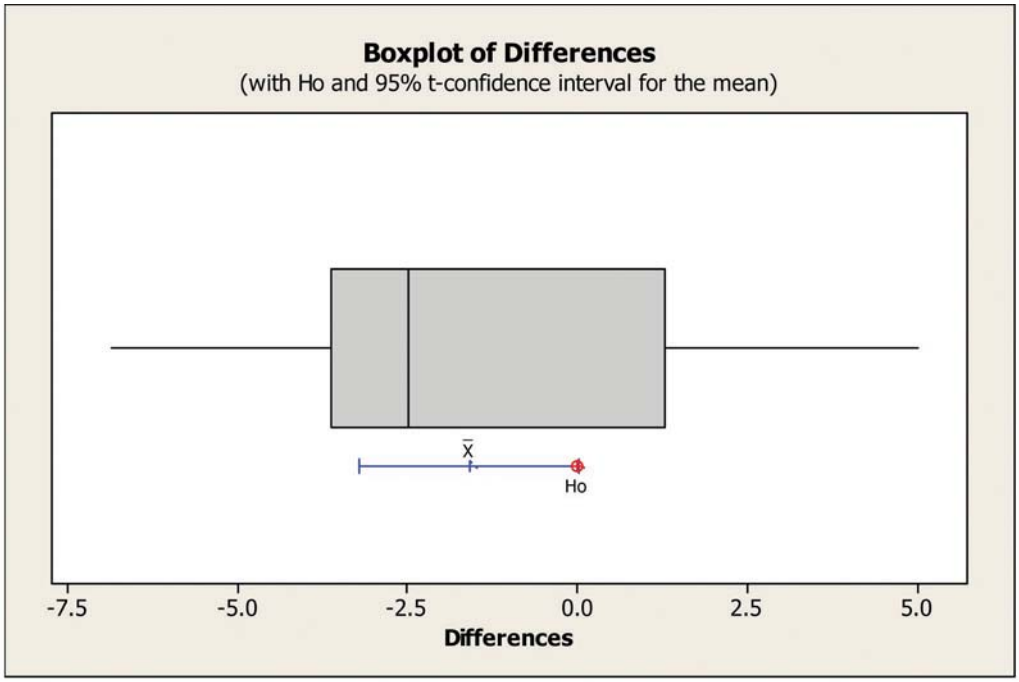

Figure B-11. Boxplot of Differences between OSLD and TLD Measurements Obtained from November 1, 2011, to April 30, 2012.

Table B-24. Results of Paired T-test of Difference between OSLD and TLD Measurements from May 1, 2012, to October 31, 2012.

	N	Mean	Std. Dev	Std. Error Mean
OSLD	17	53.31	6.98	1.69
TLD	17	55.44	5.32	1.29
Difference	17	-2.133	3.241	0.786
95% CI[a] for mean difference	(-3.800, -0.467)			
Results of T-test	T-test of mean difference = 0 (vs. not = 0); T-value = -2.71; P-value = 0.015			

a. CI = confidence interval

Considering the May to October data set, a histogram of these differences is provided in Figure B-12 and a boxplot is provided in Figure B-13.

Comparison of OSLD and TLD Measurements in Terms of Relative Error – It has been stated that there is a difference between the OSLD and TLD data which may be observed to be present statistically at the 95 percent confidence interval. While this is true, it is anticipated as they are slightly different technologies, and these devices were calibrated using different NIST

traceable sources. So while these differences objectively exist, these differences are small. These differences can be quantified.

If one observes the definition of relative error to be:

relative error OSLD=(OSLD-TLD)·100/OSLD

Then the magnitude of this difference can be described as the uncertainty in these differences. The hypothesis that the mean difference = 0 was then tested using a one-sample T-test. The results are presented in Table B-25.

Comparison of OSLD and TLD Measurements in Terms of Relative Error – It has been stated that there is a difference between the OSLD and TLD data which may be observed to be present statistically at the 95 percent confidence interval. While this is just barely true, it is anticipated as they are slightly different technologies, and these devices were calibrated using different NIST traceable sources. So while these differences objectively exist, these differences are vanishingly small. These differences can be quantified.

If one observes the definition of relative error to be:

relative error OSLD=(OSLD-TLD)·100/OSLD

Then the magnitude of this difference can be described as the uncertainty in these differences. The hypothesis that the mean difference = 0 was then tested using a one-sample T-test. The results are presented in Table B-25.

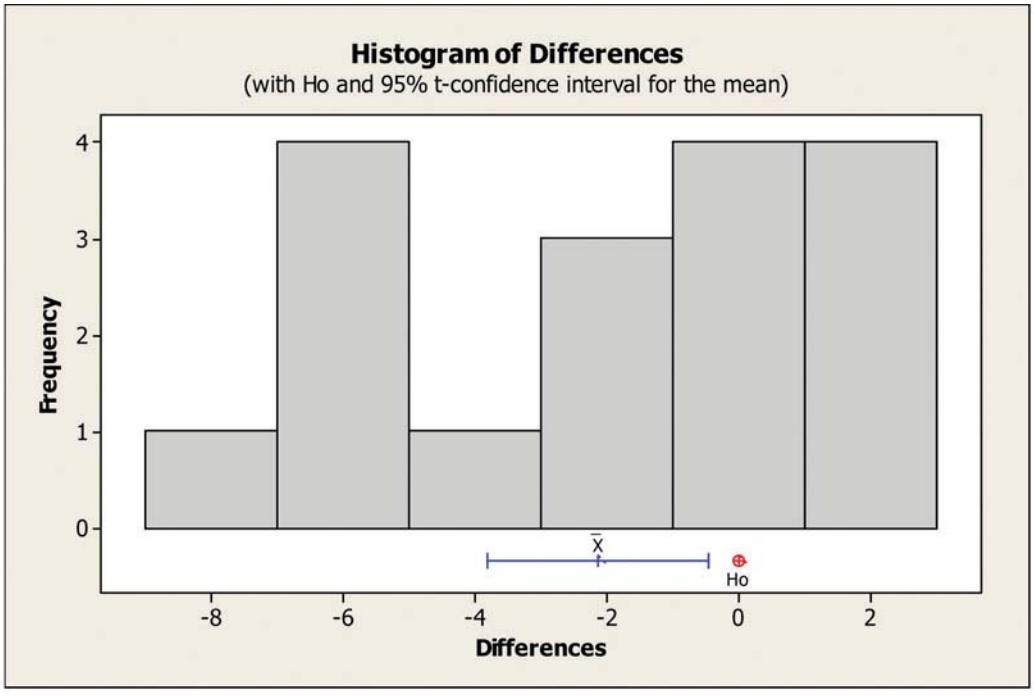

Figure B-12. Histogram of Differences between OSLD and TLD Measurements Obtained from May 1, 2012, to October 30, 2012.

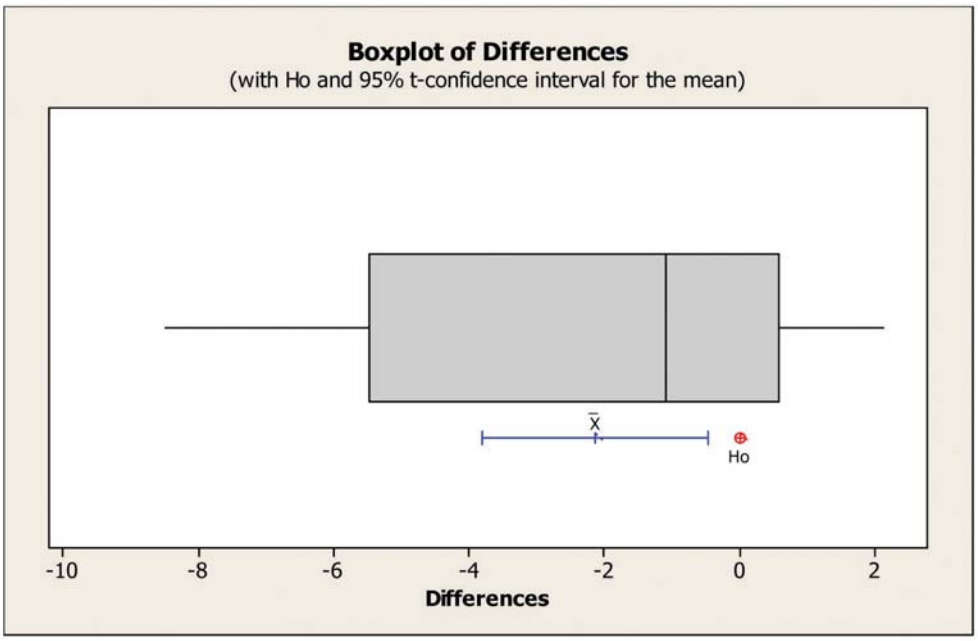

Figure B-13. Boxplot of Differences between OSLD and TLD Measurements Obtained from May 1, 2012, to October 31, 2012.

Using OSLDs as the base measurement, the average relative error is estimated to be 4.13 percent (confidence interval 1.81percent to 6.45 percent), with OSLDs generally reporting lower values.

Likewise one could define relative error in terms of the TLD and quantify the difference. If one observes the definition of relative error to be:

$$\text{relative error TLD}=(\text{TLD}-\text{OSL})\cdot 100/\text{OSL}$$

Then the magnitude of this difference can be described as can the uncertainty in these differences. The hypothesis that the mean difference = 0 was then tested using a one-sample T-test. The results are presented in Table B-26.

Using TLD as the base measurement, the average relative error is estimated to be 3.59 percent (confidence interval 1.47 percent to 5.71 percent), with OSLDs generally reporting lower values.

These measurements may be said to be very normal in their distribution. We should note that these values are within the measurement uncertainty of any signal measurement.

B.2.5 Conclusions

The field data demonstrating side by side field measurements made using OSLD and TLD technologies were highly correlated. When considering large independent data sets, one observes that the two measurement systems, employing slightly different technology and calibrated using different NIST traceable sources, provide slightly different results that can barely be identified statistically, but which nevertheless are different. The magnitudes of these differences are small and within the individual measurement uncertainty of any individual dosimeter.

Table B-25. Results of One-Sample T-test of Relative Error of OSLD Measurements.

Variable	N	Mean	Std. Dev	Std. Error Mean	95% CI[a]	T	P
Relative error OSL	34	-4.13	6.65	1.147	(-6.45, -1.81)	-3.62	0.001

a. CI = confidence interval

Table B-26. Results of One-Sample T-test of Relative Error of TLD Measurements.

Variable	N	Mean	Std. Dev	Std. Error Mean	95% CI[a]	T	P
Relative error TLD	34	-3.59	6.07	1.04	(-5.71, -1.47)	-3.44	0.002

a. CI = confidence interval

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Appendix C. Chapter 5 Addendum

Table C-1. Advanced Test Reactor Complex Cold Waste Pond Effluent Monitoring Results (2012).[a]

Parameter	Minimum	Maximum	Median
Arsenic (mg/L)	0.005 U[b]	0.0066	0.005 U
Barium (mg/L)	0.042	0.145	0.0483
Cadmium (mg/L)	0.001 U	0.001 U	0.001 U
Chloride (mg/L)	10.2	36.8	12.1
Chromium (mg/L)	0.0029	0.0085	0.0038
Conductivity (µS/cm)	429	1,374	477
Cobalt (mg/L)	0.0025 U	0.0025 U	0.0025 U
Copper (mg/L)	0.001 U	0.0074	0.0022
Fluoride (mg/L)	0.167	0.477	0.191
Iron (mg/L)	0.025 U	0.168	0.0908
Manganese (mg/L)	0.0025 U	0.0052	0.0025 U
Mercury (mg/L)	0.0002 U	0.0002 U	0.0002 U
Nitrogen, nitrate + nitrite (mg-N/L)	0.814	2.93	0.883
Nitrogen, total Kjeldahl (mg/L)	0.1 U	0.859	0.189
Selenium (mg/L)	0.00093	0.005	0.0013
Silver (mg/L)	0.005 U	0.005 U	0.005 U
Sulfate (mg/L)	21.7	535	31.9
Total dissolved solids (mg/L)	239	1040	270
Total suspended solids (mg/L)	4 U	4 U	4 U

a. Duplicate samples were collected in January and the results for the duplicate samples are included in the summary.

b. U flag indicates the result was below the detection limit.

Table C-2. Advanced Test Reactor Complex Cold Waste Pond Industrial Wastewater Reuse Permit Monitoring Well Results (2012).

WELL NAME	USGS-065 (GW-016102)		TRA-07 (GW-016103)		USGS-076 (GW-016104)		TRA-08 (GW-016105)		Middle-1823 (GW-016106)		PCS/SCS [a]
Sample Date	04/12/12	10/08/12	04/09/12	10/09/12	04/12/12	10/08/12	04/18/12	10/08/12	04/09/12	10/09/12	
Water Table Depth (ft below ground surface)	474.49	475.86	482.9	484.17	482.02	483.24	487.83	489.22	491.73	493.06	NA[b]
Water Table Elevation (above mean sea level in ft)[c]	4454.03	4452.66	4452.18	4450.91	4451.19	4449.97	4450.60	4449.21	4451.14	4449.81	NA
pH	7.62	7.74	7.75	8.04	7.82	8.0	7.84	8.01	7.8	8.04	6.5 to 8.5 (SCS)
Total Kjeldahl nitrogen (mg/L)	0.1 U[d]	0.138 [0.146][e]	0.1 U	0.11	0.1 U	0.113	0.1 U	0.163	0.1 U	0.144	NA
Nitrite nitrogen (mg/L)	0.05 U	0.05 U [0.05 U]	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	1 (PCS)
Nitrate nitrogen (mg/L)	1.42	1.46 [1.47]	1.13	1.06	1.02	1.04	0.99	1.0	0.948	0.971	10 (PCS)
Total nitrogen[f] (mg/L)	<1.57	<1.648 [<1.666]	<1.28	<1.22	<1.17	<1.203	<1.14	<1.213	<1.098	<1.165	NA
Total dissolved solids (mg/L)	471	450 [429]	468	435	304	274	316	285	293	262	500 (SCS)
Aluminum (mg/L)	0.006 U (0.0038 U)[h,i]	0.0046 [0.0057] (0.0021) [(0.0024)]	**1.910**[g] (0.0035 U)	**0.637** (0.0015)	0.0042 U (0.0041 U)	0.0036 (0.003)	**12.300** (0.0531)	**7.480** (0.0141)	0.130 (0.0026 U)	0.0909 (0.0012)	0.2 (SCS)
Antimony (mg/L)	0.0004 U	0.0004 U [0.0004 U]	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.006 (PCS)

Table C-2. Advanced Test Reactor Complex Cold Waste Pond Industrial Wastewater Reuse Permit Monitoring Well Results (2012). (cont.)

WELL NAME	USGS-065 (GW-016102)		TRA-07 (GW-016103)		USGS-076 (GW-016104)		TRA-08 (GW-016105)		Middle-1823 (GW-016106)		PCS/SCS [a]
Sample Date	04/12/12	10/08/12	04/09/12	10/09/12	04/12/12	10/08/12	04/18/12	10/08/12	04/09/12	10/09/12	
Arsenic (mg/L)	0.0011	0.0013 [0.0013]	0.001	0.0013	0.0018	0.0017	0.0028	0.0022	0.0014	0.0018	0.05 (PCS)
Barium (mg/L)	0.0488	0.0427 [0.0426]	0.104	0.0669	0.0759	0.0671	0.537	0.198	0.0675	0.062	2 (PCS)
Cadmium (mg/L)	0.00025 U	0.00025 U [0.00025 U]	0.00025 U	0.00025 U	0.00025 U	0.00025 U	0.00025 U	0.00025 U	0.00025 U	0.00025 U	0.005 (PCS)
Chloride (mg/L)	19.6	19.2 [19.2]	20.7	20.5	13.8	14.1	11.8	12.5	11.3	12.2	250 (SCS)
Cobalt (mg/L)	0.0025 U	0.0025 U [0.0025 U]	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0054	0.0025 U	0.0025 U	0.0025 U	NA
Copper (mg/L)	0.0025 U	0.0025 U [0.0025 U]	0.0133	0.0052	0.0025 U	0.0025 U	0.350	0.0204	0.0025 U	0.0025 U	1.3 (PCS)
Fluoride (mg/L)	0.242	0.219 [0.21]	0.233	0.212	0.192	0.167	0.216	0.198	0.191	0.167	4 (PCS)
Iron (mg/L)	0.155 (0.050 U)	**0.315** [0.293] (0.0639) [(0.0672)]	**1.620** (0.050 U)	**0.571** (0.0586)	0.0538 (0.050 U)	0.083 (0.0516)	**4.960** (0.050 U)	**3.260** (0.0871)	0.125 (0.050 U)	0.100 (0.0718)	0.3 (SCS)
Manganese (mg/L)	0.0025 U (0.0025 U)	0.0025 U [0.0025 U] (0.0025 U) [(0.0025 U)]	0.025 (0.0025 U)	0.0086 (0.0025 U)	0.0025 U (0.0025 U)	0.0025 U (0.0025 U)	**0.191** (0.0025 U)	**0.0678** (0.0025 U)	0.0052 (0.0027)	0.0041 (0.0025 U)	0.05 (SCS)
Mercury (mg/L)	0.0002 U	0.0002 U [0.0002 U]	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.002 (PCS)
Selenium (mg/L)	0.002	0.002 [0.0021]	0.0014	0.0017	0.0015	0.0014	0.0013	0.002	0.0013	0.0013	0.05 (PCS)

Table C-2. Advanced Test Reactor Complex Cold Waste Pond Industrial Wastewater Reuse Permit Monitoring Well Results (2012). (cont.)

WELL NAME		USGS-065 (GW-016102)		TRA-07 (GW-016103)		USGS-076 (GW-016104)		TRA-08 (GW-016105)		Middle-1823 (GW-016106)		PCS/SCS [a]
Sample Date		04/12/12	10/08/12	04/09/12	10/09/12	04/12/12	10/08/12	04/18/12	10/08/12	04/09/12	10/09/12	
Silver	(mg/L)	0.005 U	0.005 U [0.005 U]	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.1 (SCS)
Sulfate	(mg/L)	163	162 [162]	160	155	33	32.7	50.4	49.5	34.1	35.6	250 (SCS)

a. Primary constituent standards (PCS) and secondary constituent standards (SCS) in groundwater referenced in the Ground Water Quality Rule, IDAPA 58.01.11.200.01.a and b.
b. NA- Not applicable.
c. Elevation data provided using the North American Vertical Datum of 1988 (NAVD 88).
d. U flag indicates that the result was reported as below the instrument detection limit by the analytical laboratory.
e. Results shown in brackets are the results from field duplicate samples.
f. Total nitrogen is calculated as the sum of the TKN, nitrite nitrogen, and nitrate nitrogen. For results reported below the instrument detection limit, the detection limit for that parameter is used in the calculation. The resulting total nitrogen is then reported as a less than (<) number.
g. Concentrations shown in bold are above the Ground Water Quality Rule SCS.
h. Results shown in parentheses are from filtered samples used for comparison with the SCS.
i. Filtered sample results for aluminum, iron, and manganese, shown in parentheses, are used for permit compliance determinations.

Table C-3. Idaho Nuclear Technology and Engineering Center Sewage Treatment Plant Influent Monitoring Results at CPP-769 (2012).[a]

Parameter	Minimum	Maximum	Average[b]
Biochemical oxygen demand (5-day) (mg/L)	87.6	227	143
Nitrate + nitrite, as nitrogen (mg/L)	0.025[c]	0.803	0.178
Total Kjeldahl nitrogen (mg/L)	24.6	78.8	54.9
Total phosphorus (mg/L)	3.96	8.72	6.15
Total suspended solids (mg/L)	64.9	301	123

a. Duplicate samples were collected in June for all parameters. Duplicate results are included in the summaries.
b. Annual average is determined from the average of the monthly values.
c. Sample result was less than the detection limit; value shown is half the detection limit.

Table C-4. Idaho Nuclear Technology and Engineering Center Sewage Treatment Plant Effluent Monitoring Results at CPP-773 (2012).[a]

Parameter	Minimum	Maximum	Average[b]
Biochemical oxygen demand (5-day) (mg/L)	6.29	66.5	23.0
Chloride (mg/L)[c]	356	361	359
Conductivity (µS/cm) (composite)[c]	854	2,000	1,273
Nitrate + nitrite, as nitrogen (mg/L)	0.734	7.23	3.25
pH (standard units) (grab)	7.68	9.36	8.40
Sodium (mg/L)[c]	224	230	227
Total coliform (colonies/100 mL)	230	15,600	2,614
Total dissolved solids (mg/L)[c]	912	914	913
Total Kjeldahl nitrogen (mg/L)	3.82	39.1	18.8
Total phosphorus (mg/L)	0.943	6.9	4.62
Total suspended solids (mg/L)	4.7	43.3	18.2

a. Duplicate samples were collected in June for all parameters (excluding conductivity, pH, and total coliform), and the duplicate results are included in the summaries.
b. Annual average is determined from the average of the monthly values. Half the reported detection limit was used in any calculation for those data reported as below the detection limit.
c. Information obtained from January and February 2012 analytical results. New Wastewater Reuse Permit LA-00130-05, effective March 14, 2012, no longer required monitoring for this parameter.

Table C-5. Idaho Nuclear Technology and Engineering Center New Percolation Ponds Effluent Monitoring Results at CPP-797 (2012).[a]

Parameter	Minimum	Maximum	Average[b]
Aluminum (mg/L)	0.0125[c]	0.0125[c]	0.0125[d]
Arsenic (mg/L)	0.00125[c]	0.0047	0.0016
Biochemical oxygen demand (5-day) (mg/L)	1.0[c]	5.69	2.24
Cadmium (mg/L)	0.0005[c]	0.0005[c]	0.0005[d]
Chloride (mg/L)	12.0	69.1	29.4
Chromium	0.0038	0.0056	0.0046
Conductivity (µS/cm) (composite)	179	587	417
Copper (mg/L)	0.0036	0.0077	0.0051
Fluoride (mg/L)	0.228	0.256	0.243
Iron (mg/L)	0.0125[c]	0.1320	0.0714
Manganese (mg/L)	0.00125[c]	0.00360	0.00171
Mercury (mg/L)	0.0001[c]	0.0001[c]	0.0001[d]
Nitrate + nitrite, as nitrogen (mg/L)	0.786	2.33	1.55
pH (grab)	7.81	8.22	7.99
Selenium (mg/L)	0.0008	0.0015	0.0012
Silver (mg/L)	0.0025[c]	0.0025[c]	0.0025[d]
Sodium (mg/L)	9.09	32.8	19.4
Total coliform (colonies/100 mL)	4	50	17.8
Total dissolved solids (mg/L)	225	337	276
Total Kjeldahl nitrogen (mg/L)	0.191	1.42	0.569
Total nitrogen[e] (mg/L)	3.05	3.40	3.22
Total phosphorus (mg/L)	0.493	0.974	0.798
Total suspended solids (mg/L)	2.0[c]	2.0[c]	2.0[d]

a. Duplicate samples were collected in June for all parameters, except for biochemical oxygen demand (5-day), which were collected in July (excluding conductivity, pH, and total coliform), and the duplicate results are included in the summaries.
b. Annual average is determined from the average of the monthly values. Half the reported detection limit was used in the yearly average calculation for those data reported as below the detection limit.
c. Sample result was less than the detection limit; value shown is half the detection limit.
d. All the results were less than the detection limit. Therefore, the average is based on half the reported detection limit from each of the monthly values.
e. Total nitrogen is calculated as the sum of total Kjeldahl nitrogen and nitrate + nitrite, as nitrogen. Information obtained from January and February 2012 analytical results. New Wastewater Reuse Permit LA-00130-05, effective March 14, 2012, no longer required monitoring for this parameter.

Table C-6. Idaho Nuclear Technology and Engineering Center New Percolation Ponds Aquifer Monitoring Well Groundwater Results (2012).

	ICPP-MON-A-165 (GW-013006)			ICPP-MON-A-166 (GW-013007)					ICPP-MON-A-164B (GW-013011)				PCS/SCS[a]
Sample Date	4/3/2012	9/4/2012	9/11/2012[b]	4/3/2012	9/4/2012	9/4/2012[c]	9/11/2012[b]	9/11/2012[b,c]	4/4/2012	4/4/2012[c]	9/4/2012	9/11/2012[b]	
Depth to water (ft below brass cap)	502.52	503.53	503.61	509.10	510.72	510.72	510.75	510.75	501.39	501.39	502.61	502.59	NA[d]
Water elevation at brass cap (ft)[e]	4,450.39	4,449.38	4,449.30	4,450.40	4,448.78	4,448.78	4,448.75	4,448.75	4,450.78	4,450.78	4,449.56	4,449.58	NA
Aluminum (mg/L)[f]	0.0250 U[g]	0.0250 U	—	0.0250 U	0.0250 U	0.0250 U	—	—	0.0347	0.0250 U	0.0250 U	—	0.2
Arsenic (mg/L)	0.0013	0.0013	—	0.0012	0.0017	0.0017	—	—	0.0013	0.0020	0.0013	—	0.05
Biochemical oxygen demand (mg/L)	2.0 U	—	2.0 U	2.0 U	—	—	2.0 U	2.0 U	2.0 U	2.0 U	—	5.30	NA
Cadmium (mg/L)	0.0025 U	0.0025 U	—	0.0025 U	0.0025 U	0.0025 U	—	—	0.0025 U	0.0025 U	0.0025 U	—	0.005
Chloride (mg/L)	49.6	43.2	—	8.44	8.88	8.87	—	—	9.76	9.71	10.1	—	250
Chromium (mg/L)	0.0125	0.0169	—	0.0052	0.0064	0.0056	—	—	0.0088	0.0097	0.0108	—	0.1
Coliform, fecal (colonies/100 mL)	Absent	Absent	—	Absent	Absent	Absent	—	—	Absent	Absent	Absent	—	
Coliform, total (colonies/100 mL)	Absent	Absent	—	Absent	Absent	Absent	—	—	Absent	Absent	Absent	—	1 col/100 mL
Copper (mg/L)	0.0050 U	0.0050 U	—	0.0050 U	0.0050 U	0.0050 U	—	—	0.0050 U	0.0050 U	0.0050 U	—	1.3
Fluoride (mg/L)	0.233	0.221	—	0.287	0.282	0.279	—	—	0.223	0.223	0.199	—	4
Iron (mg/L)[f]	0.0868	0.0595	—	0.0725	0.0836	0.0802	—	—	0.0684	0.0678	0.0564	—	0.3
Manganese (mg/L)[f]	0.0025 U	0.0025 U	—	0.0226	0.0278	0.0292	—	—	0.0025 U	0.0025 U	0.0025 U	—	0.05
Mercury (mg/L)	0.00020 U	0.00020 U	—	0.00020 U	0.00020 U	0.00020 U	—	—	0.00020 U	0.00020 U	0.00020 U	—	0.002
Nitrate, as nitrogen (mg/L)	1.01	—	1.00	0.262	—	—	0.250	0.249	0.767	0.772	—	0.763	10
Nitrite, as nitrogen (mg/L)	0.0500 U	—	0.0805	0.0500 U	—	—	0.0500 U	0.0500 U	0.0500 U	0.0500 U	—	0.0500 U	1
pH	7.96	7.70	7.71	7.96	7.60	7.60	7.67	7.67	7.94	7.94	7.69	7.73	6.5–8.5
Selenium (mg/L)	0.0014	0.0010	—	0.00087	0.00050 U	0.00055	—	—	0.0013	0.0012	0.00085	—	0.05
Silver (mg/L)[f]	0.0050 U	0.0050 U	—	0.0050 U	0.0050 U	0.0050 U	—	—	0.0050 U	0.0050 U	0.0050 U	—	0.1
Sodium (mg/L)	17.6	16.5	—	9.26	9.42	9.48	—	—	9.04	9.16	9.58	—	NA

Table C-6. Idaho Nuclear Technology and Engineering Center New Percolation Ponds Aquifer Monitoring Well Groundwater Results (2012). (cont.)

	ICPP-MON-A-165 (GW-013006)			ICPP-MON-A-166 (GW-013007)					ICPP-MON-A-164B (GW-013011)				PCS/SCS[a]
Sample Date	4/3/2012	9/4/2012	9/11/2012[b]	4/3/2012	9/4/2012	9/4/2012[c]	9/11/2012[b]	9/11/2012[b,c]	4/4/2012	4/4/2012[c]	9/4/2012	9/11/2012[b]	
Total dissolved solids (mg/L)	330	303	—	214	196	192	—	—	249	256	239	—	500
Total Kjeldahl nitrogen (mg/L)	0.100 U	0.153	—	0.133	0.100 U	0.100 U	—	—	0.187	0.177	0.157	—	NA
Total phosphorus (mg/L)	0.0390	0.0195	—	0.0213	0.0249	0.0242	—	—	0.0490	0.0214	0.0191	—	NA

a. Primary constituent standards (PCS) and secondary constituent standards (SCS) in groundwater referenced in Idaho Administrative Procedure Act 58.01.11.200.01.a and b.
b. Sample recollected due to shipping carrier problem.
c. Duplicate sample.
d. NA—Not applicable.
e. Water level elevations referenced to North American Vertical Datum of 1988 (NAVD 88).
f. The results of dissolved concentrations of this parameter are used for secondary constituent standard compliance determinations.
g. U flag indicates the result was reported as below the detection/reporting limit.

Table C-7. Idaho Nuclear Technology and Engineering Center New Percolation Ponds Perched Water Monitoring Well Groundwater Results (2012).

	ICPP-MON-V-191 (GW-013008)		ICPP-MON-V-200 (GW-013009)		ICPP-MON-V-212 (GW-013010)		
Sample Date	4/2/2012	September/ October 2012	4/2/2012	9/5/2012	4/4/2012	9/5/2012	PCS/SCS[a]
Depth to water (ft below brass cap)	110.61	Dry[b]	113.20	119.59	236.14	236.59	NA[c]
Water elevation at brass cap (ft)[d]	4,837.35	—	4,839.77	4,833.38	4,722.20	4,721.75	NA
Aluminum (mg/L)[e]	4.98[f]	—	0.0250 U[g]	0.0250 U	0.0250 U	0.0385	0.2
Arsenic (mg/L)	0.0026	—	0.0063	0.0050	0.0018	0.0031	0.05
Biochemical oxygen demand (mg/L)	3.25	—	2.0 U	2.0 U	2.0 U	2.0 U	NA
Cadmium (mg/L)	0.0025 U	—	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.005
Chloride (mg/L)	3.06	—	40.1	36.7	65.0	58.7	250
Chromium (mg/L)	0.0187	—	0.0056	0.0072	0.0053	0.0219	0.1
Coliform, fecal (colonies/100 mL)	Absent	—	Absent	Absent	Absent	Absent	NA
Coliform, total (colonies/100 mL)	Absent	—	Absent	Absent	Absent	Absent	1 col/100 mL
Copper (mg/L)	0.0240	—	0.0050 U	0.0050 U	0.0050 U	0.0050 U	1.3
Fluoride (mg/L)	0.260	—	0.236	0.253	0.292	0.282	4
Iron (mg/L)[e]	3.99[f]	—	0.0734	0.0500 U	0.0720	0.143	0.3
Manganese (mg/L)[e]	0.338[f]	—	0.0025 U	0.0025 U	0.0025 U	0.0040	0.05
Mercury (mg/L)	0.00020 U	—	0.00020 U	0.00020 U	0.00020 U	0.00020 U	0.002
Nitrate, as nitrogen (mg/L)	0.293	—	2.56	1.82	2.60	2.18	10
Nitrite, as nitrogen (mg/L)	0.0500 U	—	0.0744	0.0500 U	0.0756	0.0812	1
pH	7.70	—	7.72	7.58	7.78	7.67	6.5–8.5
Selenium (mg/L)	0.0012	—	0.0014	0.00095	0.0014	0.00093	0.05
Silver (mg/L)[e]	0.0050 U	—	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.1
Sodium (mg/L)	8.62	—	36.4	42.8	56.5	54.6	NA
Total dissolved solids (mg/L)	240	—	308	287	352	334	500

Table C-7. Idaho Nuclear Technology and Engineering Center New Percolation Ponds Perched Water Monitoring Well Groundwater Results (2012). (cont.)

Total Kjeldahl nitrogen (mg/L)	1.08	—	0.132	0.100 U	0.235	0.105	NA
Total phosphorus (mg/L)	0.327	—	0.111	0.0985	0.0430	0.104	NA

a. Primary constituent standards (PCS) and secondary constituent standards (SCS) in groundwater referenced in Idaho Administrative Procedures Act 58.01.11.200.01.a and b.
b. ICPP-MON-V-191 was dry in September/October 2012.
c. NA—Not applicable.
d. Water level elevations referenced to North American Vertical Datum of 1988 (NAVD 88).
e. The results of dissolved concentrations of this parameter are used for secondary constituent standard compliance determinations.
f. Exceedance of groundwater quality standard. Well ICPP-MON-V-191 is an upgradient, noncompliance point, and is outside the zone of influence of the New Percolation Ponds. Therefore, exceedances in this well are not considered permit noncompliances.
g. U flag indicates the result was reported as below the detection/reporting limit.

Table C-8. Materials and Fuels Complex Industrial Waste Pipeline Monitoring Results (2012).[a]

Parameter	Minimum	Maximum	Median
Arsenic (mg/L)	0.0025 U[b]	0.005	0.0025 U
Barium (mg/L)	0.0277	0.0394	0.0371
Cadmium (mg/L)	0.001 U	0.001 U	0.001 U
Chloride (mg/L)	21.4	65.5	36.4
Chromium (mg/L)	0.0025 U	0.0029	0.0025 U
Fluoride (mg/L)	0.553	0.661	0.623
Lead (mg/L)	0.00025 U	0.00054	0.00026
Mercury (mg/L)	0.0002 U	0.0002 U	0.0002 U
Nitrogen, nitrate + nitrite (mg-N/L)	1.9	2.5	2.05
Nitrogen, total Kjeldahl (mg/L)	0.1 U	4.88	0.266
pH (standard units)	7.77	8.85	8.375
Phosphorus, total (mg/L)	0.0658	0.342	0.105
Selenium (mg/L)	0.0005 U	0.0036	0.00066
Silver (mg/L)	0.005 U	0.0069	0.005 U
Sulfate (mg/L)	17	23.5	18
Total dissolved solids (mg/L)	250	347	289
Zinc (mg/L)	0.0058	0.0232	0.0076

a. Duplicate samples were collected in June and the results for the duplicate samples are included in the data summary.
b. U flag indicates the result was below the detection limit.

Table C-9. Materials and Fuels Complex Industrial Wastewater Underground Pipe Monitoring Results (2012).

Parameter	Minimum	Maximum	Median
Arsenic (mg/L)	0.0034	0.0101	0.0062
Barium (mg/L)	0.0764	0.176	0.110
Cadmium (mg/L)	0.001 U[a]	0.001 U	0.001 U
Chloride (mg/L)	43.3	127	44.45
Chromium (mg/L)	0.0042	0.0217	0.0075
Fluoride (mg/L)	1.36	2.84	1.425
Lead (mg/L)	0.00041	0.0048	0.0019
Mercury (mg/L)	0.0002 U	0.0002 U	0.0002 U
Nitrogen, nitrate + nitrite (mg-N/L)	4.33	12.7	4.365
Nitrogen, total Kjeldahl (mg/L)	0.555	0.816	0.6975
pH (standard units)	7.68	8.71	8.015
Phosphorus, total	0.801	1.34	1.1255
Selenium (mg/L)	0.0012	0.0028	0.00125
Silver (mg/L)	0.005 U	0.005 U	0.005 U
Sulfate (mg/L)	37.6	98.2	39.9
Total dissolved solids (mg/L)	527	1050	546
Zinc (mg/L)	0.0245	0.108	0.03435

a. U flag indicates the result was below the detection limit.

Table C-10. Summary of Groundwater Quality Data Collected for the Wastewater Reuse Permit for the MFC Industrial Waste Ditch and Pond.

WELL NAME	ANL-MON-A-012 (GW-016001)		ANL-MON-A-013 (GW-016002)		ANL-MON-A-014 (GW-016003)		PCS/SCS[a]
Sample Date:	05/23/2012	09/25/2012	05/23/2012	09/25/2012	05/23/2012	09/25/2012	
Water Table Depth (ft bgs)	656.96	659.06	645.48	647.61	644.50	646.57	NA[b]
Water Table Elevation (ft above mean sea level)	4475.74	4473.64	4474.89	4472.76	4473.58	4471.51	NA
pH	8.34	8.10	8.19	8.07	8.19	8.08	6.5 to 8.5 (SCS)
Temperature (°C)	13.5	13.4	13.5	13.6	13.3	13.6	None
Conductivity (µS/cm)	364	360	375	365	371	362	None
Nitrate nitrogen (mg/L)	1.93	1.97	2.02	2.03	2.00 [2.00][c]	2.01	10 (PCS)
Phosphorus (mg/L)	0.0125	0.015	0.0139	0.0145	0.0128[0.0234]	0.0143	None
Total dissolved solids (mg/L)	238	234	251	235	252 [254]	234	500 (SCS)
Sulfate (mg/L)	16.8	16.7	19.2	18.3	18.6 [18.5]	17.5	250 (SCS)
Arsenic (µg/L)	1.7	2.7	2.1	2.7	1.6 [1.8]	2.7	50 (PCS)
Barium (µg/L)	36.6	39.7	34.1	35.4	34.2 [34.7]	36.1	2000 (PCS)
Cadmium (µg/L)	0.25 U[d]	0.25 U	0.25 U	0.25 U	0.25 U [0.25 U]	0.25 U	5 (PCS)
Chloride (mg/L)	17.3	17.9	19	18	18.7 [18.7]	18.5	250 (SCS)
Chromium (µg/L)	3.5	4.1	3.4	3.2	3.9 [3.6]	2.5 U	100 (PCS)
Iron (µg/L)	93.8	114	127	170	88.6 [183]	124	300 (SCS)
Lead (µg/L)	0.5 U	0.5 U	0.6	0.5 U	0.5 U [0.76]	0.5 U	15 (PCS)
Manganese (µg/L)	3.2	2.5 U	2.6	2.6	2.5 U [2.8]	2.5 U	50 (SCS)
Mercury (µg/L)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U [0.2 U]	0.2 U	2 (PCS)
Selenium (µg/L)	0.54	0.68	0.55	0.58	0.57 [0.64]	0.55	50 (PCS)
Silver (µg/L)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U [5.0 U]	5.0 U	100 (SCS)
Sodium (µg/L)	18,300	17,700	19,200	18,200	18,200 [18,300]	17,300	None
Zinc (µg/L)	4.3	4.1	2.5 U	2.5 U	2.5 U [6.0]	2.5 U	5000 (SCS)

a. Primary Constituent Standard (PCS) or Secondary Constituent Standard (SCS) from IDAPA 58.01.11 (Ground Water Quality Rule).
b. NA-Not applicable.
c. Concentrations shown in brackets are the results from field duplicate samples.
d. U flag indicates the result was reported as below the instrument detection limit by the analytical laboratory.

Table C-11. Advanced Test Reactor Complex Cold Waste Pond Results (2012).[a]

Parameter	Minimum	Maximum	Median
Antimony (mg/L)	0.00025 U[b]	0.0015	0.00025 U
Gross alpha (pCi/L ± 1s)	0.208 ± 0.522 U	4.15 ± 1.23	Not calculated
Gross beta (pCi/L ± 1s)	1.19 ± 1.04 U	15.8 ± 1.79	Not calculated
pH (standard units)	7.2	8.36	8.12
Potassium-40 (pCi/L ± 1s)	-18.2 ± 10.8 U	39.2 ± 6.94	Not calculated
Sodium (mg/L)	7.96	33.9	9.84

a. Only parameters with at least one detected result are shown. Field duplicates for non-radiological analyses were collected in January and duplicates for radiological analyses were collected in February. The results for the duplicate samples are included in the data summary.

b. U flag indicates the result was below the detection limit.

Table C-12. Radioactivity Detected in Groundwater Samples Collected at the Advanced Test Reactor Complex (2012).

Monitoring Well	Sample Date	Parameter	Sample Result (pCi/L)
USGS-065	04/12/12	Gross Alpha	1.98 (± 0.493)[a]
		Gross Beta	4.83 (± 0.797)
		Tritium	3,550 (± 450)
	10/08/12	Gross Alpha	1.69 (± 0.717) 2.98[b] (± 1.17)
		Gross Beta	6.63 (± 1.15) 5.08[b] (± 1.23)
		Tritium	3,500 (± 382) 4,000[b] (± 430)
TRA-07	04/09/12	Gross Alpha	3.58 (± 0.739)
		Gross beta	8.08 (± 0.966)
		Tritium	9,870 (± 1,010)
	10/09/12	Tritium	8,130 (± 833)
TRA-08	04/18/12	Gross Alpha	14.3 (± 2.14)
		Gross Beta	28.5 (± 2.63)
		Radium-228	3.23 (± 0.537)
		Tritium	1,510 (± 197)
	10/08/12	Gross Alpha	6 (± 1.6)
		Gross Beta	6.95 (± 1.56)
		Radium-226	1.25 (± 0.282)
		Tritium	1,520 (± 197)
USGS-076	04/12/12	Tritium	368 (± 124)
	10/08/12	Gross Beta	4.45 (± 1.01)
		Tritium	590 (± 124)
Middle-1823	04/09/12	Gross Beta	3.45 (± 0.753)
		Tritium	1,270 (± 198)
	10/09/12	Gross Alpha	3.61 (± 1.17)
		Tritium	1,010 (± 155)

a. One sigma uncertainty shown in parentheses.
b. Analytical result from field duplicate sample collected on October 8, 2012.

Table C-13. Liquid Influent and Effluent and Groundwater Surveillance Monitoring Results for Idaho Nuclear Technology and Engineering Center (2012).

Parameter[a]	Minimum	Maximum	Average[b]
Influent to INTEC Sewage Treatment Plant (CPP-769)			
Conductivity (µS/cm) (grab)	191	2,310	891
pH (standard units) (grab)	8.19	8.65	8.45
Effluent from INTEC Sewage Treatment Plant (CPP-773)			
Conductivity (µS/cm) (grab)	855	1,999	1,264
Gross beta (pCi/L ± 2s uncertainty)	9.0 ± 1.82	15.8 ± 4.04	10.7 ± 1.51
pH (standard units) (composite)	7.31	9.40	8.40
Effluent to INTEC New Percolation Ponds (CPP-797)			
Conductivity (µS/cm) (grab)	256	617	429
Gross alpha (pCi/L ± 2s uncertainty)	-0.40 ± 0.61[c]	5.09 ± 2.94	0.96 ± 0.43
Gross beta (pCi/L ± 2s uncertainty)	-1.31 ± 1.90[c]	8.06 ± 2.90	4.83 ± 0.79
pH (standard units) (composite)	7.71	8.06	7.92
Groundwater at INTEC New Percolation Ponds			
Gross alpha (pCi/L ± 2s uncertainty)	0.71 ± 1.34[c]	3.86 ± 2.18	1.98 ± 0.57
Gross beta (pCi/L ± 2s uncertainty)	0.54 ± 0.84	8.34 ± 3.12	2.43 ± 0.50

a. Only parameters with at least one detected result are shown.
b. For nonradiological parameters, half the reported detection limit is used in the average calculation for those data reported as below detection. Radiological average calculations are weighted by uncertainty.
c. Result was a statistical nondetect.

Table C-14. Monitoring Results for Materials and Fuels Complex Industrial Waste Pond (2012).[a]

Parameter	Minimum	Maximum
Potassium-40 (pCi/L ± 1s)	-14.7 ± 9.85 U[b]	45.5 ± 8.34
Gross alpha (pCi/L ± 1s)	0.268 ± 0.372 U	2.98 ± 0.552
Gross beta (pCi/L ± 1s)	2.75 ± 0.822	4.93 ± 1.29
Uranium-233/234[c] (pCi/L ± 1s)	1.21 ± 0.127	1.21 ± 0.127
Uranium-238[c] (pCi/L ± 1s)	0.562 ± 0.0744	0.562 ± 0.0744

a. Only parameters with at least one detected result are shown. Field duplicates were collected in April and the results for the duplicate samples are included in the data summary.
b. U flag indicates the result was below the detection limit.
c. Parameter was analyzed in August only; therefore, the minimum and maximum are the same.

Table C-15. Surveillance Monitoring Results for Materials and Fuels Complex Secondary Sanitary Lagoon (2012).[a]

Parameter	Minimum	Maximum	Median
Barium[b] (mg/L)	0.0603	0.0603	Not calculated
Chemical Oxygen Demand[b] (mg/L)	219	219	Not calculated
Chloride (mg/L)[b]	160	160	Not calculated
Fluoride (mg/L)[b]	0.211	0.211	Not calculated
Iron (mg/L)[b]	0.228	0.228	Not calculated
Manganese[b] (mg/L)	0.0546	0.0546	Not calculated
Nitrogen, nitrate + nitrite[b] (mg-N/L)	0.256	0.256	Not calculated
Nitrogen, total Kjeldahl[b] (mg/L)	18.7	18.7	Not calculated
Selenium[b] (mg/L)	0.0011	0.0011	Not calculated
Sodium[b] (mg/L)	121	121	Not calculated
Sulfate[b] (mg/L)	55.9	55.9	Not calculated
Total dissolved solids[b] (mg/L)	888	888	Not calculated
Total phosphorus[b] (mg/L)	6.83	6.83	Not calculated
Total suspended solids[b] (mg/L)	54.4	54.4	Not calculated
Zinc[b] (mg/L)	0.0088	0.0088	Not calculated
Gross alpha (pCi/L ± 1s)	0.379 ± 0.566 U[c]	2.29 ± 0.613	
Gross beta (pCi/L ± 1s)	30.3 ± 3.04	56.3 ± 4.42	Not calculated
Potassium-40 (pCi/L ± 1s)	33.9 ± 11.8	69.7 ± 11.3	Not calculated
Uranium-233/234[b] (pCi/L ± 1s)	0.098 ± 0.0372	0.098 ± 0.0372	Not calculated

a. Only parameters with at least one detected result are shown.
b. Parameter was only analyzed in the samples collected in August; therefore the minimum and maximum are the same.
c. U flag indicates the result was below the detection limit.

Turn of the Century Cast Iron Stove Part

Appendix D. In Situ Soil and Onsite Dosimeter Measurements and Locations

Figure D-1. In Situ Soil Measurements at Auxiliary Reactor Area (2012).

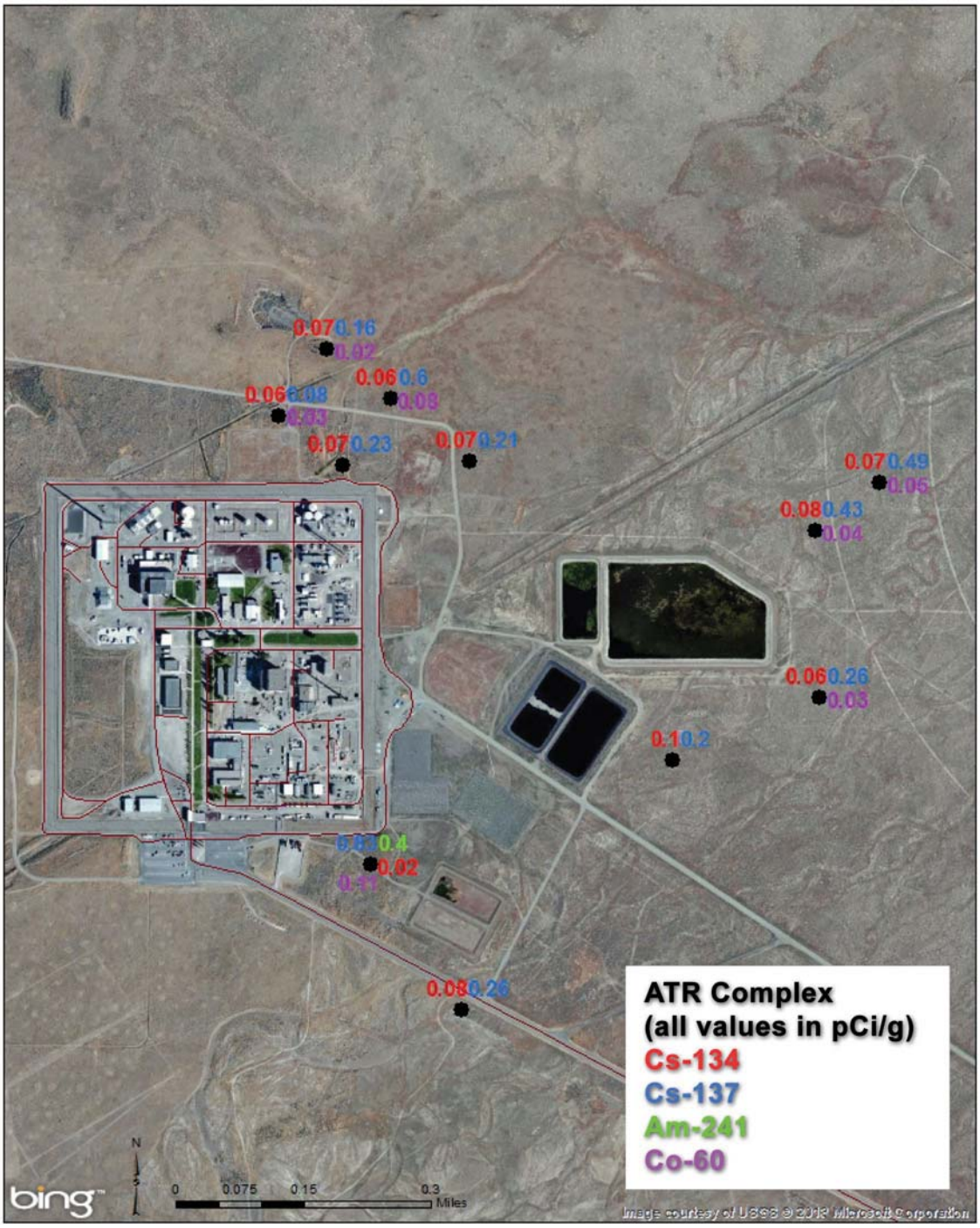

Figure D-2. In Situ Soil Measurements at Advanced Test Reactor Complex (2012).

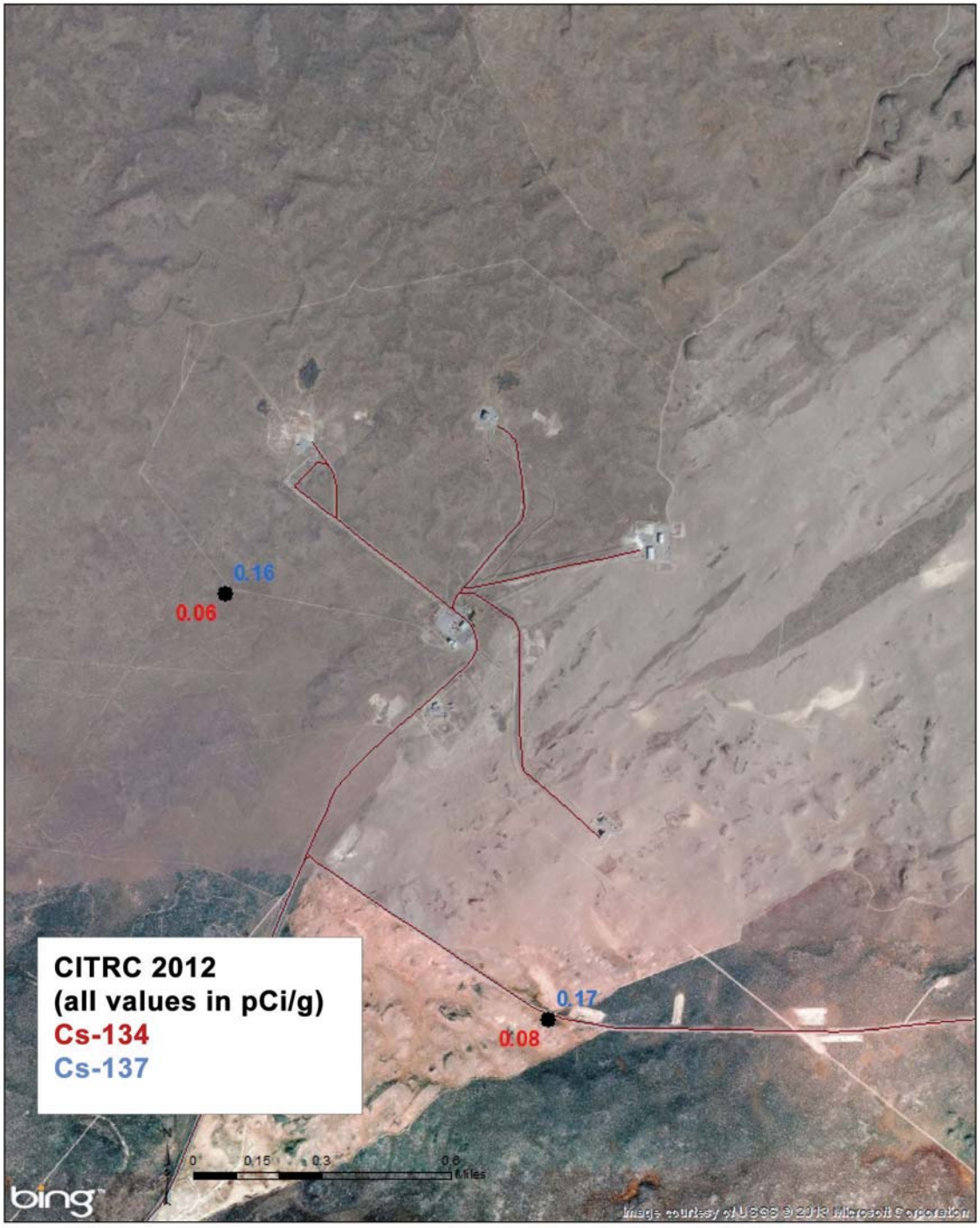

Figure D-3. In Situ Soil Measurements at Critical Infrastructure Test Range Complex (2012).

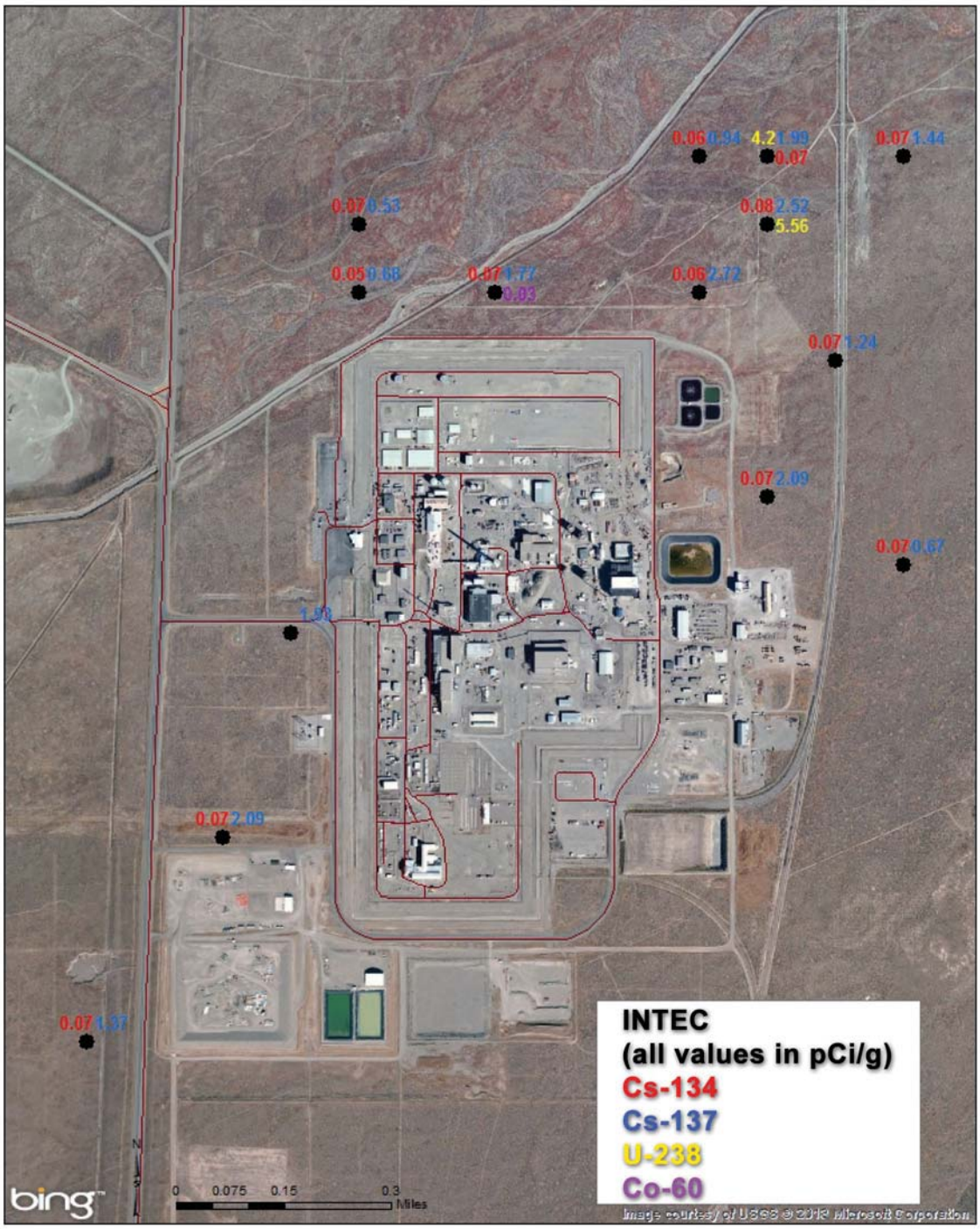

Figure D-4. In Situ Soil Measurements at Idaho Nuclear Technology and Engineering Center (2012).

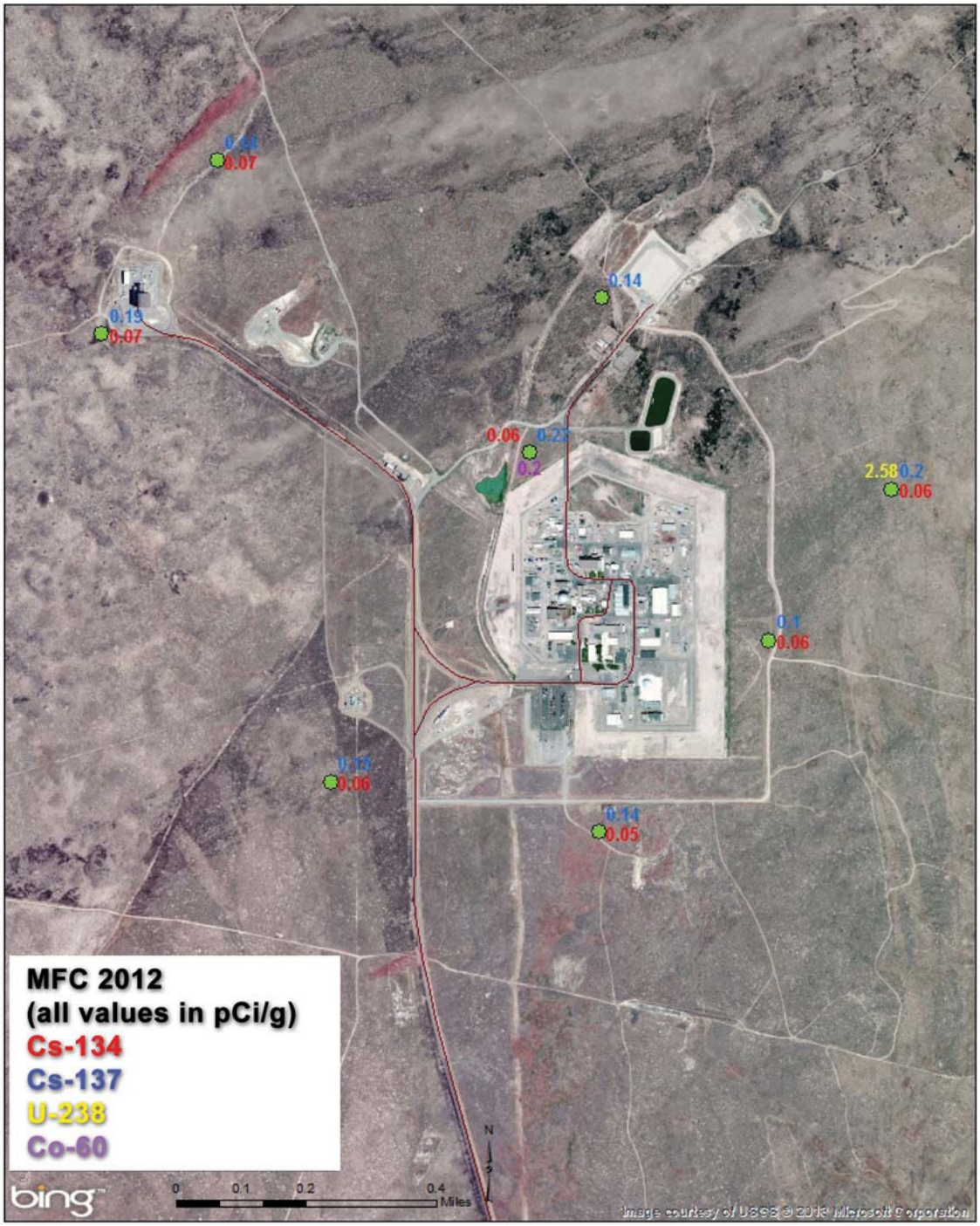

Figure D-5. In Situ Soil Measurements at Materials and Fuels Complex (2012).

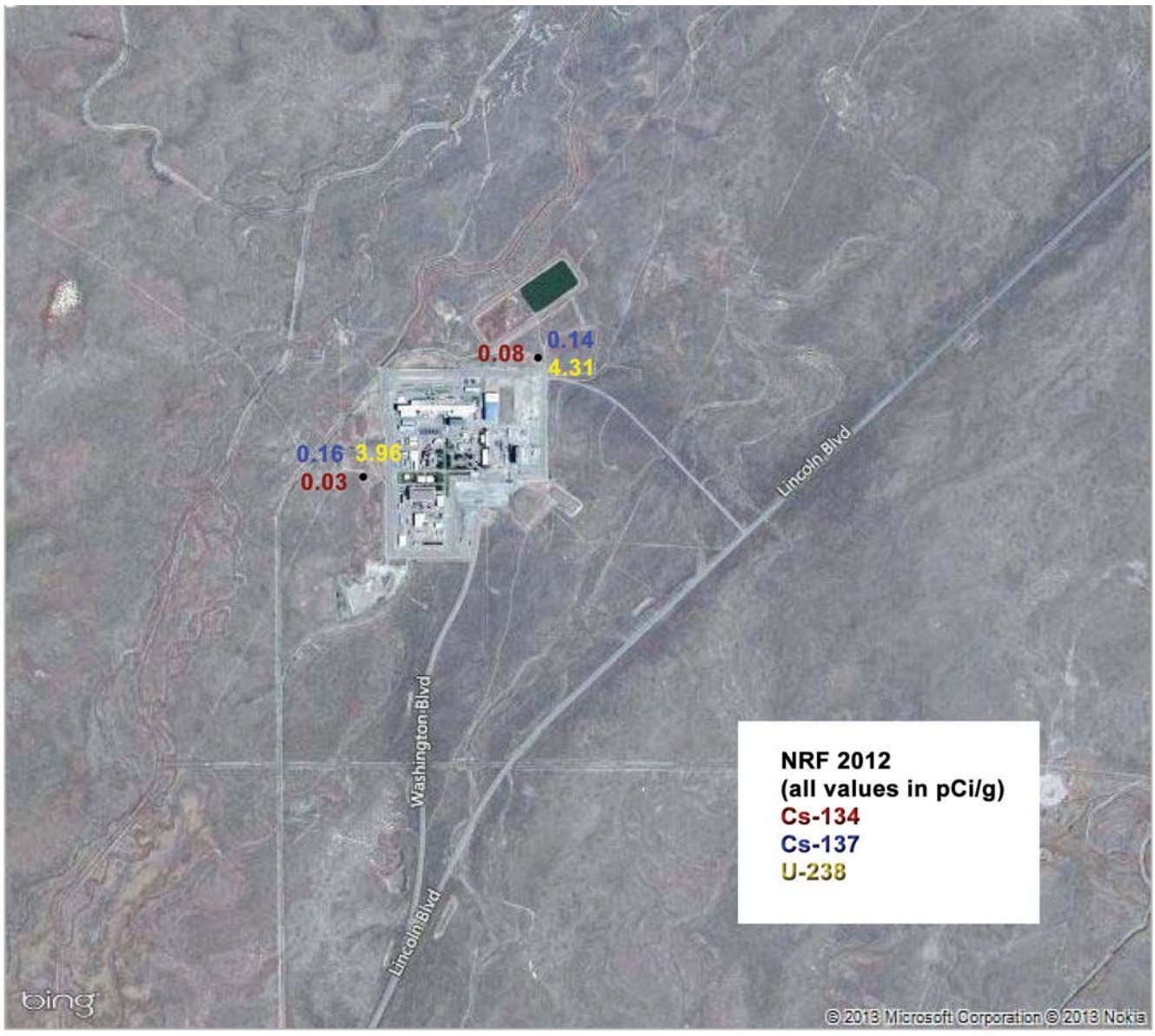

Figure D-6. In Situ Soil Measurements at Naval Reactors Facility (2012).

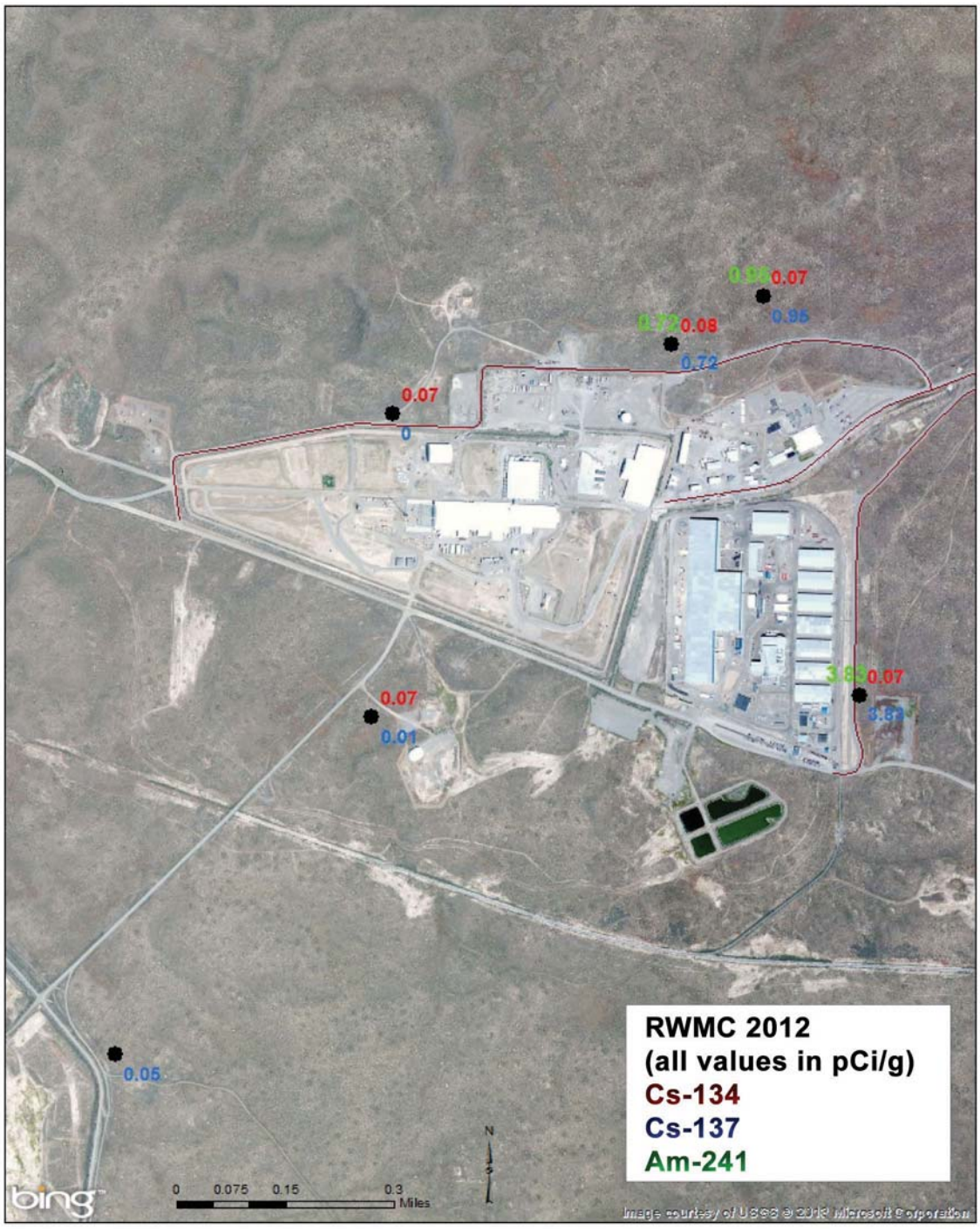

Figure D-7. In Situ Soil Measurements at Radioactive Waste Management Complex (2012).

Figure D-8. In Situ Soil Measurements at Test Area North (2012).

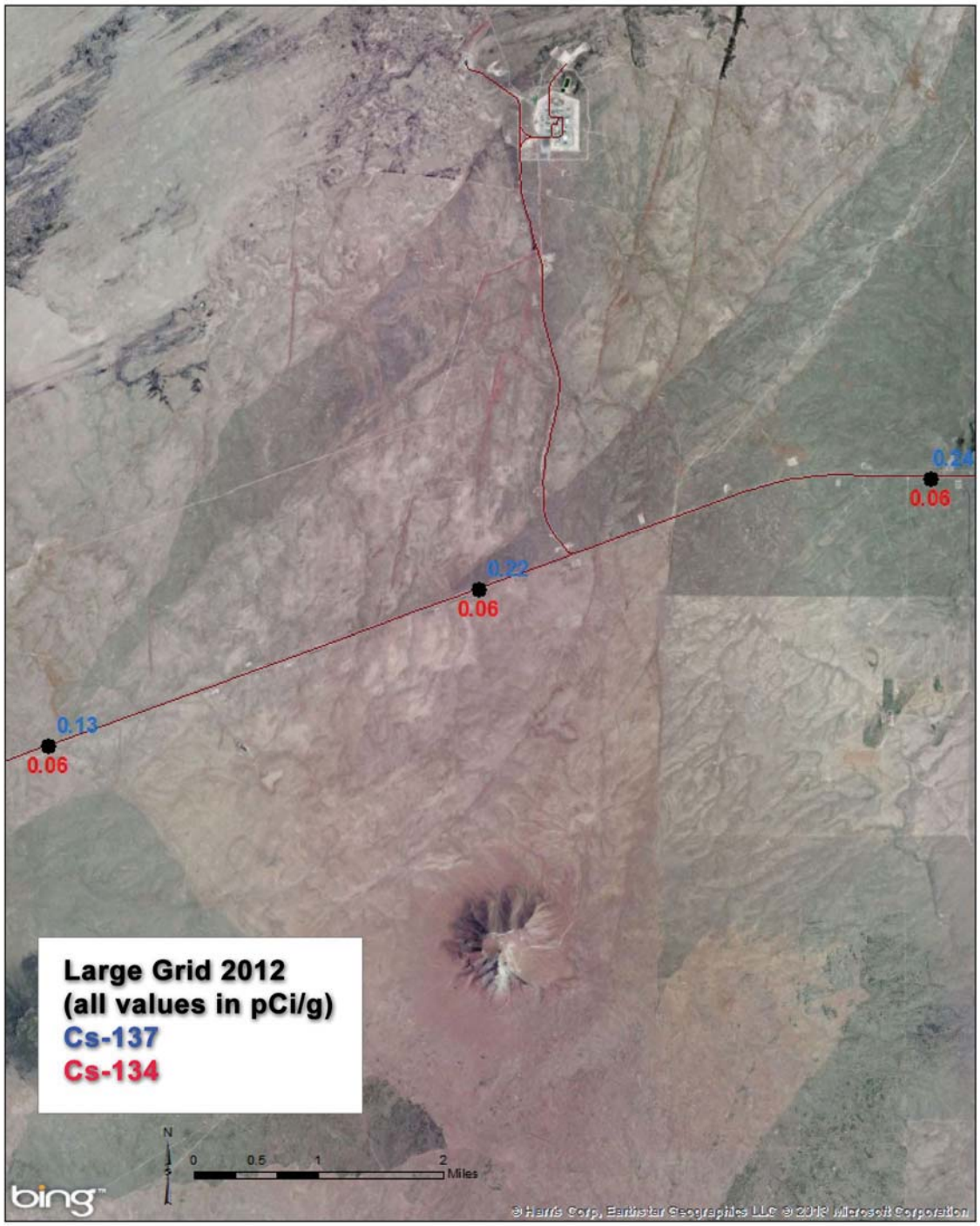

Figure D-9. In Situ Soil Measurements at Large Grid Locations (2012).

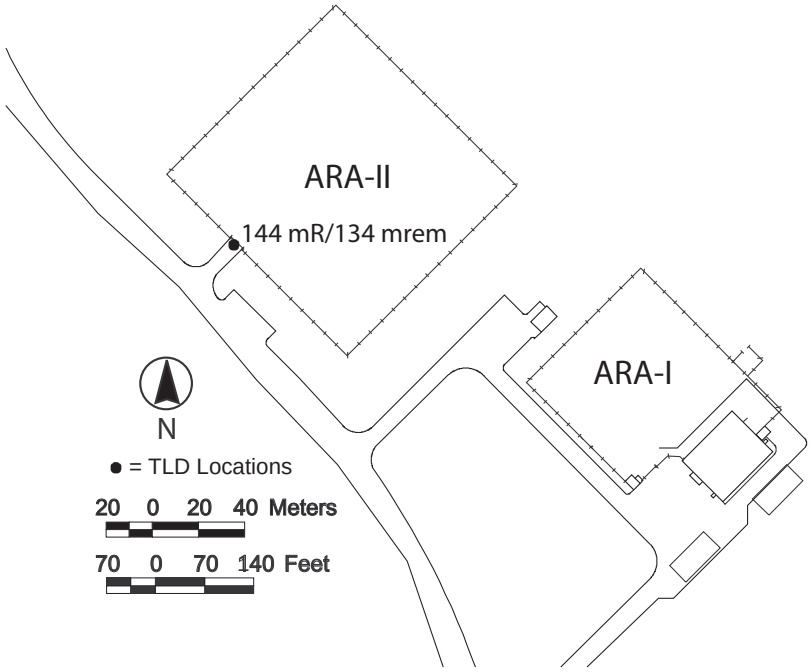

Figure D-10. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Auxiliary Reactor Area (2012).

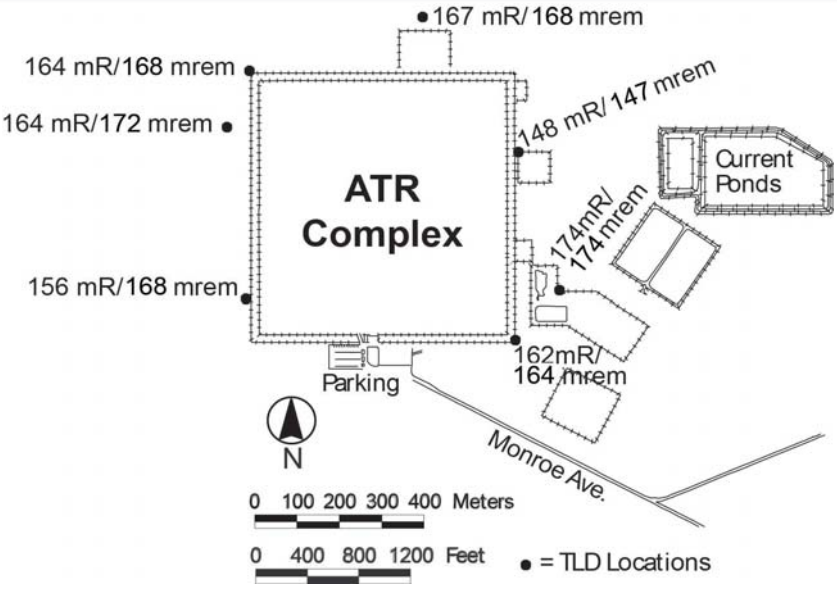

Figure D-11. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Advanced Test Reactor Complex (2012).

[1] OSLD result includes the dose accumulated during transit to Glenwood Illinois for dosimeter reading. See Section 7.3, Footnote 1, of this report.

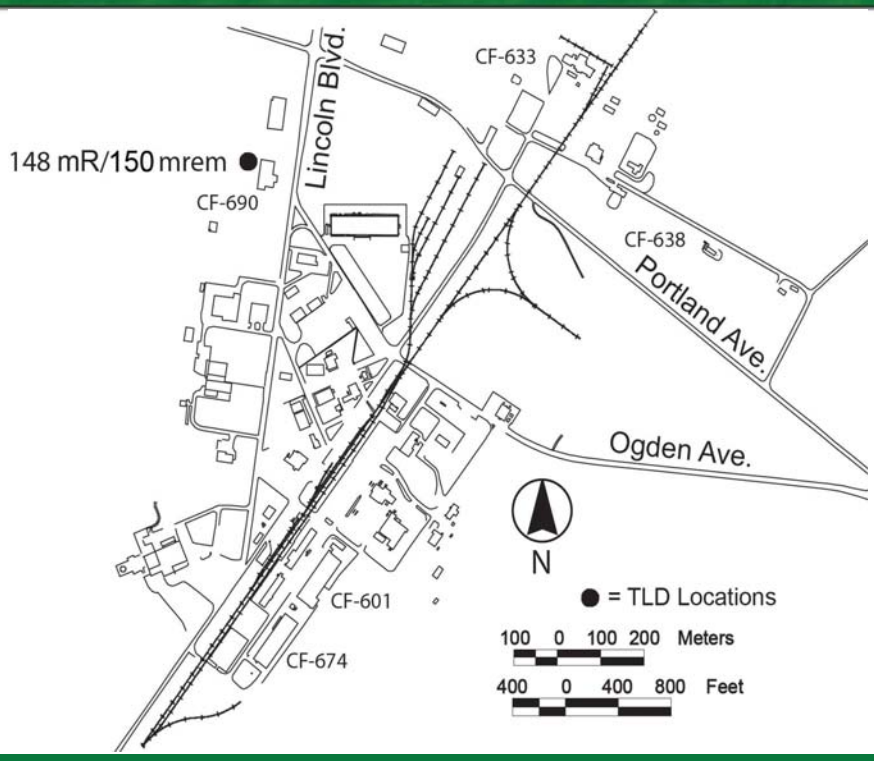

Figure D-12. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Central Facilities Area (2012).

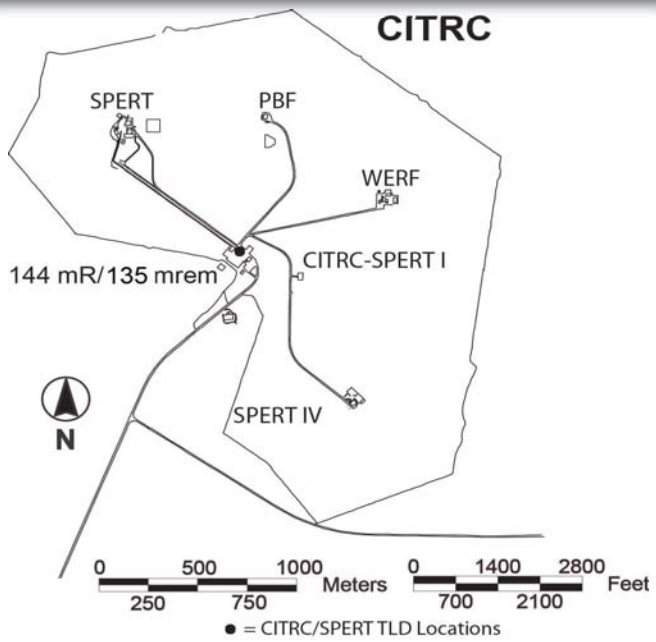

Figure D-13. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Critical Infrastructure Test Range Complex (2012).

[1] OSLD result includes the dose accumulated during transit to Glenwood Illinois for dosimeter reading. See Section 7.3, Footnote 1, of this report.

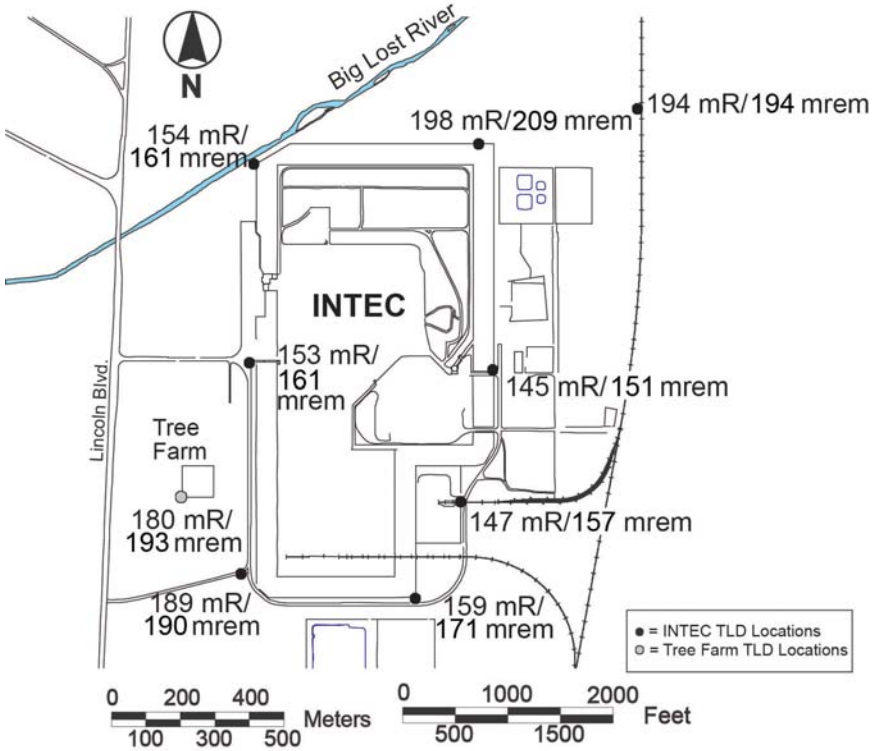

Figure D-14. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at at Idaho Nuclear Technology and Engineering Center (2012).

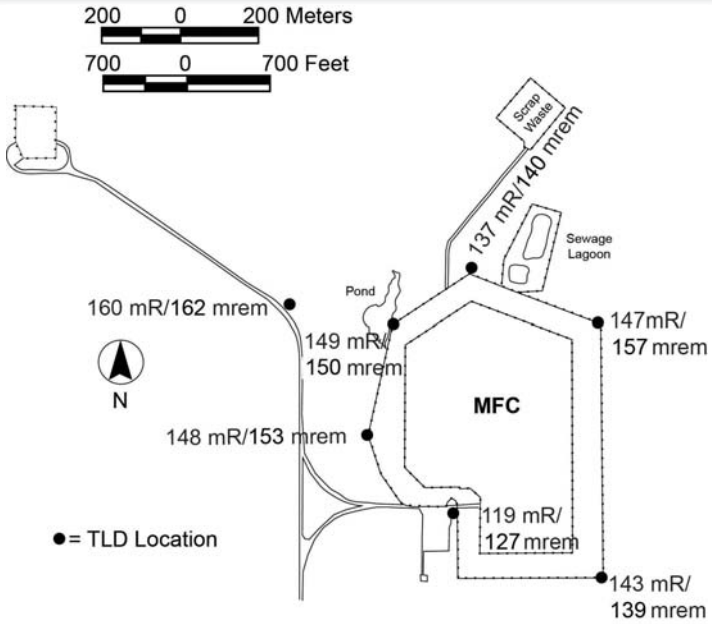

Figure D-15. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Materials and Fuels Complex (2012).

[1] OSLD result includes the dose accumulated during transit to Glenwood Illinois for dosimeter reading. See Section 7.3, Footnote 1, of this report.

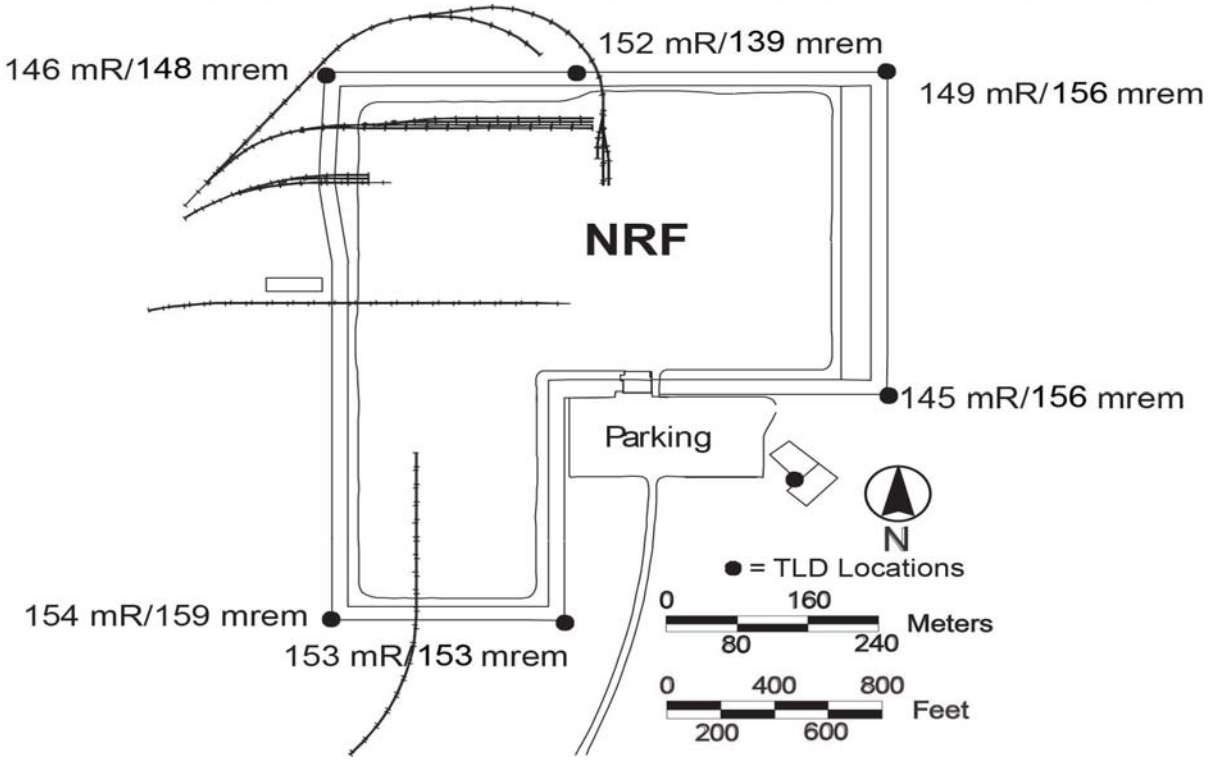

Figure D-16. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Naval Reactors Facility (2012).

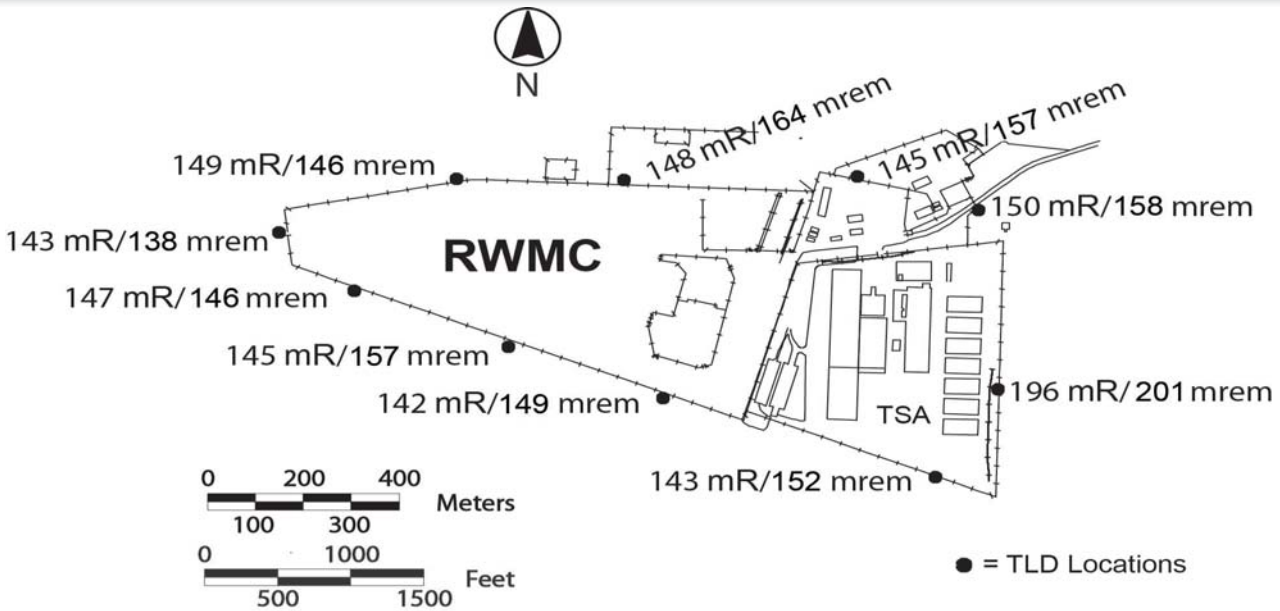

Figure D-17. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Radioactive Waste Management Complex (2012).

[1] OSLD result includes the dose accumulated during transit to Glenwood Illinois for dosimeter reading. See Section 7.3, Footnote 1, of this report.

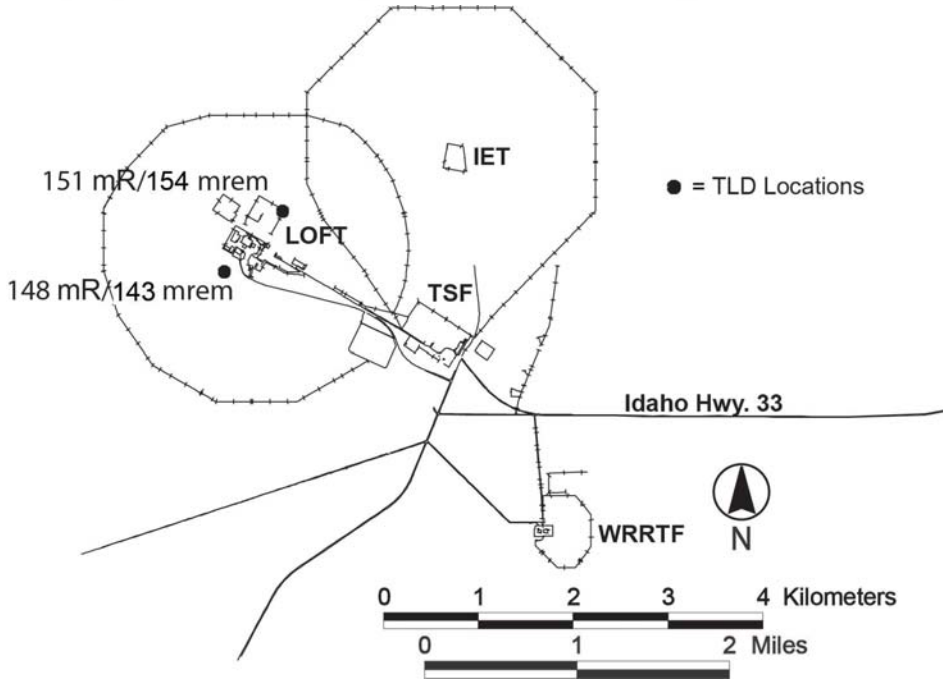

Figure D-18. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Test Area North (2012).

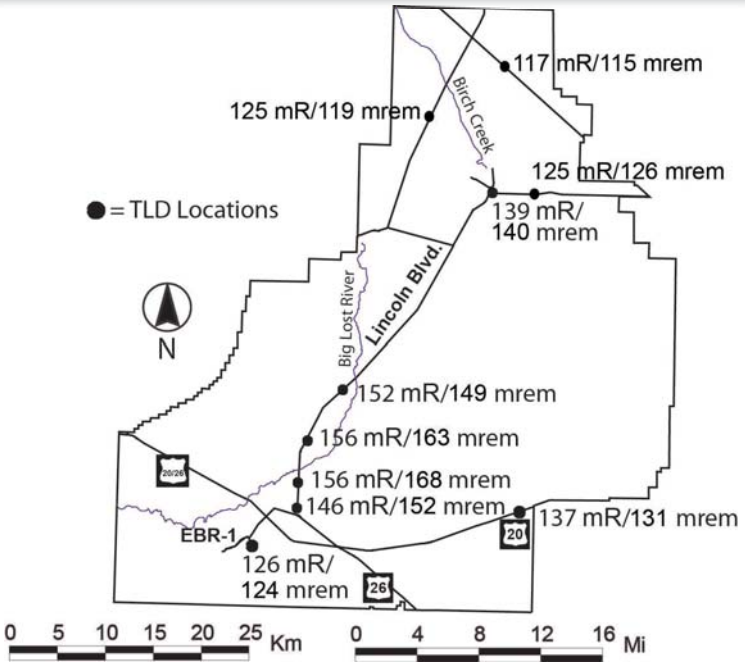

Figure D-19. Environmental Radiation Measurements (TLD Result [mR]/OSLD Result[1] [mrem]) at Sitewide Locations (2012).

[1] OSLD result includes the dose accumulated during transit to Glenwood Illinois for dosimeter reading. See Section 7.3, Footnote 1, of this report.

Table D-1. INL Contractor Environmental Radiation Measurements (November 2011 through November 2012).

Location	November 2011-April 2012 (TLD), mR ± 2σ	November 2 011-April 2012 (OSLD), mrem ± 2σ	May 2012-November 2012 (TLD), mR ± 2σ	May 2012-November 2012 (OSLD), mrem ± 2σ
INL Onsite Group				
ANL W EBR II, O-7	78 ± 15	76 ± 8	71 ± 14	77 ± 7
ANL W EBR II, O-12	64 ± 13	61 ± 6	55 ± 11	66 ± 6
ANL W EBR II, O-13	75 ± 15	69 ± 7	68 ± 13	70 ± 7
ANL W EBR II, O-15			74 ± 14	79 ± 7
ANL W EBR II, O-17	70 ± 14	70 ± 7	67 ± 13	70 ± 7
ANL W EBR II, O-18	77 ± 15	74 ± 7	72 ± 14	76 ± 7
ANL W TREAT, O-9	86 ± 17	80 ± 8	74 ± 14	82 ± 8
ARA-I II, O-1	75 ± 15	67 ± 7	69 ± 13	
CFA, O-1	77 ± 15	74 ± 7	70 ± 14	76 ± 7
EBR-I, O-1	67 ± 13	62 ± 6	59 ± 12	62 ± 6
Hwy 20, Mile 276, O-276	71 ± 14	65 ± 7	67 ± 13	66 ± 6
ICPP, O-9	101 ± 20	97 ± 10	96 ± 18	97 ± 9
ICPP, O-15	102 ± 20	103 ± 10	96 ± 19	107 ± 10
ICPP, O-17	81 ± 16	79 ± 8	73 ± 14	82 ± 8
ICPP, O-19	80 ± 16	81 ± 8	74 ± 14	80 ± 8
ICPP, O-21	98 ± 19	95 ± 10	91 ± 18	96 ± 9
ICPP, O-23	83 ± 16	78 ± 8	76 ± 15	93 ± 9
ICPP, O-25	77 ± 15	85 ± 9	70 ± 14	72 ± 7
ICPP, O-26	76 ± 15	78 ± 8	69 ± 14	73 ± 7
Hwy 22, T28, O-1	66 ± 13	58 ± 11		60 ± 6
Hwy 28, N2300, O-2	61 ± 12	56 ± 11	53 ± 5	62 ± 6
Hwy 33, T17, O-3	65 ± 13	60 ± 12	60 ± 6	66 ± 6
ICPP Tree Farm, O-3	95 ± 19	93 ± 9	85 ± 17	100 ± 10
Lincoln Blvd, O-1	77 ± 15	79 ± 8	69 ± 14	73 ± 7
Lincoln Blvd, O-3	81 ± 16	87 ± 9	75 ± 15	81 ± 8
Lincoln Blvd, O-5	81 ± 16	81 ± 8	75 ± 15	82 ± 8
Lincoln Blvd, O-9	80 ± 16	79 ± 8	73 ± 14	71 ± 7
Lincoln Blvd, O-25	72 ± 14	76 ± 8	66 ± 13	64 ± 6
NRF, O-4	79 ± 15	71 ± 7	70 ± 14	85 ± 8
NRF, O-5	79 ± 15	77 ± 8	74 ± 14	61 ± 6
NRF, O-12	76 ± 15	77 ± 8	69 ± 13	78 ± 7
NRF, O-16	76 ± 15	69 ± 7	71 ± 14	78 ± 7
NRF, O-19	81 ± 16	80 ± 8	73 ± 14	
NRF, O-20	79 ± 16	76 ± 8	74 ± 15	78 ± 7
PBF SPERT, O-1	75 ± 15	72 ± 7	69 ± 14	63 ± 6
RWMC, O-39	80 ± 16	80 ± 8	71 ± 14	78 ± 7
RWMC, O-41	104 ± 20	103 ± 10	92 ± 18	98 ± 9
RWMC, O-43	76 ± 15	73 ± 7	67 ± 13	79 ± 8
RWMC, O-46	76 ± 15	75 ± 8	69 ± 14	82 ± 8
RWMC, O-9A	77 ± 15	86 ± 9	70 ± 14	79 ± 8

Table D-1. INL Contractor Environmental Radiation Measurements (November 2011 through November 2012). (cont.)

Location	November 2011-April 2012 (TLD), mR ± 2σ	November 2 011-April 2012 (OSLD), mrem ± 2σ	May 2012-November 2012 (TLD), mR ± 2σ	May 2012-November 2012 (OSLD), mrem ± 2σ
RWMC, O-13A	79 ± 15	66 ± 7	70 ± 14	81 ± 8
RWMC, O-17A	75 ± 15	72 ± 7	68 ± 14	67 ± 6
RWMC, O-21A	76 ± 15	77 ± 8	71 ± 14	68 ± 6
RWMC, O-25A	75 ± 15	79 ± 8	70 ± 14	77 ± 7
RWMC, O-29A	74 ± 15	71 ± 7	68 ± 13	78 ± 7
TAN-LOFT, O-6	78 ± 15	69 ± 7	70 ± 14	74 ± 7
TAN-LOFT, O-7	82 ± 16	77 ± 8	69 ± 14	78 ± 7
TRA, O-2	85 ± 17	81 ± 8	76 ± 15	83 ± 8
TRA, O-4	93 ± 18	90 ± 9	81 ± 16	85 ± 8
TRA, O-6	78 ± 15	71 ± 7	70 ± 14	76 ± 7
TRA, O-8	86 ± 17	81 ± 8	81 ± 16	88 ± 8
TRA, O-10	85 ± 17	85 ± 9	79 ± 16	83 ± 8
TRA, O-11	84 ± 17	83 ± 8	79 ± 16	89 ± 9
TRA, O-13	82 ± 16	81 ± 8	74 ± 15	87 ± 8
INL REC Group				
Idaho Falls IF-627, O-30	60 ± 12	57 ± 6	57 ± 11	62 ± 6
Idaho Falls IF-675E, O-31	59 ± 12	55 ± 6	54 ± 11	57 ± 5
Idaho Falls IF-675 O-33			54 ± 11	59 ± 5
Idaho Falls IF-675 O-34			58 ± 11	63 ± 6
Idaho Falls IF-675 O-35			58 ± 11	64 ± 6
INL Boundary Group				
Arco	70 ± 14	65 ± 7	64 ± 13	68 ± 6
Atomic City	69 ± 13	71 ± 7	63 ± 12	67 ± 6
Howe	70 ± 14	64 ± 6	58 ± 11	
Monteview	65 ± 13	65 ± 7	66 ± 13	66 ± 6
Mud Lake	74 ± 15	62 ± 6	68 ± 13	69 ± 7
Reno Ranch	63 ± 12	56 ± 6	56 ± 11	62 ± 6
INL Distant Group				
Aberdeen	71 ± 14	69 ± 7	64 ± 13	70 ± 7
Blackfoot (Mountain View)	62 ± 12	57 ± 6	62 ± 12	68 ± 6
Craters of the Moon	67 ± 13	66 ± 7	69 ± 14	74 ± 7
Idaho Falls	65 ± 13	65 ± 7	69 ± 13	67 ± 6
Minidoka	64 ± 13	68 ± 7	65 ± 13	62 ± 6
Rexburg	66 ± 13	68 ± 7	68 ± 13	71 ± 7
Roberts	74 ± 15	75 ± 8	75 ± 15	72 ± 7

Appendix E. Glossary

A

accuracy: A measure of the degree to which a measured value or the average of a number of measured values agrees with the “true” value for a given parameter; accuracy includes elements of both bias and precision.

actinides: The elements of the periodic table from actinium on. Includes the naturally occurring radionuclides thorium and uranium, as well as the human-made radionuclides plutonium and americium.

alpha radiation: The emission of alpha particles during radioactive decay. Alpha particles are identical in makeup to the nucleus of a helium atom and have a positive charge. Alpha radiation is easily stopped by materials as thin as a sheet of paper and has a range in air of approximately an inch. Despite its low penetration ability, alpha radiation is densely ionizing and, therefore, very damaging when ingested or inhaled.

ambient dose equivalent: Since the effective dose cannot be measured directly with a typical survey instrument or a dosimeter, approved simulation quantities are used to approximate the effective dose (see **dose, effective**). The ambient dose equivalent is the quantity recommended by the International Commission on Radiation Units and Measurements (ICRU) to approximate the effective dose received by a human from external exposure to ambient ionizing radiation.

anthropogenic radionuclide: Radionuclides produced as a result of human activity (human-made).

aquifer: A geologic formation, group of formations or part of a formation capable of yielding a significant amount of groundwater to wells or springs.

aquifer well: A well that obtains its water from below the water table.

B

background radiation: Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material), and global fallout as it exists in the environment from the testing of nuclear explosive devices. It does not include radiation from source, byproduct, or special nuclear materials regulated by the Nuclear Regulatory Commission. The typically quoted average individual exposure from background radiation is 360 millirems per year.

basalt: The most common type of solidified lava; a dense, dark grey, fine-grained, igneous rock that is composed chiefly of plagioclase, pyroxene, and olivine; often displaying a columnar structure.

becquerel (Bq): A quantitative measure of radioactivity. This is an alternate measure of activity used internationally. One becquerel of activity is equal to one nuclear decay per second. There are 3.7×10^{10} Bq in 1 Curie (Ci).

beta radiation: Radiation comprised of charged particles emitted from a nucleus during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Beta radiation is slightly more penetrating than alpha,

and it may be stopped by materials such as aluminum or Lucite panels. Naturally occurring radioactive elements, such as potassium-40, emit beta radiation.

bias: The tendency for an estimate to deviate from an actual or real event. Bias may be the tendency for a model to over- or under-predict.

bioremediation: The process of using various natural or introduced microbes or both to degrade, destroy or otherwise permanently bond contaminants contained in soil or water or both.

biota concentration guide: The limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose limits for protection of populations of aquatic and terrestrial biota to be exceeded.

blank: Used to demonstrate that cross contamination has not occurred. See **field blank, laboratory blank, equipment blank,** and **reagent blank.**

blind sample: Contains a known quantity of some of the analytes of interest added to a sample media being collected. A blind sample is used to test for the presence of compounds in the sample media that interfere with the analysis of certain analytes.

butte: A steep-sided and flat-topped hill.

C

calibration: The adjustment of a system and the determination of system accuracy using known sources and instrument measurements of higher accuracy.

chain of custody: A method for documenting the history and possession of a sample from the time of collection, through analysis and data reporting, to its final disposition. An item is considered to be in a person's custody if the item is (1) in the physical possession of that person, (2) within direct view of that person, or (3) placed in a secured area or container by that person.

comparability: A measure of the confidence with which one data set or method can be compared to another.

composite sample: A sample of environmental media that contains a certain number of sample portions collected over a time period. The samples may be collected from the same location or different locations. They may or may not be collected at equal intervals over a predefined period (e.g., quarterly).

completeness: A measure of the amount of valid data obtained from a measurement system compared to the amount that was expected under optimum conditions.

confidence interval: A statistical range with a specified probability that a given parameter lies within the range.

contaminant: Any physical, chemical, biological, radiological substance, matter, or concentration that is in an unwanted location.

contaminant of concern: Contaminant in a given media (usually soil or water) above a risk level that may result in harm to the public or the environment. At the INL Site, a contaminant that is above a 10^{-6} (1 in 1 million) risk value.

control sample: A sample collected from an uncontaminated area that is used to compare INL Site analytical results to those in areas that could not have been impacted by INL Site operations.

cosmic radiation: Penetrating ionizing radiation, both particulate and electromagnetic, that originates in outer space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem of the 300 millirem of natural background radiation that an average member of the US public receives in a year.

curie (Ci): The original unit used to express the decay rate of a sample of radioactive material. The curie is equal to that quantity of radioactive material in which the number of atoms decaying per second and is equal to 37 billion (3.7×10^{10}). It was based on the rate of decay of atoms within one gram of radium. It is named for Marie and Pierre Curie who discovered radium in 1898. The curie is the basic unit of radioactivity used in the system of radiation units in the United States, referred to as "traditional" units. (see also **becquerel**)

D

data gap: An area between all available data and the conclusions that are drawn from the data where the existing data are sparse or nonexistent. An example would be inferring the interactions in the environment of one radionuclide that has not been studied from a chemically similar radionuclide that has been studied.

data validation: A systematic review of a data set to identify outliers or suspect values. More specifically, data validation refers to the systematic process of independently reviewing a body of analytical data against established criteria to provide assurance that the data are acceptable for their intended use. This process may use appropriate statistical techniques to screen out impossible or highly unlikely values.

data verification: The scientific and statistical evaluation of data to determine if data obtained from environmental operations are of the right type, quality, and quantity to support their intended use. Data verification also includes documenting those operations and the outcome of those operations (e.g., data do or do not meet specified requirements). Data verification is not synonymous with data validation.

decay products: Decay products are also called "daughter products". They are radionuclides that are formed by the radioactive decay of parent radionuclides. In the case of radium-226, for example, nine successive different radioactive decay products are formed in what is called a "decay chain." The chain ends with the formation of lead-206, which is a stable nuclide.

derived concentration standard (DCS): The concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by a single pathway (e.g., air inhalation or immersion, water ingestion), would result in an effective dose of 100 mrem (1 mSv). U.S. Department of Energy Order 458.1 "Radiation Protection of the Public and the Environment" establishes this limit and DOE Standard DOE-STD-1196-2011, "Derived Concentration Technical Standard" provides the numerical values of DCSs.

deterministic effect: Health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Deterministic effects generally result from the receipt of a relatively

high dose over a short time period. Skin erythema (reddening) and radiation-induced cataract formation is an example of a deterministic effect (formerly called a nonstochastic effect).

diffuse source: A source or potential source of pollutants that is not constrained to a single stack or pipe. A pollutant source with a large areal dimension.

diffusion: The process of molecular movement from an area of high concentration to one of lower concentration.

direct radiation: External radiation from radioactive plumes or from radionuclides deposited on the ground or other surfaces.

dispersion: The process of molecular movement by physical processes.

dispersion coefficient: An empirical concentration, normalized to a unit release rate, used to estimate the concentration of radionuclides in a plume at some distance downwind of the source. The National Oceanic and Atmospheric Administration, using data gathered continuously at meteorological stations on and around the INL Site and the MDIFF air dispersion model, prepared the dispersion coefficients for this report.

dose: A general term used to refer to the effect on a material that is exposed to radiation. It is used to refer either to the amount of energy absorbed by a material exposed to radiation (see **dose, absorbed**) or to the potential biological effect in tissue exposed to radiation (see **dose, equivalent** and **dose, effective**). See also: **dose, population**.

dose, absorbed: The amount of energy deposited in any substance by ionizing radiation per unit mass of the substance. It is expressed in units of rad or gray (Gy) (1 rad = 0.01 gray).

dose, effective (*E*): The summation of the products of the equivalent dose received by specified tissues and organs of the body, and tissue weighting factors for the specified tissues and organs, and is given by the expression:

$$E = \sum_T w_T \sum_R w_R \, D_{T,R} \quad or \quad E = \sum_T w_T \, H_T$$

where H_T or $w_R D_{T,R}$ is the equivalent dose in a tissue or organ, T, and w_T is the tissue weighting factor. The effective dose is expressed in the SI unit Sievert (Sv) or conventional unit rem (1 rem = 0.01 Sv). (See **dose, equivalent** and **weighting factor**).

dose, equivalent (H_T): The product of absorbed dose in tissue multiplied by a quality factor, and then sometimes multiplied by other necessary modifying factors, to account for the potential for a biological effect resulting from the absorbed dose. For external dose, the equivalent dose to the whole body is assessed at a depth of 1 cm in tissue; the equivalent dose to the lens of the eye is assessed at a depth of 0.3 cm in tissue, and the equivalent dose to the extremity and skin is assessed at a depth of 0.007 cm in tissue. Equivalent dose is expressed in units of rems (or sieverts). It is expressed numerically in rems (traditional units) or sieverts (SI units). (See **dose, absorbed** and **quality factor**).

dose, population or collective: The sum of the individual effective doses received in a given time period by a specified population from exposure to a specified source of radiation. Population

dose is expressed in the SI unit person-sievert (person-Sv) or conventional unit person-rem. (1 person-Sv = 100 person-rem). (See **dose, effective**).

dosimeter: Portable detection device for measuring the total accumulated exposure to ionizing radiation.

dosimetry: The theory and application of the principles and techniques involved in the measurement and recording of radiation doses.

drinking water: Water for the primary purpose of consumption by humans.

duplicate sample: A sample collected from the same sampling location using the same equipment and sampling technique and placed into an identically prepared and preserved container. Duplicate samples are analyzed independently as an indication of gross errors in sampling techniques.

E

eastern Snake River Plain aquifer: One of the largest groundwater “sole source” resources in the United States. It lies beneath a rolling topography extending some 308 km (191 mi) from Ashton to King Hill, Idaho, and ranges in width from 64 to 130 km (40 to 80 mi). The plain and aquifer were formed by repeated volcanic eruptions that were the result of a geologic hot spot beneath the earth’s crust.

ecosystem: The interacting system of a biologic community and its nonliving environment.

effluent: Any liquid discharged to the environment, including storm water runoff at a site or facility.

effluent waste: Treated wastewater leaving a treatment facility.

electrometallurgical treatment: The process of treating spent nuclear fuel using metallurgical techniques.

environment: Includes water, air, and land and the interrelationship that exists among and between water, air, and land and all living things.

environmental indicators: Animal and plant species that are particularly susceptible to decline related to changes, either physical or chemical, in their environment.

environmental media: Includes air, groundwater, surface water, soil, flora, and fauna.

environmental monitoring: Sampling for contaminants in air, water, sediments, soils, agricultural products, plants, and animals, either by direct measurement or by collection and analysis of samples. It is a combination of two distinct activities (effluent monitoring and environmental surveillance) that together provide information on the health of an environment.

equipment blank: Sample prepared by collecting uncontaminated water passed over or through the sampling equipment. This type of blank sample is normally collected after the sampling equipment has been used and subsequently cleaned. An equipment blank is used to detect contamination introduced by the sampling equipment either directly or through improper cleaning.

exposure: The interaction of an organism with a physical or chemical agent of interest. Examples of such agents are radiation (physical) and carbon tetrachloride (chemical).

exposure pathway: The mechanism through which an organism may be exposed to a contaminant. An example is the surface water pathway, whereby an organism may be exposed to a contaminant through the consumption of surface water containing that contaminant.

external dose or exposure: That portion of the dose received from radiation sources outside the body (i.e., external sources).

extremely hazardous chemical: A substance listed in the appendices to 40 CFR 355, "Emergency Planning and Notification."

F

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

field blank: A blank used to provide information about contamination that may be introduced during sample collection, storage, and transport. A known uncontaminated sample, usually deionized water, is exposed to ambient conditions at the sampling site and subjected to the same analytical or measurement process as other samples.

fissile material: Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning. Namely, any material that is fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.

fission: The splitting of the nucleus of an atom (generally of a heavy element) into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

fission products: The nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the subsequent decay products of the radioactive fission fragments.

fissionable material: Commonly used as a synonym for fissile material, the meaning of this term has been extended to include material that can be fissioned by fast neutrons, such as uranium-238.

flood plain: Lowlands bordering a river that are subject to flooding. A flood plain is comprised of sediments carried by rivers and deposited on land during flooding.

G

gamma radiation: A form of electromagnetic radiation, like radio waves or visible light, but with a much shorter wavelength. It is more penetrating than alpha or beta radiation, capable of passing through dense materials such as concrete.

gamma spectroscopy: An analysis technique that identifies specific radionuclides that emit gamma radiation. It measures the particular energy of a radionuclide's gamma radiation emissions. The energy of these emissions is unique for each radionuclide, acting as a fingerprint to identify a specific radionuclide.

gross alpha activity: The total radioactivity due to alpha particle emission as inferred from measurements on a dry sample. See alpha radiation.

gross beta activity: The total radioactivity due to beta particle emission as inferred from measurements on a dry sample. See beta radiation.

groundwater: Water located beneath the surface of the ground (subsurface water). Groundwater usually refers to a zone of complete saturation containing no air.

H

half-life: The time in which one-half of the activity of a particular radioactive substance is lost due to radioactive decay. Measured half-lives vary from millionths of a second to billions of years. Also called physical or radiological half-life.

hazardous air pollutant: See hazardous substance.

hazardous chemical: Any hazardous chemical as defined under 29 CFR 1910.1200 (“Hazard Communication”) and 40 CFR 370.2 (“Definitions”).

hazardous material: Material considered dangerous to people or the environment.

hazardous substance: Any substance, including any isomers and hydrates, as well as any solutions and mixtures containing these substances, designated as such under Section 311 (b)(2)(A) of the *Clean Water Act*; any toxic pollutant listed under Section 307 (a) of the *Clean Water Act*; any element, compound, mixture, solution, or substance designated pursuant to Section 102 of the *Comprehensive Environmental Response, Compensation and Liability Act*; any hazardous waste having the characteristics identified under or listed pursuant to Section 3001 of the *Solid Waste Disposal Act*; any hazardous air pollutant listed under Section 112 of the *Clean Air Act*; and any imminently hazardous chemical substance or mixture with respect to which the U.S. Environmental Protection Agency Administrator has taken action pursuant to Section 7 of the *Toxic Substances Control Act*. The term does not include petroleum, including crude oil or any fraction thereof that is not otherwise specifically listed or designated in the first paragraph, and does not include natural gas, natural gas liquids, liquefied natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas).

hazardous waste: A waste that is listed in the tables of 40 CFR 261 (“Identification and Listing Hazardous Waste”) or that exhibits one or more of four characteristics (corrosiveness, reactivity, flammability, and toxicity) above a predefined value.

high-level radioactive waste: Waste material resulting from the reprocessing of spent nuclear fuel, including both liquid and solid materials containing enough radioactivity to require permanent isolation from the environment.

hot spot: (1) In environmental surveillance, a localized area of contamination or higher contamination in an otherwise uncontaminated area. (2) In geology, a stationary, long-lived source of magma coming up through the mantle to the earth’s surface. The hot spot does not move, but remains in a fixed position. As the crust of the earth moves over a hot spot, volcanic eruptions occur on the surface.

I

infiltration: The process of water soaking into soil or rock.

influent waste: Raw or untreated wastewater entering a treatment facility.

inorganic: Relating to or belonging to the class of compounds not having a carbon basis; hydrochloric and sulfuric acids are called inorganic substances.

ionizing radiation: Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Some examples are alpha, beta, gamma, x-rays, neutrons and light. High doses of ionizing radiation may produce severe skin or tissue damage.

isopleth: A line on a map connecting points having the same numerical value of some variable.

isotope: Two or more forms of an element having the same number of protons in the nucleus (or the same atomic number), but having different numbers of neutrons in the nucleus (or different atomic weights). Isotopes of a single element possess almost identical chemical properties. Examples of isotopes are plutonium-238, plutomium-239, and plutonium-241; each acts chemically like plutonium but have 144, 145, and 146 neutrons, respectively.

L

laboratory blank: A sample, usually deionized water, that is intended to contain none of the analytes of interest and is subjected to the same analytical or measurement process as other samples to establish a zero baseline or laboratory background value. Laboratory blanks are run before and after regular samples are analyzed to measure contamination that may have been introduced during sample handling, preparation, or analysis. A laboratory blank is sometimes used to adjust or correct routine analytical results.

liquid effluent: A liquid discharged from a treatment facility.

M

management and operating (M&O) contract: An agreement under which the government contracts for the operation, maintenance, or support, on its behalf, of a government-owned or -controlled research, development, special production, or testing establishment wholly or principally devoted to one or more major programs of the contracting federal agency.

matrices/matrix/media: Refers to the physical form (solid, liquid, or gas) or composition (soil, filter, groundwater, or air) of a sample.

maximally exposed individual (MEI): A hypothetical member of the public whose location and living habits tend to maximize his or her radiation dose, resulting in a dose higher than that received by other individuals in the general population.

millirem (mrem): A unit of radiation dose that is equivalent to one one-thousandth of a rem.

millisievert (mSv): The International System of Units (SI) for radiation dose and effective dose equivalent. The SI equivalent of the millirem (1 millisievert = 100 millirem).

minimum detection concentration (MDC): The lowest concentration to which an analytical parameter can be measured with certainty by the analytical laboratory performing the

measurement. While results below the MDC are sometimes measurable, they represent values that have a reduced statistical confidence associated with them (less than 95 percent confidence).

multi-media: Covering more than one environmental media (e.g., an inspection that reviews groundwater, surface water, liquid effluent, and airborne effluent data).

N

natural background radiation: Radiation from natural sources to which people are exposed throughout their lives. Natural background radiation is comprised of several sources, the most important of which are:

- Cosmic radiation: Radiation from outer space (primarily the sun)
- Terrestrial radiation: Radiation from radioactive materials in the crust of the earth
- Inhaled radionuclides: Radiation from radioactive gases in the atmosphere, primarily radon-222.

natural resources: Land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, otherwise controlled by the United States, any state or local government, any foreign government, or Indian tribe.

noble gas: Any of the chemically inert gaseous elements of the helium group in the periodic table.

noncommunity water system: A public water system that is not a community water system. A noncommunity water system is either a transient noncommunity water system or a nontransient noncommunity water system.

nontransient noncommunity water system: A public water system that is not a community water system and that regularly serves at least 25 of the same persons over six months per year. These systems are typically schools, offices, churches, factories, etc.

O

organic: Relating or belonging to the class of chemical compounds having a carbon basis; hydrocarbons are organic compounds.

optically stimulated luminescence dosimeter (OSLD): Used to measure direct penetrating gamma radiation through the absorption of energy from ionizing radiation by trapping electrons that are excited to a higher energy band. The trapped electrons in the OSLD are released by exposure to green light from a laser.

P

perched water well: A well that obtains its water from a water body above the water table.

performance evaluation sample: Sample prepared by adding a known amount of a U.S. Environmental Protection Agency reference compound to reagent water and submitting it to the

analytical laboratory as a field duplicate or field blank sample. A performance evaluation sample is used to test the accuracy and precision of the laboratory's analytical method.

person-rem: Sum of the doses received by all individuals in a population.

pH: A measure of hydrogen ion activity. A low pH (0 – 6) indicates an acid condition; a high pH (8 – 14) indicates a basic condition. A pH of 7 indicates neutrality.

playa: A depression that is periodically inundated with water and will retain such water over time. An intermittent or seasonal water body.

plume: A body of contaminated groundwater or polluted air flowing from a specific source. The movement of a groundwater plume is influenced by such factors as local groundwater flow patterns, the character of the aquifer in which groundwater is contained, and the density of contaminants. The movement of an air contaminant plume is influenced by the ambient air motion, the temperatures of the ambient air and of the plume, and the density of the contaminants.

PM_{10}: Particle with an aerodynamic diameter less than or equal to 10 microns.

pollutant: 1) Pollutant or contaminant as defined by Section 101(33) of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), shall include, but not be limited to, any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingesting, inhalation, or assimilation into an organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction), or physical deformation, in such organisms or their offspring. The term does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under Section 101(14) (A) through (F) of CERCLA, nor does it include natural gas, liquefied natural gas, or synthetic gas of pipeline quality (or mixtures of natural gas and such synthetic gas). For purposes of the National Oil and Hazardous Substances Pollution Contingency Plan, the term pollutant or contaminant means any pollutant or contaminant that may present an imminent and substantial danger to public health or welfare of the United States. 2) Any hazardous or radioactive material naturally occurring or added to an environmental media, such as air, soil, water, or vegetation.

polychlorinated biphenyl: Any chemical substance that is limited to the biphenyl molecule that has been chlorinated to varying degrees or any combination of substances that contain such substance.

precision: A measure of mutual agreement among individual measurements of the same property. Precision is most often seen as a standard deviation of a group of measurements.

public water system: A system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. Includes any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system and any collection or

pretreatment storage facilities not under such control that are used primarily in connection with such system. Does not include any special irrigation district. A public water system is either a community water system or a noncommunity water system.

purgeable organic compound: An organic compound that has a low vaporization point (volatile).

Q

quality assurance: Those planned and systematic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily and safely in service. Quality assurance includes quality control. If quality is the degree to which an item or process meets or exceeds the user's requirements, then quality assurance is those actions that provide the confidence that quality was in fact achieved.

quality control: Those actions necessary to control and verify the features and characteristics of a material, process, product, service, or activity to specified requirements. The aim of quality control is to provide quality that is satisfactory, adequate, dependable, and economic.

quality factor: The factor by which the absorbed dose (rad or gray) must be multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage (rem or sievert) to the exposed tissue. It is used because some types of radiation, such as alpha particles, are more biologically damaging to live tissue than other types of radiation when the absorbed dose from both is equal. The term, quality factor, has now been replaced by "radiation weighting factor" in the latest system of recommendations for radiation protection.

R

rad: short for radiation absorbed dose; a measure of the energy absorbed by any material.

radioactivity: The spontaneous transition of an 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.

radioactive decay: The decrease in the amount of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied by gamma radiation.

radioecology: The study of the behavior and the effects of radioactive materials on the environment. Also includes the use of radioisotopes to study the structure and function of ecosystems and their component parts.

radionuclide: A type of atom that emits energy in the form of photons or particles (radiation) during transformation.

radiotelemetry: The tracking of animal movements through the use of a radio transmitter attached to the animal of interest.

reagent blank: A sample of any reagent used for sample preparation subjected to the same analytical or measurement process as a normal sample. A reagent blank is used to show that the reagent used in sample preparation does not contain any of the analytes of interest.

rehabilitation: The planting of a variety of plants in an effort to restore an area's plant community diversity after a loss (e.g., after a fire).

relative percent difference: A measure of variability adjusted for the size of the measured values. It is used only when the sample contains two observations, and it is calculated by the equation:

$$RPD = \frac{|R1 - R2|}{(R1 + R2)/2} \times 100$$

where R1 and R2 are the duplicate sample measurement results.

release: Spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a hazardous substance, pollutant, or contaminant into the environment.

rem (Roentgen Equivalent Man): A unit in the traditional system of units that measures the effects of ionizing radiation on humans.

reportable quantity: Any C*omprehensive Environmental Response, Compensation, and Liability Act* hazardous substance, the reportable quantity for which is established in Table 302.4 of 40 CFR 302 ("Designation, Reportable Quantities, and Notification"), the discharge of which is a violation of federal statutes and requires notification of the regional U.S. Environmental Protection Agency administrator.

representativeness: A measure of a laboratory's ability to produce data that accurately and precisely represent a characteristic of a population, a parameter variation at a sampling point, a process condition, or an environmental condition.

reprocessing: The process of treating spent nuclear fuel for the purpose of recovering fissile material.

resuspension: Windblown reintroduction to the atmosphere of material originally deposited onto surfaces from a particular source.

rhyolite: A usually light-colored, fine-grained, extrusive igneous rock that is compositionally similar to granite.

risk: In many health fields, risk means the probability of incurring injury, disease, or death. Risk can be expressed as a value that ranges from zero (no injury or harm will occur) to one (harm or injury will definitely occur).

risk assessment: The identification and quantification of the risk resulting from a specific use or occurrence of a chemical, taking into account the possible harmful effects on individuals or society of using the chemical in the amount and manner proposed and all the possible routes of exposure. Quantification ideally requires the establishment of dose-effect and dose-response relationships in likely target individuals and populations.

roentgen (R): The amount of ionization produced by gamma radiation in air. The unit of roentgen is approximately numerically equal to the unit of rem.

S

shielding: The material or process used for protecting workers, the public, and the environment from exposure to radiation.

sievert (Sv): A unit for assessing the risk of human radiation dose, used internationally. One sievert is equal to 100 rem.

sigma uncertainty: The uncertainty or margin of error of a measurement is stated by giving a range of values likely to enclose the true value. These values follow from the properties of the normal distribution, and they apply only if the measurement process produces normally distributed errors, e.g., the quoted standard errors are easily converted to 68.3 percent (one sigma), 95.4 percent (two sigma), or 99.7 percent (three sigma) confidence intervals; usually are denoted by error bars on a graph or by the following notations:

- measured value ± uncertainty
- measured value (uncertainty).

sink: Similar to a playa with the exception that it rapidly infiltrates any collected water.

spent nuclear fuel: Uranium metal or oxide and its metal container that have been used to power a nuclear reactor. It is highly radioactive and typically contains fission products, plutonium, and residual uranium.

split sample: A single sample, usually divided by the analytical laboratory, split into two separate samples. Each sample is prepared and analyzed independently as an indication of analytical variability and comparability.

spreading areas: At the INL Site, a series of interconnected low areas used for flood control by dispersing and evaporating or infiltrating water from the Big Lost River.

stabilization: The planting of rapid growing plants for the purpose of holding bare soil in place.

standard: A sample containing a known quantity of various analytes. A standard may be prepared and certified by commercial vendors, but it must be traceable to the National Institute of Standards and Technology.

stochastic effects: Effects that occur by chance and which may occur without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose. In the context of radiation protection, the main stochastic effect is cancer.

storm water: Water produced by the interaction of precipitation events and the physical environment (buildings, pavement, ground surface).

surface water: Water exposed at the ground surface, usually constrained by a natural or human-made channel (stream, river, lake, ocean).

surveillance: Parameters monitored to observe trends but not required by a permit or regulation.

T

thermoluminescent dosimeter (TLD): A device used to measure radiation dose to occupational workers or radiation levels in the environment. A dosimeter is made of one or more lithium fluoride

chips that measure cumulative exposure to ionizing radiation. Lithium fluoride absorbs the energy of radiation and releases it as light when heated.

total effective dose (TED): The sum of the effective dose (for external exposures) and the committed effective dose.

total organic carbon: A measure of the total organic carbon molecules present in a sample. It will not identify a specific constituent (e.g., benzene), but will detect the presence of a carbon-bearing molecule.

toxic chemical: Chemical that can have toxic effects on the public or environment above listed quantities. See also hazardous chemical.

traceability: The ability to trace history, application, or location of a sample standard and like items or activities by means of recorded identification.

transient noncommmunity water system: A water system that is not a community water system, and serves 25 nonresident persons per day for six months or less per year. These systems are typically restaurants, hotels, large stores, etc.

transuranic (TRU): Elements on the periodic table with an atomic number greater than uranium (>92). Common isotopes of transuranic elements are neptunium-239 and plutonium-238.

transuranic waste: Waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes (radionuclide isotopes with atomic numbers greater than uranium [92]) per gram of waste with half-lives greater than 20 years.

tritium: A radioactive isotope of hydrogen, having three times the mass of ordinary hydrogen.

V

vadose zone: That part of the subsurface between the ground surface and the water table.

W

water quality parameter: Parameter commonly measured to determine the quality of a water body or sample (i.e., specific conductivity, pH, temperature, dissolved oxygen content).

weighting factor (w_T): A multiplier that is used for converting the equivalent dose to a specific organ or tissue (T) into what is called the effective dose. The goal of this process was to develop a method for expressing the dose to a portion of the body in terms of an equivalent dose to the whole body that would carry with it an equivalent risk in terms of the associated fatal cancer probability. The equivalent dose to tissue (H_T) is multiplied by the appropriate tissue weighting factor to obtain the effective dose (E) contribution from that tissue. (See **dose, equivalent** and **dose, effective**).

wetland: An area inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include playa lakes, swamps, marshes, bogs, and similar areas as sloughs, prairie potholes, wet meadows, prairie river overflows, mudflats, and natural ponds.

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