



DOE/RL-2014-52, Rev 0

# Hanford Site

## Environmental Report for Calendar Year 2014





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Prepared for the U.S. Department of Energy  
Assistant Secretary for Environmental Management



U.S. DEPARTMENT OF  
**ENERGY**

Richland Operations  
Office

**P.O. Box 550**

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## Executive Summary

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This U.S. Department of Energy (DOE) prepares an annual Hanford Site environmental report in accordance with DOE Order [231.1B](#), *Environment, Safety and Health Reporting*, and [DOE O 458.1](#), *Radiation Protection of the Public and the Environment*. The purpose of the *Hanford Site Environmental Report for Calendar Year 2014* is to inform the public, regulators, employees, and other stakeholders of environmental and operating performance during the year. This report summarizes environmental data; environmental management performance; compliance with applicable federal, state, and local regulations; and radiological releases and doses to the public resulting from site operations.

DOE has prepared annual Hanford Site environmental reports since 1959. They are available on the Internet through Mission Support Alliance, LLC (MSA) at <http://msa.hanford.gov/page.cfm/enviroreports>. The following sections briefly summarize this year's annual report.

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## Section 1, Introduction

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The 586-square-mile (1,517-square-kilometer) Hanford Site is located north of the city of Richland, along the Columbia River in southeastern Washington State. It lies within the semiarid Pasco Basin of the Columbia Plateau. The Hanford Site was established in 1943 to produce plutonium for nuclear weapons. The site has restricted public access and provides a buffer for areas used for former nuclear materials production, waste storage, and waste disposal. Beginning in 1989, the primary mission of the Hanford Site has been to clean up the extensive contamination on the site as a result of plutonium production. The current mission focuses on environmental restoration of the site, including remediation of contaminated areas, facility decontamination and decommissioning, waste management, and related scientific and environmental research and development.

DOE is responsible for operating the Hanford Site. The Richland Operations Office (RL) and the Office of River Protection (ORP) jointly manage the site through several contractors and subcontractors. RL serves as the property owner and is responsible for cleaning up the River Corridor (a 51-mile stretch of the Columbia River) and the Central Plateau, as well as remediating groundwater. RL oversees environmental management operations and landlord services supporting the Hanford Site. RL, the U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife (WDFW) manage portions of the Hanford Reach National Monument.

ORP manages the retrieval, treatment, and disposal of approximately 56 million gallons (213 million liters) of radioactive tank waste currently stored in 177 underground tanks in Hanford's Central Plateau. ORP is responsible for safely operating the Hanford tank farms, and constructing and operating the Waste Treatment and Immobilization Plant (WTP).

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## Section 2, Compliance Summary

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To ensure the protection of human health and the environment through safe operations, DOE implements compliance programs designed to fulfill requirements of applicable federal, state, and local environmental laws and regulations, and DOE orders, directives, policies, and guidelines. In addition, the Hanford Site operates under permits required under specific environmental protection regulations. Several federal, state, and local regulatory agencies are responsible for monitoring and enforcing compliance, including the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology),

Washington State Department of Health (WDOH), and the Benton Clean Air Agency. EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in statutes enacted by Congress. In addition, the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement [TPA]) commits DOE to comply with the remedial-action provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* ([CERCLA](#)) as well as with the *Resource Conservation and Recovery Act of 1976* ([RCRA](#)) treatment, storage, and disposal (TSD) unit regulations and corrective-action provisions.

**Tri-Party Agreement.** From 1989 through January 19, 2015, a total of 1,235 TPA milestones were completed, and 334 target dates were met. During 2014, 30 specific cleanup milestones were scheduled for completion; of those milestones, 27 were completed on time, 1 milestone was missed, and 2 milestones are in dispute resolution.

**Federal Facility Compliance Act.** DOE met the annual requirement to report mixed waste information to EPA and the states (*Calendar Year 2013 Hanford Site Mixed Waste Land Disposal Restrictions Summary Report*).

**Regulatory Inspections.** During calendar year (CY) 2014, regulators conducted 76 inspections at DOE facilities on the Hanford Site: Ecology conducted 37, WDOH conducted 25, EPA Region 10 conducted 6, the city of Richland conducted 2, the Department of Transportation conducted 1, and DOE conducted 1. Nine regulatory agency enforcement actions (9 concerns and 26 compliance actions) resulted from these inspections. The fines and penalties assessed and paid totaled \$190,594.

- ⊗ **RCRA.** Ecology RCRA inspections on the Hanford Site focused on compliance of TSD units with the *Hanford Facility Dangerous Waste Permit* (WA7890008967). Waste accumulation and universal waste management areas were also inspected.
- ⊗ **CERCLA.** Field inspections of institutional controls were conducted in 2014 at waste sites on the Hanford Site. No public trespass events occurred and all approved excavation permits were in place for all active remediation activities. Site contractors provide an annual update on the effectiveness of the institutional controls to EPA and Ecology at the Area Unit Managers Meetings conducted every September.
- ⊗ **Hanford Site Emission Sources.** The WDOH inspections focused on compliance of major and minor stack air emission units with the Air Operating Permit and Radioactive Air Emissions License (FF-01). The EPA inspections focused on asbestos management under Subpart M of Title [40 Code of Federal Regulations \(CFR\) Part 61](#), “[National Emission Standards for Hazardous Air Pollutants \(NESHAPs\) for Asbestos](#).” The city of Richland inspections are limited to the 300 Area of the Hanford Site and involve implementation of the terms and conditions of the Industrial Wastewater Permit and discharges to the publicly owned treatment works.

**Environmental Occurrences.** Environmental releases of radioactive and regulated materials from the Hanford Site are reported as legally required under the following categories: Operational Emergency; Recurring; Category 1 (significant impact); Category 2 (moderate impact); Category 3 (minor impact); and Category 4 (some impact). In 2014, there were no events for Category 1, 2, and 3; however, 45 Category 4 events occurred as a result of the discovery of legacy contamination at the Hanford Site.

**Emergency Planning and Community Right to Know Act.** The *2014 Hanford Site Toxic Chemical Release Inventory* report was submitted to EPA and Ecology before the annual July 1 deadline. During CY 2014, the Hanford Site exceeded activity thresholds for lead, naphthalene, propylene, and xylene.

**Pollution Prevention Program.** In 2014, over 2,932 tons (2,660 metric tons) of non-hazardous and hazardous wastes were recycled through Hanford Site programs administered through the Mission Support Contract.

### Section 3, Environmental Management System

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Environmental management performance measures objectives for 2014 included: fleet management, alternative fuel use, potable and non-potable water use, electricity use, facility fuel use, facility energy use, Electronic Product Environmental Assessment Tool, sanitary waste reduction, and regulated waste reduction. Objectives for 2014 were achieved for all performance measures, and the alternative fuel use target and electronic product environmental assessment tool were exceeded.

### Section 4, Radiological Protection and Doses

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Hanford Site radiation protection program staff conduct ongoing monitoring of external radiation sources; perform environmental radiological surveys; and evaluate potential radiological doses to the public. Results of 2014 monitoring efforts are provided below.

#### External Radiation Monitoring

Sources of external radiation at the Hanford Site include waste materials associated with former plutonium production and processing facilities; radioactive waste handling, storage, and disposal; and cleanup and remediation activities. In 2014, external radiation fields were monitored at 115 locations near Hanford Site facilities and operations, including the 100-K Area, 100-N Area Shoreline (N Springs), 200 Area, 300 Area, 400 Area, 618-10 Burial Ground, and Integrated Disposal Facility (IDF).

**100-K Area.** The average dose rates levels seen in the 100-K Area during 2014 were, overall, slightly higher than 2013 levels. Dose rate levels in 2014 when compared to 2013 were 3 percent lower in the 100-K-East Area and at the Cold Vacuum Drying Facility and were 11 percent higher in the 100-K West Area. This was due to elevated dose rate levels at the monitoring location near the load-out area of the 105-KW (reactor) building where radioactive contaminated sludge and debris from the cleanout of the 100-K West Basin were transported.

**100-N Area Shoreline (N Springs).** Dose rates were measured along the Columbia River shoreline in the 100-N Area (N Springs) to determine potential external radiation doses to onsite workers and to the public accessing the river. The 2014 average dose rate was 2 percent lower than in 2013, and was less than the DOE annual limit of 100 millirem (1 millisievert) per year.

**200 Area.** Dose rate levels measured during 2014 in the 200 East and 200 West Areas were generally unchanged compared to 2013, except for the Environmental Restoration Disposal Facility (ERDF) located in the Central Plateau, where the average dose rates measured in 2014 (near the 200 West Area) were approximately 4 percent lower than 2013 levels.

**200 North Area.** One thermoluminescent dosimeter (TLD) monitoring site in the 200 North Area, at the formerly contaminated 212-R Railroad Car Disposition Area, continued to show reduced average dose rate



levels in 2014. As in recent years, the 2014 levels were significantly lower than levels measured in 2011 and years previous.

*300 and 400 Areas.* The average dose rates in 2014 in the 300 and 400 Areas and at the 300 Area Treated Effluent Disposal Facility were generally lower by approximately 5 percent compared to 2013 levels.

*618-10 Burial Ground.* TLD monitoring was initiated during late-February 2010 at four locations for this project. The average dose rates in 2014 were approximately 2 percent lower than 2013 levels.

*Integrated Disposal Facility (IDF).* The average dose rates in 2014 at this facility were nearly unchanged from the 2013 levels. IDF is a new unused landfill that is not actively operating.

*Active and Inactive Waste Disposal Sites Radiological Surveys.* During 2014, 875 environmental radiological surveys were conducted at active and inactive waste disposal sites and the surrounding terrain to detect and characterize radioactive surface contamination. The external dose rate at 80 percent of the outdoor contamination areas was estimated to be less than 1 millirem (0.01 millisievert) per hour, although direct dose-rate readings from isolated radioactive specks could have been higher.

#### **Radiological Release of Hanford Site Property**

No property with detectable residual radioactivity above authorized levels was released in 2014 from the Hanford Site.

*Radiological Clearance for Potentially Contaminated Personal Property with Hard-to-Detect Radionuclides.* More than 10,000 items of personal property were unconditionally released from radiological areas on the Hanford Site; however, the majority of the items did not leave the site. These items primarily consisted of small items such as flashlights, hard hats, radios, cameras, pens, pencils, respiratory protection, radiological control instruments, and industrial hygiene instruments.

*Radiological Clearance for Granular Activated Carbon for Offsite Shipment and Regeneration.* A granular activated carbon canister from a soil-vapor extraction system was removed from the system and shipped to an offsite facility for regeneration and reuse. Approximately 196,577 pounds (89,166 kilograms) of granular activated carbon was shipped off site in 2014 for regeneration.

#### **Potential Radiological Doses to the Public**

In 2014, scientists evaluated potential radiological dose to the public and biota resulting from exposure to Hanford Site liquid effluents and airborne emissions to determine compliance with pertinent regulations and limits. Potential sources of radionuclide contamination include gaseous emissions from stacks and ventilation exhausts, liquid effluent from operating wastewater treatment facilities, contaminated groundwater seeping into the Columbia River, and fugitive emissions from areas of contaminated soil and operating facilities. Potential radiological doses from 2014 Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. Radiological doses were assessed in terms of the following:

- ⊗ Dose to a hypothetical, maximally exposed individual (MEI) at an offsite location
- ⊗ Collective dose to the population residing within 50 miles (80 kilometers) of Hanford Site operation areas

- ⊗ Doses for air pathways calculated using regulation-specified EPA methods for comparison to the Clean Air Act standards in 40 CFR 61, Subpart H, *National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities*
- ⊗ Doses from recreational activities, including hunting and fishing
- ⊗ Dose to a worker consuming drinking water on the Hanford Site
- ⊗ Doses from non-DOE industrial sources on and near the Hanford Site
- ⊗ Absorbed dose received by biota exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies.

The potential dose to the MEI calculated in 2014 from Hanford Site operations was 0.33 millirem (3.3 microsievert), which is 0.33 percent of the DOE 100 millirem (1,000 microsievert) per year public dose limit specified in [DOE O458.1, Chg 2](#). The collective dose—defined as the sum of doses to all individual members of the public residing within a 50-mile (80 kilometer) radius of Hanford Site operations—was 2.1 person-rem (0.021 person-sievert) in 2014. The calculated radiological doses from Hanford Site operations in 2014 were a small percentage of national average annual doses from natural background sources, including terrestrial and cosmic background radiation and inhalation of naturally occurring radon. For example, the national annual average terrestrial radiation dose (19 millirem [190 microsievert]) is approximately 60 times larger than the 2014 Hanford operations dose to the MEI (0.33 millirem [3.3 microsievert]).

The potential air pathways dose from stack emissions to a MEI at Horn Rapids Road, directly south of the 300 Area was determined to be 0.28 millirem (2.8 microsievert) per year, which is less than 3 percent of the EPA standard of 10 millirem (100 microsievert) per year. The estimated dose from diffuse emissions to a MEI was calculated to be 0.17 millirem (1.7 microsievert per year).

Wildlife sampling also was conducted at the Hanford Site to estimate radionuclide tissue concentrations in animals from the site that potentially could have been hunted off site. The only radionuclide detected in the muscle of elk, mule deer, and quail was potassium-40, a naturally occurring radioisotope not of Hanford Site origin. Potassium-40, uranium-234, and uranium-238 were detected in tissue samples from bass and carp. The radiation dose received from consumption of fish fillets (88 pounds [40 kilograms]) with these uranium concentrations would be negligible.

## Section 5, Environmental Restoration and Waste Management

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Table ES-1 provides the 2014 waste summary data for environmental restoration and waste management activities. They include Hanford Site River Corridor closure, cleanup and remediation, facility decommissioning, waste management operations, underground waste storage tank status, construction of the Waste Treatment and Immobilization Plant and its associated facilities, and research activities related to waste cleanup. The following sections describe important 2014 cleanup and remediation activities at the Hanford Site.

**River Corridor.** The River Corridor includes the Hanford Site 100 and 300 Areas, which border the Columbia River. Through 2014, transitions have been completed for 153 of 220 square miles of the River Corridor.

**100 Area Waste Sites.** The 100 Area waste sites vary in complexity and waste type. Typical waste sites include waste burial grounds, liquid effluent waste sites, burn pits, retired septic systems, piping systems,

and miscellaneous waste sites. In 2014, remediation activities focused on hexavalent chromium release sites, pipeline sites and miscellaneous waste sites. A total of 884,500 tons (802,400 metric tons) of contaminated soil and debris from 100 Area remediation activities were disposed at ERDF.

*Table ES-1. Hanford Site Waste Summary (2014)*

Activity	Waste Type	Amount (tons)	Amount (metric tons)
Solid waste generated on the Hanford Site during cleanup activities	Mixed waste	140	127
	Radioactive waste	572	519
Solid waste received from offsite sources (includes Hanford waste treated off site and returned)	Mixed waste	38.4	35
	Radioactive waste	57	52
Dangerous waste shipped off the Hanford Site	Containerized and bulk dangerous wastes	181	164
Waste stored at the Canister Storage Building	Radioactive waste	2,300	2,086
Remediation waste disposed of at the Environmental Restoration Disposal Facility	Solid waste	1,373,500	1,246,018
Activity	Waste Type	Amount (cubic feet)	Amount (cubic meters)
Waste disposed of in Trench 31	Mixed low-level solid waste	6,568	186
Activity	Waste Type	Amount (gallons)	Amount (liters)
Wastewater volume treated and disposed of at the 200 Area Effluent Treatment Facility	Wastewater containing toxic metals, radionuclides, ammonia, and organic compounds	1,190,000	4,500,000
Waste volume received at the 200 Area Liquid Effluent Retention Facility	Liquid wastewater containing low levels of organic compounds and tritium	3,570,000	13,510,000
Effluent volume disposed at the 200 Area Treated Effluent Disposal Facility	Uncontaminated, treated liquid waste	359,000,000	1,360,000,000
Waste added to double-shell tanks	Liquid waste	158,000	598,000
Waste volume year-end in double-shell tanks	Liquid waste	26,575,000	100,597,000
Waste volume pumped from single-shell tanks to double-shell tanks (includes dilution/ flush water)	Liquid waste	262,300	992,900
Waste volume evaporated by 242-A Evaporator	Liquid waste	791,000	2,990,000

**100-K Area.** Activity continued on the 105-KE Reactor Building interim safe storage, engineering for reactor penetration sealing and the safe storage enclosure; construction activities on the 100-K Annex in support of sludge removal operations; groundwater pump-and-treat operations; and testing of systems and components to be used to remove K Basins sludge to the Maintenance and Storage Facility in the 400 Area. The K West Basin is the only remaining operating nuclear facility, and is undergoing cleanout that involves removing radioactive contaminated sludge and debris as a precursor to facility deactivation and demolition.



**100 Areas Facilities Decommissioning.** Deactivation, decontamination, decommissioning, and demolition activities in the 100 Area included demolition actions at the 100-B, 100-D, and 100-N Areas. The activities were conducted as non-time-critical removal actions under CERCLA.

**200 Area (Central Plateau) Facilities Decommissioning.** Central Plateau facilities include buildings and waste sites in the 200 East, 200 West, and 200 North Areas, as well as those on the adjoining Rattlesnake Unit. Workers at the Plutonium Finishing Plant complex completed demolition of the 270-Z and 2704-Z buildings, and removed six mobile offices from the complex. At the 236-Z Plutonium Reclamation Facility workers removed, size reduced and dispositioned 53 pencil tank units (88 percent complete). Workers at 234-5Z continued removing plutonium-contaminated process equipment, with a particular focus on removing gloveboxes, associated piping, and ductwork. Total glovebox removal to date is now 94 percent complete.

**300 Area Facilities Decommissioning.** Deactivation, decontamination, decommissioning, and demolition activities in the 300 Area continued to focus on removing physical barriers to perform remedial actions. Characterization of radioactively contaminated soils beneath the 324 Building continued in 2014, along with initial engineering evaluations of possible retrieval methods. In 2014, significant progress was made on continuing to remove the below-grade portions of two high-hazard facilities; the 309 Plutonium Recycle Test Reactor and the successful lift and transport of the 340 Waste Neutralization Facility vault to ERDF. With the exception of the ongoing work at the 324 Building and the 309 below-grade structure, all remaining surplus 300 Area facilities were demolished in 2014.

**400 Area Facilities – Fast Flux Test Facility Deactivation.** Routine surveillances were performed at the Fast Flux Test Facility in 2014.

**Solid Waste Management.** Solid waste management includes the treatment, storage, and disposal of solid waste produced as a result of Hanford Site operations or received from offsite sources authorized to ship waste to the site. Onsite solid waste facilities include the Central Waste Complex (CWC), Canister Storage Building, Low-Level Burial Grounds, and ERDF.

**Central Waste Complex.** Located in the 200 West Area, the CWC receives waste from Hanford Site sources and any offsite sources authorized by DOE to ship waste to the site for treatment, storage, and disposal. Waste received includes low-level, transuranic, or mixed waste, and radioactive waste contaminated with polychlorinated biphenyls. The volume of waste currently stored in the CWC Outside Storage Areas is 195,400 cubic feet (5,534 cubic meters), and the volume of waste stored at the end of 2014 totaled approximately 310,800 cubic feet (8,802 cubic meters).

**Canister Storage Building.** This 42,000 square feet facility, located in the 200 East Area, stores about 2,300 tons (2,086 metric tons) of spent nuclear fuel packaged in approximately 400 multi-canister overpacks from the 100-K Basins, 100-N Reactor, and T Plant.

**Low-Level Burial Grounds.** This area consists of eight burial grounds located in the 200 East and 200 West Areas that are used to dispose of low-level waste and mixed waste. In 2014, a total of 6,568 cubic feet (186 cubic meters) of waste was disposed of in Trench 31, and Trench 94 (218-E-12B Burial Ground) received two defueled U.S. Navy reactor compartments in 2014. The total number of reactor compartments received into Trench 94 to date is 127.

**Environmental Restoration Disposal Facility.** ERDF began operations in 1996 and serves as the central disposal site for contaminated waste removed during Hanford Site CERCLA cleanup operations.

The largest disposal facility in the DOE complex, ERDF currently has a capacity of 18 million tons (16.3 million metric tons). During 2014, approximately 1.37 million tons (1.25 metric tons) of solid waste was disposed of in ERDF.

**Liquid Waste Management.** Facilities are operated on the Hanford Site to store, treat, reduce, and dispose of various types of liquid effluent generated by site cleanup activities. Liquid waste management facilities include the 200 Area Liquid Effluent Retention Facility (LERF) and Effluent Treatment Facility (ETF), 200 Area Treated Effluent Disposal Facility (TEDF), and the 242-A Evaporator.

*200 Area Liquid Effluent Retention Facility.* The LERF, located in the 200 East Area, consists of three RCRA-compliant surface basins used to store aqueous waste. The volume of wastewater received for LERF basin storage in 2014 was approximately 3.57 million gallons (13.5 million liters), including 1.8 million gallons (6.81 million liters) of pipeline-transported CERCLA-regulated leachate from ERDF; 1.37 million gallons (5.19 million liters) of process condensate from the 242-A Evaporator; and approximately 0.38 million gallons (1.44 million liters) of wastewater received by tanker trucks from various other facilities. The volume of wastewater stored at this facility at the end of 2014 was approximately 13.4 million gallons (50.7 million liters).

*200 Area Effluent Treatment Facility.* Located in the 200 East Area, ETF treats liquid effluent to remove toxic metals, radionuclides, and ammonia, in addition to destroying organic compounds. The treated effluent is stored in tanks, sampled and analyzed, and discharged to the State-Approved Land Disposal Site (616-A Crib). The volume of wastewater treated at ETF and disposed of in 2014 was approximately 1.19 million gallons (4.5 million liters). This wastewater was primarily process condensate from the 242-A Evaporator.

*200 Area Treated Effluent Disposal Facility.* Located east of the 200 East Area, TEDF acts as a collection and disposal system for non-RCRA waste streams, and it includes approximately 11 miles (18 kilometers) of buried pipelines connecting three pumping stations; the 6653 Building (known as the disposal sample station); and 5-acre (2-hectare) disposal ponds. The volume of effluent disposed to TEDF in 2014 was approximately 359 million gallons (1,360 million liters).

*242-A Evaporator.* Located in the 200 East Area, the 242-A Evaporator concentrates dilute liquid tank waste by evaporation. This process reduces the volume of liquid waste sent to double-shell tanks for storage and reduces the potential need for additional double-shell tanks. In 2014, the waste volume reduction was 791,000 gallons (2.99 million liters).

**Underground Waste Storage Tanks.** Most Hanford Site waste is stored in 149 large underground single-shell and 28 double-shell tanks grouped into 18 tank farms located on the Central Plateau.

*Single-Shell Tank System.* The single-shell tank system is undergoing closure. The radioactive and hazardous waste stored in single-shell tanks is being transferred to safer double-shell tanks. In 2014, progress continued in retrieving waste from the 16 tanks in C-Farm and waste transfer is complete for 13 of the 16 tanks. Of the remaining tanks, more than 84 percent of the waste has been retrieved from tank C-102, 89 percent from tank C-112, and 95 percent from tank C-107. At the end of 2014, approximately 262,300 gallons (992,900 liters) of radioactive and hazardous waste have been removed and transferred to double-shell tanks.

**Double-Shell Tank System.** The double-shell tank system includes 28 double-shell tanks located in the 200 East and 200 West Areas. At the end of 2014, approximately 26.6 million gallons (101 million liters) of waste were stored in the double-shell tanks.

**Waste Treatment and Immobilization Plant.** The WTP is being built on 65 acres (26 hectares) located on the Central Plateau to treat radioactive and hazardous waste currently stored in 177 underground tanks.

**Pretreatment Facility.** In 2014, work continued to resolve the remaining technical issues that have impacted design and construction since 2012. Significant progress was made with the construction of the full-scale vessel testing platform. By the end of 2014, testing began at the new facility on the mixing system for the pulse-jet mixers that will be used to ensure adequate mixing of waste within the waste process vessels at this facility.

**High-Level Waste Vitrification Facility.** In 2014, DOE full engineering and design resumed at this facility, where high-level waste will be combined with glass-forming materials in high-temperature melters, poured into waste containers, and allowed to cool to form a solid, immobilized glass form. Construction work included making 18 concrete placements, along with setting 179 tons (162 metric tons) of structural steel, and placing 1,040 feet (317 meters) of pipe and 1,696 feet (517 meters) of conduit.

**Low-Activity Waste Vitrification Facility.** This facility will mix low-activity waste with glass-forming materials in high-temperature melters; the resulting mixture will be poured into waste containers and allowed to cool to form a solid, immobilized glass form. In 2014, construction continued on interior equipment and commodities installation. Workers installed melter refractory—specialized brick that acts as containment for the molten glass—for the facility’s two glass melters.

**Analytical Laboratory.** Once operational, the laboratory will process about 10,000 waste samples a year to support glass formulation and waste-form compliance. In 2014, workers completed sufficient construction and received or installed the necessary equipment to begin systemization.

**Long-Term Stewardship.** This task focused on documenting completed cleanup actions and facilitating transition of surveillance and maintenance responsibilities within the River Corridor from the cleanup contractor to the site services contractor (MSA). In 2014, transition and turnover packages were completed for 105-C, 105-D, 105-DR, 105-H, and 105-N/109-N reactor buildings. MSA also conducted surveillance of the 105-F Building and found no change in conditions since the last surveillance.

**Scientific and Technical Contributions to Hanford Site Cleanup.** Pacific Northwest National Laboratory’s scientific and technical contributions to Hanford Site cleanup in 2014 focused on conducting fundamental engineering development and leadership to support resolution of the waste mixing issues and criticality and flammable gas control at the WTP. Researchers also teamed with Savannah River National Laboratory, Catholic University, and the Missouri University of Science and Technology to develop new glass formulations capable of reducing the volume of low-activity and high-activity waste glass. In addition, the Deep Vadose Zone Applied Field Research Initiative led a multi-national laboratory effort to identify research and development needed to successfully define and apply risk-informed remediation approaches for complex sites such as Hanford.



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## Section 6, Air Monitoring

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Hanford Site contractors monitor airborne emissions from site facilities to determine compliance with federal and state regulatory requirements and assess the effectiveness of emission control equipment and pollution management practices. Ambient air—the natural state of air in the outdoor environment—also is monitored at site facilities, away from facilities, and off site in nearby and distant communities.

**Air Emissions.** Small quantities of particulate and volatilized forms of radionuclides and nonradioactive chemical pollutants are emitted to the environment from state and federally permitted emission sources. Most facility radioactive air emission units are monitored periodically or continuously if they have the potential to exceed 1 percent of the standard for public dose, which is 10 millirem (100 microsievert) per year. Nonradioactive constituents and parameters are monitored directly, sampled and analyzed, or estimated based upon inventory usage. Air emission data collected in 2014 were comparable to those collected in 2013. DOE annually submits to EPA and the WDOH a report of Hanford Site radionuclide air emissions in compliance with Subpart H of [40 CFR 61](#), *National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities*, and [WAC 246-247](#), *Radiation Protection – Air Emissions*.

**Ambient-Air Monitoring Near Facilities and Operations.** A network of continuously operating samplers at 63 locations across the Hanford Site was used during 2014 to monitor radioactive airborne materials in air near site facilities and operations. Air samples collected from locations at or directly adjacent to Hanford Site facilities had higher radionuclide concentrations than samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which are much less than EPA concentration values but greater than those measured off site. Concentrations of certain radionuclides were higher and widely variable in different operational areas, and naturally occurring radionuclides, beryllium-7, and potassium-40 were routinely identified.

**Hanford Site and Offsite Ambient-Air Monitoring.** During 2014, ambient air samples were collected at 40 continuously operating samplers: 21 stations located on the Hanford Site; 11 stations located around the site boundary (primarily downwind directions to the south and east); 7 stations in nearby Hanford communities (Basin City, Benton City, Kennewick, Mattawa, Othello, Pasco, and Richland, Washington); and 1 station located in Yakima, Washington, to provide background data. Airborne particle samples were collected biweekly at each location and analyzed for gross beta and, at some locations, gross alpha radiation. All sample results for 2014 showed very low concentrations in air. With the exception of one sample, all radionuclide concentrations were below the EPA standard of 10 millirem (100 microsievert) per year.

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## Section 7, Water Monitoring

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In 2014, water samples were collected and analyzed from seven different sources: Hanford Site drinking water systems; Columbia River surface water, sediment, and seep water; onsite pond water and sediment; offsite irrigation water; and liquid effluent.

**Hanford Site Drinking Water Monitoring.** Routine chemical, physical, and microbiological monitoring of Hanford Site drinking water is performed regularly. With the exception of the 300 Area drinking water system—where a monthly total coliform sample was inadvertently missed—all DOE-owned Hanford Site systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels during 2014. Contaminant concentrations measured during the year were similar to those observed in recent years.

**Columbia River Water Monitoring.** Columbia River water samples were collected in 2014 from fixed-location monitoring stations at Priest Rapids Dam and at the city of Richland and analyzed for radionuclides. Cross-river transects near Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the city of Richland were collected in 2014 and analyzed for radionuclides, metals, and inorganic and organic compounds

*Columbia River Water – Fixed Location Samples.* Radiological analyses of Columbia River water samples collected at the fixed locations showed individual radiological contaminant concentrations were well below DOE derived concentration guides.

*Columbia River Water – Cross-River Transect Samples.* Cross-river transect samples at the 100-N Area, Hanford Townsite, 300 Area, and city of Richland had higher tritium concentrations near the Benton County (Hanford Site) shoreline compared to the opposite (Grant-Franklin) shoreline. Strontium-90 concentrations in Hanford Reach transect samples were similar to upstream reference concentrations. Uranium concentrations in all transect samples were below the EPA drinking water standard.

Inorganic and organic analyses detected metals and anions in Columbia River transect samples upstream and downstream of the Hanford Site. Copper, nickel, uranium, and zinc were detected in most samples. All dissolved metal concentrations in river water transect samples were less than the Washington State ambient surface-water quality criteria for protection of aquatic life.

**Columbia River Sediment Monitoring.** Samples were collected from Columbia River sediments and analyzed for radionuclides and inorganic constituents. Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2014 included cesium-137, uranium-234, uranium-235, uranium-238, plutonium-239/240, and decay products from naturally occurring radionuclides. The concentrations of all other radionuclides, including strontium-90, were below the reported detection limits for most samples.

Detectable amounts of most metals were found in all river sediment samples. Maximum and average concentrations of cadmium, copper, mercury, nickel, and selenium were higher for sediment collected in the reservoir upstream of Priest Rapids Dam than in sediment from the Hanford Reach or McNary Dam. Arsenic, lead, silver, and zinc concentrations were detected at higher rates in White Bluffs sediment in comparison to all other sediment collection locations.

**Columbia River Seep Water.** Samples of Columbia River seep water and one associated shoreline sediment sample were collected along the Hanford Reach in 2014 and analyzed for radiological, inorganic, and organic contaminants. Radiological contaminants of Hanford Site origin, including gross alpha, gross beta, carbon-14, strontium-90, tritium, and total uranium, were detected in seep water samples. Inorganic and organic contaminants originating from the Hanford Site, including metals and anions of interest (chloride, nitrate, and sulfate) were detected in seep water. Concentrations of volatile organic compounds were near or below the analytical laboratory's required detection limits in all samples. Constituents found above

detection limits in the shoreline seep sediment included cesium-137 and uranium isotopes, and metals, particularly chromium and hexavalent chromium.

**Pond Water and Sediment.** Water from West Lake, the only naturally occurring pond on the site, and the FFTF Pond, a retired disposal site, were sampled periodically in 2014. FFTF pond water was analyzed for gross alpha, gross beta, tritium, and gamma-emitting radionuclides. No gross alpha concentrations were detected in any sample, while gross beta concentrations increased slightly from 2013. Tritium concentrations were slightly lower in 2014 than they were in 2013. West Lake water was analyzed for tritium, uranium-234, uranium-235, and uranium-238. The uranium-234 and uranium-238 concentrations were above applicable DOE derived concentration guides, and tritium concentrations were below the reported detection limit. One sediment sample collected from West Lake during 2014 was analyzed for radionuclides, with detections similar to previous reported measurements.

**Offsite Irrigation Water.** To assess the potential for Hanford Site-associated contaminants to affect food products irrigated with Columbia River downstream of the site, water samples were collected three times during the irrigation season from the Horn Rapids irrigation pumping station, east of the river, and at a Riverview irrigation system, downstream of the site. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, strontium-90, and tritium. All radionuclide concentrations were within the historical range and were less than their respective DOE derived concentration guides and Washington State ambient surface-water quality criteria.

**Liquid Effluent Monitoring.** Liquid effluents were discharged to ground disposal units from a few Hanford Site facilities in 2014. Only one of those waste streams is permitted for radioactive constituents; however, all discharges are sampled and analyzed for select radioactive parameters and nonradioactive hazardous materials. Discharge monitoring results are reported to Ecology, and EPA is notified if chemicals in effluents exceed reportable quantities.

## Section 8, Groundwater Monitoring

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During Hanford Site operations, chemical and radioactive waste was released into the environment and contaminated the soil and groundwater beneath portions of the site, mostly in the 200 East Area, 200 West Area, 300 Area, 1100 Area, and the 100 Area reactor areas along the river. This section summarizes the results of Hanford Site groundwater monitoring for 2014, including results for RCRA TSD units, CERCLA groundwater operable units, and the requirements of the *Atomic Energy Act of 1954*. DOE publishes details on CERCLA remediation activities (for example, pump-and-treat operations) in separate reports that are summarized and referenced in this report. The monitoring data presented in this section—and information on monitoring well locations, construction details, and screened intervals—can be found through the DOE Environmental Dashboard Application at <https://ehs.hanford.gov/eda/> or on the PHOENIX website at <http://phoenix.pnnl.gov>. The data and additional groundwater monitoring details are available in the *Hanford Site Groundwater Monitoring Report for 2014* ([DOE/RL-2015-07](#)).



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## Section 9, Soil Monitoring

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Soil samples are collected near facilities and operations on the Hanford Site to detect potential migration and deposition of facility emissions and evaluate long-term trends in the environmental accumulation of radioactive materials. Fifty total samples were collected in 2014 and analyzed for radionuclides expected to occur in the areas sampled (300, 400, and 600 Areas, and the 200 Areas) for comparison to concentrations of radionuclides measured in samples collected from Grant, Yakima, Walla Walla, Adams, Benton, and Franklin counties in 2008.

In general, radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2014 were higher than the concentrations in samples collected farther away. Also, as expected, concentrations of certain radionuclides in 2014 were higher in different operational areas when compared to concentrations measured in distant communities in previous years.

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## Section 10, Biota Monitoring

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DOE conducted agricultural monitoring at four locations near the Hanford Site to assess potential contaminant concentrations in food and farm products as a result of site activities. Plant and animal species on the site also are monitored to assess abundance, condition, and population distributions. Data collection and analysis are integrated with environmental monitoring of biotic and abiotic media, and analytical results are used to characterize potential risks or impacts.

*Agricultural Monitoring.* Samples of cherries, leafy vegetables, milk, potatoes, and tomatoes were collected in 2014 at East Wahluke, Riverview, Sagemoor, and Sunnyside. Radionuclide concentrations in most samples were below levels that could be detected by analytical laboratories; however, some potential Hanford Site-produced contaminants (such as tritium) were found at low levels in some samples.

*Animal Monitoring.* In 2014, five fish and wildlife species were sampled and analyzed for potential Hanford Site contaminants: smallmouth bass, common carp, mule deer, Rocky Mountain elk, and California quail. All fish and wildlife samples were monitored for strontium-90 and a number of gamma emitters, including cesium-137. Trace metals associated with Hanford Site operations (e.g., copper, lead, and mercury) that have a potential to accumulate in certain fish and wildlife tissues are also monitored. Cesium-137 was not found above detection limits in any of the tested animal tissues. Strontium-90 was detected in one carp sample and all seven deer and elk bone samples, but no other animal tissue samples. Trace metals were found above detection limits in most of the tested animal tissues, at variable but fairly low concentrations.

*Vegetation Monitoring.* Plant populations and habitats that occur on the Hanford Site are surveyed and monitored to assess potential risks or impacts to biota. Hanford Site and offsite vegetation samples are analyzed for information about atmospheric deposition of contaminants in and around operational areas on site and in uncultivated areas off site, and to provide a baseline against which unplanned releases can be compared. In general, radionuclide concentrations in vegetation samples collected from, or adjacent to, waste disposal facilities in 2014 were higher than concentrations in samples collected farther away, including concentrations measured off site. Generally, the predominant radionuclides were activation and fission products in the 100 Areas, fission products in the 200 Areas and 600 Area, and uranium in the 300 Area and 400 Area.

***Vegetation Control.*** Vegetation control activities help prevent, limit, or remove contaminated plants or undesirable plant species. Approximately 7,425 acres (3,005 hectares) were treated with herbicides in 2014 on radiological waste sites, around operations areas, and along roadways to keep areas free of deep-rooted vegetation (e.g., Russian thistle, also known as tumbleweed). Follow-up treatments are included in the total treated acres; several areas received more than one herbicide application.

***Waste Site Remediation and Revegetation.*** In 2014, 2 acres (0.81 hectare) were planted with native grass seed to stabilize areas where repair and maintenance activities disturbed existing vegetation. Waste sites in the 200 East Area and 200 West Area were designed and constructed with a cap of perennial grass. Integrated Biological Control has been actively restoring vegetative caps on other waste sites.

## Section 11, Resource Protection

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DOE is responsible for managing and protecting biological and cultural resources on the Hanford Site. Ecological and cultural resource monitoring are conducted to collect and track data needed to ensure compliance with an array of laws, regulations, and policies governing DOE activities.

***Ecological Protection.*** Ecological monitoring data provide baseline information about the plants, animals, and habitats under RL stewardship at Hanford that is required to make cleanup decisions. During 2014, DOE continued to monitor and evaluate species that are protected by federal or state laws and regulations or are of special interest to the public and stakeholders. Fall Chinook salmon redds, steelhead redds, and bald eagle nesting and night roosting activity were assessed because these species have the potential to be impacted by Hanford Site operations. Additional monitoring efforts included nesting raptors and migratory birds.

***Endangered and Threatened Species.*** Two endangered and threatened fish species, Upper Columbia spring-run Chinook salmon and steelhead, are known to occur regularly on the Hanford Site. One additional fish species (bull trout) was recorded at the site but scientists believe it is transient. Umtanum desert buckwheat and White Bluffs bladderpod, federally threatened plant species, also occur on the site. No other plants or animals known to occur on the Hanford Site are currently federally threatened or endangered, but greater sage grouse and Washington ground squirrel are currently candidates for federal listing.

***Cultural and Historic Resource Protection.*** DOE is responsible for managing and protecting the Hanford Site's cultural and historic resources in accordance with applicable federal cultural resources laws and regulations and DOE management plans. Hanford Site archaeologists reviewed 17 undertakings that had the potential to affect cultural resources. Approximately 634 hectares (1,566 acres) of new ground were surveyed because of the 17 undertakings. Of the 17 undertakings, 13 were identified as No Historic Properties Affected, while 4 were determined to have No Adverse Effects to historic properties. In addition, five projects (most in the 200 Areas) were reviewed and completed under an emergency declaration (Post Reviews)

The Hanford Collection comprises artifacts from the Manhattan Project and Cold War era. During 2014, 47 artifacts were picked up from Hanford Site facilities and delivered to the 4732-A Artifact Staging Facility. Another 42 artifacts (of 743 tagged artifacts still left for collection) were reviewed but not collected; 3 were determined to be unfeasible to collect, 12 have radiological concerns that must be resolved before being released, and 27 are scheduled for collection between 2015 and 2048.

## **Section 12, Quality Assurance**

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Quality assurance and control programs for the Hanford Site and offsite environmental surveillance were documented through project-specific quality assurance plans and describe applicable quality assurance elements. Samples were collected and analyzed according to documented standard procedures. Analytical data quality was verified by a continuing program of internal laboratory quality control, participation in inter-laboratory crosschecks, duplicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories. No issues were identified that significantly affected the quality assurance and control for Hanford Site sampling and analytical activities during 2014.

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## Acronyms

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AEA	<i>Atomic Energy Act</i>
AFRI	Applied Field Research Initiative
ALARA	as low as reasonably achievable
ALARACT	As Low As Reasonably Achievable Control Technology
ARAR	applicable or relevant and appropriate requirement
ASCEM	Advanced Simulation Capability for Environmental Management
ASME	American Society of Mechanical Engineers
ATL	Advanced Technologies and Laboratories, Inc.
BNI	Bechtel National, Inc.
BRMP	Biological Resources Management Plan
C&D	construction and demolition
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CFR	<i>Code of Federal Regulations</i>
CHPRC	CH2M HILL Plateau Remediation Company
CHRP	Cultural and Historic Resource Protection
CLUP-EIS	<i>Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement</i> , DOE/EIS-0222-F
COC	contaminant of concern
Council	Hanford Natural Resource Trustee Council
CRR	Cultural Resource Review
CSB	Canister Storage Building
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CVDF	Cold Vacuum Drying Facility
CWC	Central Waste Complex
CY	calendar year
D4	deactivation, decommission, decontamination and demolition
DAHP	Washington State Department of Archaeology and Historic Preservation
DOE	U.S. Department of Energy (also USDOE)
DOE-CAP	DOE Consolidated Audit Program
DOE-HQ	U.S. Department of Energy, Headquarters
DNFSB	Defense Nuclear Facility Safety Board
DST	double-shell tank
DWS	drinking water standard
EA	environmental assessment
Ecology	Washington State Department of Ecology
EDP	environmental data point
ETF	200 Area Effluent Treatment Facility
EIS	Environmental Impact Statement
EM	U.S. Department of Energy, Office of Environmental Management
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
EPCRA	<i>Emergency Planning and Community Right-to-Know Act of 1986</i>
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FFTF	Fast Flux Test Facility

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FONSI	finding of no significant impact
FR	Federal Register
FS	feasibility study
FY	fiscal year
GEA	gamma energy analysis
GEL	General Engineering Laboratories, LLC
GIS	Geographic Information System
HAB	Hanford Advisory Board
HAMMER	Volpentest HAMMER Federal Training Center
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HEPA	high-efficiency particulate absorber
HLW	high-level waste
HPMC	HPMC Occupational Medical Services
HRM	Hanford River Mile
HRNM	Hanford Reach National Monument
HRS	Hazard Ranking System
HSS	U.S. Department of Energy, Office of Health, Safety, and Security
HTO	tritiated water vapor
HQ	U.S. Department of Energy, Headquarters
IC	institutional control
ICRP	International Commission on Radiological Protection
IDF	Integrated Disposal Facility
ISMS	Integrated Safety Management System
ISS	interim safe storage
KBC	K Basins Closure Project
LERF	Liquid Effluent Retention Facility
LLBG	low-level burial ground
LLW	low-level waste
LOSS	large onsite sewer systems
LTS	long-term stewardship
MAPEP	Mixed Analyte Performance Evaluation Program
MARS	Mobile Arm Retrieval System
MBTA	<i>Migratory Bird Treaty Act</i>
MEI	maximally exposed individual
MNA	monitored natural attenuation
MSA	Mission Support Alliance, LLC
NCRP	National Council on Radiation Protection
NEPA	<i>National Environmental Policy Act of 1969</i>
NESHAP	“National Emission Standards for Hazardous Air Pollutants”
NHPA	<i>National Historic Preservation Act of 1966</i>
NLOP	north load-out pit
NOAA	National Oceanic and Atmospheric Administration
NRDWL	Nonradioactive Dangerous Waste Landfill
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
NRDA	natural resource damage assessment

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NRDAR	natural resource damage assessment and restoration
NRHP	National Register of Historic Places
OEI	Office of Independent Enterprise Assessments
OFI	opportunities for improvements
ORP	U.S. Department of Energy, Office of River Protection
OSHA	Occupational Safety and Health Administration
OSS	onsite sewer systems
P&T	pump and treat
PCB	polychlorinated biphenyl
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PT	pretreatment
PUREX	Plutonium/Uranium Extraction (Plant)
QA	quality assurance
QC	quality control
QRA	quantitative risk assessment
RBDA	risk-based disposal approval
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RCW	<i>Revised Code of Washington</i>
REDOX	reduction/oxidation (Plant)
RI	remedial investigation
RFID	radiofrequency identification
RL	U.S. Department of Energy, Richland Operations Office
ROD	record of decision
RPD	relative percent difference
RUM	Ringold Formation upper mud unit
SARA	<i>Superfund Amendments and Reauthorization Act</i>
SDWA	Safe Drinking Water Act
SEP	special environmental project
SHPO	Washington State Historic Preservation Office
SST	single-shell tank
SWL	Solid Waste Landfill
TCP	Traditional Cultural Property
TEDF	Treated Effluent Disposal Facility
TLD	thermoluminescent dosimeter
TPA	<i>Hanford Federal Facility Agreement and Consent Order</i> , aka Tri-Party Agreement
TRIDEC	Tri-Cities Economic Development Council
Tri-Party Agencies	U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology
TSD	treatment, storage, and disposal
USC	<i>United States Code</i>
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey
VPP	Voluntary Protection Program
WAC	<i>Washington Administrative Code</i>
WBGT	wet-bulb global temperature
WCH	Washington Closure Hanford, LCC

WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health
WESF	Waste Encapsulation and Storage Facility
WIPP	Waste Isolation Pilot Plant
WMA	waste management area
WNHP	Washington Natural Heritage Program
WRAP	Waste Receiving and Processing (Facility)
WRPS	Washington River Protection Solutions, LLC
WSCF	Waste Sampling and Characterization Facility
WTP	Waste Treatment and Immobilization Plant



## 1.0 Introduction

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*SA Thompson*

Since 1959, the U.S. Department of Energy (DOE) has published the Hanford Site Environmental Report annually to inform the public, regulators, stakeholders, and other interested parties of the site's environmental performance during the year. The Hanford Site Environmental Report for Calendar Year (CY) 2014 includes a brief description of the Hanford Site mission; compliance with applicable federal, state, and local environmental laws, regulations permits, executive orders, DOE policies and directives; and descriptions of summary data from environmental-related programs. The annual environmental reports are available on the Internet at <http://msa.hanford.gov/page.cfm/enviroreports>. The reports include sections that describe the following:

- ⊗ Site compliance with local, state, and federal environmental standards and requirements
- ⊗ Site operations, including environmental restoration efforts and cleanup and closure activities
- ⊗ Environmental management performance
- ⊗ Environmental occurrences and responses
- ⊗ Effluents and emissions from site facilities
- ⊗ Results of onsite and offsite environmental and groundwater monitoring efforts
- ⊗ Cultural and biological resource assessments.

Additional detail is provided in the appendices, and descriptions of specific analytical and sampling methods used for the 2014 monitoring efforts are provided in the *Hanford Site Environmental Monitoring Plan* ([DOE/RL-91-50](#)).

Section 1.0 provides information on the Hanford Site's location and environmental setting, including mission, management, primary operations and activities, and climate and meteorology. It also discusses stakeholder involvement, the role of Native American tribes, and Hanford regulatory oversight.

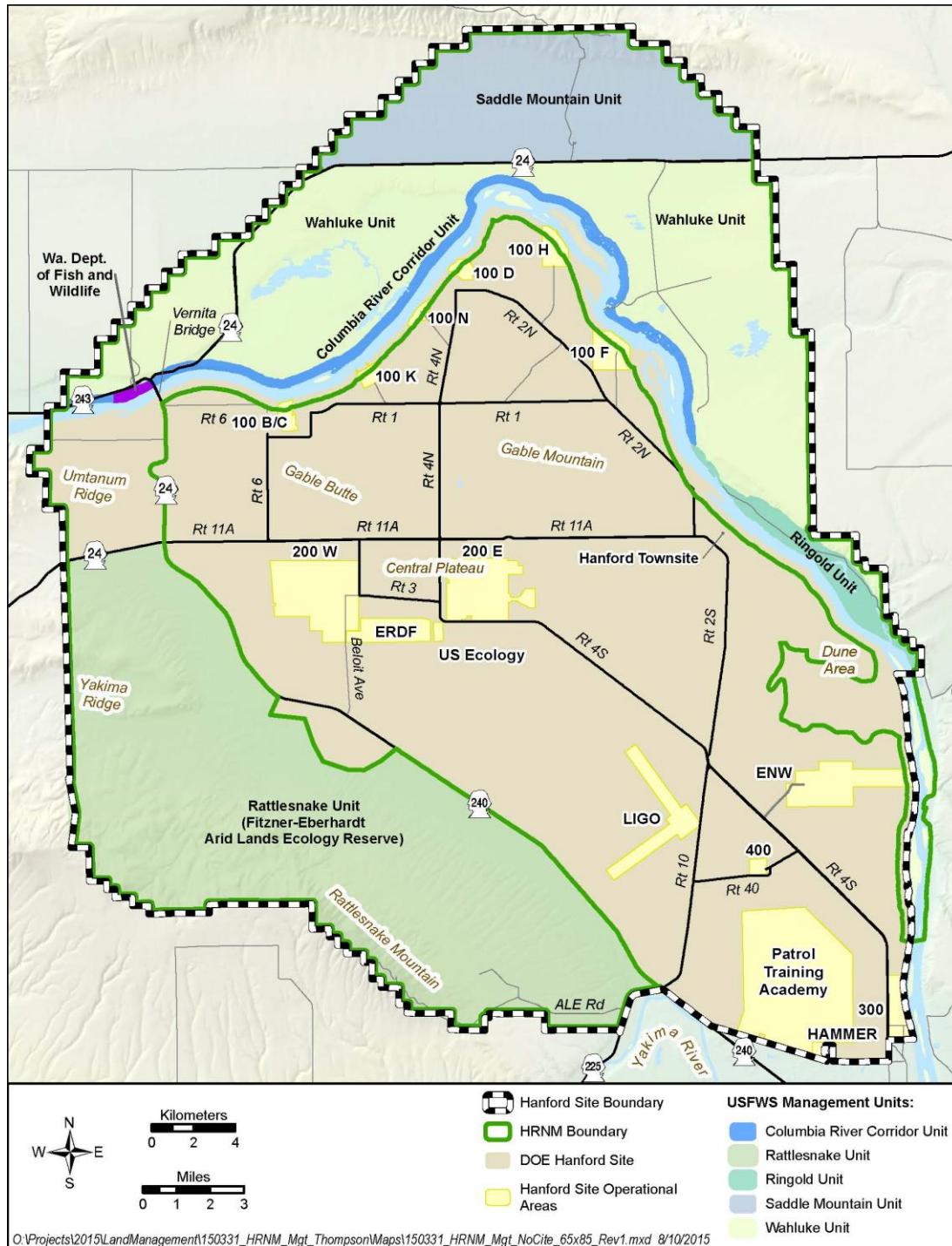
### 1.1 Hanford Site Location,

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State (Figure 1.1). The site occupies an area of approximately 586 square miles (1,517 square kilometers) north of the confluence of the Yakima and Columbia rivers. This land, with restricted public access, provides a buffer for areas once used for nuclear materials production, waste storage, and waste disposal. The Columbia River flows through the northern part of the site, and turning south, forms part of the eastern site boundary. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries, and the Saddle Mountains form the northern boundary. Adjoining lands are principally range and agriculture land. The cities of Richland, Pasco, and Kennewick (the Tri-Cities) constitute the nearest population centers and are located southeast of the Hanford Site ([PNNL-6415 Rev 16](#)).

The region's climate is greatly influenced by the Pacific Ocean, the Cascade Range to the west, and other mountain ranges located to the north and east. Other geographic features include the White Bluffs, Gable Mountain, and Gable Butte. Average annual precipitation is 7.08 inches (17.98 centimeters). In addition

to the Columbia River, natural surface waters on the Hanford Site include Rattlesnake and Snively springs and West Lake. The Hanford Site is characterized as a shrub-steppe ecosystem. Plant and wildlife communities include both terrestrial and aquatic species, some of which are considered rare and/or declining or are of significant interest to federal, state, or tribal governments or the public.

**Figure 1.1. Hanford Site and Hanford Reach National Monument (HRNM)**



## 1.2 Hanford Site Mission

The Hanford Site played a pivotal role in the nation's defense for more than 40 years. During the World War II Manhattan Project and Cold War, Hanford Site facilities were dedicated primarily to the production of plutonium to fuel atomic weapons and management of the resulting legacy waste. In 1989, when the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and DOE (Tri-Party Agencies) signed the *Hanford Federal Facility Agreement and Consent Order* ([Ecology et al. 1989a](#)) (also known as the Tri-Party Agreement or TPA), the primary mission shifted to developing new waste treatment and disposal technologies and characterizing and cleaning up contamination left from historical operations. The Hanford Site's current mission focuses on environmental restoration, which includes remediation of contaminated areas, decontamination and decommissioning of Hanford Site facilities, waste management, and related scientific and environmental research and development of waste management technologies.

## 1.3 Primary Operations and Activities

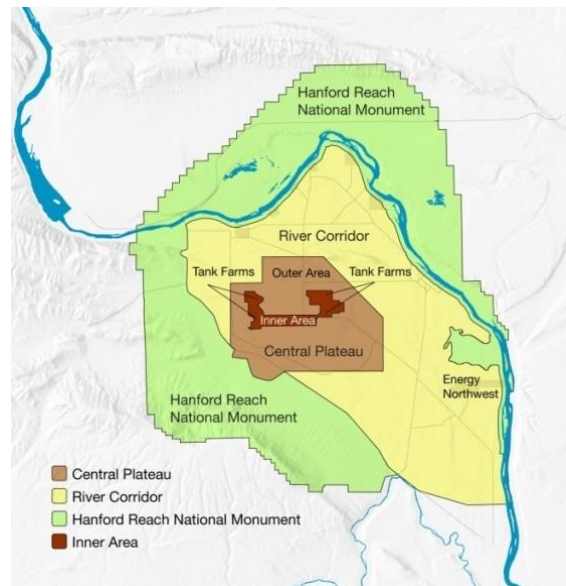
The major DOE operational, administrative, and research areas on and around the Hanford Site include the following:

- ⊗ **100 Area** – The 100 Area consists of six distinct sites (100-B/C, 100-D, 100-F, 100-H, 100-K, and 100-N) that are located along the shore of the Columbia River in the northern portion of the Hanford Site. These areas were the location of nine nuclear reactors that have since been retired. Collectively, the 100 Area occupies approximately 4 square miles (11 square kilometers). The B Reactor, a National Historic Landmark, is located in the 100-B Area. As the world's first industrial-scale nuclear reactor, B Reactor produced plutonium for the first atomic explosion (Trinity Test) and the atomic bomb that was detonated over Nagasaki, Japan.
- ⊗ **200 Area** – The 200-East and 200-West Areas cover approximately 6 square miles (16 square kilometers) and are located on the Central Plateau, approximately 5 and 7 miles (8 and 11 kilometers) south and west of the Columbia River. The plateau surface is approximately 328 feet (100 meters) above the level of the Columbia River and about 280 feet (85 meters) above the underlying water table. These areas contain underground waste storage tanks and housed facilities (known as separations plants) that extracted plutonium from dissolved irradiated fuel. The 200-North Area covers approximately 58.6 acres (23.7 hectares), and operations here are mainly related to irradiated nuclear fuel interim storage. Thermal cooling of the spent fuel required water, which was disposed of at several sites within the 200-North Area. Remediation of these sites is ongoing.
- ⊗ **300 Area** – The 300 Area is located just north of the city of Richland and covers approximately 0.6 square mile (1.5 square kilometers). From the early 1940s until the advent of the environmental cleanup mission in 1989, nuclear fuel fabrication and research and development activities were performed at the 300 Area. Remediation of waste sites and decommissioning of 300 Area facilities is ongoing.
- ⊗ **400 Area** – The 400 Area is located northwest of the 300 Area, and covers approximately 0.23 square mile (0.61 square kilometer). This area includes the Fast Flux Test Facility (FFTF), a nuclear reactor designed and used to test various types of nuclear fuel, produce medical and industrial isotopes, and

conduct cooperative international research. The FFTF operations were discontinued in 1992, and the facility is now in a low-cost, long-term surveillance and maintenance condition.

- ⊗ **600 Area** – The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.
- ⊗ **1100 Area** – The former 1100 Area is located between the 300 Area and the city of Richland and covers 1.2 square miles (3.1 square kilometers). In October 1998, this area was transferred to the Port of Benton as part of DOE's economic diversification efforts and is no longer part of the Hanford Site. However, DOE contractors continue to lease facilities in this area.
- ⊗ **Richland North Area** (off site) – This area includes the Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory (PNNL), and other DOE and contractor facilities (mostly office buildings), generally located in the northern part of the city of Richland.
- ⊗ **700 Area** (off site) – The 700 Area includes DOE administrative buildings in the central region of the city of Richland.
- ⊗ **Volpentest HAMMER Federal Training Center** (HAMMER) – HAMMER is a worker safety training facility located on the Hanford Site near the city of Richland and is used by site contractors, federal and state agencies, tribal governments, and private industry. HAMMER contracts with emergency response agencies and offers classes in fire suppression, hostage rescue, high-speed pursuit, and drug enforcement. The center also works with the U.S. Department of State to train international border patrol agents and homeland security staff. The facility consists of a 0.12-square-mile (0.31-square-kilometer) main site and a 15.6-square-mile (40.4-square-kilometer) law enforcement and security-training site.
- ⊗ **Non-DOE Operations and Activities on Hanford Site Leased Land** – Energy Northwest operates a commercial nuclear power reactor at the Columbia Generating Station, north of the 300 Area, on 1,090 acres (440 hectares). US Ecology Washington operates a commercial low-level radioactive waste burial site, located west of the 200-East Area on 99 acres (40 hectares). West of the 400 Area, the California Institute of Technology and Massachusetts Institute of Technology jointly operate the Laser Interferometer Gravitational-Wave Observatory, which is sponsored by the National Science Foundation.
- ⊗ **Non-DOE Nuclear Operations Near the City of Richland** – AREVA NP, Inc., operates a commercial nuclear fuel fabrication facility near the southern boundary of the Hanford Site, and Perma-Fix Northwest, Inc., operates a low-level and mixed low-level radioactive waste processing facility located immediately adjacent to the southern boundary of the Hanford Site on 53 acres (21 hectares). In addition, Westinghouse Electric Company operates the Richland Service Center in north Richland, which provides chemical cleaning, chemical decontamination, and related chemical and waste processing services to the nuclear industry.
- ⊗ **Hanford Reach National Monument** – The Hanford Reach National Monument (Figure 1.1), established by Presidential Proclamation *Establishment of the Hanford Reach National Monument* (65 FR 37253) in June 2000, covers 195,000 acres (78,900 hectares). The purpose of the monument is to protect the nation's only non-impounded stretch of the Columbia River upstream of Bonneville Dam and the remaining shrub-steppe ecosystem that once blanketed the Columbia River Basin. The

monument is divided into five distinct administrative units: Rattlesnake (Fitzner/Eberhardt Arid Lands Ecology Reserve), Columbia River Corridor, Ringold, Wahluke, and Saddle Mountain. The U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), and DOE, Richland Operations Office (RL) manage portions of the monument. DOE-RL manages a 14-square-mile (36.4 kilometer) area of the monument north and west of State Highway 24 and south of the Columbia River in Benton County known as McGee Ranch/Riverlands. DOE also manages the River Corridor Unit, which includes Hanford Reach islands (Benton County) and a 0.25-mile (0.4-kilometer)-wide strip of land along the Hanford Reach shoreline from Vernita Bridge to just north of the 300 Area. This 39-square-mile (101-square-kilometer) area in Benton, Franklin, and Grant counties also includes the 9.9-square-mile (25.6-square-kilometer) Hanford Site dunes north of Energy Northwest.



## 1.4 Hanford Site Management

*SA Thompson*

DOE is responsible for operating the Hanford Site. DOE-RL and the Office of River Protection (ORP) jointly manage the site through several contractors and their subcontractors. Each contractor is responsible for safe, environmentally sound maintenance and management of its activities or facilities; waste management; evaluation and determination of all discharges to the environment; and for monitoring any potential effluent to ensure environmental regulatory compliance. DOE, the USFWS, and the WDFW each manage portions of the Hanford Reach National Monument, as described above.

The **DOE Richland Operations Office** serves as the Hanford Site property owner and oversees cleanup along the Columbia River and in Hanford's Central Plateau, including groundwater and waste site cleanup; management of solid waste, spent nuclear fuel and sludge; facility cleanout, deactivation and demolition; environmental restoration; plutonium management; and all site support services. The principal contractors for RL and their respective responsibilities include the following:

- ⊗ [Mission Support Alliance, LLC](#) (MSA) was awarded the Mission Support Contract for the Hanford Site in 2009. MSA is a joint venture between Lockheed Martin, Jacobs, and Centerra Group, as well as several partners with specialized Hanford expertise. MSA is responsible for site infrastructure services for the Hanford Cleanup mission, including but not limited to: roads and transportation services; electrical and water services; facility maintenance; emergency response (fire and patrol) services; network and software engineering; cyber security and records management; as well as environmental compliance and clean energy solutions.



- ⊗ [CH2M HILL Plateau Remediation Company](#) (CHPRC) was awarded the Plateau Remediation Contract in 2008. CHPRC is responsible for the safe environmental cleanup of the Central Plateau at the Hanford Site, including waste retrieval and fuels management, groundwater and vadose zone remediation, demolition of facilities and canyons, closure of the Plutonium Finishing Plant (PFP), and remediating the 100-K Area along the Columbia River, which includes preparing for treatment of highly radioactive sludge that is now in the K-West Basin, where it will be stored until it can be treated.
- ⊗ [Washington Closure Hanford, LLC](#) (WCH) was awarded the River Corridor Closure Contract in March 2005. WCH is made up of the Washington Division of URS Corporation, Bechtel National, Inc. (BNI), and CH2M HILL Hanford Group, Inc. WCH workers are responsible for cleaning up waste sites at Hanford, decontaminating and decommissioning former plutonium production nuclear reactors and surplus facilities, and disposing of contaminated waste. WCH is expected to complete its mission for DOE-RL by 2016.
- ⊗ [HPMC Occupational Medical Services](#) (HPMC) was awarded the occupational medical contract for the Hanford Site in 2012. HPMC Occupational Medical Services provides occupational medical services to DOE and Hanford employees. It is responsible for the health and safety needs of more than 10,000 Hanford workers. HPMC has clinics in Richland and the Hanford 200-West Area.

The **DOE Office of River Protection** was established by Congress in 1998 as a field office to manage the retrieval, treatment, and disposal of approximately 53 million gallons (200 million liters) of radioactive tank waste currently stored in 177 underground tanks in the central part of the site. The tank waste is material left over from years of World War II and post-war production of nuclear weapons fuel. In support of this mission, ORP is responsible for the safe operation of the tank farms and construction and operation of the Waste Treatment and Immobilization Plant (WTP), located on the Central Plateau. ORP and its principal contractors and their respective responsibilities include the following:

- ⊗ [Advanced Technologies and Laboratories International, Inc.](#) (ATL) was awarded the Laboratory Analytical Services and Testing contract in 2009. ATL operates the 222-S Laboratory Complex, the primary onsite laboratory for analysis of highly radioactive samples in support of all Hanford projects. Located in the 200-West Area, this laboratory is equipped and staffed to receive, analyze, and store samples and report analytical results to the appropriate contractor. Technicians test some 25,000 samples of materials in support of the Hanford cleanup mission every year.
- ⊗ [Bechtel National Inc.](#) (BNI) was awarded the contract to design, construct, and startup the WTP in 2000. Construction of WTP is the largest of its kind in the world. When complete, the WTP will be used to transform the approximately 53 million gallons (200 million liters) of radioactive and chemical wastes being stored in underground tanks at the Hanford 200 Area into a stable glass form for permanent disposal.
- ⊗ [Washington River Protection Solutions LLC](#) (WRPS) was awarded the Tank Operations Contract in 2008. WRPS is made up of the URS Corporation, Energy Solutions, and AREVA as the primary subcontractor. WRPS is responsible for safely managing the underground waste storage tanks until the waste is prepared for disposal. The waste is stored in 149 older single-shell tanks and 28 newer and

safer double-shell tanks that are grouped into 18 farms located in the 200 Area on the Hanford Site Central Plateau.

The **Office of Science** manages DOE's science and technology programs, goals, and objectives at the Hanford Site. Its principal contractor is Pacific Northwest National Laboratory (PNNL), described below:

- ⊗ [PNNL](#), operated by Battelle Memorial Institute for DOE, was awarded the Laboratory contract in 1965 and is one of 10 DOE national laboratories managed by the Office of Science. PNNL is responsible for conducting research and delivering scientific solutions from multiple scientific disciplines to solve energy, environmental, and national security challenges. PNNL supports not only DOE, but the U.S. Department of Homeland Security, National Nuclear Security Administration, and other government agencies, universities, and industry.

## 1.5 Climate and Meteorology

*PJ Perrault*

The Hanford Meteorology Station is located at the Hanford Site Central Plateau. Researchers take meteorological measurements to support Hanford Site operations, emergency preparedness and response, and atmospheric dispersion calculations for dose assessments. Support is provided through weather forecasting and by maintaining and distributing climatological data. Forecasting is provided to help manage weather-dependent operations. Climatological data are provided to help plan weather-dependent activities and to assess the environmental effects of site operations.

Hanford Meteorology Station staff rely on data provided by the Hanford Meteorological Monitoring Network. This network consists of 28 remote monitoring stations that transmit data to the Hanford Meteorology Station through radio telemetry every 15 minutes. There are 2 towers that are 10 feet (3 meters) high, 24 towers that are 30 feet (9 meters) high, and 3 towers that are 200 feet (61 meters) high. Meteorological information collected at these stations includes wind speed, wind direction, temperature, precipitation, atmospheric pressure, dewpoint temperature, wet-bulb global temperature (WBGT), solar radiation, relative humidity, and subsurface soil temperature; however, not all these data are collected at all stations.

Regional temperatures, precipitation, and winds are affected by mountain barriers. The Cascade Range, beyond Yakima to the west, greatly influences the climate of the Hanford Site because of its rain-shadow effect. The Rocky Mountains and ranges in southern British Columbia in Canada protect the region from severe, cold polar air masses moving southward across Canada and winter storms associated with them.

Prevailing wind direction in the Central Plateau is from the northwest all year long. The secondary wind direction is from the southwest. Summaries of wind directions indicate that winds from the northwestern quadrant occur most often during winter and summer. During spring and fall, the frequency of southwesterly winds increases, with a corresponding decrease in the northwesterly flow. Monthly average wind speeds are lowest during winter months, averaging about 6 to 7 miles per hour (3 meters per second), and highest during summer, averaging about 8 to 9 miles per hour (4 meters per second).

Wind speeds well above average are usually associated with southwesterly winds. However, summertime drainage winds are generally northwesterly and frequently exceed 30 miles per hour (13 meters per



second). These winds are most prevalent over the northern portion of the Hanford Site. Figure 1.2 shows the 2014 wind roses (i.e., diagrams showing direction and frequencies of wind) measured at a height of 30 feet (9 meters) for the 28 meteorological monitoring stations located at and around the Hanford Site.

Atmospheric dispersion is a function of wind speed, wind duration and direction, atmospheric stability, and mixing depth. Dispersion conditions are generally good if winds are moderate to strong, the atmosphere is of neutral or unstable stratification, and there is a deep mixing layer. Good dispersion conditions associated with neutral and unstable stratification exist approximately 57 percent of the time during summer. Less-favorable conditions may occur when wind speed is light and the atmospheric dispersion-mixing layer is shallow. These conditions are most common during winter when moderate to extremely stable stratification exists (approximately 66 percent of the time). Occasionally, there are extended periods of poor dispersion conditions, primarily during winter, that are associated with stagnant air in stationary high-pressure systems.

### **1.5.1 Historical Climatological Information**

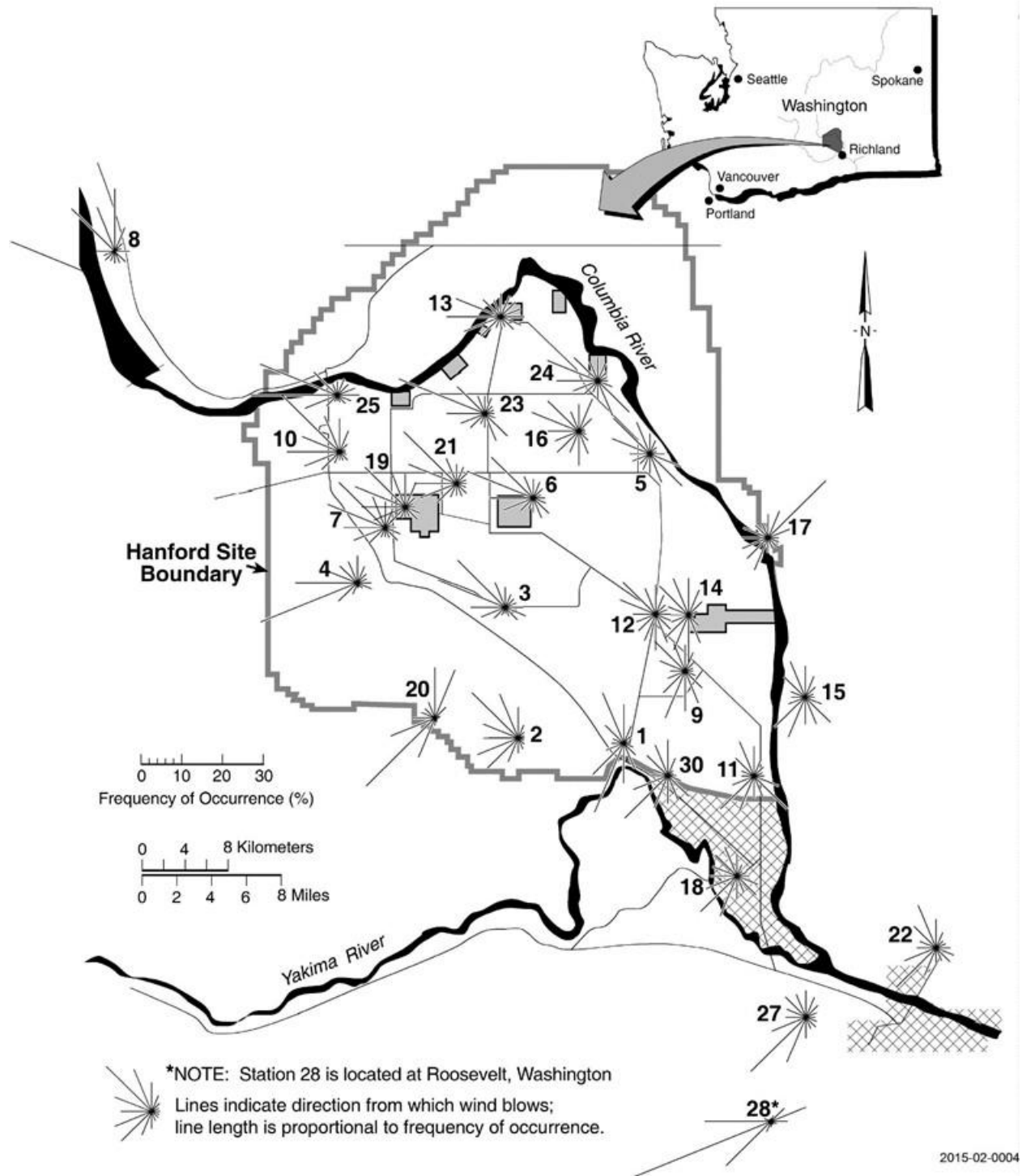
The following climatological information is for the Hanford Meteorological Station covering the period 1945 through 2014.

The normal annual average temperature at the Hanford Meteorological Station is 53.9° Fahrenheit (F) [12.2° Celsius (C)]. The monthly average temperature ranges from a high of 77.1°F (25.1°C) in July to a low of 31.1°F (-0.5°C) in December. The record highest monthly average temperature is 82.8°F (28.2°C) recorded in July 2014, and the record lowest monthly average temperature is 12.1°F (-11.1°C) recorded in January 1950. The highest daily temperature ever recorded at the Hanford Meteorological Station is 113°F (45°C) on three separate occasions: August 1961, July 2002, and July 2006. The lowest daily temperature ever recorded has been -23°F (-31°C) in February 1950.

The normal annual relative humidity at the Hanford Meteorological Station is 55.3 percent. Relative humidity is highest during winter (Dec-Jan), averaging 77.2 percent, and lowest during summer (Jun-Aug), averaging 36.5 percent. The record highest monthly average relative humidity is 90.5 percent recorded in December 1950. The record lowest monthly average relative humidity is 21.9 percent recorded in July 1959. The hourly relative humidity has ranged from 100 percent to 6 percent.

Normal annual precipitation at the Hanford Meteorological Station is 7.08 inches (17.98 centimeters). Most precipitation occurs during the winter, with more than half of the annual amount occurring from November through February. The wettest year on record, 1995, received 12.31 inches (31.23 centimeters) of precipitation; the driest, 1976, received 2.99 inches (7.59 centimeters). The highest 24 hour total of precipitation is 1.91 inches (4.9 centimeters) recorded in October 1957. The normal seasonal snowfall is 15.3 inches (38.9 centimeters). The record highest seasonal snowfall total is 56.1 inches (142.5 centimeters) recorded in the 1992-1993 season. The record lowest seasonal snowfall total is 0.3 inch (0.8 centimeter) recorded in the 1957-1958 season. The most snowfall from a single storm is 12.4 inches (31.5 centimeters) recorded in February 1993. The record for snow depth is 15.6 inches (39.6 centimeters) in December 1985.

**Figure 1.2. Meteorological Monitoring Network Wind Roses**  
Measured at a height of 30 feet [9 meters]



The normal annual wind speed at the Hanford Meteorological Station is 7.6 miles per hour (3.4 meters per second). The monthly average wind speed ranges from a high of 9.0 miles per hour (4.0 meters per

second) in June to a low of 5.9 miles per hour (2.6 meters per second) in December. The record highest monthly average wind speed is 11.1 miles per hour (5.0 meters per second) on multiple dates: April 1959 and 1972, and February 1999. The record lowest monthly average wind speed is 2.9 miles per hour (1.3 meters per second) in November 1956 and January 1985. The record highest daily wind speed is 33.7 miles per hour (15.1 meters per second) recorded in January 1972, and the record lowest daily wind speed is 0.3 mile per hour (0.1 meter per second) in January 1982 and November 1989. The record highest peak wind gust is 80 miles per hour (36 meters per second) in January 1972. The record highest hourly wind speed is 51 miles per hour (23 meters per second) in January 1972.

The normal annual station pressure at the Hanford Meteorological Station is 29.213 inches of mercury. The monthly average station pressure ranges from a high of 29.329 inches in December to a low of 29.129 inches in August. The record highest monthly station pressure is 29.638 inches in December 1985, and the record lowest monthly station pressure is 28.999 inches in February 1998. The record highest hourly station pressure is 30.23 inches (adjusted sea level pressure of 1053.8 millibars) in January 1979. The record lowest hourly station pressure is 28.10 inches (adjusted sea level pressure of 977.3 millibars) in December 1951.

Daily and monthly averages and extremes of ambient temperature, dew point temperature, wet bulb temperature, pressure, wind, precipitation, sky cover, fog, solar radiation, relative humidity, thunderstorms, and other miscellaneous weather phenomena for 1945 through 2004 are reported in *Climatological Summary 2004 with Historical Data* ([PNNL-15160](#)).

### 1.5.2 Monitoring

The average temperature for 2014 was 56.1 °F (13.4 °C), which was 2.2 °F above normal. This made 2014 the fifth warmest year on record. During 2014, 10 months were warmer than normal, 2 months were cooler than normal, and December had the greatest positive departure at 5.9 °F above normal. July and October were 5.7 °F and 5.6 °F above normal. February had the greatest negative departure at -4.3 °F below normal. July's monthly average temperature of 82.8 °F (28.2 °C) was an all-time record for highest monthly temperature.

Precipitation totaled 6.53 inches (16.59 centimeters), which is 92 percent of normal precipitation (7.08 inches [17.98 centimeters]). Greatest monthly total of precipitation was 1.12 inches (2.84 centimeters) in February, and lowest monthly total was 0.04 inch (0.10 centimeter) in July. March 27-28, had the greatest 24-hour precipitation at 0.50 inch (1.27 centimeters). This included 0.21 inch (0.53 centimeter) that fell in 35 minutes. Snowfall for 2014 totaled 14.8 inches (37.6 centimeters), which is 97 percent of normal (15.3 inches ([38.6 centimeters])). This included 11.9 inches (30.2 centimeters) that fell in February for the fifth snowiest February on record. On March 27 and August 2, a trace amount of hail [0.25 inch (0.64 centimeter)] fell at the Hanford Meteorological Station. The average is approximately 1 occurrence of hail every 2 years.

Average wind speed was 8.4 miles per hour (3.8 meters per second), which was 0.8 mile per hour (0.4 meter per second) above normal. This ties for the second highest annual average wind speed on record. The peak gust for the year was south-southwest at 66 miles per hour (30 meters per second) and occurred on January 11. This was the third highest gust ever recorded in January. The peak gust of 55

miles per hour (25 meters per second) recorded on July 23, out of the west-southwest, tied for the third highest gust ever recorded for July. The peak gust recorded on August 12, of 61 miles per hour (27 meters per second) out of the southwest, is the second highest gusts ever recorded for August. Each of these events caused blowing dust with reduced visibility, dropping to as low as 0.75 mile in August. In November, the highest wind recorded on Rattlesnake Mountain was a sustained southwest wind of 79 miles per hour (35 meters per second) with gusts to 95 miles per hour (42 meters per second).

A record for the longest growing season ever recorded was set in 2014. The last frost in the spring was March 31, and the first frost in the fall was November 11. This made the growing season 224 days, which surpassed the previous record of 216 days in 1994.

Monthly and annual climatological data collected at the Hanford Meteorology Station is provided in Table 1.1. Real-time and historical data from the Hanford Meteorology Station are available at <http://www.hanford.gov/hms>. The website data includes hourly weather observations, 15-minute data, monthly climatological summaries, and historical data

## **1.6 Stakeholder Involvement**

DOE encourages information exchange and public involvement in discussions and decision making regarding Hanford Site cleanup and remediation actions. Active participants include the public; Native American tribes; local, state, and federal government agencies; advisory boards; activist groups; and other entities in the public and private sectors. The roles and involvement of selected stakeholders are described in the following sections.

### **1.6.1 Role of Native American Tribes**

*JA Conrad*

The role of Native American tribes at the Hanford Site is guided by *Department of Energy American Indian Tribal Government Interactions and Policy* ([DOE O 144.1](#)), which communicates departmental, programmatic, and field responsibilities for interacting with American Indian governments. This order incorporates both policy and consultation guidance in working with Native American tribes. DOE will consult with any American Indian or Alaska Native tribal government with regard to any property to which that tribe attaches religious or cultural importance, which might be affected by a DOE action. The policy outlines the trust relationship that DOE has with Native American tribes and commits the agency to institute government-to-government relations with the tribes. [DOE O 144.1](#), Attachment 3, “Offices of Environmental Management, Science, Nuclear Energy, and the National Nuclear Security Administration Framework for Implementing the Department of Energy’s American Indian and Alaska Native Policy,” provides additional guidance on how tribal consultation is to be conducted.

**Table 1.1. Meteorology Station Monthly and Annual Climatological Data**  
*Hanford Meteorology Station, 25 miles (40 kilometers) northwest of Richland, Washington*  
*latitude 46° 34'N, longitude 119° 35'W, elevation 733 feet (223 meters)*

Month	Temperature, °F								Precipitation (inches)				Relative Humidity (%)		15-m Wind <sup>a</sup>				
	Averages				Extremes										Peak Gusts				
	Daily Maximum	Daily Minimum	Monthly	Departure <sup>b</sup>	Highest	Date	Lowest	Date	Total	Departure <sup>b</sup>	Total	Departure <sup>b</sup>	Average	Departure <sup>b</sup>	Average Speed (mph)	Departure <sup>b</sup>	Speed (mph)	Direction	Date
Jan	41.5	28.9	35.2	+1.8	59	13	18	4	0.37	-0.57	0.4	-3.0	79.2	-0.6	6.2	-0.1	66	SSW	11
Feb	41.9	25.9	33.9	-4.3	61	12	4	7	1.12	+0.42	11.9	-2.3	67.8	-2.9	8.4	+1.5	52	SW	18
Mar	59.6	35.6	47.6	+1.1	70	15	19	3	1.00	+0.43	1.5	-0.4	53.4	-3.8	9.1	+1.2	48	WNW	17
Apr	68.3	42.5	55.4	+1.9	82	30	33	14	0.38	-0.17	0	0	41.7	-6.6	9.7	+1.2	46	SW	19
May	79.7	51.5	65.6	+3.5	91	15	44	12 <sup>c</sup>	0.24	-0.27	0	0	35.3	-7.9	9.4	+0.6	41	WNW	16
Jun	84.6	57.1	70.9	+1.3	95	23	48	21	0.26	-0.25	0	0	34.0	-5.6	10.1	+1.1	42	NW	10
Jul	98.4	67.2	82.8	+5.7	110	16	54	25 <sup>c</sup>	0.04	-0.14	0	0	25.8	-8.3	8.8	+0.2	55	WSW	23
Aug	93.3	65.0	79.2	+3.4	104	5 <sup>c</sup>	58	24	0.88	+0.70	0	0	35.6	-0.1	8.2	+0.2	61	SW	12
Sep	82.7	55.6	69.2	+2.8	93	21	47	14	0.16	-0.15	0	0	39.2	-3.8	8.4	+1.1	42	WNW	30
Oct	70.0	47.5	58.7	+5.6	93	6	38	29 <sup>d</sup>	0.77	+0.28	0	0	59.5	+3.4	7.6	+0.9	52	SW	25
Nov	46.6	28.9	37.8	-2.7	69	4	8	30	0.38	-0.57	0.9	-2.0	70.8	-3.1	7.3	+0.6	56	SW	28
Dec	43.7	30.4	37.0	+5.9	59	21	8	31	0.93	-0.27	0.1	-5.5	78.0	-3.2	7.0	+1.1	43	SW	20
Year <sup>d</sup>	67.5	44.7	56.1	+2.2	110	Jul 16	4	Feb 7	6.53	-0.55	14.8	-0.5	51.7	-3.6	8.4	+0.8	66	SSW	Jan 11

Note: Refer to Appendix A, Table A.2, Conversion Table, in the Helpful Information section for unit conversion information.

<sup>a</sup> Measured on a tower 50 feet (15 meters) above ground.

<sup>b</sup> Departure columns indicate positive or negative departure of meteorological parameters from 30-year (1981-2010) climatological normal.

<sup>c</sup> Latest of multiple occurrences.

<sup>d</sup> Yearly averages, extremes, and totals.

The U.S. government has a unique political and legal relationship with tribal governments as defined by treaties, the U.S. Constitution, court decisions defining the federal trust responsibility, and executive orders. Additional federal laws and regulations requiring DOE to consult with Native American tribes on certain issues include the *American Indian Religious Freedom Act*, the *National Environmental Policy Act of 1969* ([NEPA](#)), *Archaeological Resources Protection Act of 1979*, *National Historic Preservation Act of 1966* (NHPA) ([16 USC 470](#)), and *Native American Graves Protection and Repatriation Act of 1990*.

As Hanford Site cleanup progresses, Native American tribes review various aspects of cleanup activities, including how these activities will affect cultural, natural, and biological resources, and the tribes' future ability to use and consume the resources that once existed at the site.

DOE works primarily with four Native American tribes. The Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation ([CTUIR](#)), and the Nez Perce Tribe negotiated treaties with the U.S. government in 1855 (*Treaty with the Nez Perce, 1855; Treaty with the Walla Walla, Cayuse, etc., 1855; Treaty with the Yakama, 1855*). Each treaty included provisions that reserved the rights of Native American tribes to fish at all usual and accustomed places, hunt, gather roots and berries, and pasture horses and cattle on open and unclaimed land, among other rights.

The Wanapum Band, located in Priest Rapids, once resided on lands that are now the Hanford Site. The Wanapum have historic ties to the site and a longstanding relationship with DOE.

DOE provides financial assistance through cooperative agreements with the Confederated Tribes and Bands of the Yakama Nation, [CTUIR](#), and the Nez Perce Tribe to support tribal involvement in decisions made at Hanford. Funding enables Native American tribes to retain staff to facilitate reviews and comment on site-related draft documents and plans, as well as participate in meetings and activities. Tribal experts in tribal culture, history, and resources often contribute their insight and expertise to Hanford Site decision-making processes and activities. Further information regarding the DOE Tribal Affairs Program is available on the following website: <http://www.hanford.gov/page.cfm/inp>.

### **1.6.2 Cultural and Historic Resource Consultations**

*MK Wright*

The NHPA ([16 USC 470](#)) requires DOE to consult with the Washington State Historic Preservation Officer, Native American tribes, local government representatives, the public, and other interested parties on cultural and historic resource matters. Regulations require that DOE solicit and gather input from Native American tribes and interested parties, obtain concurrence from the Washington State Historic Preservation Officer on the identification of cultural resources, evaluate the significance of these resources, and assess impacts of DOE activities on cultural resources. The *Hanford Cultural Resources Management Plan* ([DOE/RL-98-10](#)) provides guidance to DOE on cultural and historic resources issues.

DOE's Cultural and Historic Resource Protection ([CHRP](#)) program consults with the Washington State Historic Preservation Officer, the [Confederated Tribes and Bands of the Yakama Nation](#), the [CTUIR](#), the [Nez Perce Tribe](#), and the [Wanapum](#) through individual meetings and discussions, field walk-downs, and project comment resolution. Tribal cultural experts discuss project scope and design on a monthly basis with DOE, tribal representatives, and other interested parties.

DOE also consults with the Washington State Historic Preservation Officer and other parties that express an interest in historic resources located on the Hanford Site, including groups such as the B Reactor



Museum Association, White Bluffs Pioneers, Benton County Historical Society, East Benton County Historical Museum, and Franklin County Historical and Museum Society.

### 1.6.3 Hanford Natural Resource Trustee Council

#### *TC Post and SH Witness*

The *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA) ([42 USC 9601](#)) and implementing regulations in [40 CFR 300](#), “National Oil and Hazardous Substances Pollution Contingency Plan,” establish DOE as both the CERCLA lead response agency at departmental facilities and a trustee for natural resources under its jurisdiction. As the lead response agency, DOE is mandated to conduct response actions to correct or mitigate threats to human health and the environment that result from the release of hazardous substances during the execution of its assigned missions. CERCLA also provides authority for assessment and restoration of natural resources that have been damaged by a hazardous substance release or response.

Under CERCLA, the United States is liable for damages or injury to, destruction of, or loss of natural resources resulting from release of hazardous substances or from removal or remedial activities made necessary because of such releases, including the cost of assessing such damage. The President of the United States, by [Executive Order 12580](#), *Superfund Implementation*, appointed the Secretary of Energy as the primary trustee for all natural resources located on, over, or under land administered by DOE, including the Hanford Site.

Natural resource trustees are government officials who act on behalf of the public when there is injury to, destruction of, loss of, or threat to natural resources (for which they have management responsibility) because of the release of a contaminant. Federal, state, and tribal entities are authorized to act as trustees pursuant to CERCLA, Section 301(c), which covers natural resource damage assessments (NRDA).

The trustees for the Hanford Site include:

- ⊗ DOE on behalf of the U.S. federal government
- ⊗ U.S. Department of the Interior through the USFWS
- ⊗ U.S. Department of Commerce through the National Oceanic and Atmospheric Administration
- ⊗ State of Washington (through Ecology) in consultation with the WDFW
- ⊗ State of Oregon through the Oregon Department of Energy
- ⊗ Confederated Tribes and Bands of the Yakama Nation (Yakama Nation)
- ⊗ CTUIR
- ⊗ Nez Perce Tribe.

The [Hanford Natural Resource Trustee Council](#) (Council) was established in 1996 via a [memorandum of agreement](#) (DOE et al. 1996), and is a voluntary association of trust organizations. Members collaborate and coordinate on many issues, documents, and actions concerning natural resources. The primary purpose of the council is to facilitate the coordination and cooperation of the trustees in their efforts to mitigate effects to natural resources that result from either hazardous substance releases on the Hanford Site or remediation of those releases. The council has adopted bylaws to direct the process of arriving at consensus on all substantive decisions.



Hanford NRDA work in fiscal year (FY) 2014 focused primarily on continuation of injury studies initiated in prior years and planning for implementation of the Injury Assessment Plan, with a goal of completing injury assessment and preparing a Restoration Plan by 2024. Planning efforts resulted in the completion of a project execution plan. The project execution plan defines the overall work scope, schedule, and budget for the Hanford injury assessment and establishes the means to execute, monitor, and control the project in a disciplined manner. The project execution plan is a 'living document' that will be updated annually based on actual budgets and new information gained from the injury assessment process.

In 2014, the Council continued to meet monthly to plan, organize, implement, and direct Hanford NRDA activities. Technical work groups also met on a regular basis to assist in developing and overseeing studies, reviewing environmental/contaminant release data, and making recommendations to the Council. Each technical work group prepared, and the Council approved, updated five-year work plans providing a prioritized list of tasks, task descriptions, and sequencing information for work within the technical work group.

Initial injury studies are in various stages of completion. In 2014, a final report summarizing results of a Groundwater Contaminant Plume Mapping Study was drafted by the U.S. Geological Survey (USGS) contractor, and the USGS continued to work on the Mussel Toxicity Study, a significant accomplishment during the year. The study compared contaminant concentrations in soils, sediment, and surface water to literature-based injury thresholds. The effort used a substantial amount of existing data, comparing Hanford contaminants of concern concentrations to thresholds in literature and identifying data gaps that will aid the Council in prioritizing and focusing future studies and data collection efforts. Three tribal service loss studies have been approved by the Council, and all three are underway.

In 2014, the Restoration Technical Work Group continued to identify, screen, and develop potential early restoration projects focused mainly on terrestrial resources. Field visits were conducted to observe habitat conditions at some of the proposed project locations. Criteria for the evaluation of early restoration pilot project sites were refined. The Restoration Technical Work Group took the lead in planning and convening a workshop in June to explore streamlined injury assessments and early restoration based on lessons learned from other NRDA sites across the country. It is anticipated that initial restoration projects will be implemented as pilot sites to help develop and refine the Trustee's technical and logistic capability for ecological restoration.

Information about the Council, including its objectives, history, and projects, is available online at <http://www.hanford.gov/page.cfm/hnrtc>.

#### **1.6.4 Public Involvement in Hanford Site Decisions**

*K Skopec*

RL and ORP believe public involvement is essential to the ultimate success of Hanford Site cleanup. Both field offices have staff that coordinate, plan, and schedule public participation activities for DOE on the Hanford Site.

The *Hanford Public Involvement Plan* ([TPA 2012a](#)), previously known as the *Community Relations Plan*, outlines the public participation processes used by the Tri-Party Agencies and outlines ways the public can be involved in Hanford Site cleanup decision-making processes and serves as the overall guidance

document for public participation and outreach activities at Hanford. The first plan was developed and approved with public input in 1990 and was last revised in November 2012.

A key goal of public involvement is to facilitate broad-based participation and obtain stakeholder and public perspectives on Hanford Site cleanup decisions. DOE uses various forums to inform the public of upcoming public involvement and participation opportunities. These include, but are not limited to, the following:

- ⊗ *Hanford Cleanup Line.* Staff administering the Hanford Cleanup Line at (800) 321-2008 respond to information requests about the TPA cleanup activities. The Tri-Party Agencies strive to provide a timely response to all requests. The line is advertised frequently in a variety of ways, including TPA announcements; media information such as newspaper articles, brochures, and meeting notices; and Hanford Site fact sheets.
- ⊗ *Listserv Notices and Printed Mailings.* The Tri-Party agencies use a Listserv to communicate electronically about upcoming public involvement activities, along with information on ways to be involved in Hanford cleanup decisions. It's our goal to "Go Green" and reduce the environmental impact of paper mailings, but we understand that some people want to get information by mail. To be added to the Listserv or to the printed mailing list, send an email to [Hanford@ecy.wa.gov](mailto:Hanford@ecy.wa.gov). Or, call the Hanford Cleanup Line at (800) 321-2008.
- ⊗ *Hanford Site Public Involvement Activities.* The Hanford Site Events Calendar is available at the following website: <http://www.hanford.gov>. The calendar provides an overview of public involvement opportunities for the coming months and identifies current forums and emerging opportunities to inform and involve stakeholders and the public.
- ⊗ *Tri-Party Agencies Public Involvement Calendar for the Hanford Site.* This calendar is available online at [http://www.ecy.wa.gov/programs/nwp/PI/pdf/TPA\\_PI\\_Calendar.pdf](http://www.ecy.wa.gov/programs/nwp/PI/pdf/TPA_PI_Calendar.pdf). It provides a 12-month overview of upcoming key public involvement activities, including the Hanford Advisory Board (HAB) meeting dates and locations.
- ⊗ *Hanford Site Informational Links.* Information concerning Hanford Site events, issues, cleanup activities, and public involvement opportunities is available at the following website: <http://www.hanford.gov/>.
- ⊗ *Comment and Response Documents.* Following a DOE or TPA public comment period, a comment and response document is developed to record public comments received on an issue. Comment and response documents are distributed to members of the public who provide comments or request a copy. These documents are available at the DOE Public Reading Room (Washington State University Tri-Cities Consolidated Information Center, 2710 University Drive, Richland, Washington); on the TPA Administrative Record website at <http://pdw.hanford.gov/arpir/>; and, for proposed changes to the TPA that underwent public comment, on the TPA website at <http://www.hanford.gov/?page=81>.
- ⊗ *Informational Public Meetings.* All TPA quarterly public involvement planning meetings, semiannual meetings, special meetings, and workshops are open to the public. In addition, the Tri-Party Agencies welcome opportunities for co-sponsoring meetings organized by local, state, and tribal governments and citizen groups.

Hanford Site cleanup documents are also available to the public through the TPA Administrative Record and Public Information Repository available at <http://pdw.hanford.gov/arpir/>. Responsible federal and state governments provide the public a variety of opportunities to offer input and influence Hanford Site cleanup decisions including informal and formal public comment periods, such as those described in [Ecology et al. 1989a](#), CERCLA, RCRA, and NEPA; HAB meetings; State of the Hanford Site presentations; and other Hanford Site-related public involvement and information meetings, workshops, or activities.

For more information about Hanford Site cleanup activities, contact the Tri-Party Agencies at the following contact numbers:

RL	(509) 376-7501
ORP	(509) 372-8656
Hanford Site Cleanup Line/Ecology	(800) 321-2008
EPA	(509) 376-8631

For more information about Hanford Site public involvement, visit the Hanford Site website at <http://www.hanford.gov>.

### **1.6.5 State of Oregon**

*K Skopec*

DOE recognizes the State of Oregon's unique role and interests at the Hanford Site, and its concerns to protect Columbia River resources. DOE is interested in sharing, facilitating, and accommodating the exchange of information with the State of Oregon. RL and ORP entered into a [Memorandum of Understanding](#) in 2004, with the State of Oregon to consult, and whenever possible, cooperate on Hanford Site environmental issues. DOE will consult with and include the Oregon Department of Energy in planning and conducting Hanford Site-related public involvement activities in the State of Oregon.

### **1.6.6 Hanford Advisory Board (HAB)**

*K Skopec*

The HAB is a broadly representative body consisting of a balanced mix of members that represent diverse interests affected by Hanford Site cleanup decisions. The HAB was created in 1994 by the Tri-Party Agencies and ultimately chartered as one of eight environmental management site-specific advisory boards across the country. The HAB comprises 32 members and their alternates, including representatives from the Nez Perce Tribe and the Confederated Tribes and Bands of the Yakama Nation. A representative of the CTUIR participates on the board in an ex-officio status. Current members with their affiliations are listed on the HAB website at <http://www.hanford.gov/page.cfm/hab>.

The HAB assists the broader public in becoming more informed and meaningfully involved in Hanford Site cleanup decisions through its open public meetings. Board members' formal advice on cleanup issues reflects the values of its constituents. Copies of their advice and DOE's responses are on the HAB website for Advice and Responses at <http://www.hanford.gov/?page=453>.

Information about the HAB, including its charter (operating ground rules) is available on the HAB website for Operating Ground Rules at <http://www.hanford.gov/?page=449>.

## 1.7 Hanford Site Regulatory Oversight

*SA Thompson*

Several federal, state, and local regulatory agencies are responsible for monitoring and enforcing compliance with applicable environmental regulations at the Hanford Site, including EPA, Ecology, Washington State Department of Health (WDOH), and the Benton Clean Air Agency. EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in federal statutes. In some instances, EPA has delegated authority to the state or authorized the state program to operate in lieu of the federal program when the state's program meets or exceeds EPA requirements. In other activities, the state program is assigned direct environmental oversight of the DOE program, as provided by federal law. Where federal regulatory authority is not delegated or only partially authorized to the state, the EPA Pacific Northwest Regional Office (Region 10) is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site. EPA periodically reviews state environmental programs and may directly enforce federal environmental regulations.

### 1.7.1 Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)

*RE Piippo and CP Noonan*

The TPA ([Ecology et al. 1989a](#)) is an agreement among the Tri-Party Agencies to achieve environmental regulation compliance on the Hanford Site with CERCLA and RCRA treatment, storage, and disposal (TSD) unit regulations and corrective action provisions. The TPA is an interagency agreement under CERCLA, Section 120, a corrective action order under RCRA, and a consent order under the Washington State [Hazardous Waste Management Act of 1976](#) (RCW 70.105) that 1) defines RCRA and CERCLA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones. Attachment 2 of the TPA, the Action Plan ([Ecology/EPA/DOE 1989b](#)), describes how public information and involvement activities are conducted for TPA decisions.

The TPA has evolved as Hanford Site cleanup has progressed. Since its initial publication in 1989, the Tri-Party Agencies have negotiated changes to the agreement to meet the changing conditions and needs of cleanup activities on the Hanford Site. All significant changes undergo a process of public involvement designed to enhance communication and address public concerns prior to final approvals. Revision 8 of the TPA was published in July 2011. As new change control forms are approved through the TPA change control process, they are incorporated into the TPA and available online at: <http://www.hanford.gov/?page=81>. Printed copies of Revision 8 of the TPA are publicly available at DOE's Public Reading Room located in the Washington State University Tri-Cities Consolidated Information Center, 2770 University Drive, Richland, Washington, and at public information repositories in Seattle and Spokane, Washington, and Portland, Oregon. To be placed on the mailing list to obtain TPA information, call the Hanford Cleanup Line at (800)321-2008 or send an e-mail to [hanford-info@listserv.wa.gov](mailto:hanford-info@listserv.wa.gov).

#### 1.7.1.1 Tri-Party Agreement Milestone Status

The TPA commits DOE to comply with the remedial-action provisions of CERCLA as well as with [Resource Conservation and Recovery Act of 1976](#) (RCRA) TSD unit regulations and corrective-action

provisions, including Washington State's implementing regulations ( *Washington Administrative Code* [[WAC](#)] 173-303, "Dangerous Waste Regulations"). From 1989 through January 19, 2015, a total of 1,235 TPA milestones were completed, and 334 target dates were met. During 2014, 30 specific cleanup milestones were scheduled for completion; of those, 27 milestones were completed on time, 1 milestone was missed, and 2 milestones are in dispute resolution.

### 1.7.1.2 Tri-Party Agreement Approved Modifications

During 2014, 12 negotiated change control forms to the TPA were approved; these changes can be viewed on the TPA website at <http://www.hanford.gov/c.cfm/tpa/>.

## 1.8 Additional Hanford/Area Websites

SA Thompson

Company	Website
AREVA NP Inc.	<a href="http://www.aveva.com/en/operations-925/aveva-inc--richland-nuclear-fuel-production.html">http://www.aveva.com/en/operations-925/aveva-inc--richland-nuclear-fuel-production.html</a>
Battelle Memorial Institute	<a href="http://www.battelle.org/">http://www.battelle.org/</a>
City of Kennewick	<a href="http://www.go2kennewick.com/">http://www.go2kennewick.com/</a>
City of Pasco	<a href="http://www.pasco-wa.gov/">http://www.pasco-wa.gov/</a>
City of Richland	<a href="http://www.ci.richland.wa.us/">http://www.ci.richland.wa.us/</a>
City of West Richland	<a href="http://www.westrichland.org/">http://www.westrichland.org/</a>
Environmental Molecular Sciences Laboratory	<a href="http://www.emsl.pnl.gov/emslweb/">http://www.emsl.pnl.gov/emslweb/</a>
ERDF	<a href="http://www.hanford.gov/page.cfm/erdf">http://www.hanford.gov/page.cfm/erdf</a>
Geology of Washington, Columbia Basin	<a href="http://www.dnr.wa.gov/researchscience/topics/geologyofwashington/pages/columbia.aspx">http://www.dnr.wa.gov/researchscience/topics/geologyofwashington/pages/columbia.aspx</a>
Hanford Reach National Monument	<a href="http://www.fws.gov/refuge/hanford_reach/">http://www.fws.gov/refuge/hanford_reach/</a>
Hanford Site Tours	<a href="http://www.hanford.gov/page.cfm/hanfordsitetours">http://www.hanford.gov/page.cfm/hanfordsitetours</a>
Lockheed Martin Corporation	<a href="http://www.lockheedmartin.com/">http://www.lockheedmartin.com/</a>
Mission Support Alliance	<a href="https://msa.hanford.gov">https://msa.hanford.gov</a>
Pacific Northwest National Laboratory	<a href="http://www.pnnl.gov">http://www.pnnl.gov</a>
Pacific Northwest Seismic Network	<a href="http://pnsn.org/">http://pnsn.org/</a>
Perma-Fix Northwest, Inc.	<a href="http://www.perma-fix.com/facilities/pf_nuclear_richland/">http://www.perma-fix.com/facilities/pf_nuclear_richland/</a>
Port of Benton	<a href="http://www.portofbenton.com/">http://www.portofbenton.com/</a>
Tri-Cities Visitor & Convention Bureau	<a href="http://www.visittri-cities.com/">http://www.visittri-cities.com/</a>
URS Corporation	<a href="http://www.urscorp.com/">http://www.urscorp.com/</a>
US Ecology, Inc.	<a href="http://www.americanecology.com/richland.htm">http://www.americanecology.com/richland.htm</a>
Volpentest HAMMER Federal Training Center	<a href="http://www.hammertraining.com/">http://www.hammertraining.com/</a>
Washington Department of Fish and Wildlife	<a href="http://wdfw.wa.gov/">http://wdfw.wa.gov/</a>

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## 2.0 Compliance Summary

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SA Thompson

To ensure the protection of human health and the environment through safe operations, the Hanford Site implements compliance programs designed to fulfill requirements of applicable federal, state, and local environmental laws and regulations; and with DOE orders, notices, directives, policies, and guidance. This includes specific requirements, actions, plans, and schedules identified in the TPA and other compliance or consent agreements. RL and ORP recognize the importance of maintaining a proactive program of self-assessment and regulatory reporting to ensure environmental compliance is achieved and maintained at the Hanford Site. This report fulfills the requirements for reporting annual compliance status with environmental standards provided in *Environmental, Safety and Health Reporting* (DOE O 231.1B).

This section summarizes the laws and regulations that govern Hanford Site activities with regard to federal environmental protection statutes and associated state and local environmental regulations. It also discusses the permits required under specific environmental protection regulations, as well as notices of violations and notices of noncompliance issued by EPA or Ecology. Notices of violation are the regulatory means of informing organizations that their work activities are not meeting requirements. Notices of noncompliance are informal notifications of regulatory violations.

### 2.1 Hazardous Materials and Waste Management Statutes and Regulations

This section provides compliance information regarding federal environmental statutes and regulations related to hazardous materials and waste management at the Hanford Site.

#### 2.1.1 Federal Facility Compliance Act of 1992

RE Piippo and CP Noonan

The *Federal Facility Compliance Act of 1992* ([Public Law 102-386](#)), enacted by Congress on October 6, 1992, amends Section 6001 of RCRA to specify that the U.S. waives sovereign immunity from civil and administrative fines and penalties for RCRA violations. In addition, RCRA requires EPA to conduct annual inspections of all federal facilities. Authorized states are given authority to conduct inspections of federal facilities to enforce compliance with state hazardous waste programs. A portion of [Public Law 102-386](#) also requires DOE to provide mixed waste information to EPA and the states. DOE provides this information annually as part of the Hanford Site Mixed Waste Land Disposal Restrictions Summary Reports pursuant to TPA Milestone M-26. In 2014, *Calendar Year 2013 Hanford Site Mixed Waste Land Disposal Restrictions Summary Report* ([DOE/RL-2014-17](#)) met the reporting requirement.

#### 2.1.2 Resource Conservation and Recovery Act of 1976

DI Weyns

Congress enacted RCRA in 1976 to protect human health and the environment. In 1984, the [Hazardous and Solid Waste Amendments of 1984](#) (Public Law 98-616) reauthorized RCRA, imposing new requirements on hazardous waste management. RCRA's central principle is to establish cradle-to-grave management to track hazardous waste from its generation to TSD. The Hanford Site dangerous waste



activities are subject to applicable provisions of [WAC 173-303, “Dangerous Waste Regulations,”](#) (including provisions of the Chapter as applied in the TPA).

### 2.1.2.1 Hanford Facility RCRA Permit

JK Perry

EPA assigned the Hanford Site a single EPA identification number for permitting purposes (WA7890008967); as such, the Hanford Site is a single RCRA facility, although there are numerous TSD units spread over large geographic areas. Currently, there are 14 TSD units incorporated in the existing permit (WA7890008967, Rev. 8C). The permit is issued to eight permittees: RL and ORP as the owners/operators, and six of their contractors: BNI, CHPRC, MSA<sup>a</sup>, PNNL, WCH; and WRPS. [WAC 173-303](#) requires Ecology to reissue a permit after a term of up to 10 years. The initial *Hanford Facility RCRA Permit* (WA7890008967, 1994) was issued on September 27, 1994, for a 10-year term. DOE submitted a permit renewal application on March 30, 2004. The permit (WA7890008967) expired on September 27, 2004; since that time, Ecology has been endeavoring to prepare and issue a new permit. Until a new permit is issued, DOE continues to operate under the expired permit, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste* (WA7890008967, Rev. 8C).

In May 2012, Ecology issued a draft *Hanford Facility Dangerous Waste Permit* ([WA7890008967, Rev. 9](#)), incorporating the remaining TSD units not previously clean closed. Ecology received more than 4,000 comments on the draft *Hanford Facility Dangerous Waste Permit* during the comment period held from May 1 to October 22, 2012. Ecology received approximately 1,800 comments from the public and 3,000 comments from DOE. Issues raised during the comment period identified substantial new questions; as a result, Ecology plans to modify the draft *Hanford Facility Dangerous Waste Permit*, Rev. 9, to address the substantial new questions and reopen the comment period for the draft permit. Ecology expects this effort to take several years and will include performing the following activities:

- ⊗ Review and evaluate the comments received from the first comment period
- ⊗ Revise the permit based on significant information and issues raised
- ⊗ Re-issue the permit with revisions and responses to the original comments
- ⊗ Reopen the comment period for sections that were changed
- ⊗ Prepare responses to the next round of public comments
- ⊗ Issue the final permit.

No TSD unit additions or deletions occurred during 2014; however, modifications were submitted for unit-specific permit conditions for the following TSD units during 2014 pursuant to [WAC 173-303-830, Permit Changes](#):

- ⊗ Liquid Effluent Retention Facility (LERF) and 200 Area Effluent Treatment Facility (ETF) (Operating Unit 3)
- ⊗ 242-A Evaporator (Operating Unit 4)

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<sup>a</sup> MSA is a permittee, but not a “co-operator.”

- ⊗ 325 Hazardous Waste Treatment Unit (Operating Unit 5)
- ⊗ WTP (Operating Unit 10)
- ⊗ Integrated Disposal Facility (IDF) (Operating Unit 11).

### 2.1.2.2 Regulatory Agency Inspections

*JW Cammann*

The Regulatory Agency Inspection Database includes documentation for regulatory agency inspections of DOE facilities on the Hanford Site. Regulatory agency inspections can result in noncompliance or enforcement actions for alleged violations of applicable federal, state, and local laws and regulations. As such, the Regulatory Agency Inspection Database links to the Environmental Action Tracking System. The Environmental Action Tracking System documents alleged regulatory noncompliance and enforcement actions and their status for the Hanford Site (see Section 2.9).

During CY 2014, 76 regulatory agency inspections were conducted at DOE facilities on the Hanford Site. Ecology conducted 37, WDOH conducted 25, EPA (Region 10) conducted 6, the city of Richland conducted 2, the Department of Transportation conducted 1, and DOE conducted 5. Of these inspections, regulators issued 9 enforcement actions (9 concerns and 26 compliance actions). The fines and penalties assessed and paid (see Section 2.9) totaled \$190,594.

#### 2.1.2.2.1 RCRA Inspections

The Ecology inspections focused on TSD unit compliance with the *Hanford Facility Dangerous Waste Permit* (WA7890008967, 1994). The TSD units inspected during 2014 included the following facilities:

- ⊗ 200 Area ETF
- ⊗ 222-S Laboratory
- ⊗ 242-A Evaporator
- ⊗ 300/400 Area facilities
- ⊗ 325 Building
- ⊗ 331 Building
- ⊗ 350 Complex
- ⊗ B Plant
- ⊗ IDF
- ⊗ LERF
- ⊗ Central Waste Complex (CWC)
- ⊗ Low-Level Burial Grounds (LLBG) Trenches 31 and 34
- ⊗ LLBG Trench 94
- ⊗ Tank Farms
- ⊗ T-Plant
- ⊗ Waste Receiving and Processing (WRAP) Facility
- ⊗ Waste Sampling and Characterization Facility (WSCF)
- ⊗ 90-day accumulation areas
- ⊗ Satellite accumulation areas
- ⊗ Universal waste management operations.

Section II.O of the RCRA permit addresses general inspection requirements. General inspections are conducted in addition to the TSD unit inspections specified in Parts III, V, and/or VI of the RCRA permit. The RCRA permit requires general inspections of the 100, 200-East, 200-West, 300, and 400 Areas and the Columbia River shoreline. Inspections are performed annually in these areas to identify and correct potential malfunctions, deterioration, operator errors, and discharges, which may cause or lead to the release of dangerous waste constituents to the environment, or that threaten human health. RCRA permit general inspection summary reports are maintained in the Hanford Facility Operating Record.

#### **2.1.2.2.2 Clean Air Act Inspections**

In 2014, the WDOH inspections focused on compliance of major and minor stack air emission units with the Air Operating Permit and Radioactive Air Emissions License (FF-01) ([WDOH 2012](#)). The EPA inspections focused on asbestos management under the *Clean Air Act of 1986* and the “National Emission Standards for Hazardous Air Pollutants (NESHAPs) for Asbestos” ([40 CFR 61, Subpart M](#)). The city of Richland inspections are limited to the 300 Area of the Hanford Site and involved implementation of the terms and conditions of the Industrial Wastewater Permit (CR-IU-010) and discharges to the publicly owned treatment works.

The WSCF laboratory was shutdown in September 2014, and all analytical equipment in the laboratory rooms was removed. All satellite and 90-day hazardous waste accumulation areas inside and outside the laboratory have been shut down and removed. The power to the exhaust fans for the laboratory area ventilation system was removed, and the fan inlets were isolated by 'blanking off' fan inlets. Because the laboratory area ventilation system still contains high-efficiency particulate air (HEPA) filters and has a 'potential to emit' radioactive materials, the emission unit was reassigned as a diffuse and fugitive emission unit in the Hanford Radioactive Air Emissions License (FF-01), Table 2-1. The laboratory area ventilation system will remain in the FF-01 license as a diffuse and fugitive emission unit until such time funding becomes available to dispose of the HEPA filters.

#### **2.1.2.3 RCRA Groundwater Monitoring**

##### *LA Brouillard*

The Soil and Groundwater Remediation Project (see Section 8) conducts the RCRA groundwater monitoring for the Hanford Site. To determine if contaminated groundwater with dangerous constituents was present, 14 RCRA TSD units were monitored in 2014, 7 sites were monitored to assess the extent of known contaminants, and 2 sites were monitored under corrective action programs.

LERF (Section 5.3.4.2) and IDF (Section 5.3.3.7) are two of the 14 TSD units operating under Part III of the RCRA permit (WA7890008967). Since June 2006, IDF was operated under a unit-specific groundwater monitoring plan. Because the unit has not yet received waste, monitoring is performed under a Pre-Active Life Program (standby mode).

The other 12 TSD units monitored under RCRA are scheduled to be closed under Part V of the RCRA permit (WA7890008967). A summary of groundwater monitoring activities for these sites during 2014 is provided in Section 8. The detailed groundwater monitoring information for 2014 will be available in September 2015 with the release of *Hanford Site Groundwater Monitoring Report for 2014*.

Groundwater monitoring is required for three regulated, non-RCRA waste facilities. The 200 Area Treated Effluent Disposal Facility ([TEDF], Section 5.3.4.3) and the State-Approved Land Disposal Site (Section 5.3.4.1) are monitored under [WAC 173-216](#), “State Waste Discharge Permit Program.” The Solid Waste Landfill is monitored for compliance with requirements in [WAC 173-350](#), “Solid Waste Handling Standards.” Wells near these facilities were monitored in 2014 for waste constituents specified in the facility permits.

### 2.1.3 Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

*JW Cammann*

In 1980, Congress passed CERCLA to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. Because nuclear production and disposal facilities at the Hanford Site resulted in past releases of hazardous substances, pollutants, or contaminants, the facility is subject to CERCLA provisions.

For waste sites where hazardous substances, pollutants, or contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure, CERCLA requires a review every 5 years to evaluate the implementation and performance of a remedy to determine if the remedy is or will be protective of human health and the environment. The 5-year review requirement applies to all remedial actions selected under [CERCLA §121](#). The CERCLA Five-Year Review Report documents the methods, findings, and conclusions of the 5-year reviews, which can require institutional controls and/or National Resource Damage Assessment and Restoration (NRDAR) Program mitigation. The results of the three 5-year reviews conducted since 2000 are documented in the *USDOE Hanford Site First Five-Year Review Report* ([EPA 2001](#)); the *Second CERCLA Five-Year Review Report for the Hanford Site* ([DOE/RL-2006-20](#)); and the *Third CERCLA Five-Year Review Report* ([DOE/RL-2011-56](#)).

During CY 2014, work was initiated on the *Fourth CERCLA Five-Year Review Report*. A draft of the report is planned to be completed by September 30, 2015. The final report is planned for issuance by November 30, 2016.

#### 2.1.3.1 Superfund Amendments and Reauthorization Act of 1986

The [Superfund Amendments and Reauthorization Act](#) (SARA) amended CERCLA on October 17, 1986. SARA reflected EPA's experience in administering the complex Superfund program during its first 6 years and made several important changes and additions to the program. SARA:

- ⊗ Stressed the importance of permanent remedies and innovative treatment technologies in cleaning up hazardous waste sites
- ⊗ Required Superfund actions to consider the standards and requirements found in other state and federal environmental laws and regulations
- ⊗ Provided new enforcement authorities and settlement tool
- ⊗ Increased state involvement in every phase of the Superfund program
- ⊗ Increased the focus on human health problems posed by hazardous waste sites
- ⊗ Encouraged greater citizen participation in making decisions on how sites should be cleaned up
- ⊗ Increased the size of the trust fund to \$8.5 billion.

SARA also required EPA to revise the [Hazard Ranking System](#) (HRS) to ensure that it accurately assessed the relative degree of risk to human health and the environment posed by uncontrolled hazardous waste sites that may be placed on the [National Priorities List](#) (NPL).

## 2.1.4 Emergency Planning and Community Right-to-Know Act of 1986

GM Fritz

Title III of SARA, also known as the [\*Emergency Planning and Community Right-to-Know Act of 1986\*](#) (EPCRA), requires owners and operators of facilities that handle certain hazardous chemicals onsite to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. EPCRA has four major provisions: emergency planning, emergency release notification, hazardous chemical inventory reporting, and toxic chemical release inventory reporting. Table 2.1 summarizes sections of EPCRA and its requirements, including two annual reports: the *Tier Two Emergency and Hazardous Chemical Inventory*, which provides information about hazardous chemicals stored at each facility in amounts exceeding minimum threshold levels, and the *Toxic Chemical Release Inventory*, which describes total annual releases of certain toxic chemicals and associated waste management activities. Table 2.2 provides an overview of reporting under the EPCRA during 2014.

The *2014 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2015-09) was submitted to Ecology's Community Right-To-Know Unit; local emergency planning committees for Benton, Franklin, and Grant counties; and the city of Richland and Hanford Site Fire Department before the annual March 1 deadline. The Hanford Site had 41 hazardous chemicals that exceeded the reporting thresholds. One chemical category (lead acid batteries, which contain sulfuric acid, an extremely hazardous substance) exceeded the reporting threshold for offsite locations (700 Area, 1100 Area, and the Federal Building). Table 2.3 lists the average quantities of the 10 hazardous chemicals stored in greatest quantity on the Hanford Site in 2014.

The *2014 Hanford Site Toxic Chemical Release Inventory* report (DOE/RL-2015-43) was submitted to EPA and Ecology before the annual July 1 deadline. During CY 2014, the Hanford Site exceeded activity thresholds for lead, naphthalene, propylene, and xylene. Information concerning these chemicals is described in Table 2.4.

**Table 2.1. Emergency Planning and Community Right-to-Know Act Requirements Summary**

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
302	40 CFR 355: Emergency Planning Notifications	The presence of an extremely hazardous substance in quantity equal to or greater than threshold planning quantity at any one time.	Within 60 days of threshold planning quantity exceedance.	Local Emergency Planning Committee; State Emergency Response Commission
302	40 CFR 355: Emergency Planning Notifications	Change occurring at a facility that is relevant to emergency planning.	Within 30 days after the change has occurred.	Local Emergency Planning Committee
304	40 CFR 355: Emergency Release Notifications	Release of an extremely hazardous substance or a CERCLA hazardous substance in quantity equal to or greater than reportable quantity.	Initial notification: immediate (within 15 minutes of knowledge of reportable release). Written follow-up: within 14 days of the release.	Local Emergency Planning Committee; State Emergency Response Commission

**Table 2.1. Emergency Planning and Community Right-to-Know Act Requirements Summary**

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
311	40 CFR 370: Material Safety Data Sheet Reporting	The presence at any one time at a facility an Occupational Safety and Health Administration (OSHA) hazardous chemical in quantity equal to or greater than 10,000 pounds (4,500 kilograms), or an extremely hazardous substance in quantity equal to or greater than threshold planning quantity or 500 pounds (230 kilograms), whichever is less.	Revised list of chemicals due within 3 months of a chemical exceeding a threshold.	Local Emergency Planning Committee; State Emergency Response Commission; Local Fire Departments
312	40 CFR 370: Tier Two Report	The presence at any one time at a facility an OSHA hazardous chemical in quantity equal to or greater than 10,000 pounds (4,500 kilograms), or an extremely hazardous substance in quantity equal to or greater than threshold planning quantity or 500 pounds (230 kilograms), whichever is less.	Annually by March 1	Local Emergency Planning Committee; State Emergency Response Commission; Local Fire Departments
313	40 CFR 372: Toxic Release Inventory Report	Manufacture, process, or use at a facility, any listed Toxic Release Inventory chemical in excess of its threshold amount during the course of a CY. Thresholds are 25,000 pounds (11,300 kilograms) for manufactured or processed or 10,000 pounds (4,500 kilograms) for otherwise used except for persistent, bio-accumulative, toxic chemicals, which have thresholds of 100 pounds (45 kilograms) or less.	Annually by July 1	EPA; State Emergency Response Commission

**Table 2.2. Emergency Planning and Community Right-to-Know Compliance Reporting**

Section	Description of Reporting	Status	Notes
302	Emergency planning notifications	Yes	
304	Extremely hazardous substance release notification	Not required	No releases occurred.
311	Material safety data sheet	Yes	
312	Chemical inventory	Yes	
313	Toxic release inventory	Yes	

**Table 2.3. Average Quantity of the 10 Hazardous Chemicals Stored in Greatest Quantities**

CAS#	Chemical	TPQ	Average Amount, lb
7440 23-5	Sodium	10,000	4,624,378

*Table 2.3. Average Quantity of the 10 Hazardous Chemicals Stored in Greatest Quantities*

CAS#	Chemical	TPQ	Average Amount, lb
7647-14-5	Sodium chloride	10,000	3,273,385
8012-95-1	Mineral oil	10,000	1,393,680
7664-93-9	Sulfuric acid	500	350,349
00-00-0	Lead acid batteries	500	297,040
00-00-0	Diesel fuel (Grades 1 and/or 2)	10,000	277,145
00-00-0	Petroleum distillates (unspecified/trade secret)	10,000	271,749
1305-78-8	Calcium oxide	10,000	247,677
00-00-0	Gasoline	10,000	178,979
74-98-6	Propane	10,000	159,707

*Table 2.4. Toxic Chemicals Exceeding Reporting Thresholds*

Chemical	CAS No.	Non-Exempt Use Description
Lead	7439-92-1	Ammunition fired during range practice by Hanford Safeguards and Security
Naphthalene	91-20-3	Diesel used for stationary equipment
Propylene	115-07-1	Propane gas used site-wide
Xylene	1330-20-7	Gasoline used for stationary equipment

### 2.1.5 Reportable Releases

#### *TH Pysto*

Federal regulations establish reporting requirements for certain environmental releases, which are reported to the National Response Center, the federal central point of contact for reporting hazardous substances and oil spills. Reportable releases include spills or discharges of hazardous substances to the environment, other than releases permitted under state or federal law. [CERCLA](#), Section 103, requires reporting for releases of hazardous substances that equal or exceed specified reportable quantities, including releases that are continuous and stable in quantity and rate but exceed specified limits. Washington State regulations ([WAC 173-303-145, "Spills to the Environment"](#)) also require that spills or non-permitted discharges of dangerous waste or hazardous substances to the environment be reported. The requirement applies to spills or discharges onto the ground, into groundwater or surface water (Columbia River), or in the air such that human health or the environment are threatened, regardless of the quantity of dangerous waste or hazardous substance.

During the reporting period, hazardous substance releases were conservatively assessed under [WAC 173-303-145](#), and notifications were provided to Ecology for various spills and releases. These spills were cleaned up, and materials were disposed in accordance with applicable requirements.



### 2.1.6 Toxic Substances Control Act

DI Weyns

The Hanford Site has a well-structured program that complies with the *Toxic Substances Control Act* (TSCA) requirements that primarily involve regulation of polychlorinated biphenyls (PCB). Federal regulations for PCB use, storage, and disposal are provided in [40 CFR 761](#), “Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions.” Background information regarding Hanford Site PCB management activities are as follows:

- ⊗ PCB wastes on the Hanford Site are stored and/or disposed of in accordance with [40 CFR 761](#)
- ⊗ Some radioactive PCB waste remains in extended storage onsite pending the development of adequate treatment and disposal technologies and capacities
- ⊗ Electrical equipment that might contain PCBs is maintained and serviced in accordance with [40 CFR 761](#).
- ⊗ The *Framework Agreement for Management of Polychlorinated Biphenyls (PBCs) in Hanford Tank Waste* (EPA et al. 2000), signed on August 31, 2000, resulted in the Tri-Party Agencies and DOE contractors working together to resolve the regulatory issues associated with managing PCB waste at the WTP, tank farms, and affected waste management units adjacent to the tank farms.
- ⊗ RL submitted the *2014 Hanford Site Polychlorinated Biphenyl Annual Document Log* (DOE/RL-2015-25) and the *2014 Hanford Site Polychlorinated Biphenyl Annual Report* (DOE/RL-2015-24) to EPA on June 26, 2015, as required by [40 CFR 761.180](#), “Records and Monitoring.” These documents describe the PCB waste management and disposal activities occurring on the Hanford Site.
- ⊗ Work performed under risk-based disposal approvals (RBDA) continued in 2014, including but not limited to single-shell tank (SST) waste retrieval activities in accordance with EPA Phase I and II RDBAs for the use of double-shell tank (DST) PCB remediation waste in accordance with [40 CFR 761.61\(c\)](#), “PCB Remediation Waste.” **Note:** Phase I identifies general conditions that apply to the overall strategy and retrieval process, and Phase II identifies tank-specific conditions.
- ⊗ The EPA’s 2005 RBDA letter allowed for the solidification of the K-Basins North Load-Out Pit (NLOP) sludge, which was a multi-phasic (mixture of liquid and non-liquid phases) PCB remediation waste. The waste was solidified at the Hanford Site T Plant facility to meet radiological treatment standards in preparation for disposal.
- ⊗ Condition 5 of the NLOP RBDA, requires DOE to submit to EPA plans and schedules for final decontamination and/or disposal of the NLOP treatment system. As of 2015, DOE is developing plans to place additional K-Basins sludge containers in T Plant, which will require removal of the NLOP treatment equipment. When the K-Basins Sludge Project is finalized, EPA will be notified of plans to decontaminate or dispose of the NLOP treatment equipment.

### 2.1.7 National Environmental Policy Act of 1969 (NEPA)

ES Pennala

NEPA was enacted to ensure that potential impacts as well as technical factors and costs are considered during federal decision making. NEPA requires that an environmental impact statement (EIS) be prepared

for major federal agency actions that have the potential to significantly affect human health or the environment. A record of decision (ROD) documents decisions concerning EIS proposed actions. An environmental assessment (EA) is prepared when it is uncertain if a proposed action would require preparation of an EIS. A finding of no significant impact (FONSI) may be issued to present the reasons why an action will not have a significant effect on human health or the environment and, therefore, not require preparation of an EIS. A supplement analysis is prepared to consider significant new information or changed circumstances relevant to environmental concerns and bearing on the proposed action or its impacts.

Certain proposed actions may be categorized into classes that have been analyzed and determined to individually or cumulatively have no significant environmental impact ([10 CFR 1021](#), Subpart D, Appendices A and B). Known as categorical exclusions, these actions are exempt from NEPA EA or EIS requirements if certain eligibility criteria found at [10 CFR 1021.410](#) (proposed action fits classes of actions, proposed action has no extraordinary circumstances, and proposed action is not segmented into smaller actions to avoid significance or connected to other actions with potentially significant impacts) and conditions that are integral elements (found at [10 CFR 1021](#), Subpart D, Appendix B) are met. Some categorical exclusions are applicable to general DOE actions and do not require written documentation for application.

#### **2.1.7.1 Hanford Site Environmental Impact Statements**

The following subsections summarize the status of NEPA documentation planned or underway at the Hanford Site during CY 2014. The NEPA documentation for the Hanford Site is available online at <http://www.hanford.gov/page.cfm/officialdocuments>. Ongoing environmental impact statements related to the Hanford Site are described in the following sections.

##### **2.1.7.1.1 Natural Gas Pipeline EIS (DOE/EIS-0467)**

On January 23, 2012, DOE published a Notice of Intent to Prepare [DOE/EIS-0467](#) for the Acquisition of a Natural Gas Pipeline and Natural Gas Utility Service at the Hanford Site, Richland, Washington; and Notice of Floodplains and Wetlands Involvement ([77 FR 3255](#)). The EIS will evaluate the environmental impacts of a proposal to enter into a contract with Cascade Natural Gas Corporation (Cascade) a natural gas supplier in Washington State to construct, operate, and maintain a natural gas pipeline. The pipeline would deliver natural gas to support the WTP (Section 5.6) and the 242-A Evaporator (Section 5.4.4.4) operations in the 200-East Area. The proposed pipeline would begin from a new interconnect tap on the existing Williams Northwest Pipe transmission line in Franklin County, north of the Pasco, Washington, airport, and then run westerly across non-DOE lands and under the Columbia River, crossing near the Hanford Site 300 Area, before turning northwest and paralleling Route 4S. The pipeline would terminate at the WTP and 242-A Evaporator.

Preparation of the draft Natural Gas Pipeline EIS continued during CY 2014. Activities included evaluating the Proposed Action and No Action Alternative, as well as pipeline route alternatives and 200-East Area interface options (direct piping of natural gas to the WTP and 242-A Evaporator steam boilers or direct piping of natural gas to a new steam plant to be constructed with steam piped to the boilers). The Final Natural Gas Pipeline EIS will contain comments made to the draft EIS and responses to the comments, and will identify a preferred main pipeline route alternative and a preferred 200-East Area

interface option. The schedules for the issuance and publication of the draft (for public comment), Final EIS, and ROD are to be determined.

#### **2.1.7.1.2 Final Long-Term Management and Storage of Elemental Mercury Supplemental Environmental Impact Statement (DOE/EIS-0423-S1)**

Pursuant to the *Mercury Export Ban Act of 2008* ([Public Law 110-414](#)), DOE was directed to designate a facility or facilities for the long-term management and storage of elemental mercury generated within the United States. As a result, the DOE issued the *Final Long-Term Management and Storage of Elemental Mercury Environmental Impact Statement (Mercury Storage EIS)* ([DOE/EIS-0423](#)) in January 2011. The EIS evaluated the environmental impacts associated with the reasonable alternatives for managing and storing elemental mercury at seven candidate locations (Colorado, Idaho, Missouri, Nevada, South Carolina, Texas, and Washington); and identified the Waste Control Specialists, LLC, site near Andrews, Texas, as the Preferred Alternative for the long-term management and storage of elemental mercury. On June 5, 2012, DOE announced an intent to prepare a supplement ([DOE/EIS-0423-S1](#)) to the January 2011 EIS to evaluate alternatives for a facility at and near the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico.

Based on analysis in this SEIS and public comment, DOE has not changed its Preferred Alternative, the Waste Control Specialists, LLC, site near Andrews, Texas. DOE will issue a Record of Decision no sooner than 30 days after publication of the EPA Notice of Availability for the *Final Mercury Storage SEIS* in the *Federal Register*. The selection of a site will be based on the January 2011 *Mercury Storage EIS*, this *Mercury Storage SEIS*, and other appropriate factors and will be announced in a Record of Decision in the *Federal Register*.

#### **2.1.7.2 Hanford Site Environmental Assessments**

Ongoing environmental assessments related to the Hanford Site are described in the following sections.

##### **2.1.7.2.1 Draft Environmental Assessment for Closure of the Solid Waste Landfill and the Nonradioactive Dangerous Waste Landfill (DOE/EA-1707)**

This draft environmental assessment ([DOE/EA-1707](#)) provides information and analyses of proposed DOE activities associated with closure of the DOE Hanford Site's Nonradioactive Dangerous Waste Landfill (NRDWL) and the Solid Waste Landfill (SWL), located southeast of the Central Plateau off Army Loop Road (refer to Section 5.2.2.2.2). Work on [DOE/EA-1707](#) has been temporarily suspended. The final EA and FONSI are on hold pending program priority decisions.

##### **2.1.7.2.2 Draft Environmental Assessment for Hanford Land Conveyance and Notice of Potential Floodplain and Wetland Involvement at the Hanford Site, Richland, Washington (DOE/EA-1915)**

On September 19, 2012, DOE published a *Notice of Intent to Prepare an Environmental Assessment and Notice of Potential Floodplain and Wetland Involvement for the Proposed Conveyance of Land at the Hanford Site, Richland, Washington* ([DOE/EA-1915](#)) in the Federal Register ([77 FR 58112](#)).

DOE announced its intent to prepare an EA to assess the potential environmental effects of conveying approximately 1,641 acres of Hanford Site land to a local economic development organization. Conveyance of the land could include title transfer, lease, easement, license, or a combination of these realty actions. The Tri-City Development Council (TRIDEC), a DOE designated Community Reuse

Organization and 501(c)(6) nonprofit corporation, submitted a proposal to DOE in May 2011 (amended October 2011) requesting the transfer of the approximately 1,641 acres of land located in the southeastern corner of the Hanford Site near the city of Richland in Benton County, Washington, for economic development purposes. Due to continuing mission needs on some of the requested lands, DOE began assessing a 4,413-acre area to identify sufficient land that would be suitable for conveyance to TRIDEC for economic development.

On December 19, 2014, Congress passed the [\*Howard P. “Buck” McKeon National Defense Authorization Act for Fiscal Year 2015\*](#), which contains language directing DOE to transfer 1,641 acres of land to the west of Hanford’s 300 Area (the land conveyance area) to TRIDEC by September 30, 2015. Conveyance of land out of DOE ownership will necessitate modification of the *Hanford Facility Resource Conservation and Recovery Act Permit* (see Section 2.1.2.1).

#### **2.1.7.2.3 Final Environmental Assessment for Expansion of Borrow Areas on the Hanford Site (DOE/EA-1934)**

The *Final Environmental Assessment for Expansion of Borrow Areas on the Hanford Site* ([DOE/EA-1934](#), August 15, 2013), evaluated the potential environmental impacts of expansion or continued use of existing sand and gravel pits located on the Hanford Site (Pits F, H, N, 6, 9, 18, 21, 23, 24, 30, and 34) and establishing one new borrow area source in the 100 Area for ongoing construction activities and fill material following remediation activities. The scope of this EA did not include borrow sources for silt-loam material. On October 15, 2013, the *Expansion of Borrow Areas on the Hanford Site Mitigation Action Plan for DOE/EA-1934* ([WCH-561](#)) was issued. The purpose of the proposed action in this EA is to meet DOE’s need to secure raw aggregate sand and gravel material (approximately 10,714,000 bank cubic meters) to support ongoing environmental cleanup restoration projects (backfill of remediated waste sites), as well as construction and maintenance activities across the Hanford Site. Although final remedial action decisions have yet to be made for some cleanup work, the proposed action would support the projected needs for sand and gravel for a period of approximately 10 years.

Section 4.g of DOE Order 451.1B, Change 3, NEPA Compliance Program, requires “Tracking and annually reporting progress in implementing a commitment for environmental impact mitigation that is essential to render the impacts of a proposed action not significant, or that is made in a record of decision.” The [DOE/EA-1934 Mitigation Action Plan Annual Report Calendar Year 2014](#) required by DOE Order 451.1B was issued in February 2015. This annual report provides a summary of *DOE/EA-1934 Mitigation Action Plan implementation in CY 2014*.

#### **2.1.7.2.4 Draft Programmatic Environmental Assessment for Recycle of Scrap Metals Originating from Radiological Areas (DOE/EA-1919)**

During CY 2014, work continued on completing the *Programmatic Environmental Assessment for the Recycle of Scrap Metals Originating from Radiological Areas* ([DOE/EA-1919](#)). DOE senior managers are reviewing the EA and comment response document. This EA evaluates alternatives for the management of scrap metal originating from DOE radiological control areas, including the proposed action to allow for the recycle of uncontaminated scrap metal that meets the requirements of *Radiation Protection of the Public and the Environment* ([DOE O 458.1](#)). Metals with volumetric radioactive contamination are not included in the scope of this Programmatic EA. DOE plans to complete the Programmatic EA; issue a

FONSI or prepare a Programmatic EIS prior to deciding whether to implement a change to the policy established by the Secretary of Energy in a July 13, 2000, memorandum ([Richardson 2000](#)). The memorandum imposed an agency-wide suspension on the unrestricted release of scrap metal originating from radiological areas at DOE facilities for recycling; in response to public concerns about the potential effects of radioactivity in or on metal recycled from DOE facilities.

### 2.1.7.3 Hanford Site Categorical Exclusions

Categorical exclusions encompass classes of actions that DOE has analyzed and determined do not individually or cumulatively have a significant effect on human health or the environment, and for which neither an EA nor an EIS is required ([76 FR 63764, "National Environmental Policy Act Implementing Procedures"](#)).

On August 9, 2012, the DOE NEPA Compliance Officer directed the elimination of 16 sitewide categorical exclusions, effective December 31, 2012, and requested Hanford Site contractors to submit for approval annual categorical exclusions for routine and recurring work activities in accordance with the provisions of the newly modified NEPA implementing procedures. Activity-specific categorical exclusions continue to be submitted to the DOE NEPA compliance officer for non-routine, non-recurring, project-specific work activities. A standard format was developed for use by the DOE NEPA compliance officer to perform and document the results of NEPA review screening activities.

Copies of annual and activity specific categorical exclusions approved by the DOE NEPA Compliance Officer for CY 2014 are posted on the DOE NEPA web page at <http://www.hanford.gov/page.cfm/categorialexclusions>.

### 2.1.8 Institutional Controls Plan

*DR Ranade*

The *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions* ([DOE/RL-2001-41](#)) describes the institutional controls for the Hanford Site, in addition to implementation and maintenance in accordance with CERCLA and/or RCRA decision documents. The CERCLA decision documents present the selected remedial actions chosen in accordance with CERCLA, as amended by the SARA and implemented under [40 CFR 300](#). CERCLA decision documents are developed as part of the cleanup mission at the Hanford Site, which began in 1989 following the end of the national defense mission. The selected remedies chosen may include institutional controls and the CERCLA decision documents identify specific requirements for these controls.

Institutional controls are primarily administrative in nature and typically are used to augment the engineered components of a selected remedy to minimize the potential for human exposure to contaminants. Active institutional controls, such as controlling access to the Hanford Site or activities that may affect remedial action, generally are employed during remediation. After remediation is completed, passive institutional controls are employed such as permanent markers, retaining public records and archives, or sustaining regulations regarding land or resource use. Some active institutional controls, such as monitoring and controlling access to the area, also may be employed after remediation is completed.

Hanford Site institutional controls assessments are generally conducted in conjunction with the Hanford Site CERCLA five-year review. DOE will continue to conduct institutional controls assessments as

required by the CERCLA and/or RCRA decision documents. The ongoing review of the institutional controls by individual projects also will continue. The Hanford Site institutional controls assessment, in conjunction with the CERCLA Five-year review, will be a 'roll up' of these reviews and will serve as a means to evaluate effectiveness of the institutional controls. Based on the ongoing review, contractors will provide an annual update on the effectiveness of the institutional controls to EPA and Ecology at the area unit managers meetings conducted every September. Minutes from the unit manager's meeting are available in the TPA Administrative Record and can be accessed online at <http://www5.hanford.gov/arpir>.

The Long-Term Stewardship organization is responsible for managing institutional controls related to Hanford Site access control and the wastes sites in the 100-F Area. In CY 2014, one excavation permit was issued in the 100-F Area for anchoring a trailer to support surveillance and maintenance activities at the 105-F Interim Safe Storage (ISS) building. The excavation was within the institutional controls limit of 15 feet (4.6 meters). In addition, remote-monitored video cameras were installed in the 100-F Area along the Columbia River to monitor warning signs installed as an institutional control. The remote camera system detected a warning sign along the Columbia River that was knocked down by a windstorm in fall 2014; the remote monitoring system allowed the Long-Term Stewardship organization to quickly reinstall the sign. The warning signs along Hanford Site boundary are in place, and no broken fences were observed.

The River Corridor Project has a number of institutional controls in both interim action and final ROD documents. In CY 2014, access controls were in place and active for the River Corridor Project, and no public trespass events at waste sites were reported. In addition, approved excavation permits were in place for all active remediation activities assessed. Warning signs were in place at access road entrances to active remediation areas in the 100 and 300 Areas. Vegetation partially obscuring portions of some of the signs was removed. Required shoreline signage checked during the 2014 institutional controls assessment was present at the 300 Area and at the reactor areas in the 100 Area, with the exception of the Spanish-language shoreline sign at 100-H. The missing 100-H sign was subsequently replaced.

The Central Plateau Project also has a number of institutional controls in both interim and final ROD documents. In 2014 an assessment of institutional controls at 200-UP-1 Operable Unit, 221-U Facility, and 200-ZP-1 Operable Unit did not identify deficiencies with land-use management, entry restrictions, groundwater management, or warning signs.

### **2.1.9 Federal Insecticide, Fungicide, and Rodenticide Act**

*JM Rodriguez*

EPA administers the [\*Federal Insecticide, Fungicide, and Rodenticide Act\*](#). The Washington State Department of Agriculture administers standards to regulate implementation of the Act in the state, including the "Washington Pesticide Control Act" ([RCW 15.58](#)), the "Washington Pesticide Application Act" ([RCW 17.21](#)), and rules relating to general pesticide use codified in [WAC 16-228](#), "General Pesticide Rules." Commercial pesticides are applied on the Hanford Site by commercial pesticide operators that are listed on one of two commercial pesticide applicator licenses, and by a licensed private commercial applicator.



## 2.2 Radiation Protection Statutes and Regulations

*JW DeMers*

The Hanford Site is subject to radiation protection statutes and regulations designed to protect the health and safety of the public, workforce, and the environment. Relevant laws and regulations are described in the following sections.

### 2.2.1 Atomic Energy Act of 1954

The *Atomic Energy Act of 1954* ([AEA](#)), promulgated to ensure proper management of radioactive materials, and its amendments include provisions to delegate roles and responsibilities to control radioactive materials and nuclear energy primarily to DOE, the U.S. Nuclear Regulatory Commission (NRC), and EPA. Through the AEA, DOE regulates the control of radioactive materials under its authority, including the TSD of low-level radioactive waste from its operations. Sections of the AEA authorize DOE to establish radiation protection standards for itself and its contractors. Accordingly, DOE promulgated a series of regulations (e.g., [10 CFR 820](#), “Procedural Rules for DOE Nuclear Activities;” [10 CFR 830](#); “Nuclear Safety Management;” and [10 CFR 835](#), “Occupational Radiation Protection”). Additional DOE directives to protect public health and the environment from potential risks associated with radioactive materials include [DOE O 435.1, Chg. 1, Radioactive Waste Management](#), and [DOE O 458.1, Chg. 2, Radiation Protection of the Public and Environment](#). Hanford Site operations are subject to these regulations and directives.

DOE directives may be accessed via the Departmental Directives Program website at: <https://www.directives.doe.gov/>. DOE standards may be accessed via the DOE Office of Health, Safety, and Security website at: <http://energy.gov/ehss/services/nuclear-safety/departement-energy-technical-standards-program>.

### 2.2.2 DOE O 458.1, Radiation Protection of the Public and the Environment

The purpose of [DOE O 458.1](#) is to establish standards and requirements for conduct of DOE and DOE contractor operations with respect to radiological protection of the public and the environment. This order was developed and issued consistent with DOE’s policy to implement legally applicable radiation protection requirements; consider and adopt, as appropriate, recommendations by authoritative organizations (e.g., the National Council on Radiation Protection and Measurements [NCRP] and the International Commission on Radiological Protection [ICRP]); and adopt and implement standards generally consistent with those of the NRC for DOE facilities and activities not subject to NRC authority. Specifically, relative to guidance, standards, and regulatory requirements existing at the time of its issuance, this order adopted applicable standards issued by the ICRP and the NCRP, incorporated regulatory requirements applicable to DOE operations, and consolidated and upgraded DOE guidance for contaminated property.

[DOE O 458.1](#) applies to all DOE elements and contractors performing work for DOE, as provided by law and/or contract, and as implemented by the appropriate contracting officer. This order was developed and issued under the authority of the [AEA](#) as amended, which authorizes DOE to provide for the radiological health and safety of the public for operations conducted under DOE direction.

Relative to the radiological health and safety of the public, the objectives of [DOE O 458.1](#) are to ensure that DOE operations achieve the following:



- ⊗ Maintain radiation exposures to the public within established limits
- ⊗ Control radioactive contamination through the management of real and personal property
- ⊗ Ensure potential exposures to the public are as far below established limits as is reasonably achievable
- ⊗ Ensure DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and non-routine releases and to assess doses to the public.

In addition to providing radiological protection to the public, the objective of [DOE O 458.1](#) is to provide radiological protection of the environment to the extent practical.

[DOE O 458.1](#) also provides derived concentration guide values as reference values for conducting radiological environmental protection programs at operational DOE facilities and sites. Table 2.5 provides the radiation standards (dose limits) for protection of the public from all routine DOE concentrations. These DOE-derived concentration guide values are based on a committed dose standard of 100 millirem (1 millisievert) due to ingestion, inhalation, or direct exposure during a given year, and are provided for three exposure pathways: ingestion of water, inhalation of air, and immersion in a gaseous cloud. This order also provides radiological protection requirements and guidelines for cleanup of residual radioactive material, management of the resulting wastes and residues, and clearance of property. These requirements and guidelines are applicable at the time the property is released.

### 2.2.3 DOE O 435.1, Radioactive Waste Management

*MS Collins*

The purpose of [DOE O 435.1, Chg. 1](#) is to establish requirements to manage of all high-level waste (HLW), transuranic waste, and low-level waste (LLW), including the radioactive component of mixed waste (HLW, transuranic waste, and LLW containing chemically hazardous constituents) in a safe manner that is protective of the worker, public health, and the environment. The order takes a cradle-to-grave approach to managing waste and includes requirements for waste generation, storage, treatment, disposal, and post-closure monitoring of facilities.

Radioactive waste shall be managed such that the requirements of other DOE orders, standards, and regulations are met, including the following:

- ⊗ [10 CFR 835](#), “Nuclear Safety Management”
- ⊗ [DOE O 440.1A](#), *Worker Protection Management for DOE Federal and Contractor Employees*
- ⊗ [DOE O 458.1](#), *Radiation Protection of the Public and the Environment*.

**Table 2.5**      **Radiation Standards for Protection of the Public from all Routine DOE Concentrations (Dose Limits)<sup>a</sup>**

<b>All Pathways (<a href="#">DOE O 458.1</a>)</b>		
Effective dose equivalent for any member of the public from all routine DOE operations <sup>b</sup> shall not exceed the values below.		
	<b>Effective Dose Equivalent<sup>c</sup></b>	
	<b>mrem/year</b>	<b>mSv/year</b>
Routine public dose	100	1
Potential authorized temporary public dose <sup>d</sup>	500	5
<b>Dose to Native Aquatic Animal Organisms from Liquid Discharges (<a href="#">DOE O 458.1</a>)</b>		
Radioactive material in liquid waste discharged to natural waterways shall not cause an absorbed dose <sup>e</sup> to native aquatic animal organisms that exceed 1 rad (10 milligray) per day.		
<b>Drinking Water Pathway Only</b> (40 CFR Parts 9, 141, and 142 ( <a href="#">65 FR 76708, National Primary Drinking Water Regulations; Radionuclides; Final Rule</a> ); <a href="#">WAC 246-290, Group A Public Water Supplies</a> ; and <a href="#">DOE O 458.1</a> )		
Radionuclide concentrations in DOE-operated public drinking water supplies shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 millirem (0.04 millisievert) per year. DOE operations shall not cause private or public drinking water systems downstream of the facility discharge to exceed the radiological drinking water limits in <a href="#">40 CFR</a> Parts 9, <i>OMB Approvals Under the Paperwork Reduction Act</i> ; 141, <i>National Primary Drinking Water Regulations</i> ; and 142, <i>National Primary Drinking Water Regulations Implementation</i> .		
<b>Air Pathways Only (<a href="#">40 CFR 61, National Emission Standards for Hazardous Air Pollutants[NESHAPs]</a>)</b>		
Public dose limit at location of maximum annual air concentration as a consequence of routine DOE operations <sup>2</sup>	<b>Effective Dose Equivalent<sup>3</sup></b>	
	<b>mrem/year</b>	<b>mSv/year</b>
	10	0.1
<sup>a</sup> Radiation doses received from natural background, residual weapons testing and nuclear accident fallout, medical exposure, and consumer products are excluded from the implementation of these dose limits. <sup>b</sup> Routine DOE operations imply normal, planned activities and do not include actual or potential accidental or unplanned releases. <sup>c</sup> Effective dose equivalent is expressed in rem (or millirem) and Sv (or millisievert). <sup>d</sup> Authorized temporary annual dose limits may be greater than 100 mrem (1 mSv) per year (but cannot exceed 500 mrem [5 mSv]) per year if unusual circumstances exist that make avoidance of doses greater than 100 mrem (1 mSv) per year to the public impracticable. The DOE Richland Operations Office is required to request and receive specific authorization from DOE HQ for an increase from the routine public dose limit to a temporary annual dose limit. <sup>e</sup> Absorbed dose is expressed in rad (or millirad) with the corresponding value in gray (or milligray) in parentheses.  mrem = millirem rem = roentgen equivalent in man mSv = millisievert		

## 2.3 Air Quality Statutes and Regulations

*RA Kaldor*

This section provides information on federal, state, and local statutes applicable to the Hanford Site air quality program.

### 2.3.1 Air Quality Regulatory Authority

The federal *Clean Air Act* was enacted to protect and enhance air quality and is the legal basis for federal, state, and local air quality regulations. The law, originally passed in 1967, has been revised extensively on numerous occasions. The [Clean Air Act Amendments of 1990](#), the most recent revision of the Act, provides the framework for a significant portion of current federal air quality regulations.

The “[Washington Clean Air Act](#)” (RCW 70.94), which parallels and supplements federal law, has been revised periodically to keep pace with changes at the federal level.

EPA provides high-level programmatic oversight of the air quality program on the Hanford Site but has delegated authority for implementing applicable *Clean Air Act* regulations to designated state and local regulatory agencies.

The WDOH regulates radioactive air emissions on the Hanford Site by enforcing applicable federal requirements in [40 CFR 61](#), NESHAPs, Subparts A and H, as well as the state requirements in [WAC 173-480](#), “Ambient Air Quality Standards and Emission Limits for Radionuclides,” and [WAC 246-247](#), “Radiation Protection-Air Emissions.” Federal regulations for radioactive air emissions are contained in [40 CFR 61, Subpart H](#).

Ecology regulates criteria and toxic air pollutant emissions at the Hanford Site by enforcing applicable federal requirements in [40 CFR 52](#), “Approval and Promulgation of Implementation Plans;” [40 CFR 60](#), “Standards of Performance for New Stationary Sources;” [40 CFR 61](#); [40 CFR 63](#), “NESHAPs for Source Categories;” [40 CFR 68](#), “Chemical Accident Prevention Provisions;” and [40 CFR 82](#), “Protection of Stratospheric Zone;” as well as the state requirements in [WAC 173-400](#), “General Regulations for Air Pollution Sources;” [WAC 173-460](#), “Controls for New Sources of Toxic Air Pollutants;” [WAC 173-480](#); and [WAC 173-491](#), “Emission Standards and Controls for Sources Emitting Gasoline Vapors.” Criteria and toxic air pollutant emissions are often referred to as nonradioactive air emissions at the Hanford Site. Criteria pollutants are particulate matter, nitrogen oxides, sulfur oxides, carbon monoxide, lead, and volatile organic compounds. Toxic pollutants are other chemical contaminants as regulated by Washington State.

The Benton Clean Air Agency regulates demolition and asbestos renovation activities at the Hanford Site in accordance with federal requirements in [40 CFR 61](#), Subpart M, “National Emission Standard for Asbestos.” The Benton Clean Air Agency also regulates outdoor burning activities at the Hanford Site in accordance with state requirements in [WAC 173-425](#), “Outdoor Burning.”

### 2.3.2 Air Permits

Hanford Site contractors evaluate each proposed new or modified emission unit using the new source review requirements of radioactive air emissions [WAC 246-247](#), *Radiation Protection – Air Emissions*, and criteria and toxic air pollutants ([WAC 173-400-110](#), *New Source Review (NSR) for Sources and Portable Sources*; and [WAC 173-460-040](#), *New Source Review*) to determine whether a notice of construction application must be submitted to the WDOH and/or Ecology (as applicable) for approval before construction or operation of the proposed source.

Hanford Site radioactive air emission sources are operated in accordance with the Radioactive Air Emissions License for the Department of Energy Richland Operations Office Hanford Site, License Number FF-01 ([WDOH 2012](#)) issued by the WDOH in February 2012. The FF-01 license is a compilation

of all applicable radioactive air emission requirements (ALARACT) and is renewed every 5 years. For each emission unit, the FF-01 license includes either 1) an approval to modify/construct, or 2) an operating license. Overall, Hanford Site radioactive air emissions are controlled to sufficiently low levels to ensure the resultant exposure to any offsite individual remains well below the 10 millirem (100 microsievert) per year standard specified in [40 CFR 61.92](#), “Standard.” Hanford Site radioactive air emissions data are published annually in the radionuclide air emissions report for the Hanford Site ([DOE/RL-2015-12](#), *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2014*).

As a major source of air pollutants, the Hanford Site is subject to the air operating permit requirements in [40 CFR 70](#), “State Operating Permit Programs;” and [WAC 173-401](#), “Operating Permit Regulation.” In coordination with WDOH and the Benton Clean Air Agency, Ecology issued Renewal 2 of the Air Operating Permit for a period of 5 years, effective April 1, 2013. Renewal 2 was issued to incorporate new WDOH and Ecology air emission licenses, approval orders, and updated regulatory requirements. The [Air Operating Permit](#) is a compilation of applicable *Clean Air Act* requirements for both radioactive and criteria/toxic air pollutant emissions, including the radioactive air emissions license FF-01 ([WDOH 2012](#)) issued by WDOH and notice of construction approval orders issued by Ecology. The [Air Operating Permit](#) requires the submittal of semiannual reports to the regulatory agencies documenting the status of required monitoring and permit deviations. In addition, an annual report documenting the compliance status of Hanford Site emission sources against applicable *Clean Air Act* requirements, and an annual report that documents total emissions of criteria and toxic pollutants is also required.

The WDOH, Ecology, and the Benton Clean Air Agency conduct regular inspections of Hanford Site emission sources to verify compliance with applicable *Clean Air Act* requirements. Hanford Site contractors and DOE actively work to resolve any potential compliance issues identified during these inspections. During 2014, regulatory agencies conducted over 30 *Clean Air Act* inspections on the Hanford Site, and no violations were issued.

## 2.4 Water Quality Statutes and Regulations

*CJ Clement*

This section provides information on federal, state, and local requirements and permit, related to protection of water quality.

### 2.4.1 Federal Permit – Discharges to Columbia River

The *Clean Water Act of 1977*, as amended, applies to discharges to surface waters in the United States. At the Hanford Site, regulations are applied through the *EPA Administered Permit Programs: The National Pollutant Discharge Elimination System* ([NPDES] [40 CFR 122](#)). DOE does not currently have any discharges to the Columbia River requiring permits.

### 2.4.2 State Waste Discharge Permit – Discharges to the Soil Column/Groundwater

Ecology’s Wastewater Discharge Permit program regulates discharges to state waters, including groundwater. Four Ecology state waste discharge permits were in effect during 2014 ([ST-4500](#), [ST0004502](#), [ST0004511](#), and [ST0045514](#)). DOE is the holder of all state waste discharge permits. Ecology’s waste water discharge permits webpage is located at <http://www.ecy.wa.gov/programs/nwp/permitting/wwd/index.html>.

Two Ecology general permits for sand and gravel were in effect during 2014: [WAG-50-5180](#) and [WAG-50-5181](#). They were issued to BNI.

WDOH issues annual permits to DOE to operate Hanford Site onsite sewage systems, which include some holding-tank sewage systems. Most onsite sewage systems (septic systems) operate under permits issued by the WDOH.

### **2.4.3 Local Discharge Permit – Discharges to the City of Richland Sewer**

The city of Richland regulates industrial wastewater discharges to its sewer collection system in accordance with city of Richland Code, *Richland Pretreatment Act* – [Chapter 17.30](#). DOE is the holder of Permit No. CR-IU010, which allows discharges from the 300 Area facilities.

### **2.4.4 Safe Drinking Water Act of 1974 (SDWA)**

*LM Kelly*

The [Safe Drinking Water Act of 1974](#) (SDWA) established a cooperative program among local, state, and federal agencies to institute drinking water regulations applicable to all public water systems in the United States. States were granted primary responsibility—known as primacy—for administering and enforcing the SDWA. To obtain primacy, states were required to meet certain criteria, including adoption of regulations equal to or more stringent than EPA regulations.

Washington State was awarded primacy in 1978. The State Board of Health and WDOH became partners in developing and enforcing state drinking water regulations. Hanford Site water systems were designated as public water systems in 1986 and became formally registered as public systems under the jurisdiction of the WDOH in 1987.

The SDWA was amended in 1986 and 1996 ([Safe Drinking Water Act Amendments](#)). Although the 1986 amendments included provisions that emphasized treatment to ensure safe drinking water, the 1996 amendments focused on source water protection, funding for water system improvements, operator training, providing public information, and strengthening EPA's scientific work, including the use of risk and cost benefit analysis in establishing drinking water standards (DWS). Between 1975 and 2006, these amendments resulted in the development of 18 new drinking water regulations. Post-1996 regulations have included more complex compliance determinations and more advanced treatment technologies. Based on site-specific conditions, many public water systems are either using or investigating the use of new treatment technologies to comply with the increasingly complex requirements.

The [Microbial and Disinfection Byproduct Rules](#) include nine drinking water regulations, address acute threats from microbial contamination and chronic threats from disinfectant residuals and disinfection byproducts. These rules limit disinfectant residuals and disinfection byproducts in the distribution systems while improving particle removal in the drinking water treatment plants. In 2014, affected Hanford Site water systems demonstrated compliance with the filtration and disinfection treatment technique requirements and limits for disinfectant residuals and disinfection byproducts.

To protect the health of workers using public water supplies on the Hanford Site, water systems were monitored during 2014 for microbiological, chemical, physical, and radiological constituents. There were no microbiological detections during the 2014 monitoring cycle, and all chemical concentrations in drinking water were well below the maximum contaminant levels established by EPA. Table 2.6 provides selected drinking water standards. System-specific information and analytical results for 2014 radiological monitoring are summarized in Section 7.1.3. Table 2.7 provides the selected surface freshwater quality criteria for toxic pollutants, and Table 2.8 provides the Washington State water quality criteria for the Hanford Reach of the Columbia River.

*Table 2.6. Selected Drinking Water Standards*

Constituent	DWS <sup>a</sup>		Agency <sup>b</sup>
Antimony	6 µg/L	0.006 ppm	EPA, WDOH
Arsenic	10 µg/L	0.01 ppm	EPA, WDOH
Barium	2,000 µg/L	2 ppm	EPA, WDOH
Cadmium	5 µg/L	0.005 ppm	EPA
Carbon tetrachloride	5 µg/L	0.005 ppm	EPA, WDOH
trihalomethanes <sup>c</sup>	80 µg/L	0.08 ppm	EPA
Chromium	100 µg/L	0.1 ppm	EPA, WDOH
cis-1,2-Dichloroethene	70 µg/L	0.07 ppm	EPA, WDOH
Copper	1,300 µg/L	1.3 ppm	EPA
Cyanide	200 µg/L	0.2 ppm	EPA, WDOH
Fluoride	4 mg/L	4 ppm	EPA, WDOH
Lead	15 µg/L	0.015 ppm	EPA
Mercury (inorganic)	2 µg/L	0.002 ppm	EPA, WDOH
Methylene chloride	5 µg/L	0.005 ppm	EPA, WDOH
Nitrate, as NO <sub>3</sub> <sup>-</sup>	10 mg/L	10 ppm	EPA, WDOH
Nitrite, as NO <sub>2</sub> <sup>-</sup>	1.0	1.0 ppm	EPA, WDOH
Selenium	50 µg/L	0.05 ppm	EPA, WDOH
Tetrachloroethene	5 µg/L	0.005 ppm	EPA, WDOH
Thallium	2 µg/L	0.002 ppm	EPA, WDOH
Trichloroethene	5 µg/L	0.005 ppm	EPA, WDOH
Antimony-125	300 pCi/L <sup>d</sup>	11.1 Bq/L	EPA
Beta particle and photon activity	4 mrem/yr <sup>e</sup>	40 µSv/yr	EPA, WDOH
Carbon-14	2,000 pCi/L <sup>d</sup>	74.1 Bq/L	EPA
Cesium-137	200 pCi/L <sup>d</sup>	7.4 Bq/L	EPA
Cobalt-60	100 pCi/L <sup>d</sup>	3.7 Bq/L	EPA
Iodine-129	1 pCi/L <sup>d</sup>	0.037 Bq/L	EPA
Ruthenium-106	30 pCi/L <sup>d</sup>	1.11 Bq/L	EPA
Strontium-90	8 pCi/L <sup>d</sup>	0.296 Bq/L	EPA, WDOH
Technetium-99	900 pCi/L <sup>d</sup>	33.3 Bq/L	EPA
Total alpha (excluding uranium)	15 pCi/L <sup>d</sup>	0.56 Bq/L	EPA, WDOH
Tritium	20,000 pCi/L <sup>d</sup>	740 Bq/L	EPA, WDOH
Uranium	30 µg/L	0.03 ppm)	EPA, WDOH

<sup>a</sup> Maximum contaminant level for drinking water supplies.

<sup>b</sup> WDOH = Washington State Department of Health at [WAC 246-290](#).EPA at [40 CFR 141](#), *National Primary Drinking Water Regulations*; [40 CFR 143](#), *National Secondary Drinking Water Regulations*; and [EPA 822-R-96-001](#), *Drinking Water Regulations Health Advisories*.<sup>c</sup> Standard is for total trihalomethanes.<sup>d</sup> EPA DWSs for radionuclides were derived based on a 4-mrem/yr dose standard using maximum permissible concentrations in water specified in *National Bureau of Standards Handbook 69* (U.S. Department of Commerce, August 1963, as amended).<sup>e</sup> Beta and gamma radioactivity from anthropogenic radionuclides. Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose >4 mrem/yr. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr. Compliance may be assumed if annual average concentrations of total beta, tritium, and strontium-90 are <50, 20,000, and 8 pCi/L, respectively.

Bq = Becquerel

pCi/L = picocuries per liter

L = liter

ppm = parts per million

yr = year

µg/L = micrograms per liter

**Table 2.7. Selected Surface Freshwater Quality Criteria for Toxic Pollutants**

Compound	Level that Yields Acute Toxicity <sup>a</sup>		Level that Yields Chronic Toxicity <sup>a</sup>		Protective Level for Human Health Consumption of Water and Organisms <sup>b</sup>	
	µg/L	ppm	µg/L	ppm	µg/L	ppm
<b>Dissolved Metals</b>						
Antimony	–	–	–	–	14	0.014
Arsenic	360.0	0.360	190.0	0.19	0.018	0.000018
Cadmium	1.6	0.0016 <sup>c</sup>	0.59	0.00059 <sup>d</sup>	–	–
Chromium (VI)	15	0.015	10	0.01	–	–
Copper	8.4	0.0084 <sup>e</sup>	6.0	0.006 <sup>f</sup>	–	–
Lead	28	0.028 <sup>g</sup>	1.1	0.0011 <sup>h</sup>	–	–
Mercury	2.1	0.0021	–	–	0.14	0.00014
Nickel	750	0.75 <sup>i</sup>	83	0.083 <sup>j</sup>	610	0.61
Silver	0.94	0.00094 <sup>k</sup>	–	–	–	–
Thallium	–	–	–	–	1.7	0.0017
Zinc	60	0.060 <sup>l</sup>	55	0.055 <sup>m</sup>	–	–
<b>Total Recoverable Metals</b>						
Chromium(III) <sup>n</sup>	300	0.30 <sup>o</sup>	96	0.096 <sup>p</sup>	–	–
Mercury	–	–	0.012	0.000012	–	–
Selenium	20	0.02	5.0	0.005	–	–
<b>Anions</b>						
Cyanide <sup>q</sup>	22.0	0.022	5.2	0.0052	700	0.70
Chloride <sup>r</sup>	860,000	860	230,000	230	–	–
<b>Organic Compounds</b>						
Benzene	–	–	–	–	1.2	0.0012
Carbon tetrachloride	–	–	–	–	0.25	0.00025
Chloroform	–	–	–	–	5.7	0.0057
1,2-Dichloroethane	–	–	–	–	0.38	0.00038
Methylene chloride	–	–	–	–	4.7	0.0047
Toluene	–	–	–	–	6,800	6.80
Tetrachloroethene	–	–	–	–	0.8	0.0008
1,1,2-Trichloroethane	–	–	–	–	0.60	0.0006
Trichloroethene	–	–	–	–	2.7	0.0027
Vinyl chloride	–	–	–	–	2	0.002
1,4-Dichlorobenzene	–	–	–	–	400	0.40

<sup>a</sup> [WAC 173-201A-240](#), *Toxic Substances*. For hardness-dependent criteria, the minimum value of 47 mg CaCO<sub>3</sub>/L for 1992-2010 water samples collected near the Vernita Bridge by the U.S. Geological Survey is used. Parts per million (ppm) values are<sup>b</sup> (1.4620 - [ln (hardness)]) 0.1457)

exp (1.273[ln (hardness)] - 4.705).

<sup>i</sup> (0.998) exp (0.8460 [ln (hardness)] + 3.3612).<sup>j</sup> (0.997) exp (0.8460 [ln (hardness)] + 1.1645).<sup>k</sup> (0.85) exp (1.72[ln (hardness)] - 6.52).



equivalent to the reported micrograms per liter (µg/L) concentrations shown.

<sup>b</sup> [40 CFR 131.36](#), *Toxics Criteria for those States not Complying with Clean Water Act Section 303(c)(2)(B)*.

<sup>c</sup>  $(1.1367 - [\ln(\text{hardness})] 0.04184) \exp(1.128[\ln(\text{hardness})] - 3.828)$ . Hardness expressed as mg CaCO<sub>3</sub>/L.

<sup>d</sup>  $(1.1017 - [\ln(\text{hardness})] 0.04184) \exp(0.7852[\ln(\text{hardness})] - 3.490)$ .

<sup>e</sup>  $(0.960) \exp(0.9422[\ln(\text{hardness})] - 1.464)$ .

<sup>f</sup>  $(0.960) \exp(0.8545[\ln(\text{hardness})] - 1.465)$ .

<sup>g</sup>  $(1.4620 - [\ln(\text{hardness})] 0.1457) \exp(1.273[\ln(\text{hardness})] - 1.460)$ .

<sup>l</sup>  $(0.978) \exp(0.8473 [\ln(\text{hardness})] + 0.8604)$ .

<sup>m</sup>  $(0.986) \exp(0.8473 [\ln(\text{hardness})] + 0.7614)$ .

<sup>n</sup> Where methods to measure trivalent chromium are unavailable, these criteria are to be represented by total recoverable chromium.

<sup>o</sup>  $(0.316) \exp(0.8190 [\ln(\text{hardness})] + 3.688)$ .

<sup>p</sup>  $(0.860) \exp(0.8190 [\ln(\text{hardness})] + 1.561)$ .

<sup>q</sup> Criteria based on weak and dissociable method.

<sup>r</sup> Dissolved in association with sodium.

**Table 2.8. Washington State Water Quality Criteria for the Columbia River, Hanford Reach<sup>a</sup>**

Parameter	Permissible Levels
Fecal coliform	Geometric mean value less than or equal to 100 colonies/100 milliliters (0.026 gallon) Not more than or equal to 10 percent of samples may exceed the geometric mean value of 200 colonies/100 milliliters (0.026 gallon)
Dissolved oxygen	Greater than 8 mg/L (8 ppm)
Temperature	Less than or equal to 18°C (64°F) as a result of human activities When natural conditions exceed 18°C (64°F), no temperature increases will be allowed that will raise the temperature of the receiving water by more than 0.3°C (0.54°F) Incremental temperature increases resulting from point sources shall not at any time exceed $t = 28 / (T + 7)$ , where t = maximum permissible temperature increase measured at a mixing zone boundary and T = background temperature. Incremental temperature increases resulting from non-point sources shall not exceed 2.8°C (5.04°F).
pH	6.5 to 8.5 range Less than 0.5-unit induced variation
Turbidity	Turbidity shall be less than or equal to 5 nephelometric turbidity units over background turbidity when the background turbidity is 50 nephelometric units or less, and shall not increase more than 10 percent when the background turbidity is >50 nephelometric units
Aesthetic value	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste
Radioactive substances	Deleterious concentrations of radioactive materials for all classes shall be as determined by the lowest practicable level attainable and in no case shall exceed 1/12.5 of the values listed in <a href="#">WAC 246-221-290</a> or exceed EPA drinking water regulations for radionuclides, as published in <a href="#">EPA-570/9-76-003</a> or subsequent revisions thereto (Table 2.1)
Toxic substances	Shall not be introduced above natural background levels in waters of the state that have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent on those waters, or adversely affect public health, as determined by the department (Table 2.8)

<sup>a</sup> [WAC 173-201A](#), *Water Quality Standards for Surface Waters of the State of Washington*.

## 2.5 Natural and Cultural Resources

This section provides information on federal statutes and assessments related to ecological and cultural resource compliance at the Hanford Site.

## 2.5.1 Ecological Compliance

JA Pottmeyer

DOE policies require that all Hanford Site projects with the potential to adversely affect biological resources conduct an ecological compliance review before the project starts. DOE uses the review to determine if the project will comply with the *Endangered Species Act of 1973* ([16 USC 1531](#)), the *Migratory Bird Treaty Act of 1918* ([16 USC 703](#)), and the *Bald and Golden Eagle Protection Act* ([16 USC 668-668c](#)), as well as Executive Order [11988](#), *Floodplain Management* ([32 CFR 644.320](#)), and Executive Order [11990](#), *Protection of Wetlands* ([32 CFR 644.319](#)). The review also addresses whether other significant resources such as Washington State-listed species of concern, wetlands, and native shrub-steppe habitats are adequately considered during the project planning process. When adverse effects are identified, mitigation actions are prescribed. Mitigation actions may include avoidance of significant resources, minimization of effects, and rectification or compensation if resources are affected.

There were 212 ecological compliance reviews performed during 2014, including 125 reviews to support general Hanford Site activities and 87 reviews for River Corridor environmental restoration activities. In comparison, 191 ecological compliance reviews were performed during 2013, including 97 reviews to support general Hanford Site activities, and 94 reviews for River Corridor environmental restoration activities.

### 2.5.1.1 Endangered Species Act of 1973 (16 USC 1531)

Several protected species of plants and animals exist on the Hanford Site and along the Hanford Reach of the Columbia River. Upper Columbia River Steelhead trout (*Oncorhynchus mykiss*) and spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are listed under the *Endangered Species Act of 1973* ([16 USC 1531](#)) as either threatened or endangered ([50 CFR 17](#), Subpart B, Lists) and occur onsite. Critical habitat for these species has been designated within the Hanford Reach. The *Threatened and Endangered Species Management Plan: Salmon and Steelhead* ([DOE/RL-2000-27](#)) is in place for these species. The bull trout (*Salvelinus confluentus*) is also listed under [16 USC 1531](#) and may occasionally occur in the Hanford Reach; critical habitat for bull trout was designated in the Hanford Reach in 2010 ([USFWS 2010a, Final Bull Trout Critical Habitat Designation](#)). Two plant species, the Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Physaria douglasii* ssp. *tupleshensis*) are now listed under [16 USC 1531](#). Other species on the Hanford Site are listed by the WDFW as endangered, threatened, or sensitive (refer to Section 11.2).

### 2.5.1.2 Migratory Bird Treaty Act (16 USC 703)

[16 USC 703](#) prohibits taking or disturbing listed migratory birds or their feathers, eggs, or nests. Over 100 species of birds that regularly occur on the Hanford Site are protected by [16 USC 703](#). All Hanford Site projects with a potential to affect federal or state-listed species of concern complied with the requirements of this Act by using the ecological compliance review process as described in the *Hanford Site Biological Resource Management Plan*, [DOE/RL-96-32](#). When applicable, ecological reviews produce recommendations to minimize adverse impacts to migratory birds, such as performing work outside of the nesting season and minimizing the loss of habitat. MSA maintains migratory bird permits issued by the USFWS (MB14155A-2 & MB81249A-1) that allow for certain *Migratory Bird Treaty Act*-related actions. A report of all activities conducted under this permit is provided to USFWS annually.

### 2.5.1.3 Bald and Golden Eagle Protection Act (16 USC 668)

[16 USC 668](#) provides for the protection of the bald eagle and golden eagle by prohibiting, except under certain specified conditions, the taking, possession, or commerce of such birds. A revised *Bald Eagle Management Plan for the Hanford Site, South Central Washington* ([DOE/RL-94-150](#)) was published in 2013 to direct Hanford Site activities in accordance with current federal and state regulations and guidelines. This management plan outlines seasonal access restrictions around documented nesting and communal roosting sites at the Hanford Site between November 15 and March 15, and establishes guidelines for the protection of perches, roosts, and alternative nest sites. When applicable, ecological reviews have produced recommendations to minimize adverse impacts to bald eagles, including performing work outside of the winter season; staying out of established buffer areas; or entering buffer areas at mid-day, minimizing impacts by avoiding eagle roosting periods.

DOE continued to maintain a bald eagle take permit from the USFWS (MB30480-A-1) to cover potential disturbance to eagles using the night roosts in the vicinity of the 100 HX pump-and-treat system between 100-H and 100-D Areas.

### 2.5.1.4 Executive Orders 11988 and 11990

Executive Orders [11990](#) and [11988](#) require federal agencies to minimize the loss or degradation of wetlands on federal lands, and account for floodplain management when developing water- and land-use plans, respectively. DOE implements the requirements of these two executive orders through [10 CFR 1022](#), “Compliance with Floodplain and Wetlands Environmental Review Requirements.” It is DOE policy to 1) restore and preserve natural and beneficial values served by floodplains; 2) minimize the destruction, loss, or degradation of wetlands; and 3) preserve and enhance the natural and beneficial value of wetlands. Compliance with these executive orders, as well as the wetland provisions of the *Clean Water Act of 1977* ([Public Law 107-303](#)), are implemented at the Hanford Site through the ecological compliance review process in conjunction with the appropriate site environmental compliance officers. The compliance process includes the identification, protection, and when necessary, mitigation of wetlands and floodplains on the Hanford Site.

## 2.5.2 Cultural Resource Compliance

### TE Marceau

The *Department of Energy Management of Cultural Resources* ([DOE P 141.1](#)) requires compliance with cultural resource-related laws and regulations. The laws include the *Antiquities Act of 1906* ([16 USC 433](#)), *Historic Sites Act of 1935* ([16 USC 461](#)), *National Historic Preservation Act of 1966* ([16 USC 470](#)), NEPA, *Archaeological and Historic Preservation Act of 1974* ([16 USC 469](#)), *American Indian Religious Freedom Act of 1978* ([42 USC 1996](#)), *Archaeological Resources Protection Act of 1979* ([16 USC 470](#)), and *Native American Graves Protection and Repatriation Act*.

Regulations applicable to cultural resources include the *National Register of Historic Places* ([36 CFR 60](#)); *Determinations of Eligibility for Inclusion in the National Register of Historic Places* ([36 CFR 63](#)); *National Historic Landmarks Program* ([36 CFR 65](#)); *Curation of Federally Owned and Administered Archaeological Collections* ([36 CFR 79](#)); *Protection of Historic Properties* ([36 CFR 800](#)); *Protection of Archaeological Resources* ([43 CFR 7](#)); and *Native American Graves Protection and Repatriation and Regulations* ([43 CFR 10](#)).

Executive orders applicable to cultural resources include [Executive Order 11593](#), *Protection and Enhancement of the Cultural Environment* (36 FR 8921); [Executive Order 13007](#), *Indian Sacred Sites* (61 FR 26771); [Executive Order 13175](#), *Consultation and Coordination with Indian Tribal Governments* (65 FR 67249); [Executive Order 13287](#), *Preserve America* (68 FR 10635); and Presidential Proclamation 7319, *Establishment of the Hanford Reach National Monument* ([65 FR 37253](#)). Refer to Section 11.3 for details regarding Hanford Site Cultural Resource programs.

## 2.6 Sustainability Statutes

Information regarding additional statutes is presented in the following sections.

### 2.6.1 Chemical Management Systems

Hanford Site contractors have developed and documented formal systems to manage chemicals. Chemical management systems apply to the acquisition, use, storage, transportation, and final disposition of chemicals, including hazardous chemicals as defined in [29 CFR 1910](#), Subpart Z, “Occupational Safety and Health Standards.” Chemical management systems are reviewed periodically and improvements are made as needed.

### 2.6.2 Pollution Prevention Program (42 USC 133)

*SW Davis*

The [Pollution Prevention Act of 1990](#) (42 USC 133) requires that pollution be prevented or reduced at the source whenever possible, and pollution that cannot be prevented be recycled or treated in an environmentally safe manner. The Hanford Site Pollution Prevention Program was created to address these requirements. RL is responsible for the Hanford Site Pollution Prevention Program and provides program implementation guidance to Hanford Site contractors. The Pollution Prevention Program reflects federal and DOE policies to reduce, reuse, and/or recycle wastes, as established by [42 USC 133](#).

[Executive Order 13423](#), *Strengthening Federal Environmental, Energy, and Transportation Management* (72 FR 3919); [Executive Order 13514](#), *Federal Leadership in Environmental, Energy, and Economic Performance* (74 FR 52117); and [DOE O 436.1](#), *Departmental Sustainability*, establish pollution prevention and environmental stewardship requirements. In accordance with these requirements, pollution prevention and waste minimization activities are documented, tracked, and reported. Table 2.9 summarizes Hanford Site pollution prevention and waste minimization quantities recycled in FY 2014.

**Table 2.9. Recycle Quantities**

FY 2014 Recycled Material	Quantity (Metric Tons)
<b>Non-Hazardous Material</b>	
Cardboard	45.18
CI shredded paper	690.67
Furniture	137.82
Plastic bottles	23.62
Tires	43.61
Wood pallets	36.49
Software/media	6.70
CHPRC zero waste picnic	0.9072
WCH scrap metal	1,009.85
Brass metals	0.00
Ferrous metals	488.04

Non-ferrous metals	39.26
WRPS zero waste picnic	0.935
<b>Subtotal</b>	<b>2,515.9</b>
<b>Regulated Solid Wastes</b>	
Aerosol cans	0.00
Antifreeze	7.23
Antifreeze – fleet	3.46
Ballasts	3.20
Batteries	4.83
Fluorescent bulbs	4.68
Lamps	1.41
Lead acid batteries	37.22
Lead acid batteries (fleet)	10.45
Polychlorinated biphenyl (PCB) waste oil <50 ppm	12.10
Toner cartridges	11.82
Used engine oils (fleet)	25.09
Used oil	22.57
<b>Subtotal</b>	<b>144.06</b>
<b>Total</b>	<b>2,659.9</b>

### 2.6.2.1 Pollution Prevention and Waste Minimization Accomplishments and Awards

The Hanford Site did not receive any DOE, federal agency, state agency, or industry-sponsored awards for pollution prevention and waste minimization accomplishments in CY 2014.

### 2.6.2.2 Accomplishments

The Hanford Site has recycled 80 percent of non-hazardous solid waste and certain hazardous waste, excluding construction and demolition (C&D) debris. The Hanford Site recycled 2,659.9 metric tons of regulated (hazardous and universal waste) and non-hazardous solid wastes. During 2014, the Hanford Site contractors continued to divert C&D from landfill disposal. The Hanford Site diverted approximately 93 percent (3,346.3 metric tons) of C&D debris from the inert landfill, disposing 253.3 metric tons of debris to the landfill. Hanford continues to implement additional power management initiatives. There were several ongoing power management and other environmentally preferable initiatives throughout 2014 including the following:

- ⊗ Thin Client (Zero Clients) implementation (replacing desktop computers with energy efficient Thin Clients) continued, and 1,052 Zero Clients were deployed. Implementation of the Thin Client (Zero Clients) and this category of products are not covered by ENERGY STAR™ or EPEAT, but have superior energy efficiency.
- ⊗ Increased use of “Convenience Copiers” allowed for removal of standalone and network printers.
- ⊗ 100 percent of the equipment on the Hanford Site is set to automatic duplexing, including printers, copiers, and multifunction devices.
- ⊗ Further tested the “Network in a Box” initiative, which allows Wi-Fi connection for workers away from their computers in the 100 Area.
- ⊗ Over 328 computers, monitors, printer, televisions, and servers were recycled through a certified recycler.

### 2.6.3 Environmental Orders

*CJ Clement*

One DOE order and two Presidential Executive Orders addressing sustainability are complied with at the Hanford Site.

[Executive Order 13423](#) (72 FR 3919) established a policy for federal agencies to conduct legally, environmentally, economically, and fiscally sound environmental, transportation, and energy-related activities in an integrated, efficient, continuously improving, and sustainable manner. The order established goals for the following areas: improved energy efficiency; reduced greenhouse gas emissions; use of renewable energy sources; renewable energy generation; reduced water consumption; acquisition of bio based, environmentally preferable, energy-efficient, water-efficient, and recycled products; reduced use of toxic and hazardous chemicals and materials; increased waste minimization, prevention, and recycling; use of sustainable building practices; reduced use of petroleum products for vehicles; and electronics stewardship. In addition, [Executive Order 13423](#) requires that an Environmental Management System (EMS) be established as the mechanism for managing environmental goals, as well as other impacts to the environment from Hanford Site operations, and establishing environmental objectives and targets. The order also requires establishing environmental management training, environmental compliance review and auditing, and leadership awards to recognize outstanding environmental, energy, or transportation management performance.

[Executive Order 13514](#) (74 FR 52117), states that federal agencies shall increase energy efficiency; measure, report, and reduce their greenhouse gas emissions from direct and indirect activities; conserve and protect water resources through efficiency, reuse, and storm water management; eliminate waste, recycle, and prevent pollution; leverage agency acquisitions to foster markets for sustainable technologies and environmentally preferable materials, products, and services; design, construct, maintain, and operate high performance sustainable buildings in sustainable locations; strengthen the vitality and livability of the communities in which federal facilities are located; and inform federal employees about and involve them in the achievement of these goals. In addition, [Executive Order 13514](#) requires that targets for baseline Scope 1 (generated from site operations and activities) and Scope 2 (associated with the purchase of energy [electricity, heat, or steam] used by site contractors) greenhouse gas emissions, along with 2020 reduction targets, be established.

Similar numbers for Scope 3 (emissions associated with ancillary activities related to Hanford Site operations, including business travel, employee commuting, vendor activities, delivery services) emissions must be established. [Executive Order 13514](#) also sets goals for improved water use efficiency and management, promotion of pollution prevention and waste elimination, advancement of regional and local integrated planning, implementation of sustainable building lifecycle management practices, advancement of sustainable acquisition, and promotion of electronics stewardship. [Executive Order 13514](#) requires continued implementation of a formal sustainable EMS.

[DOE O 436.1](#) requires developing a Site Sustainability Plan that is integrated with the Hanford Site operational plans. In addition, the order requires developing an EMS that is certified to or conforms with the ISO 14001:2004 standard, submittal of sustainability goal data and reports, as well as *Emergency Planning and Community Right-to-Know Act of 1986* reporting. Implementation of DOE orders and executive orders by Hanford Site contractors is addressed in Section 3.0.



MSA, as the Hanford Site services and infrastructure contractor, updated the sustainability plan for the Hanford Site in 2014 with input from DOE and Hanford Site contractors. The plan describes the energy management program and identifies planned energy efficiency, water conservation, transportation fleet management, and sustainable buildings activities, as required by [DOE O 436.1](#). Environmental objectives developed in 2010 were maintained in 2014, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship (see Section 3.0).

## **2.7 Occurrence Reporting and Processing of Operations Information**

*TH Pysto*

Releases of radioactive and regulated materials to the environment are reported to DOE and other federal and state agencies as required by law. The specific agencies notified depend on the type, amount, and location of each release event. This section addresses releases or potential releases to the environment that may not be documented by other reporting mechanisms during the reporting period. All Hanford Site occurrences are reported to the Hanford Emergency Operations Center Shift Office and subsequently recorded in the Occurrence Reporting and Processing System. This system is a DOE electronic database that tracks occurrence reports across the DOE complex ([DOE M 231.1-2](#), *Occurrence Reporting and Processing of Operations Information*). The following sections summarize occurrences that may have impacted the Hanford Site environment in 2014. The occurrences are arranged according to significance category, which are assigned based on the nature and severity of the occurrence. The categories include Operational Emergency; Recurring; or Category 1 (Significant Impact), Category 2 (Moderate Impact), Category 3 (Minor Impact), and Category 4 (Some Impact).

### **2.7.1 Operational Emergency; Recurring; or Category 1**

There were no Hanford Site environmental occurrences ranked as Operational Emergency, Recurring, or Category 1, Significant Impacts.

### **2.7.2 Operational Emergency; Recurring; or Category 2**

There were no Hanford Site environmental occurrences ranked as Operational Emergency, Recurring, or Category 2, Moderate Impacts.

### **2.7.3 Operational Emergency; Recurring; or Category 3**

There were no Hanford Site environmental occurrences ranked as Operational Emergency, Recurring, or Category 3, Minor Impacts.

### **2.7.4 Operational Emergency; Recurring; or Category 4**

Category 4 occurrences are defined as having some impact on safe facility operations, worker or public safety and health, regulatory compliance, or public and business interests. Summarized below is one Category 4 occurrence with potential environmental implications that occurred on the Hanford Site during the reporting period, and the discoveries of legacy contamination.

**Discovery of Legacy Contamination.** Each year on the Hanford Site, legacy contamination is spread because of environmental conditions. Some contamination is discovered during routine survey work. Biological vectors also spread contamination; tumbleweeds, rodents, and birds are all common biological vectors. Tumbleweeds have a deep taproot that can sequester contamination from below the soil surface



into the plant body on the surface. Rodents eat vegetation located in contaminated areas and then deposit contaminated feces outside of the contaminated area. Birds build nests and occasionally use materials from contaminated areas, resulting in the transfer of contamination to uncontaminated areas. Of these three biological vectors, contaminated tumbleweeds occur most frequently and have the potential to transfer contamination the farthest distance from their original locations. High winds may contribute to the spread of legacy contamination beyond posted areas. Reports of legacy contamination discovered throughout the year are consolidated into quarterly reports. In 2014, there were 45 documented occurrences of legacy contamination.

## 2.8 Standards and Permits

*JK Perry, RA Kaldor, CJ Clement, and JW Wilde*

Hanford Site operations must conform to a variety of government standards and permits. The primary environmental quality standards and permits applicable to Hanford Site operations are listed in Table 2.10.

*Table 2.10. Environmental Permits*

### **Dangerous Waste Permit (RCRA)**

*Hanford Facility RCRA Permit* (WA7890008967) was issued on September 27, 1994, and has undergone several revisions. The permit expired on September 27, 2004; however, Permit WA7890008967, Rev. 8C, remains in effect until a new permit is issued. Ecology issued a draft permit for public review and comment, from May 1, 2012 through October 22, 2012 ([WA7890008967, Rev. 9](#)). Ecology received more than 4,000 comments on the draft permit, including approximately 1,800 comments from the public and 3,000 comments from the DOE. Because information and arguments brought up during the comment period raised substantial new questions, Ecology plans to revise the draft permit and reopen the comment period (see Section 2.1.2.1).

### **Air Permits**

Hanford Site Air Operating Permit 00-05-006, Renewal 2, covers operations on the Hanford Site having a potential to emit airborne emissions. This permit was effective on April 1, 2013, and expires March 31, 2018. The permit is intended to provide a compilation of applicable *Clean Air Act* requirements for both radioactive and non-radioactive emissions at the Hanford Site. It will be implemented through federal and state programs (see Section 2.3.2).

*Radioactive Air Emissions License for the Department of Energy Richland Operations Office Hanford Site, License Number FF-01* (WDOH 2012), is issued to RL by the Washington State Department of Health. This permit was effective February 23, 2012, and expires December 31, 2017. The FF-01 license is a compilation of all applicable radioactive air emission requirements.

### **Drinking Water Permits**

ID# 00177 J is a permit to operate the 100-K Area drinking water system. WDOH issues the permit.

ID# 00100 4 is a permit to operate the 200-West Area drinking water system. WDOH issues the permit.

Table 2.10. Environmental Permits

ID# 41840 8 is a permit to operate the 300 Area drinking water system. WDOH issues the permit.

ID# 41947 0 is a permit to operate the 400 Area drinking water system. WDOH issues the permit.

#### Wastewater Permits

Permit [CR-IU010](#), 300 Area Industrial Wastewater Discharge Permit, is issued to RL by the city of Richland. Permit CR-IU010 governs the discharges from the 300 Area facilities into the city of Richland sewer collection system.

HAN002 through HAN074 permit onsite sewage systems to operate on the Hanford Site. WDOH issues these permits.

Permit [ST-4500](#), *State Waste Discharge Permit*, allows treated wastewater from the Effluent Treatment Facility to be discharged to the State-Approved Land Disposal Site. This permit expired August 1, 2005; old permit will remain in effect until the new permit is issued. On December 15, 2014, Ecology reissued the permit as [ST0004500](#). It became effective on January 1, 2015.

Permit [ST0004502](#), *State Waste Discharge Permit*, allows treated effluent from the 200-East and 200-West Areas to be discharged to the 200 Area Treated Effluent Disposal Facility. This permit is effective until June 30, 2017.

Permit [ST0004511](#) is a Categorical State Waste Discharge Permit that authorizes the discharge of wastewater from maintenance, construction, and hydro testing activities and allows for cooling water, condensate, and industrial storm water discharges at the Hanford Site. This permit was issued January 1, 2014, and will expire February 16, 2019.

Permit [ST0045514](#), *State Waste Discharge Permit*, is for the 200-West Area Evaporative Sewage Lagoon a domestic wastewater treatment facility located northeast of the 200-West Area. The facility consists of double-lined evaporative lagoons and is designed to have no liquid discharge to the ground. The system will provide domestic wastewater treatment for the 200-West and 600 Areas, as well as treatment for domestic wastewater hauled from the 200-East Area and other locations within the site.

Permit [WAG-50-5180](#), Washington State Sand and Gravel General Permit for the Concrete Batch Plant in the 200-East Area. The Concrete Batch Plant supports construction of WTP; its primary function is making concrete. The permit provides coverage for discharges of process water and storm water associated with Ready Mix Concrete operations. Bechtel National is the owner of the permit. This permit was effective October 1, 2010, and expires on October 1, 2015.

Permit [WAG-50-5181](#), Washington State Sand and Gravel General Permit for Pit 30 Quarry in the 200-East Area. Ecology issued the permit to BNI as the owner and operator. This permit was effective October 1, 2010, and expires on October 1, 2015. The Pit 30 Quarry supports the construction of the WTP, and the primary function is making construction sand and gravel.

*Table 2.10. Environmental Permits***Wildlife Permits**

Permit MB14155A-2, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to MSA, authorizes the collection of migratory birds from transformers and conductors when imminent threat of fire and power outages. This permit expired March 31, 2014.

Permit MB30480A-1, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to CHPRC, authorizes incidental take of bald eagles associated with operations at 100-K Area and the 100-HX Pump and Treat System. This permit expired March 31, 2014.

Permit MB81249A-1, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to MSA; authorizes the collection of migratory birds for danger to human safety and health and the determination and control of contamination. This permit expired March 31, 2015.

Review Reference Number 13260-2009-I-0121, Federal Fish and Wildlife Section 7 Review, issued to Environmental Assessment Services in July 2009, for the potential of incidental take of salmonids during fishing activities in the Columbia River. This review has no expiration listed.

Review Reference Number 13260-2011-I-0080, Federal Fish and Wildlife Section 7 Review, issued to DOE in July 2011 for the potential of incidental take of bull trout during fishing activities in the Columbia River. This review has no expiration listed.

Permit 13-304a, Scientific Collection Permit issued by WDFW to Environmental Assessment Services through September 2014, authorizes the collection of food fish, shellfish, game fish, and wildlife for research purposes. This permit is renewed annually.

Permit 13-075, Scientific Collection Permit issued by WDFW to MSA for May 2013 through May 2014; authorizes the collection of food fish, shellfish, game fish, and wildlife for research purposes. This permit is renewed annually.

Permit 14-151a, Scientific Collection Permit issued by WDFW to MSA for May 2014 through May 2015; authorizes the collection of food fish, shellfish, game fish, and wildlife for research purposes. This permit is renewed annually.

**Agency Contact Information**

State of Washington Department of Ecology P.O. Box 47600 Olympia, WA 98504-7600	U.S. Environmental Protection Agency Region 10 1200 Sixth Avenue Seattle, WA 98101	U.S. Department of Energy Richland Operations Office 825 Jadwin Avenue Richland, WA 99352
U.S. Fish and Wildlife Service Migratory Bird Permit Office 911 N.E. 11th Avenue Portland, OR 97232-4181	Washington State Department of Health P.O. Box 47890 Olympia, WA 98504-7890	

## 2.9 Environmental Noncompliance

*JW Cammann*

During CY 2014, there were 12 regulatory agency enforcement actions filed against the DOE and its contractors for alleged violations of regulatory requirements (2-Washington State Attorney General, 2-WDOH, 5-Ecology, and 3-EPA Region 10). Nine of the 12 enforcement actions resulted from regulatory agency inspections of DOE facilities on the Hanford Site (see Section 2.1.2.2). The enforcement actions resulted in 9 concerns and 26 compliance actions that contributed to \$190,594 in fines and penalties. Table 2.11 summarizes the Notices of Violation and Notices of Alleged Violation. Figure 2.1 shows noncompliance concerns, violations, and special environmental projects (SEP).

**Table 2.11. Notices of Violation and Notices of Alleged Violation Summary, 2009 - 2014**

Program Area	Notices of Violation/Notices of Alleged Violation					
	2009	2010	2011	2012	2013	2014
CAA	0	3	0	0	4	2
CWA	0	1	0	0	0	0
RCRA	3	3	1	2	4	7
CERCLA	0	0	0	3	1	0
Others	0	4	1	2	1	1
<b>Total Notices of Violation</b>	<b>3</b>	<b>11</b>	<b>2</b>	<b>7</b>	<b>10</b>	<b>10</b>

The following summarizes the alleged violations for CY 2014; though, not all alleged violations resulted in a monetary fine or penalty.

January 1, 2014, the WDOH issued a letter to the ORP and its contractor WRPS closing out the inspection of tank farm emission units 296-P-43, P-44, and P-45. However, WDOH requested an ALARACT demonstration to address: 1) actions taken to place emission units in layup, 2) steps to restart emission units, and 3) description of surveillance and maintenance actions during layup. Visual inspection and review of records revealed that conditions of the Hanford Radioactive Air Emission License (FF-01) were not reflective of the current non-operational status of these tank farm emission units. The ALARACT demonstration was completed and transmitted to WDOH on September 12, 2014. No fines or penalties have been assessed to date.

January 24, 2014, Ecology, RL, and CHPRC signed the *Agreed Order and Stipulated Penalty Docket No. DE 10156, Hanford Solid Waste Operations Complex* ([14-NWP-023](#)) to improve waste management practices at the CWC, WRAP, and T Plant to comply with alleged violations of [WAC 173-303](#). The Agreed Order requires immediate notification to Ecology for spills/other incidents; prompt response to incidents; better reporting of causes and corrective actions; better sampling of waste; better management of waste containers; and frequent inspections. DOE agreed to a stipulated penalty of \$261,000; CHPRC paid \$15,000 immediately and Ecology suspended the \$246,000 balance pending completion of corrective actions according to an agreed schedule. All corrective actions were completed and none of the suspended portion of the penalty was requested or paid during CY 2014.

March 21, 2014, Ecology issued an Administrative Order to ORP and WRPS pertaining to a double-shell tank 241-AY-102 leak from the primary tank into the secondary tank annulus area. Ecology alleged four

violations of the dangerous waste regulations: 1) failure to stop the flow of hazardous waste into secondary containment in accordance with [40 CFR 265.196\(a\)](#), “Response to leaks or spills and disposition of leaking or unfit-for-use tank systems”; 2) failure to inspect the tank to determine the cause of the release in accordance with [40 CFR 265.196\(a\)](#); 3) failure to remove, at the earliest practicable time, as much of the waste as is necessary to prevent further release of hazardous waste to the environment and allow inspection and repair of the tank to be performed in accordance with [40 CFR 265.196\(b\)](#); and 4) failure to remove all released materials from the secondary containment system within 24 hours or in as timely a manner as is possible to prevent harm to human health and the environment in accordance with [40 CFR 265.196\(b\)\(2\)](#). Settlement agreement PCHB-14-041c was signed on September 29, 2014, stipulating corrective measures and associated schedule for completion. Several actions were completed during CY 2014, including ORP submittal to Ecology of a revised pumping plan, technical safety requirement and safety basis evaluations, monitoring and contingency plans, integrity assessment for secondary containment system, and work plan for removing remaining tank waste. No fines or penalties have been assessed to date.

March 31, 2014, the attorney general of Washington issued a letter to the U.S. Department of Justice proposing to amend the consent decree ([Washington v. Chu, U.S.D.C. Eastern No. 08-5085-FVS, State of Washington's Proposal to Amend Consent Decree](#) [Ecology 2014a]). On April 18, 2014, the attorney general of Washington issued a letter to DOE in [Response to Department of Energy's March 31, 2014, Proposal to Amend Consent Decree](#) (Ecology 2014b). To address these concerns, Washington provided to the defendants a formal proposal to amend the Consent Decree. While Washington's proposal reflected agreement between DOE and Washington in several key areas, it did not adequately account for the realities of technical issues resolution, project management requirements, and budget constraints; therefore, DOE did not accept Washington's proposal to amend the Consent Decree. On April 23, 2014, the attorney general of Washington issued a letter [Washington V Chu USDC Eastern No 08-5085-FVS Washington's Notice Invoking Dispute Resolution Based on Department of Energy's Refusal to Accept Washington's March 31, 2014, Proposal to Amend Consent Decree](#) (Ecology 2014c). After extending the deadline for resolving the dispute twice, on September 5, 2014, the Washington State attorney general and governor declined any further extensions and filed a motion in U.S. District Court to amend the Consent Decree. On December 5, 2014, DOE filed a response (No. 08-5085-RMP) in U.S. District Court to Washington's petition to modify the Consent Decree stating that the petition should be denied because it would establish requirements that are unachievable, beyond the scope of the parties' original agreement, and in conflict with DOE's exclusive regulatory authority under the AEC. No fines or penalties have been assessed to date. The Consent Decree governs milestones through the startup of WTP and the retrieval of 19 single-shell tanks. Washington alleged that DOE's inability to meet key Consent Decree requirements, together with its failure to present Washington with a comprehensive recovery plan, puts the tank waste retrieval and treatment missions at risk.

April 10, 2014, WCH paid a \$44,000 fine to EPA for alleged violations of the federal requirements of the Clean Air Act, NESHAPs for Asbestos ([40 CFR Part 61](#), Subpart M). The alleged violations and associated penalty were the result of an inspection conducted by EPA during FY 2013. On April 2, 2014, the EPA, RL, and WCH signed a Consent Agreement and Final Order (Docket No. CAA-10-2014-0073) alleging two violations of applicable regulations. Count 1 alleged failure to submit adequate notification of intent to

demolish prior to demolition. Count 2 alleged failure to remove regulated asbestos-containing materials prior to demolition activities.

April 24, 2014, CHPRC paid a \$131,594 fine to EPA for alleged violations of the federal requirements of the Clean Air Act, NESHAPS for Asbestos ([40 CFR Part 61](#), Subpart M). The alleged violations and associated penalty were the result of an inspection conducted by EPA during FY 2013, where EPA found 1) failure to remove more than 100,000 square feet (9,290 square meters) of asbestos prior to demolishing buildings and structures as required by federal law, 2) failure to provide complete and accurate notifications to EPA or local air agency (Benton Clean Air Agency) as demolition projects were under way, and 3) inspection of waste storage trailer showed some wastes not properly contained in leak-tight containers.

June 5, 2014, WDOH issued a Notice of Concern (AIR 14-603) to ORP and WRPS regarding standards and maintenance requirements for ventilation systems in Hanford tank farm facilities. WDOH expressed concerns regarding an alleged decline in the maintenance and condition of the ventilation control and monitoring systems in the tank farms. Evidence from WDOH inspections and ORP and WRPS environmental notifications to WDOH indicated these aging systems are deteriorating and are in need of repair. As a result, WDOH identified the following issues: 1) aging HEPA filter operation, 2) maintenance of moisture and condensate control equipment, 3) sample probe obstruction, and 4) non-operational emission units. On October 3, 2014, ORP and WRPS issued a letter (14-ECD-0047) to WDOH transmitting a written plan for addressing WDOH concerns.

July 10, 2014, Ecology issued a Notice of Violation ([14-NWP-135](#)) to ORP and BNI alleging violations of [WAC 173-303-060](#)(2) regarding EPA/state identification numbers for dangerous waste sites based on definitions found at [WAC 173-303-040](#). On May 19, 2014, Ecology conducted a waste generator inspection at the WTP Material Handling Facility. Ecology alleged the Material Handling Facility is not located on the Hanford Site nor is it contiguously bound to the Hanford Site. Additionally, Ecology alleged the Material Handling Facility is a new BNI location for supporting WTP construction. Ecology alleged the Hanford Site EPA ID# WA7890008967 could not be used for this new location per the WAC regulations. On March 4, 2015, a letter ([15-ESQ-0042](#)) was sent to Ecology requesting a new Dangerous Waste Site Identification Number for the Material Handling Facility. The Material Handling Facility currently operates as a small quantity generator of dangerous waste from the limited maintenance of WTP fleet vehicles and general warehousing activities. Although obtaining a dangerous Waste Site Identification Number is not a WAC requirement for small quantity generators, activities at the Material Handling Facility may exceed small quantity generator limits in the future; therefore, ORP is requesting an identification number and has identified the Material Handling Facility as a large quantity generator. No fines or penalties have been assessed to date.

July 22, 2014, Ecology issued a Notice of Violation ([14-NWP-152](#)) to ORP and BNI for alleged violations based on observations of dangerous waste management and review of records at the WTP. Ecology alleged the following violations of [WAC 173-303](#): 1) improper completion of shipping manifest #006356185, 2) dangerous waste training plan deficiencies, 3) dangerous waste training deficiencies, 4) obscured dangerous waste labels on containers, and 5) incomplete container inspection logs. There were also four areas of concern identified by Ecology including 1) documentation for managing mixed waste, 2) documentation for the process to move newly generated dangerous waste to centralized



satellite accumulation areas, 3) contingency plan inadequacies, and 4) training plan and training record deficiencies. All alleged violations have been addressed. No fines or penalties have been assessed to date.

August 25, 2014, Ecology issued a Notice of Violation ([14-NWP-183](#)) to RL and WCH identifying two alleged violations based on observations of dangerous waste management and records review of satellite accumulation areas at the Sample Storage and Shipping Facility on July 2, 2014. Ecology alleged the following: 1) the Sample Storage and Shipping Facility is located off the Hanford Site and cannot use the Hanford Site EPA ID# WA7890008967, and 2) the facility address on the shipping manifest was incorrect. All alleged violations have been addressed. No fines or penalties have been assessed to date.

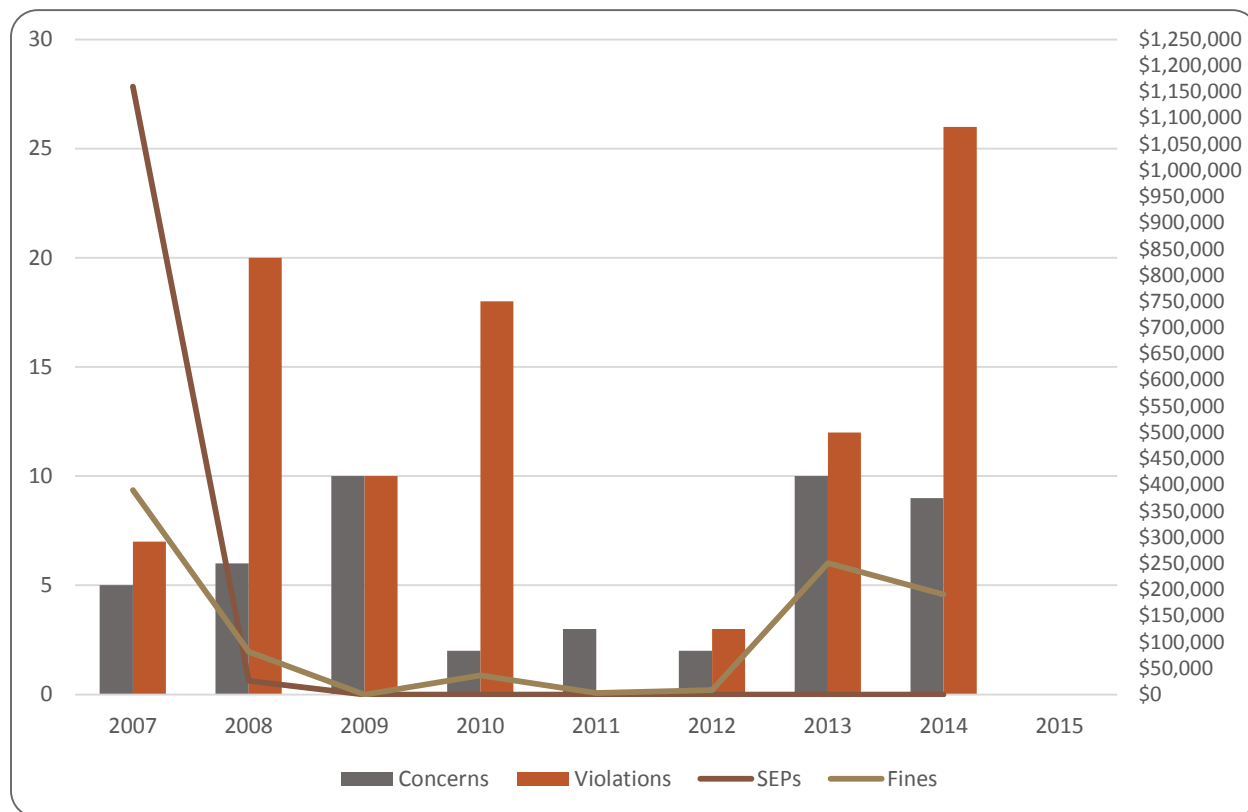
October 14, 2014, EPA sent a letter to RL, for *Disapproval of Proposed New Date for Milestone M-016-175, Begin Sludge Removal from 105-KW Fuel Storage Basin, and Notice of Failure to Comply with Milestone M-016-175 and the Assessment of Stipulated Penalties* ([15-AMRP-0031](#)). On June 12, 2014, RL notified EPA (*Notification of TPA Milestone M-016-175, Begin Sludge Removal from 105-KW Fuel Storage Basin, September 30, 2014, Will be Missed* ([14-AMRP-0214](#))) that TPA Milestone M-016-175 would be missed for 'good cause' due to congressional funding levels for RL being below the president's budget requests for prior years, due to the impacts of the FY 2013 Budget Control Act (sequestration), and the FY 2014 Continuing Resolution. On September 30, 2014, RL submitted a request for the extension of TPA Milestone M-016-175 ([14-AMRP-0311](#), *Begin Sludge Removal from 105-KW Fuel Storage Basin*, due date September 30, 2014), proposing a new date for TPA Milestone M-016-175 to TBD until a full-year budget resolution or appropriation was passed and FY 2016-2018 budget levels were established. On October 14, 2014, the EPA disapproved the milestone extension request. On October 21, 2014, RL transmitted a letter to EPA initiating dispute resolution based on EPA's disapproval of the milestone extension request, ([15-AMRP-0014](#), *Initiation of Dispute Resolution Regarding Disapproval of TPA Change Control Form M-16-14-02*). On November 7, 2014, EPA agreed to extend the dispute for change request M-16-14-02 at the project manager level to December 3, 2014. On December 3, 2014, RL transmitted to EPA the *Statement of Dispute Regarding Disapproval of Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Change Control Form M-16-14-02* ([15-AMRP-0031](#)). No fines or penalties have been assessed to date.

November 19, 2014, the Washington State attorney general issued a Notice of Intent to the Secretary of Energy, WRPS president, and EPA administrator (Ecology 2014d). The notice said the attorney general "hereby provides ORP and WRPS with a *Notice of Endangerment and Intent to File Suit* pursuant to the RCRA §7002(a)(1)(B), 42 U.S.C. § 6972(a)(1)(B)." The attorney general intends to file suit, on behalf of the people of the state of Washington, against ORP and WRPS due to releases of vapors from hazardous waste being stored and treated in underground tanks and tank systems at the Hanford Site tank farms. The attorney general alleged that escaping vapors present an imminent and substantial endangerment to health and the environment. On February 10, 2015, ORP and WRPS issued the *Implementation Plan for Hanford Tank Vapor Assessment Report Recommendations*. In April 2014, WRPS chartered Savannah River National Laboratory (Tank Vapor Assessment Team) to establish and oversee a panel of external, independent experts to examine chemical vapors management and related worker-protection measures at the Hanford tank farms. The team released the *Hanford Tank Vapor Assessment Report* ([SRNL-RP-2014-00791](#)), on October 30, 2014. To address the Tank Vapor Assessment Team report



recommendations, WRPS developed an implementation plan with multiple proposed response actions, a corresponding schedule, and estimated costs. No fines or penalties have been assessed to date.

**Figure 2.1. Environmental Noncompliance Concerns and Associated Fines**



SEP = Supplemental environmental project (performed to benefit the local community in lieu of a penalty payment).

### 2.9.1 Waste Water Permit Deviations

*CJ Clement*

During CY 2014, seven wastewater permit deviations were reported.

- ⊗ On February 11, 2014, a permit deviation for HAN050 was reported to WDOH regarding a sewage release to the ground at lift from station 2607-E12.
- ⊗ On May 14, 2014, MSA, Water and Sewer Utilities management, and Ecology self-identified compliance issues with the Large Onsite Sewer Systems/Onsite Sewer Systems (LOSS/OSS) and the 200-West Area Lagoon Treatment System (ST0045514). Issues were identified concerning not following operation and maintenance manuals completely, not having all procedures in place to operate the systems, and incomplete data regarding permit system locations.
- ⊗ On May 29, 2014, a permit deviation (ST0004502) was reported to Ecology for a lab-reported detection level above the permit-specified quantitation level.
- ⊗ On July 9, 2014, a permit deviation (ST0004502) was reported to Ecology for a lab exceedance of the hold time for a nitrate analysis.

- ⊗ On August 5, 2014, a permit deviation (ST0004502) was reported to Ecology for minor leaks in air vacuum relief valves.
- ⊗ On October 23, 2014, a permit deviation for HAN071 was reported to WDOH regarding a sewage release to the ground at lift station 2607-E1A.
- ⊗ On November 14, 2014, a permit deviation for HAN071 was reported to WDOH regarding a sewage release to the ground at lift station 2607-E6.

### 3.0 Environmental Management System (EMS)

*SL Vaughn*

DOE requires Hanford Site contractors to develop and operate under an Integrated Safety Management System (ISMS). In accordance with contract obligations, contractors maintain an EMS that is consistent with ISO 14001 standard *Environmental Management Systems – Requirements with Guidance for Use*. All but one Hanford Site contractor has established ISMS as mandated by their contracts with DOE. These systems are intended to protect workers, the public, and the environment by integrating environmental, safety, and health considerations into the way work is planned, performed, and improved. DOE verified that Hanford Site entities incorporated appropriate environmental program elements within their ISMS under the authority of [DOE M 450.4-1](#), *Integrated Safety Management System Manual*. The dates that DOE approved the Hanford Site contractor's ISMS are provided in Table 3.1.; Table 3.2 lists the applicable DOE orders and their approval dates.

Performance related to EMS must be reported annually to DOE, Headquarters (HQ). Each contractor is given an overall ranking of red, yellow, or green based on the previous fiscal year's performance. Rankings for Hanford Site contractors are provided in Table 3.1 along with rankings for both RL and ORP.

MSA, as the services and infrastructure contractor for the Hanford Site, developed a sustainability plan for the Hanford Site in 2014 with input from site contractors. The plan describes the energy management program and identifies planned energy efficiency, water conservation, transportation fleet management, and sustainable buildings activities, as required by [DOE O 436.1](#). Environmental objectives, developed in 2010, were maintained in 2014, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship.

Several contractors have made their environmental policy and environmental aspects available to the public through company Internet websites (Table 3.3). An EMS is a systematic approach to environmental performance ensuring planned activities lead to continual improvement and demonstrating to stakeholders a commitment to the environment.

**Table 3.1. DOE Contract Actions and Contractor Implementation**

DOE Contract Actions & Contractor Implementation	Richland Operations Office				Office of River Protection		
	HPMC	CHPRC	MSA	WCH	ATL	BNI	WRPS
Contractor Start Date	October 1, 2012	October 1, 2008	August 24, 2009	August 27, 2005	May 5, 2005	December 11, 2000	October 1, 2008
DOE Approval of Contractor ISMS	NA	November 2009	January 2011	November 2007	March 2006	February 2003	September 2009
Direction to Implement DOE EO 13423	October 2012	October 2008	August 2009	June 2009	NA	NA	October 2008
Direction to Implement DOE EO 13514	NA	June 2012	May 2011	October 2012	NA	NA	March 2011
Direction to Implement DOE O 430.2B	NA	June 2009	August 2009	June 2009	NA	NA	October 2008
Direction to Cancel DOE O 430.2B	NA	July 2012	July 2012	October 2012	NA	NA	September 2014

*Table 3.1. DOE Contract Actions and Contractor Implementation*

DOE Contract Actions & Contractor Implementation	Richland Operations Office				Office of River Protection		
	HPMC	CHPRC	MSA	WCH	ATL	BNI	WRPS
Direction to Implement DOE O 450.1A	October 2012	June 2009	August 2009	June 2009	November 2009	NA	October 2009
Direction to Cancel DOE O 450.1A	October 2012	July 2012	December 2012	October 2012	September 2013	NA	September 2014
Direction to Implement DOE O 436.1	NA	July 2012	July 2012	October 2012	NA	NA	October 2013
Contractor EMS Established	October 2012	November 2009	December 2009	September 2009	NA	NA	September 2009
ISO 14001 Certification	NA	July 2012	Sept. 2011/ 2014	NA	NA	NA	NA
DOE Declared DOE O 450.1A Conformance	NA	December 2009	December 2009	November 2009	NA	NA	September 2009
Most Recent Declaration of Conformance	NA	November 2009	September 2014	November 2012	NA	NA	September 2012
Contractor EMS Scorecard Rating	Red	Green	Green	Green	Red	Red	Green
EMS Scorecard for 2014		Green			Yellow		
ATL	= Advanced Technologies and Laboratories, Inc.			HPMC	= HPMC Occupational Medical Services.		
BNI				MSA	= Mission Support Alliance, LLC.		
CHPRC	= CH2M HILL Plateau Remediation Company.			WCH	= Washington Closure Hanford, LLC.		
EMS	= Environmental Management System.			WRPS	= Washington River Protection Solutions, LLC.		

*Table 3.2. DOE Order and Executive Order Issuance*

Order	Approval Date
<a href="#">DOE Order 450.1</a>	January 15, 2003
<a href="#">Executive Order 13423</a>	January 26, 2007
<a href="#">DOE Order 430.2B</a>	February 27, 2008
<a href="#">DOE Order 450.1A</a>	June 4, 2008
<a href="#">Executive Order 13514</a>	October 8, 2009
<a href="#">DOE Order 436.1</a>	May 2, 2011

*Table 3.3. Hanford Site Environmental Management System Internet Links*

Contractor	Website	Category
CHPRC	<a href="http://chprc.hanford.gov/files.cfm/prc-pol-sh-5053.pdf">http://chprc.hanford.gov/files.cfm/prc-pol-sh-5053.pdf</a>	Policy
MSA	<a href="http://msa.hanford.gov/files.cfm/ems.pdf">http://msa.hanford.gov/files.cfm/ems.pdf</a>	Policy, Aspects
WCH	<a href="http://www.washingtonclosure.com/about_us/environmental_stewardship">http://www.washingtonclosure.com/about_us/environmental_stewardship</a>	Policy, Aspects
WRPS	<a href="http://wrpstoc.com/tank-operations/environmental-management/">http://wrpstoc.com/tank-operations/environmental-management/</a>	Policy, Aspects

### 3.1 Environmental Performance Measures

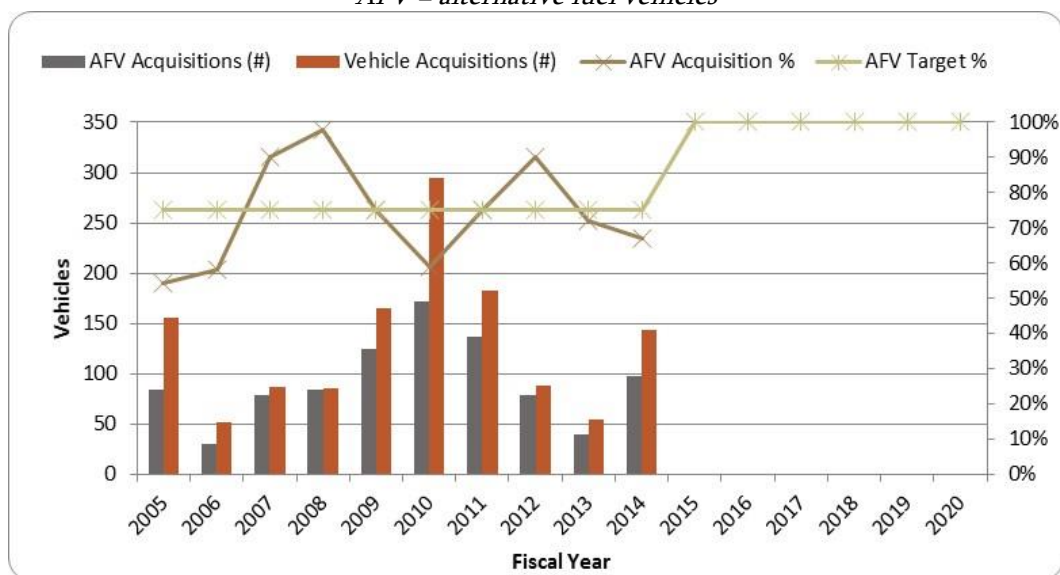
MSA, in consultation with DOE and other Hanford Site prime contractors, developed and maintains environmental performance measures for the Hanford Site. Performance measures address the goals of [DOE O 436.1](#), [Executive Order 13423](#) (72 FR 3919), and [Executive Order 13514](#) (74 FR 52117). The measures developed in response to these executive and DOE orders include regulated waste reduction; toxic and hazardous material reduction; sustainable acquisition; compliance with electronic product environmental assessment tool standards; sanitary waste diversion; construction waste diversion; electricity use; facility fuel use; water use; vehicle fuel use; numbers of alternative fuel vehicles; on-time environmental deliverables; environmental inspections; environmental non-compliances; and greenhouse gas reduction. Baseline data were obtained in accordance with guidance in the orders.

Where no guidance was available, data from 2009 or 2010 were used to establish performance baselines. Performance measurement data are used as a tool to ensure environmental goals within the DOE orders are appropriately managed. Performance related to EMS must be reported annually to HQ.

**Fleet Management.** The acquisition target for alternative fuel vehicles was not met in 2014 (Figure 3.1). DOE requires that a minimum of 75 percent of all non-mission critical light-duty vehicles purchased during FY 2014 be alternative fuel vehicles ([DOE O 436.1](#)). This percentage increases to 100 percent beginning in FY 2015.

*Figure 3.1. Fleet Management – Acquisitions*

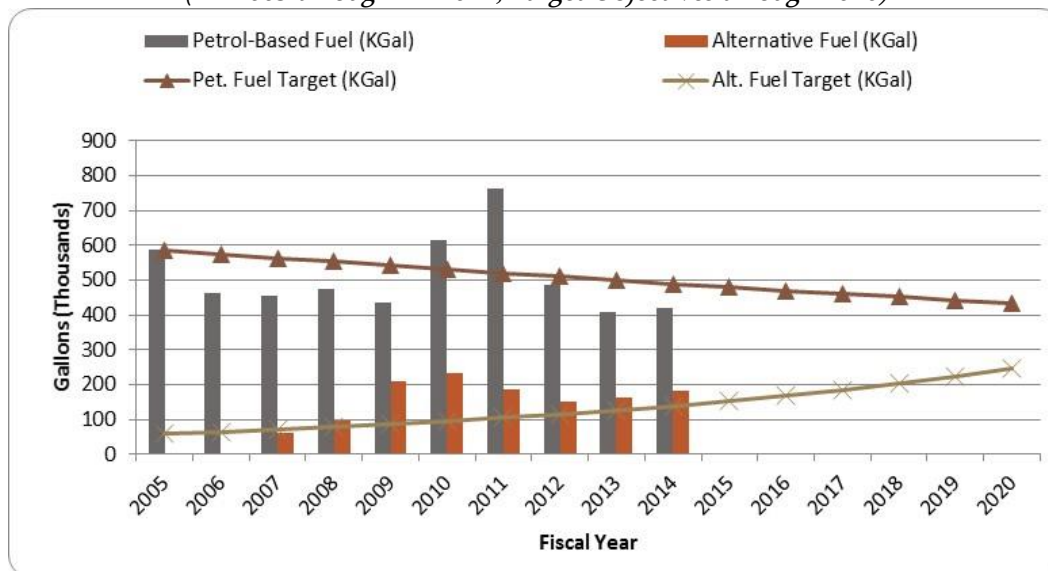
*(FY 2005 through FY 2020)  
AFV = alternative fuel vehicles*



**Alternative Fuel Use.** The alternative fuel use target was surpassed for FY 2014, as was the target for petroleum-based fuel use (Figure 3.2). The requirement specifies that Hanford Site contractors fleets operate alternative fuel vehicles exclusively on alternative fuels to the maximum extent possible to reduce the amount of petroleum-based fuels used by 2 percent annually through FY 2020, relative to a FY 2005 baseline and to increase the amount of alternative fuels used by 10 percent annually through to FY 2015, relative to a FY 2005 baseline ([Executive Order 13514](#) [74 FR 52117]).

**Figure 3.2. Vehicle Fuel Use**

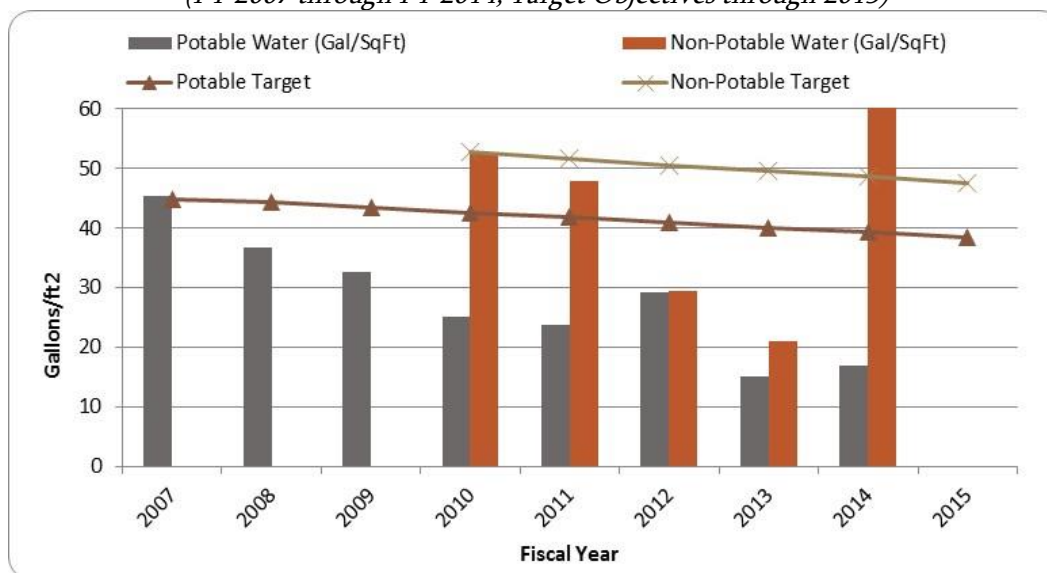
*(FY 2005 through FY 2014, Target Objectives through 2020)*



**Potable and Non-Potable Water Use.** The target objectives for potable was met in FY 2014. However, the target for non-potable water use was not (Figure 3.3). The increase in non-potable water use in FY 2014 was due to several breaks in the 24-inch distribution line and operation of the 242-A Evaporator. Water use requirements, as specified by Executive Order 13514 (74 FR 52117), stipulate the reduction of potable water consumption intensity by 2 percent annually through FY 2020, or 26 percent by the end of FY 2020, relative to a baseline of water consumption in FY 2007. Correspondingly, there is a requirement to reduce non-potable water use by 2 percent annually through the end of FY 2020, or 20 percent by the end of FY 2020, relative to a FY 2010 baseline.

Figure 3.3. Water Use

(FY 2007 through FY 2014, Target Objectives through 2015)

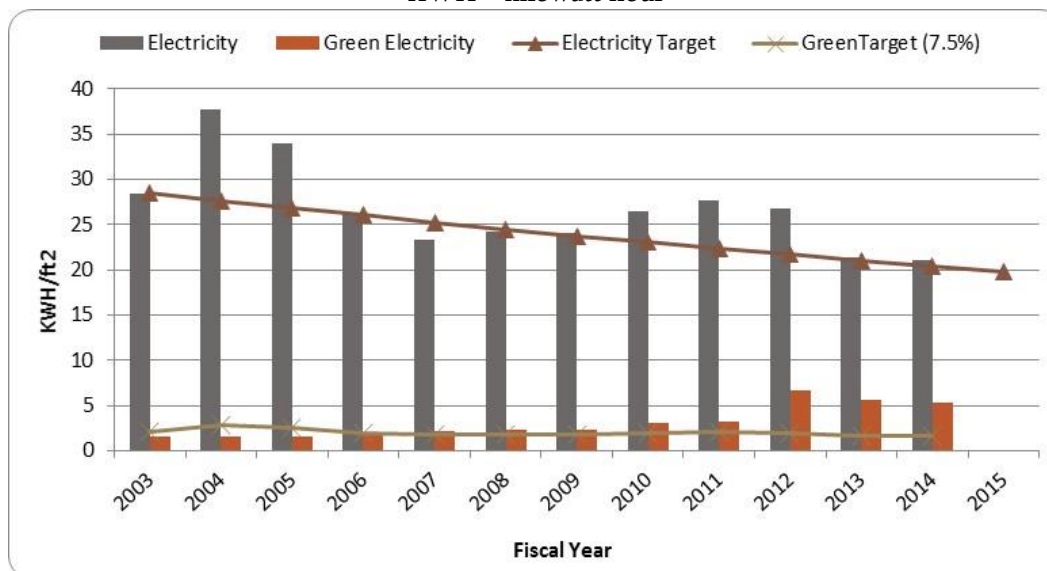


**Electricity Use.** The target objective for green electricity was met; however, the target objective for standard electricity was not met in FY 2014 (Figure 3.4). Targets and objectives for electricity use designate improvements to increase energy efficiency and energy management. Requirements call for the reduction of standard electricity use by 3 percent annually, or 45 percent through the end of FY 2020, relative to the FY 2003 baseline, and an increase in renewable energy consumption (green electricity) equivalent to 7.5 percent of the annual electricity and thermal consumption total by FY 2010.

Figure 3.4. Electricity Use

(FY 2003 through FY 2014, Target Objectives through 2015)

KWH = kilowatt hour





**Facility Fuel Use.** The target objectives for facility fuel use were met in FY 2014 (Figure 3.5). Objectives were established to demonstrate improvements in energy efficiency and effective management of energy use. The target requirements include reducing energy use by 3 percent annually (or 45 percent through the end of FY 2020) relative to the FY 2003 baseline.

**Facility Energy Use.** The target objective for facility energy use was met in FY 2014 (Figure 3.6). Requirements call for the reduction of energy use, a combination of electricity, fuel oil, and natural gas use, by 3 percent annually, or 45 percent through the end of FY 2020, relative to the FY 2003 baseline.

**Electronic Product Environmental Assessment Tool.** The target objectives for the electronic product environmental assessment tool were exceeded in FY 2014, with 99 percent of the purchases meeting the requirements (Figure 3.7). [Executive Order 13514](#) (74 FR 52117) specifies 95 percent of procured electronic assets (notebooks, computers, and monitors) must comply with the electronic product environmental assessment tool standard in an effort to reduce or eliminate the environmental impacts of electronic assets by incorporating electronic stewardship practices.

**Sanitary Waste Reduction.** The target objective for sanitary waste reduction requires the diversion of post-consumer materials suitable for reuse and recycling from landfills by 10 percent per year, based on a FY 2010 baseline (Figure 3.8). More Hanford Site sanitary waste was recycled than was sent to landfills in FY 2014.

**Figure 3.5. Facility Fuel Use**

*(FY 2003 through FY 2014, Target Objectives through 2015)*

*KBTU = one thousand British thermal units*

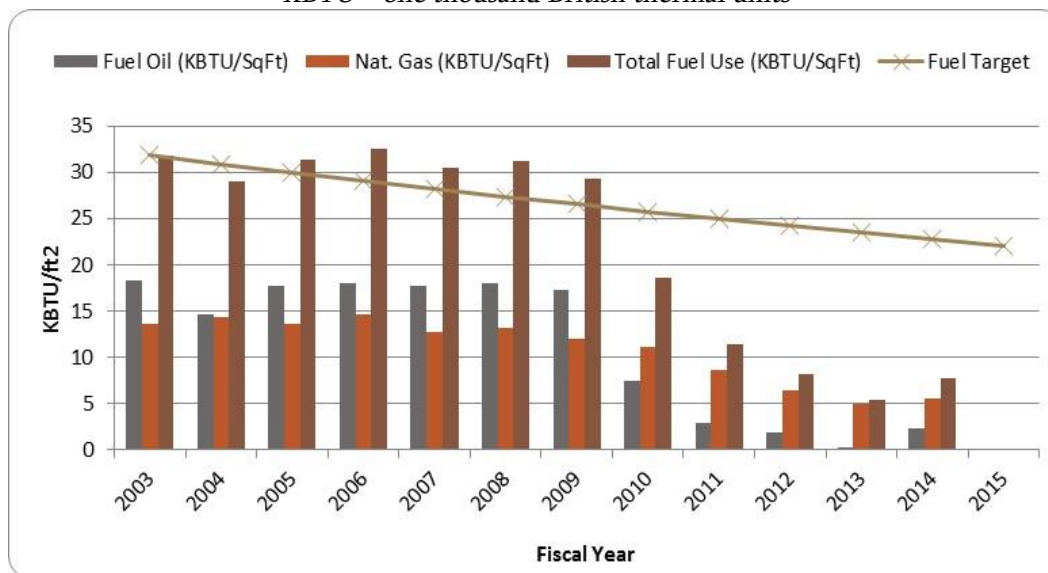


Figure 3.6. Facility Energy Use

(FY 2003 through FY 2014, Target Objectives through 2015)

KBTU = one thousand British thermal units

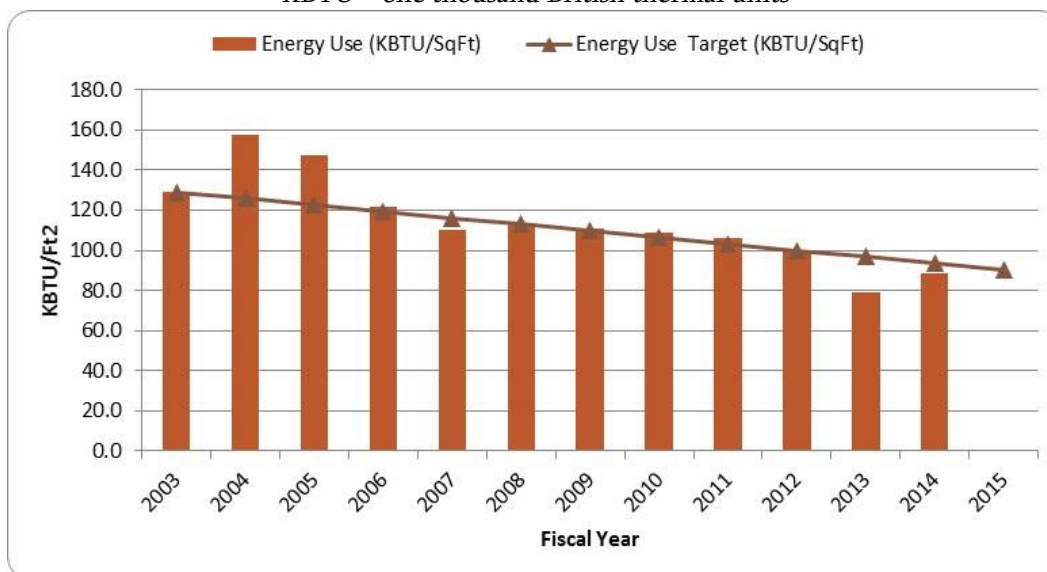
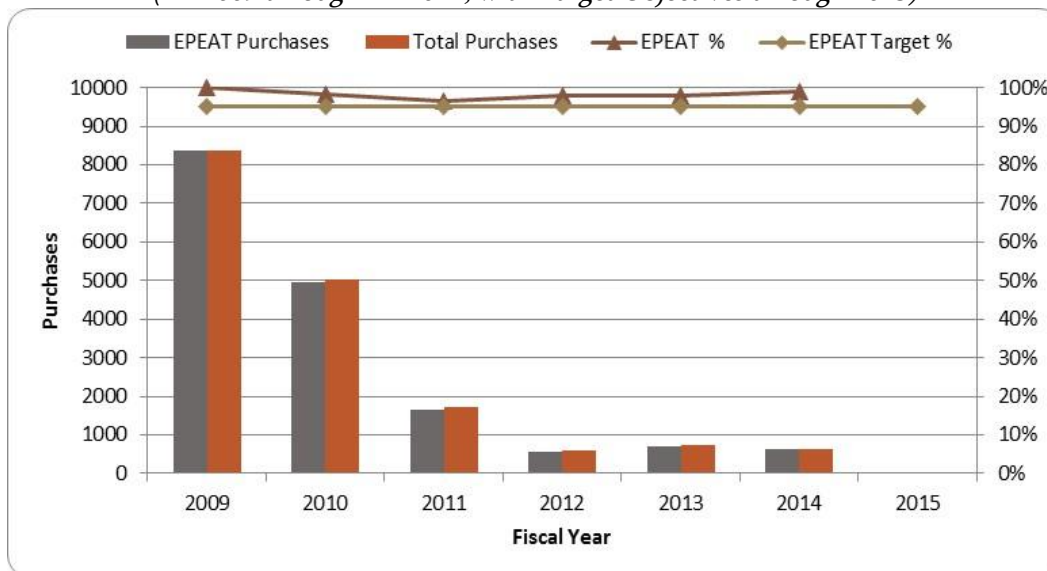
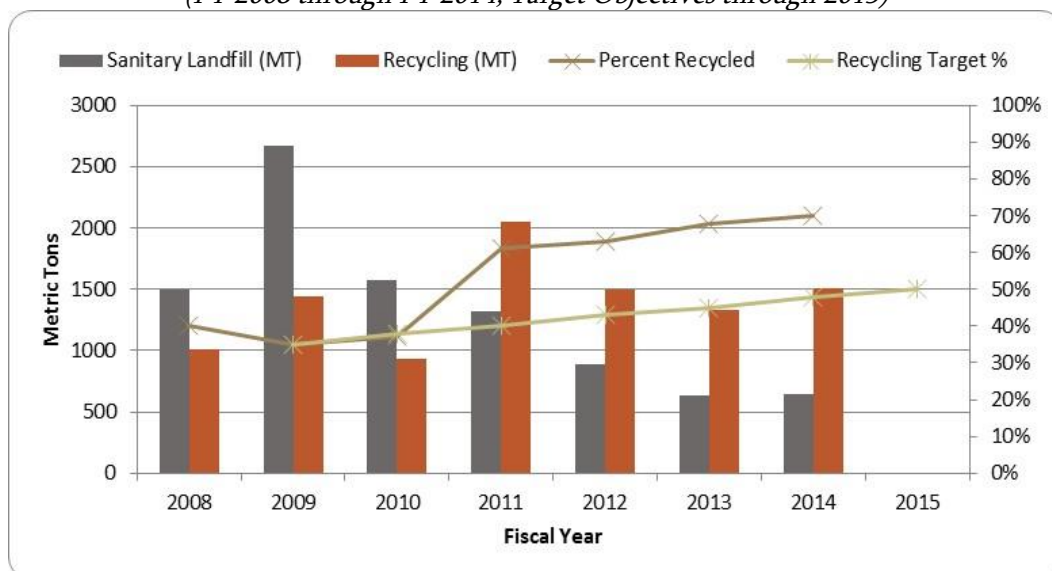


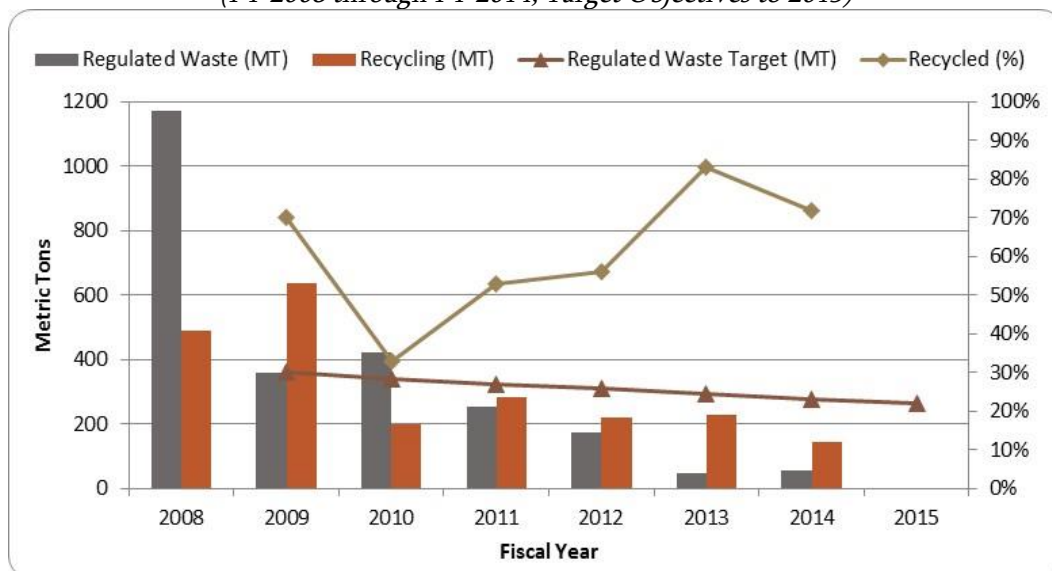
Figure 3.7. Electronic Product Environmental Assessment Tool Standards Compliance

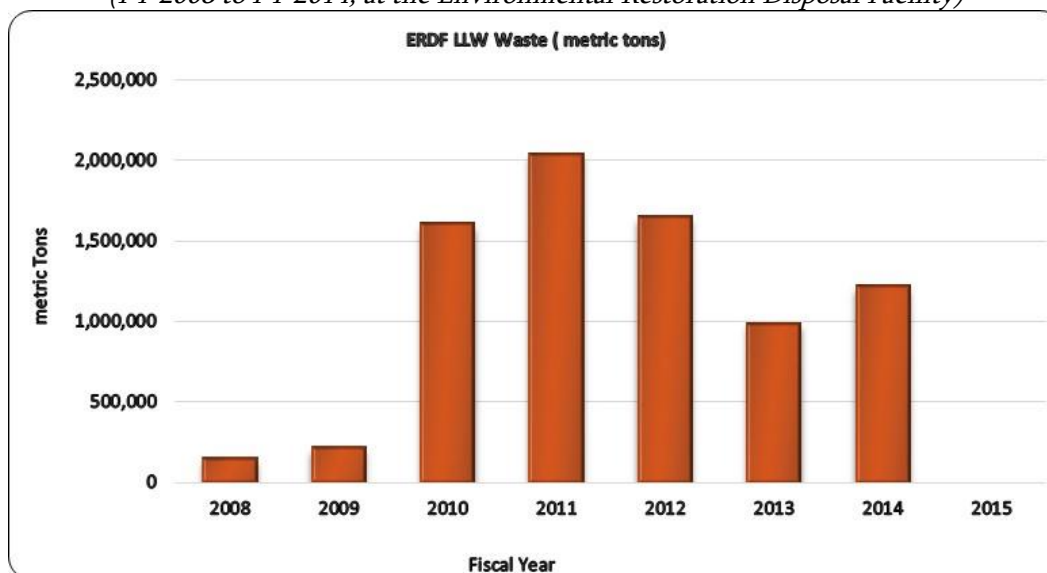
(FY 2009 through FY 2014, with Target Objectives through 2015)



**Figure 3.8. Sanitary Waste Reduction***(FY 2008 through FY 2014, Target Objectives through 2015)*

**Regulated Waste Reduction.** The target objective for regulated waste reduction was met in FY 2014 (Figure 3.9). Objectives for regulated waste reduction on the Hanford Site include eliminating or minimizing waste generation 5 percent annually (based on FY 2009 generation) through source reduction, including segregation, substitution, and reuse that would otherwise require storage, treatment, and long-term monitoring and surveillance. Regulated waste includes waste such as hazardous, universal, special, and state-regulated industrial and radioactive waste not suitable for disposal in sanitary or construction and demolition landfills. Regulated waste from Hanford's ERDF is not included in Figure 3.9. Waste to this facility increased in FY 2014 (Figure 3.10).

**Figure 3.9. Regulated Waste Reduction***(FY 2008 through FY 2014, Target Objectives to 2015)*

*Figure 3.10. Onsite Waste Disposal**(FY 2008 to FY 2014, at the Environmental Restoration Disposal Facility)*

In addition to these metrics, each contractor has established company-specific performance measures within their EMS.

## 3.2 Hanford Site Awards and Recognition

*SW Davis*

### 3.2.1 Advanced Technologies and Laboratories

In October 2013, ATL received *EHS Today* magazine's America's Safest Companies Award for demonstrating transformational environment, safety, and health leadership in the form of support from management and employee involvement; innovative solutions to safety challenges; injury and illness rates significantly lower than the average for their industries; comprehensive training programs; evidence that prevention of incidents is the cornerstone of the safety process; and excellent communication internally and externally about the value of safety. In February 2014, ATL completed 3 years without a recordable or lost workday or illness event. In April 2014, DOE-HQ completed its Voluntary Protection Program (VPP) recertification of ATL at the VPP Star level for the third consecutive time since receiving Star status in 2008. In August 2014, ATL received its second consecutive DOE-HQ VPP Star of Excellence Award for having occupational injury and illness rates greater than 50% below the industry average. ATL has worked in a Hazard Category 3 nuclear facility since May 2005 without a radiological skin or clothing contamination event or an uptake of radiological material. Finally, in December 2014, ATL received the Hazardous Materials Identification and Control Research Award from the Eastern Washington Chapter of Certified Hazardous Material Managers in recognition of ATL's implementation of radiofrequency identification (RFID) technology to manage more than 5,000 chemical containers, improving the accuracy of the inventory while significantly reducing the time it takes to complete the inventory, and reducing the potential for chemical spills and ergonomic injuries.

### **3.2.2 CH2M Hill Plateau Remediation Company**

CHPRC attained VPP Star status in 2014. CHPRC also maintained certification of its [ISO 14001:2004](#) status in 2014 by successfully passing an external surveillance. The audit team had zero findings and zero opportunities for improvements (OFI), as well as three areas the lead auditor deemed “Best in Class.” In summer 2014, CHPRC received an honorable mention from the Washington E3 Green Apple Awards for its 2014 zero waste events.

### **3.2.3 Mission Support Alliance, LLC**

MSA, Safeguards and Security, and HAMMER all attained Star status in the VPP in 2014. MSA also renewed certification to the ISO 14001:2004 standard in 2014 by successfully passing a reassessment audit of its EMS by a third party registrar.

### **3.2.4 Washington Closure Hanford, LLC**

The National Safety Council recognized WCH in July 2014 for achieving 1 million hours of safe work.

## 4.0 Radiological Protection and Doses

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This section provides information on the Hanford Site radiological program and doses as well as cleanup activities as DOE progresses toward site closure and the likely transfer of property to other entities.

### 4.1 External Radiation Monitoring

*CJ Perkins*

External radiation is defined as radiation originating from a source external to the human body. External radiation was monitored at the Hanford Site in relative proximity to known or potential radiation sources. Sources of external radiation at the Hanford Site include waste materials associated with the historical production of plutonium for defense; residual nuclear inventories in former production and processing facilities; radioactive waste handling, storage, and disposal activities; waste cleanup and remediation activities; atmospheric fallout from historical nuclear weapons testing; and natural sources such as cosmic radiation. During any given year, external radiation levels can vary up to 10 percent at any location due to changes in natural background radiation that can occur as a result of changes in annual cosmic and terrestrial radiation and from 15 percent to 25 percent because of shielding factors caused by changes in soil moisture and snow cover (NCRP 2009).

The Harshaw<sup>TM1</sup> thermoluminescent dosimeter (TLD) system is used to measure external radiation on the Hanford Site. This system includes the Harshaw 8800-series dosimeter and the Harshaw 8800 reader. The Harshaw 8800-series environmental dosimeter consists of two TLD-700 chips and two TLD-200 chips and provides both shallow- and deep-dose measurement capabilities using filters in the dosimeter. Data obtained from the two TLD-700 chips were used to determine the average total environmental dose at each location. The two TLD-200 chips were included to determine doses in the event of a radiological emergency and were not used in calculating average total environmental dose. The average daily dose rate was determined by dividing the average total environmental dose by the number of days the dosimeter was exposed. Daily dose equivalent rates (millirem per day) at each location were converted to annual dose equivalent rates (millirem per year) by averaging the daily dose rates and multiplying by 365 days per year. The TLDs were positioned approximately 3.3 feet (1 meter) above ground and were collected and read quarterly.

External radiation fields were monitored in 2014 at 115 locations near Hanford Site facilities and operations. The TLD results were used individually or averaged to determine dose rates in a given area for a specific sampling period. Table 4.1 compares 2013 and 2014 results for TLDs located near waste-handling facilities at the Hanford Site. Individual TLD results and detailed maps of monitoring locations are available upon request.

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<sup>1</sup> Harshaw is a trademark of Thermo Fisher Scientific, Inc., Waltham, Massachusetts.



**Table 4.1. Thermoluminescent Dosimeter Results**  
(millirem/year)<sup>a</sup>

Location	No. of Dosimeters	2013		2014		Percentage Change <sup>e</sup>
		Maximum <sup>b</sup>	Average <sup>c, d</sup>	Maximum <sup>b</sup>	Average <sup>c, d</sup>	
100-K	14	112 ± 12	86 ± 17	177 ± 140	89 ± 52	3
100-N	1	87 ± 13	84 ± 7	91 ± 14	82 ± 14	-2
200-East	42	230 ± 131	105 ± 56	217 ± 256	104 ± 57	0
200-West	24	158 ± 9	104 ± 41	157 ± 14	102 ± 42	-1
200-North	1	91 ± 14	86 ± 14	107 ± 16	91 ± 27	5
300 Area	8	124 ± 9	95 ± 26	114 ± 14	90 ± 20	-4
300 TEDF	6	93 ± 13	91 ± 4	91 ± 14	88 ± 8	-2
400 Area	7	100 ± 58	92 ± 9	98 ± 11	88 ± 11	-3
618-10	4	84 ± 11	83 ± 3	81 ± 8	80 ± 2	-2
CVDF	4	82 ± 13	80 ± 3	78 ± 9	77 ± 2	-2
ERDF	3	91 ± 11	88 ± 6	89 ± 22	84 ± 8	-4
IDF	1	102 ± 15	92 ± 16	97 ± 14	90 ± 13	-1

<sup>a</sup> To convert to international metric system units, multiply millirem/year by 0.01 to obtain millisievert/year.

<sup>b</sup> Maximum values are ± analytical uncertainty.

<sup>c</sup> ± 2 standard deviations.

<sup>d</sup> Each dosimeter is collected and read quarterly.

<sup>e</sup> Numbers indicate a decrease (-) or increase from the 2013 mean.

CVDF = Cold Vacuum Drying Facility (100-K Area).

ERDF = Environmental Restoration Disposal Facility (200-West Area).

IDF = Integrated Disposal Facility (200-East Area).

TEDF = 300 Area Treated Effluent Disposal Facility.

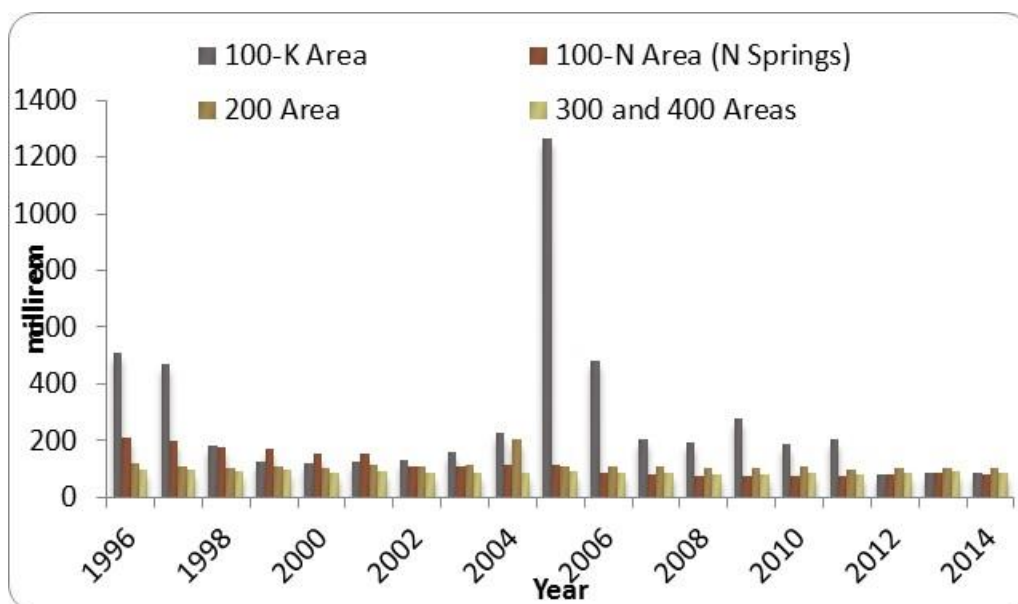
Radiation surveys with portable instruments are conducted at active and inactive waste disposal sites and the surrounding terrain to monitor and detect contamination and to provide a coarse screening for external radiation fields. The types of areas surveyed included underground radioactive material areas, contamination areas, soil contamination areas, high-contamination areas, roads, and fence lines.

Additional information on radiation, dose rates, and dose terminology can be found in Appendix A, Glossary, and Appendix B, “Helpful Information.”

#### 4.1.1 External Radiation Measurements

**100-K Area.** The average dose rate levels seen in the 100-K Area during 2014 were, overall, slightly higher than 2013 levels (Figure 4.1). Dose rate levels in 2014 when compared to 2013 were 3 percent lower in the 100-K East Area and at the Cold Vacuum Drying Facility and were 11 percent higher in the 100-K West Area. This was due to elevated dose rate levels at the monitoring location near the load-out area of the 105-KW (reactor) building where radioactive contaminated sludge and debris from the cleanout of the 100-K West Basin were transported.

Figure 4.1. Average Thermoluminescent Dosimeter Results



**100-N Area Shoreline (N Springs).** Dose rates were measured along the Columbia River shoreline in the 100-N Area (N Springs) to determine potential external radiation doses to onsite workers and to the public accessing the river. Cleanup activities at the retired 116-N-1 and 116-N-3 Trenches (located near the Columbia River) have decreased dose rates notably over the past few years (Figure 4.1). The 2014 average dose rate was 2 percent lower than in 2013, and was less than 100 millirem (1 millisievert) per year.

**200 Area.** Dose rate levels measured during 2014 in the 200 East and 200 West Areas were generally unchanged compared to 2013 (Figure 4.1, with the exception of ERDF where the average dose rates measured in 2014 (located near the 200 West Area) were approximately 4 percent lower than 2013 levels. Additional information on ERDF operations is provided in Section 5.3.3.8.

**200-North Area.** One TLD monitoring site, located in the 200 North Area at the formerly contaminated 212-R Railroad Car Disposition Area, continued to show reduced average dose rate levels in 2014. As in recent years, the 2014 levels were significantly lower than levels measured in 2011 and years previous. This TLD location was established in 2000 to monitor expected high radiation levels emitted from contaminated railroad cars. During the fourth quarter of 2010, dose rate levels began to fall as the radiologically contaminated railroad cars were dispositioned.

**300 and 400 Areas.** The average dose rates in 2014 in the 300 and 400 Areas and at the 300 Area TEDF were generally lower by approximately 5 percent compared to 2013 levels (Figure 4.1). Additional information about TEDF operations is provided in Section 5.3.4.3.

**618-10 Burial Ground.** TLD monitoring was initiated during late-February 2010 at four locations for this project. The average dose rates in 2014 were approximately 2 percent lower than 2013 levels. Additional information about the 618-10 Burial Ground cleanup project is provided in Section 5.1.4.

**Integrated Disposal Facility (IDF).** The average dose rates in 2014 at this facility were nearly unchanged from the 2013 levels. IDF is a new unused landfill that is not actively operating (see Section 5.3.3.7).

### **4.1.2 Waste Disposal Sites Radiological Surveys**

*JW Wilde*

During 2014, 875 environmental radiological surveys were reported as performed at active and inactive waste disposal sites and the surrounding terrain to detect and characterize radioactive surface contamination. Radiation surveys with portable instruments are conducted to monitor and detect contamination and to provide a coarse screening for external radiation fields. The types of areas surveyed included underground radioactive material areas, contamination areas, soil contamination areas, high-contamination areas, roads, and fence lines. Vehicles equipped with radiation detection devices and global positioning systems were used to measure accurately the extent of contamination. Area measurements were entered into the Hanford Geographical Information System, a computer database maintained by MSA. Routine radiological survey locations included former waste disposal cribs and trenches, retention basin perimeters, ditch banks, solid waste disposal sites (e.g., burial grounds), unplanned release sites, tank farm perimeters, stabilized waste disposal sites, roads, and firebreaks in and around the Hanford Site operational areas. These sites were posted as underground radioactive material areas, contamination areas, and soil contamination areas. The external dose rate at 80 percent of the outdoor contamination areas was estimated to be less than 1 millirem (0.01 millisievert) per hour, although direct dose-rate readings from isolated radioactive specks could have been higher.

Underground radioactive material areas are regions where radioactive materials occur below the soil surface. These areas are typically stabilized cribs, burial grounds, covered ponds, trenches, and ditches. Barriers have been placed over the contamination sources to inhibit radionuclide transport to the surface. These areas are surveyed at least annually to assess the effectiveness of the barriers.

Contamination areas and soil contamination areas may or may not be associated with an underground structure containing radioactive material. A breach in the surface barrier of a contaminated underground area may result in the growth of contaminated vegetation. Insects or animals may burrow into the soil and bring contamination to the surface. Vent pipes or risers from an underground structure may be sources of speck contamination (particles with a diameter less than 0.25 inch [0.6 centimeter]). Areas of contamination not related to subsurface structures can include sites contaminated with fallout from effluent stacks or with materials from unplanned releases (e.g., contaminated tumbleweeds and animal feces).

All contaminated areas may be susceptible to contaminant migration and are surveyed at least annually to assess their current radiological status. In addition, onsite paved roadways on which radioactive materials are transported to ERDF are surveyed annually.

## **4.2 Potential Radiological Doses**

*R Perona and RT Ryti*

Potential radiological doses to the public and biota from Hanford Site operations in 2014 were evaluated to determine compliance with pertinent regulations and limits. Potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, liquid effluent from operating wastewater treatment facilities, contaminated groundwater seeping into the Columbia River, and fugitive emissions from areas of contaminated soil and operating facilities. A summary of the methods and results of the public and biota dose assessments is provided here. Details of the methods used to calculate radiological doses are provided in Appendix D.

The radiological impacts of Hanford Site operations were assessed in terms of the following:

- ⊗ Dose to a hypothetical, maximally exposed individual (MEI) at an offsite location, evaluated by using a multimedia pathway assessment [DOE O 458.1](#) Section 4.2.1)
- ⊗ Collective dose to the population residing within 50 miles (80 kilometers) of Hanford Site operation areas (Section 4.2.2)
- ⊗ Doses for air pathways calculated using regulation-specified EPA methods for comparison to the Clean Air Act standards in [40 CFR 61](#), Subpart H, “National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities” (Section 4.2.3)
- ⊗ Doses from recreational activities including hunting and fishing (Section 4.2.4.1)
- ⊗ Dose to a worker consuming drinking water on the Hanford Site (Section 4.2.4.2)
- ⊗ Doses from non-DOE industrial sources on and near the Hanford Site (Section 4.2.5)
- ⊗ Absorbed dose received by biota exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (Section 4.2.6).

Radiological dose assessments related to environmental releases are ideally based on direct measurements of radionuclide concentrations in specific exposure media; however, amounts of many radioactive materials released to the Columbia River or the atmosphere in 2014 from Hanford Site sources were too small to be measured in environmental media after they were dispersed in the offsite environment. For the radionuclides present in measurable amounts, it can be difficult to distinguish the small contribution of Hanford Site sources from contributions caused by fallout from historical nuclear weapons testing and naturally occurring radionuclides such as uranium and its decay products. As a result, computer models are employed to calculate offsite radionuclide concentrations based on measured and estimated releases. In specific instances, such as ambient air measurements of tritium at offsite locations near the 300 Area, radionuclide concentrations may be distinguishable from background levels, and these measurements are used to support the dose assessment.

Calculations of radiation dose require the use of biological and radiological models of the behavior of radioactive material in the human body. Scientific understanding of these processes has improved over time. In the 1960s, the annual environmental reporting at the Hanford Site used the recommendations and methodologies of the ICRP Report 2 ([ICRP 1959](#), *Permissible Dose for Internal Radiation*). In the 1970s, the annual reports began to follow the newer recommendations in ICRP Reports 26 and 30 ([ICRP 1977](#), *Recommendations of the ICRP*, and [ICRP 1979a,b](#), *Limits for Intakes of Radionuclides by Workers*), incorporated in the dose factors from the EPA in Federal Guidance Reports 11 and 12 ([EPA 520/1-88-020](#), *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*; [EPA-402-R-93-081](#), *External Exposure to Radionuclides in Air, Water, and Soil*). The GENII Version 1 computer code, used at the Hanford Site beginning in 1988, used ICRP 26/30 methods ([ICRP 1977](#), [1979a, b](#)) and EPA dose factors. The GENII Version 2 computer code, used for the annual report dose calculations beginning in 2009, uses ICRP Report 60 methods ([ICRP 1991](#), *1990 Recommendations of the International Commission on Radiological Protection*) and updated EPA dose factors ([EPA 402-R-99-001](#), *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*).

Offsite dose for a MEI (Section 4.2.1) and collective dose for the population residing within 50 miles (80 kilometers) of Hanford Site operation areas (Section 4.2.2) are calculated separately for liquid releases to the Columbia River and stack air emissions. Radiological doses from the water pathways are calculated

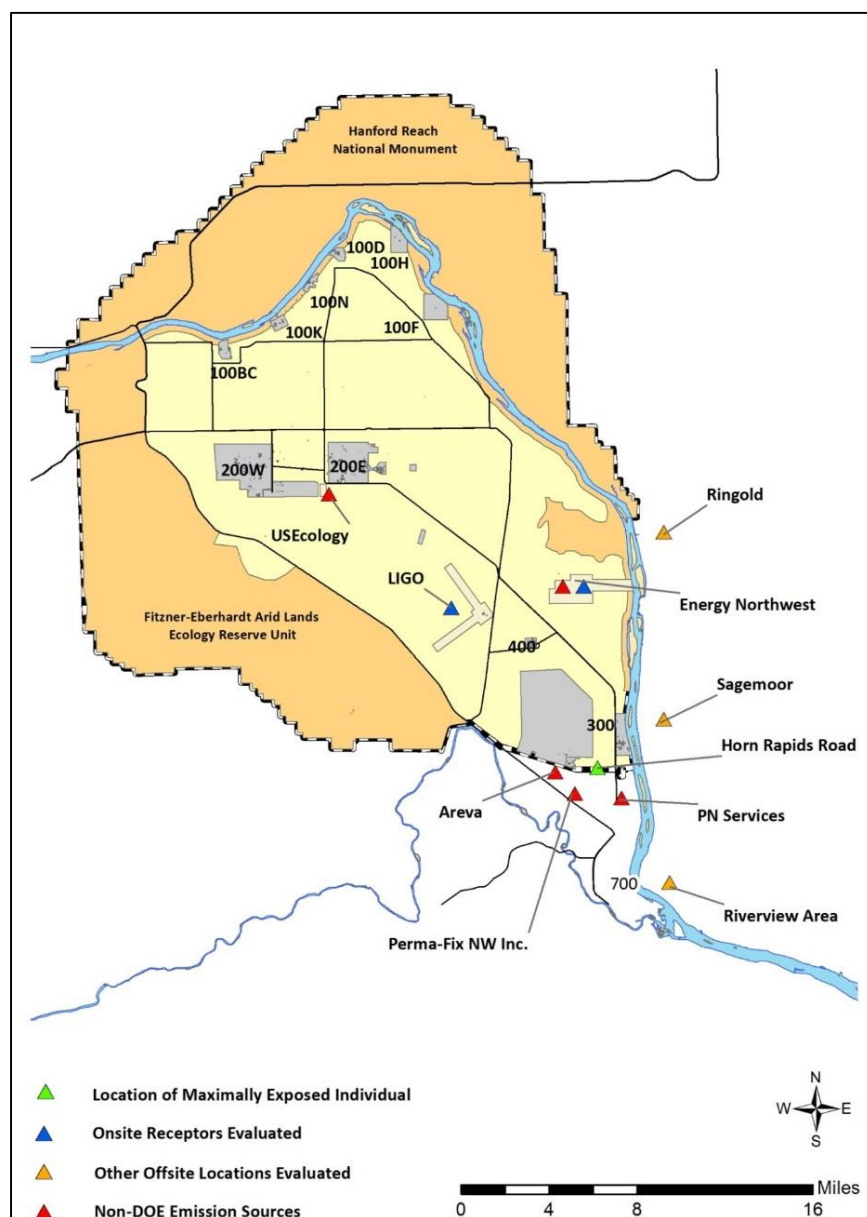
based on differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. Although the downstream minus upstream radionuclide concentrations potentially include groundwater-related contributions from other operating areas, they have been assigned to the 200 Area for tabulation of radiological dose. No direct discharge of radioactive materials from the 100 or 300 Areas to the Columbia River was reported during 2014. Radiological doses from the air pathways are calculated based on stack emissions measurements from approximately 60 emission points in Hanford Site operation areas.

Columbia River shoreline spring and seep water-containing radionuclides is known to enter the river along the portion of the Hanford Site shoreline extending from the 100-BC Area downstream to the 300 Area. Tritium and uranium isotopes were found in the Columbia River downstream of the Hanford Site (Richland Pumphouse station, HRM 46.4) in 2014 at concentrations statistically greater than upstream (Priest Rapids Dam station) levels (Appendix D). Radioactive air emissions are discussed in Section 6.1 and summarized in Table 6.1. For the GENII Version 2.10 ([PNNL-14583, Rev 3a](#)) calculations supporting this dose assessment, ingrowth of short-lived radioactive progeny during environmental transport was calculated to develop a complete set of radionuclide release estimates. Details on the development of air pathway and water pathway radioactive release estimates are provided in Appendix D.

#### **4.2.1 Maximally Exposed Individual Dose (Offsite Resident)**

The MEI is a hypothetical person whose location and lifestyle are such that it is unlikely any actual member of the public would have received a higher radiological dose from Hanford Site releases during 2014. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides in Hanford Site liquid effluents and air emissions using a multimedia pathway assessment ([DOE O 458.1](#), Section 4.e). In reality, such a combination of maximized exposures to radioactive materials is highly unlikely to apply to any single individual. The individual pathway dose calculations themselves also incorporate conservative assumptions intended to ensure that modeled concentrations of radionuclides in exposure media and resulting doses are protective. For these reasons, the dose assessment results for the MEI represent a hypothetical upper bound of potential individual dose rather than an anticipated dose to an actual individual.

The location of the hypothetical MEI varies depending on the relative contributions of radioactive air emissions and liquid effluent releases from Hanford Site operational areas. Four offsite locations were evaluated to determine the location of the MEI (Figure 4.2). The Ringold locations receive maximal air pathway impacts from the 200 Area. Depending on year-to-year differences in the prevailing wind direction, either the Sagemoor or Horn Rapids Road location may receive maximal air pathway impacts from the 300 Area. A small population of West Pasco residents obtains their drinking water from the Riverview location via a community water system, and the domestic drinking water pathway is applied to that location. Residences in the vicinity of Horn Rapids Road receive drinking water from the city of Richland, which has an intake downstream of the Hanford Site, so the domestic drinking water pathway is also applied here. Both Riverview and Horn Rapids Road are locations where Columbia River water is withdrawn for irrigation.

*Figure 4.2. Locations Important to Hanford Site Dose Calculations*

Dose calculations for 2014 releases indicate that the MEI is located at the PNNL Physical Sciences Facility, an offsite business just to the south of the Hanford Site 300 Area at 638 Horn Rapids Road. For the Horn Rapids Road receptor dose calculations, the following exposure routes were evaluated:

- ⊗ Inhalation and external radiation exposure related to airborne radionuclides
- ⊗ External radiation exposure and inadvertent soil ingestion for radionuclides deposited on the ground
- ⊗ Ingestion of domestic drinking water from the Columbia River
- ⊗ Ingestion of locally grown food products irrigated with Columbia River water and/or containing radionuclides deposited from the air
- ⊗ External radiation exposure to radionuclides in Columbia River water and sediments near the Hanford Site during recreational activities, and inadvertent ingestion of water while swimming
- ⊗ Consumption of locally caught Columbia River fish.



A graphical depiction of the conceptual site model showing all potentially complete exposure pathways for the Horn Rapids Road MEI evaluated using GENII Version 2.10 ([PNNL-14583, Rev 3a](#)) is provided in Figure 4.3. Additional information related to the selection of the MEI location for releases is provided in Appendix D. Exposure variable input values related to residency and recreational exposure times, intake rates for water, foods, other media, and agricultural pathway assumptions for the MEI are provided in Appendix D.

The total dose to the MEI at Horn Rapids Road in 2014 was calculated to be 0.33 millirem (3.3 microsievert) per year (Table 4.2; Figure 4.4). This dose is 0.33 percent of the 100 millirem (1,000 microsievert) per year public dose limit specified in [DOE O 458.1](#), Chg. 2 and 1.3 percent of the 25-millirem (250-microsievert)-per-year threshold where a supplemental assessment of dose to the lens of the eye, skin, and extremities is required. Water pathway contributions assigned to the 200 Areas contributed approximately two-thirds of the total dose of 0.33 millirem (3.3 microsievert) per year, with the remaining 33 percent related to air pathway exposures.

The primary radionuclides and exposure pathways contributing to the MEI dose are as follow:

- ⊗ *Air Releases:* Consumption of food products containing tritium released from the 300 Area contributed approximately 84 percent of the total air pathways dose of 0.087 millirem (0.87 microsievert) per year. Inhalation of the radioactivity progeny of radon-220 released from the 300 Area contributed most of the remaining 8 percent, or 0.094 millirem (0.94 microsievert), of the of the total air pathways dose of 0.11 millirem (1.1 microsievert) per year. Inhalation of tritium and the radioactive progeny of radon-220 released from the 300 Area, which contributed most of the remaining 16 percent of the total air pathway dose.
- ⊗ *Water Releases:* Consumption of fish from the Columbia River contributed 0.18 millirem (1.8 microsievert), or 81 percent of the total water pathways dose of 0.22 millirem (2.2 microsievert) per year. Consumption of food grown using Columbia River water withdrawn downstream from the Hanford Site contributed almost all of the remaining total water pathways dose of 0.037 millirem (0.37 microsievert), or 17 percent of the 0.22 millirem (2.2 microsievert) per year total. Potassium-40, a naturally occurring radionuclide not of Hanford origin, contributed approximately 77 percent (0.17 millirem 1.7 millisievert) of the water pathways dose, with isotopes of uranium and their progeny, particularly uranium-234 and uranium-238, contributing most of the remainder.

The MEI dose in 2014 of 0.33 millirem (3.3 microsievert) is more than twice the 0.15 millirem (1.5 microsievert) MEI dose calculated in 2013 ([DOE/RL-2013-47](#), *Hanford Site Environmental Report for Calendar Year 2013*). This large relative difference between the 2013 and 2014 dose estimates is almost entirely attributable to the inclusion of naturally occurring potassium-40 in the 2014 water pathways dose calculations. Potassium-40 was included in the 2014 dose calculations for water releases because average downstream river concentrations were statistically greater than upstream concentrations. In 2013, the downstream potassium-40 concentrations were not statistically different from those measured upstream. The 2014 MEI dose without the contribution of potassium-40 is 0.16 millirem (1.6 microsievert). This is approximately equivalent to the 2013 MEI dose of 0.154 millirem (1.5 microsievert). The relationship of the 2014 MEI dose to values calculated for the period of 2010 to 2013 is shown in Figure 4.4.

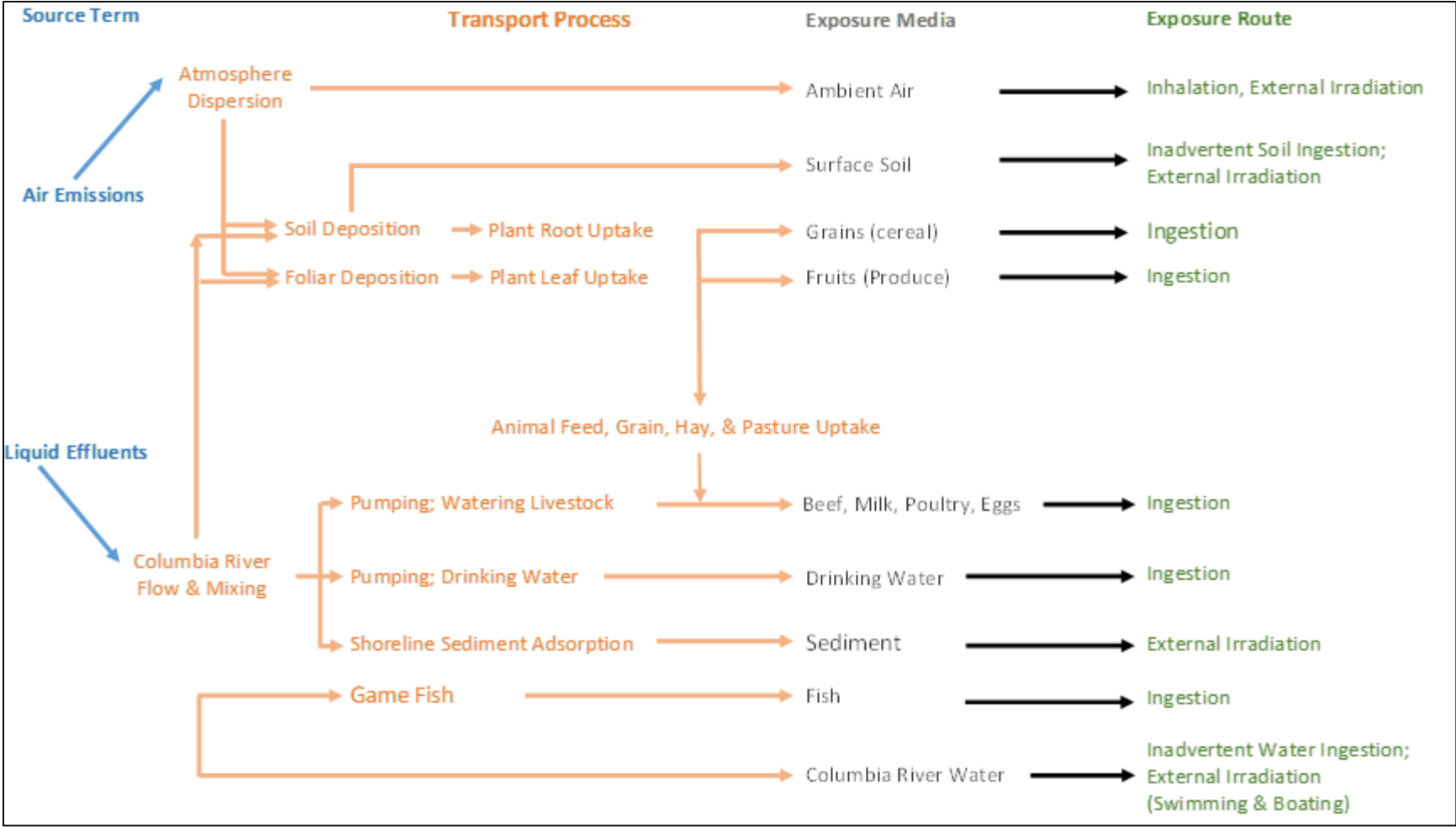
The MEI dose estimate incorporates a number of conservative assumptions to ensure that pathway doses are protective and therefore calculated doses are likely to be overestimated. In the air pathways

calculations, measurements of gross alpha and gross beta radiation in stack emissions from the 100 Area, 200 Area, and 300 Area were protectively added to the measured emissions of plutonium-239/240 (an alpha-emitting radionuclide related to Hanford operations) and strontium-90 (a beta-emitting radionuclide related to Hanford operations), respectively. The actual measured air releases of plutonium-239/240 and strontium-90 are a small fraction (6 to 27 percent) of the assumed concentrations, including the contribution of the gross radioactivity values. Although gross alpha and gross beta levels in stack emissions are similar to ambient air background, this was done to ensure that contributions from any unmeasured operations-related radionuclides are incorporated in the estimated doses.

In the irrigation pathways calculations, all produce eaten by the MEI was assumed to originate from areas irrigated with Columbia River water. For the fish consumption pathway, near-shore water samples were protectively used to represent Columbia River water generally, and it was assumed that all fish consumed by the MEI are resident species rather than anadromous fish, such as salmon or steelhead.

Because anadromous fish spend most of their lives in the ocean they would have a much lesser exposure to contaminants associated with the Hanford Reach compared to species that spend their entire lives in the Hanford Reach, such as sturgeon.

Figure 4.3 Conceptual Site Model of Exposure Pathways Evaluated in Dose Calculations  
(Horn Rapids Road MEI)



**Table 4.2. Pathway Doses for the Hypothetical, Maximally Exposed Individual Residing at Horn Rapids Road**

Release Type	Exposure Pathway	Dose Contributions from Operational Areas, mrem <sup>a</sup>				
		100 Areas	200 Areas <sup>b</sup>	300 Area <sup>c</sup>	400 Area	Pathway Total
Air	Food Ingestion	1.0E-07	1.2E-04	0.094	1.6E-07	0.095
	Inhalation	7.9E-07	5.7E-05	0.018	7.5E-07	0.018
	External, Soil Ingestion	5.3E-10	1.6E-07	0.00018	2.2E-09	0.00018
	Subtotal Air	8.9E-07	1.8E-04	0.11	8.9E-07	0.11
Water	Irrigation (food and soil ingestion; external)	NA <sup>d</sup>	0.037 <sup>e</sup>	NA	NA	0.037
	Drinking Water Ingestion	NA <sup>d</sup>	0.0077 <sup>e</sup>	NA	NA	0.0077
	Recreation (river water and sediments; external and ingestion)	NA <sup>d</sup>	0.0013 <sup>e</sup>	NA	NA	0.0013
	Fish Ingestion	NA <sup>d</sup>	0.18 <sup>e</sup>	NA	NA	0.18
	Subtotal Water	NA	0.22	NA	NA	0.22
Air + Water Total		8.9E-07	0.22	0.11	8.9E-07	<b>0.33 <sup>f</sup></b>

<sup>a</sup>To convert millirem (mrem) to International System dose units (microsievert;  $\mu\text{Sv}$ ), multiply by 10.

<sup>b</sup>Integrates releases from all operational areas based on the difference between downstream and upstream Columbia River radionuclide concentrations.

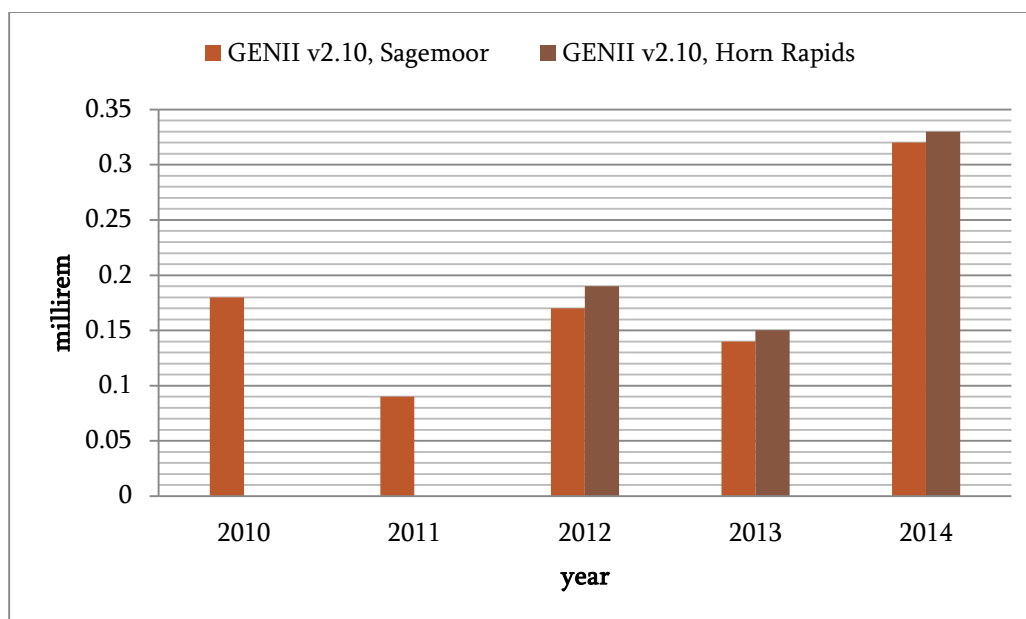
<sup>c</sup>Measured tritium air concentrations at offsite locations near the 300 Area indicate modeled air pathways doses may be biased low by up to approximately 0.05 mrem; refer to text.

<sup>d</sup>No measured releases; the last 100 Areas NPDES-permitted outfall (1908-K Outfall) ceased releases in March 2011.

<sup>e</sup>Water pathways dose without potassium-40, a naturally occurring radionuclide not of Hanford origin, is 0.053 millirem.

<sup>f</sup>Air + Water pathways dose without potassium-40, a naturally occurring radionuclide not of Hanford origin, is approximately 0.16 millirem.

NA: Not applicable. All liquid discharges reflected in the difference between upstream and downstream radionuclide concentrations are assigned to the 200 Area.

*Figure 4.4. Total Dose for the Hypothetical, Maximally Exposed Individual Over Time<sup>a</sup>*

<sup>a</sup> The 2014 MEI Horn Rapids MEI total dose without the contribution of potassium-40, a naturally occurring radionuclide not of Hanford origin, is 0.16 millirem (1.6 microsievert).

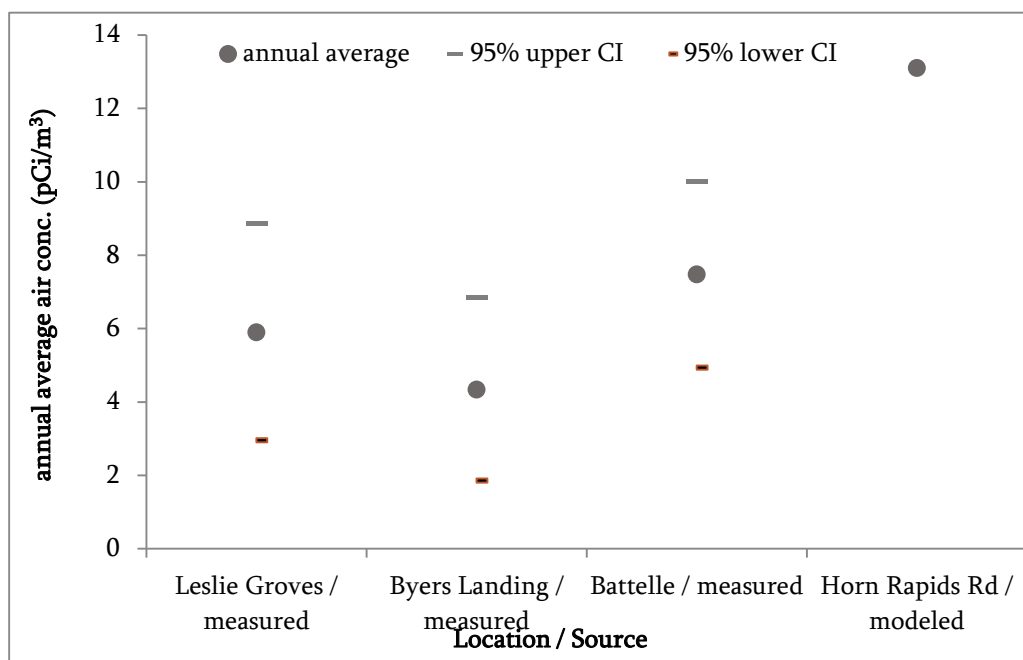
Because releases of tritium from the 300 Area are the major source of calculated Hanford-related radiological dose for the hypothetical MEI, modeled annual-average tritium concentrations at locations near the 300 Area were compared to concentrations based on air monitoring station samples. Figure 4.5 shows the 2014 modeled annual average air concentrations of tritiated water vapor (HTO) at the Horn Rapids Road MEI location and 2014 annual averages based on measured values at three offsite locations south and east of the 300 Area. Measured monthly tritium concentrations vary substantially at each monitoring location. The 95 percent upper and lower confidence intervals of the annual average values are shown on Figure 4.5 in addition to the annual average.

The modeled annual-average tritium concentration at the Horn Rapids Road MEI location is above the range of the 95 percent upper and lower confidence intervals of the mean of the measured values at the three nearby offsite monitoring locations. The potential significance of the lower mean values for the measured concentrations of tritium at the nearby offsite monitoring stations depends on their having a relationship to Hanford Site 300 Area annual tritium emissions. A relationship between 300 Area monthly tritium air emissions and onsite ambient air concentrations in 2006 was shown by Barfuss (2007), but there was little correlation of monthly emissions and air concentrations for a combined group of four nearby offsite monitoring locations. GENII air dispersion calculations from Building 325 in the 300 Area were performed to compare annual average modeled and measured HTO air concentrations for two specific locations at approximately the same distance from Building 325 as the Horn Rapids Road MEI with the following results:

Monitoring Location	HTO Measured Concentration (pCi/m <sup>3</sup> )	HTO Modeled Concentration (pCi/m <sup>3</sup> )
Battelle Complex	7.5	6.0
Byers Landing	4.3	4.3

The relationship of modeled and measured annual average air concentrations at these two nearby onsite monitoring stations in the 300 Area is relatively good. This suggests that the modeled HTO air concentration of 13.1 pCi/m<sup>3</sup> used for the 2014 MEI air pathways dose calculations is also reasonable. Exact correspondence between modeled and measured annual average values would not be expected because the episodic nature of HTO releases is not captured in the GENII air dispersion modeling, which assumes a constant rate of HTO emissions. Note also that the modeled tritium values do not account for regional background levels of tritium, which would add between 1.5 and 4 pCi/m<sup>3</sup> to the modeled values (Barfuss 2007, Figure 11).

**Figure 4.5 Comparison of Measured and Modeled Tritium Air Concentrations near the 300 Area**  
(Error bars are 95% confidence intervals of the mean)



#### 4.2.2 Collective Dose

Collective dose is defined as the sum of doses to all individual members of the public within a defined distance of a specific release location. The regional collective dose from 2014 Hanford Site operations was estimated by calculating the radiological dose to the population residing within a 50-mile (80-kilometer) radius of onsite operating areas ([DOE O 458.1](#), Chg. 2; Section 4.e(d)). The collective doses reported are based on regional population data from the 2010 census, as described in Appendix D.

The conceptual site model of potentially complete exposure pathways for the Horn Rapids Road MEI shown in Figure 4.3 is also applicable to the collective dose calculations. Like the Horn Rapids Road MEI, the collective dose calculation also incorporates the drinking water exposure pathway because the cities of Richland and Pasco obtain all or part of their municipal water directly from the Columbia River downstream from the Hanford Site, and the city of Kennewick obtains its municipal water indirectly from wells adjacent to the river. A primary distinction between the MEI and collective dose calculations is the use of population-average values for certain exposure variables in place of reasonable upper bound values. Exposure variable input values related to residency and recreational exposure times, intake rates for foods



and other media, and agricultural pathway assumptions for the collective dose calculations are provided in Appendix D. The air pathways collective dose calculations employ population data from the 2010 census broken out according to direction and distance in order to coincide with air dispersion and deposition modeling conducted within the GENII Version 2.10 computer code ([PNNL-14583, Rev 3a](#)).

The annual collective dose is reported in units of person-rem (person-sievert), which is the sum of doses to all individual members of the exposed population. The total collective dose calculated for this population in 2014 was 2.1 person-rem (0.021 person-sievert) per year (Table 4.3), which is higher than the collective doses calculated between 2010 and 2013 (Figure 4.6). Water pathway contributions assigned to the 200 Area contributed approximately 60 percent, and air pathway contributions from releases in the 300 Area contributed approximately 40 percent to the total collective dose of 2.1 person-rem (0.021 person-sievert) in 2014.

The primary radionuclides and exposure pathways contributing to the collective dose are as follows:

- ☉ **Air Releases:** Consumption of food products grown downwind of the 300 Area contributed slightly less than 80 percent of the of the air pathways collective dose of 0.86 person-rem (0.0086 person-sievert). The remaining air pathways collective dose is primarily related to inhalation. About 90 percent of these food and inhalation air pathways doses, which combined account for approximately 97 percent of the total air pathways collective dose, are due to releases of tritium from the 300 Area. The remaining 10 percent of the total air pathways collective dose of 0.86 person-rem (0.0086 person-sievert) is largely associated with inhalation of the radioactive progeny of radon-220 released from the 300 Area. Air releases from the 100 Area, 200 Area, and 400 Area had negligible contributions to the air pathways collective dose.
- ☉ **Water Releases:** Consumption of drinking water withdrawn from the Columbia River downstream of the Hanford Site contributed approximately 90 percent of the total water pathways collective dose of 1.3 person-rem (0.013 person-sievert). Consumption of Columbia River fish, and ingestion of food products grown with Columbia River irrigation water, contributed approximately 60 percent and 40 percent of the remaining total water pathways dose, respectively. Naturally occurring isotopes of uranium (uranium-234, uranium-235, and uranium-238) and their progeny from releases assigned to the 200 Area were the largest contributors (approximately 70 percent) to the drinking water collective dose. Potassium-40, a naturally occurring radionuclide not of Hanford origin, contributed most of the remaining 30 percent of the water pathways collective dose.

**Table 4.3. Collective Pathway Doses**  
(Within a 50-mile [80-Kilometer] Radius)

Release		Dose Contributions from Operational Areas, person-rem <sup>a</sup>				
		100 Areas	200 Areas	300 Area	400 Area	Pathway Total
<b>Air</b>	Food Ingestion	1.3E-05	0.013	0.66	5.8E-06	0.67
	Inhalation	0.00020	0.012	0.17	4.3E-05	0.18
	External, Soil Ingestion	8.7E-08	1.5E-05	0.0012	7.8E-08	0.0012
	Subtotal Air	0.00022	0.025	0.83	4.9E-05	0.86
<b>Water</b>	Irrigation (food and soil ingestion; external)	NA <sup>b</sup>	0.048 <sup>c</sup>	NA	NA	0.048
	Recreation (river water and sediments; external and ingestion)	NA <sup>b</sup>	0.0088 <sup>c</sup>	NA	NA	0.0088
	Fish Ingestion	NA <sup>b</sup>	0.066 <sup>c</sup>	NA	NA	0.066
	Drinking Water	NA <sup>b</sup>	1.1 <sup>c</sup>	NA	NA	1.1
	Subtotal Water	NA	1.3	NA	NA	1.3

**Table 4.3. Collective Pathway Doses**  
(Within a 50-mile [80-Kilometer] Radius)

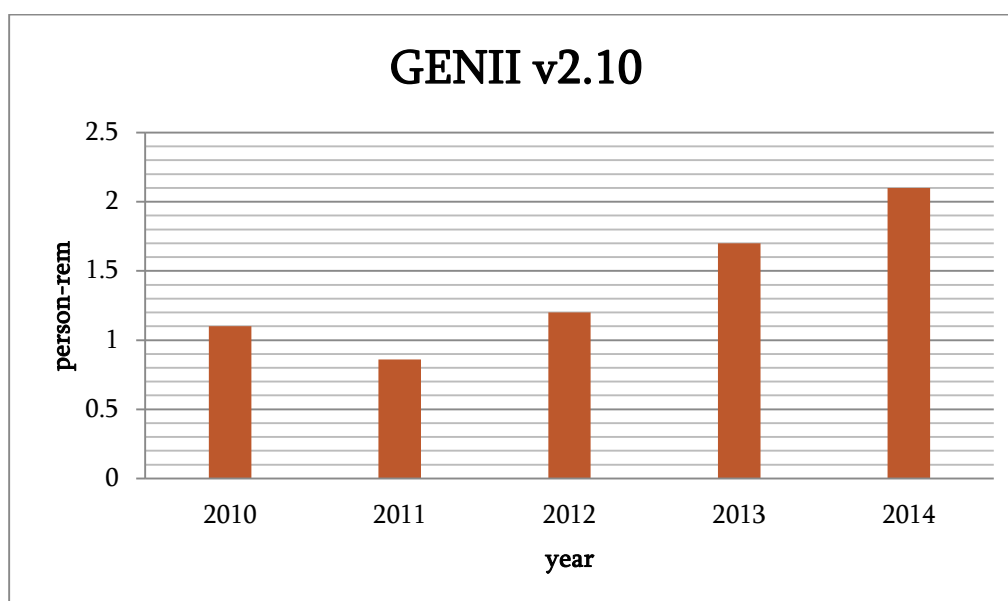
Release Type	Exposure Pathway	Dose Contributions from Operational Areas, person-rem <sup>a</sup>				
		100 Areas	200 Areas	300 Area	400 Area	Pathway Total
	Air + Water Total	0.00022	1.3	0.83	4.9E-05	2.1

<sup>a</sup> To convert person-rem to International System dose units (person-Sievert), divide by 100.

<sup>b</sup> No measured releases; the last 100 Areas NPDES-permitted outfall (1908-K Outfall) ceased releases in March 2011.

<sup>c</sup> Integrates releases from all operational areas, based on the difference between downstream and upstream Columbia River radionuclide concentrations.

NA: Not applicable. All liquid discharges reflected in the difference between upstream and downstream radionuclide concentrations are assigned to the 200 Area.

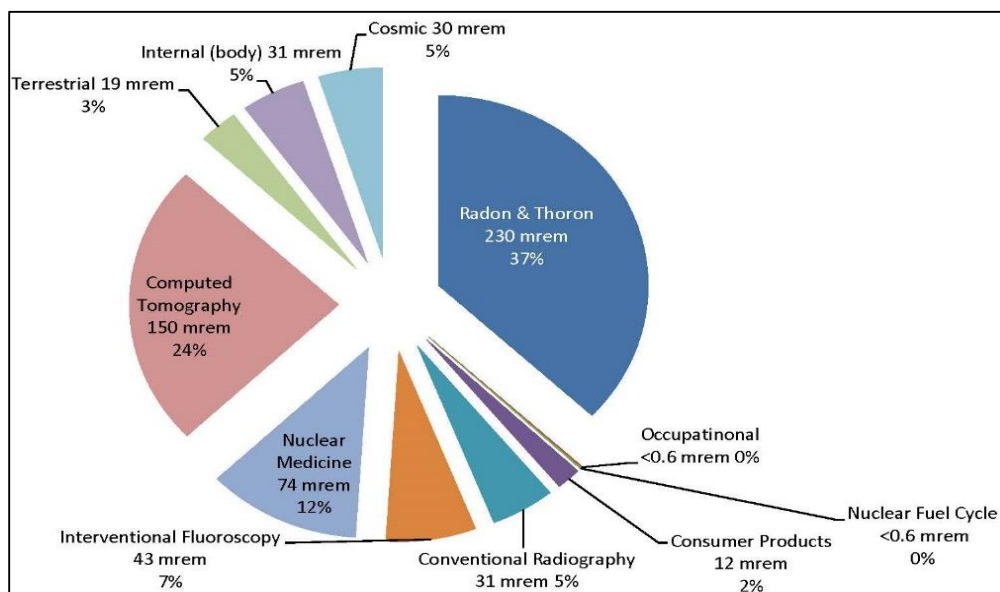
**Figure 4.6. Collective Total Dose**  
(Within 50-mile [80-kilometer] radius)

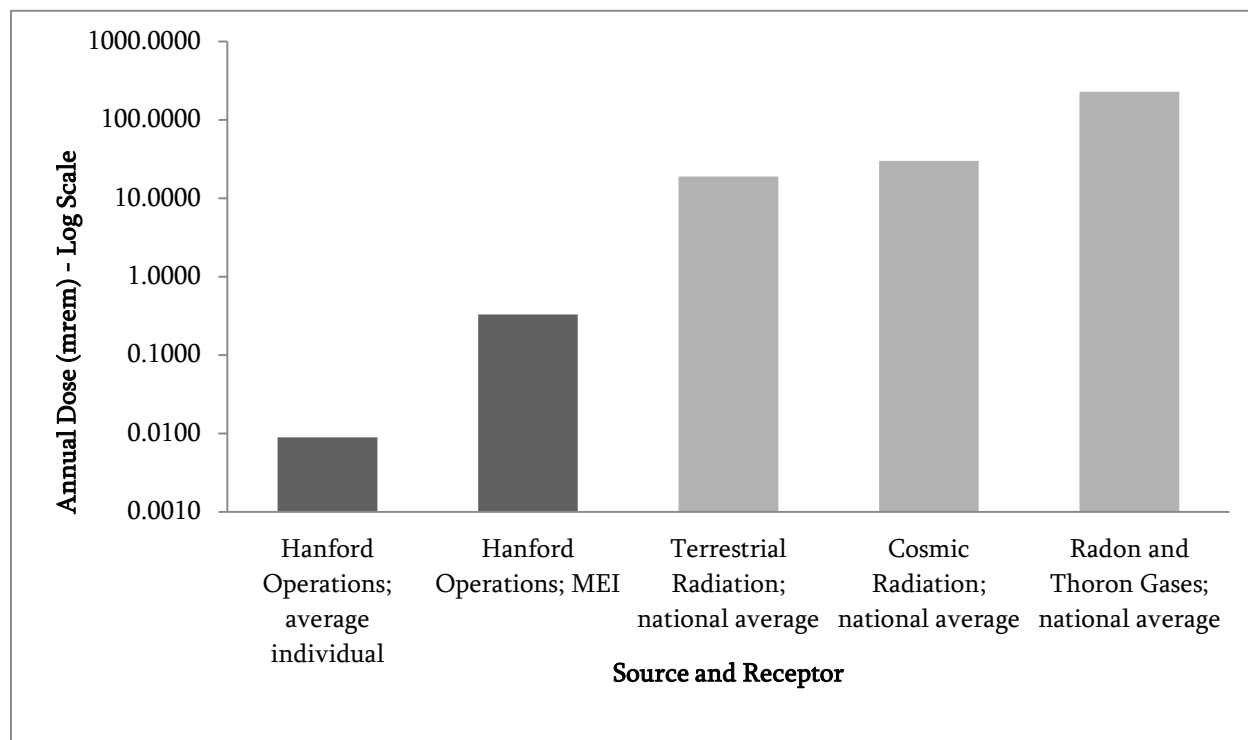
The dose for the MEI in 2014 was 0.33 millirem (3.3 microsievert) (Section 4.2.1). The average individual dose from Hanford Site operations in 2014, based on the 50-mile (80-kilometer) radius population exposed to air emissions and the Tri-Cities populations exposed to water pathways releases to the Columbia River, was approximately 0.0089 millirem (0.089 microsievert). To place the MEI and average individual estimated doses into perspective, the estimated doses may be compared with doses received from other routinely encountered sources of radiation. The National Council on Radiation Protection (NCRP) issued Report 160 in March 2009 that estimated the overall average exposure to ionizing radiation for the average American to be 620 millirem (6,200 microsievert) per year (NCRP 2009). Approximately 50 percent of the 620 millirem (6,200 microsievert) per year average annual dose is related to natural sources, with the remaining 50 percent attributable primarily to medical procedures.

The most relevant radiation sources for comparison to doses received from environmental media include natural terrestrial and cosmic background radiation, and inhalation of naturally occurring radon (Figure 4.7). Average annual individual background dose related to terrestrial radiation (19 millirem [190 microsievert]), cosmic background radiation (30 millirem [300 microsievert]), and radon (radon-222)

and thoron (radon-220) gases (230 millirem [2,300 microsievert]) are shown relative to Hanford Site operational doses in Figure 4.8. The calculated radiological doses from Hanford Site operations in 2014 were a small percentage of national average annual doses from these natural background sources. Note that annual dose is shown on a logarithmic scale in Figure 4.8, where each increment represents a factor of 10. For example, the national annual average terrestrial radiation dose (approximately 19 millirem [190 microsievert]) is approximately 60 times larger than the 2014 Hanford Operations dose to the MEI (0.33 millirem [3.3 microsievert]).

*Figure 4.7. United States Annual Average Radiological Doses from Various Sources (2009 National Council on Radiation Protection and Measurement)*



**Figure 4.8.** Radiological Doses from Hanford Site Operations Compared with Annual Average from Natural Sources

### 4.2.3 Compliance with Clean Air Act Standards

Historically at the Hanford Site, there has been one primary expression of radiological risk to an offsite individual—this is the MEI dose; however, the MEI dose is currently calculated by two different methods in response to two different requirements. One MEI dose computation is required by [DOE O 458.1](#), Chg. 2 and is calculated using the GENII computer code as described in Section 4.2.1. This calculation considers all reasonable environmental pathways (e.g., from releases to both air and water) that maximize a hypothetical individual's offsite exposure to the Hanford Site's radiological liquid effluents and air emissions. A second estimate of MEI dose is required by the *Clean Air Act* and must be calculated using an EPA dose modeling computer code (CAP-88) or other methods accepted by the EPA under the *Clean Air Act* for estimating offsite exposure. The Hanford Site stack emissions and emissions from diffuse and unmonitored sources (e.g., windblown dust) are considered in the offsite dose for the *Clean Air Act*, and are based solely on an airborne radionuclide emissions pathway.

In addition to complying with the all-pathways dose limits established by [DOE O 458.1](#), Chg. 2, (100-millirem [1,000-microsievert] per year), officials managing DOE facilities are required to demonstrate their facilities comply with standards established by EPA for airborne radionuclide emissions under the *Clean Air Act* in [40 CFR 61](#), Subpart H. This regulation specifies that no member of the public shall receive a dose greater than 10 millirem (100 microsievert) per year from exposure to airborne radionuclide emissions (other than radon) released at DOE facilities. Whereas DOE uses the GENII computer code at the Hanford Site to determine dose to the all-pathways MEI, EPA requires the use of the CAP-88 computer code ([EPA 402-R-00-004](#), *Updated User's Guide for CAP88-PC*) or other EPA-approved computer models to demonstrate compliance with the requirements in [40 CFR 61](#), Subpart H. The assumptions embodied in the CAP-88 computer code differ slightly from standard air pathways

assumptions used with the GENII computer code; therefore, air-pathway doses calculated by the two codes may differ somewhat. In principle, the MEI for air pathways assessed under [40 CFR 61](#), Subpart H, may be evaluated at a different location from the all-pathways MEI if dose from the water pathways exceeds that from air pathways (Appendix D).

The *Clean Air Act* regulation also requires that an annual report for each DOE facility be submitted to EPA that supplies information about atmospheric emissions for the preceding year and any potential contributions to offsite dose. For more detailed information about 2014 air emissions at the Hanford Site, refer to DOE's report to EPA ([DOE/RL-2015-12](#), *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2014*).

#### **4.2.3.1 Dose from Stack Emissions to an Offsite Maximally Exposed Individual**

Using CAP-88, the maximally exposed offsite individual for air pathways in 2014 was at PNNL's Physical Sciences Facility, an offsite business located at 638 Horn Rapids Road in north Richland, Benton County, Washington, directly south of the Hanford Site 300 Area (Figure 4.2). The potential air pathway dose from stack emissions to a MEI at that location calculated using the CAP-88 computer code was determined to be 0.28 millirem (2.8 microsievert) per year, which is less than 3 percent of the EPA standard of 10 millirem (100 microsievert) per year. The CAP-88 result is approximately 2.5 times higher than the air pathway dose for stack emissions calculated with GENII (Table 4.2).

Dose related to radon-220 and radon-222 is not included in the dose calculated for compliance with the EPA standard in [40 CFR 61](#), Subpart H, but is regulated by the 10-millirem (100-microsievert) per year standard established by Ecology in [WAC 246-247](#). A release of 75.2 curies of radon-220 and 0.024 curies of radon-222 was calculated from engineering estimates for stack emissions from Building 325 in the 300 Area. A total radon-220 and radon-222 dose of 0.019 millirem (0.19 microsievert) per year was calculated for the MEI at Horn Rapids Road, far below the [WAC 246-247](#) standard.

#### **4.2.3.2 Dose from Diffuse and Fugitive Radionuclide Emissions to an Offsite Maximally Exposed Individual**

The December 15, 1989, revisions to [40 CFR 61](#), Subpart H, required DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE and EPA interpreted the regulation to include diffuse and fugitive (nonpoint source) emissions, as well as emissions from monitored point sources (i.e., stacks) described in Section 4.2.3.1. EPA has not specified or approved standardized methods to estimate diffuse airborne emissions because of the wide variety of sources at DOE sites. The method developed at the Hanford Site to estimate potential diffuse emissions is based on environmental monitoring measurements of airborne radionuclides at the site perimeter ([DOE/RL-2015-12](#)).

The Horn Rapids Road location immediately south of the 300 Area was chosen for purposes of demonstrating compliance with the MEI dose standard for diffuse and fugitive emissions ([DOE/RL-2015-12](#)). The estimated dose from diffuse emissions to a MEI at Horn Rapids Road in was calculated using the CAP-88 computer code to be 0.17 millirem (1.7 microsievert) per year. Therefore, the potential combined dose from stack emissions and diffuse emissions (excluding radon) during 2014 at the Horn Rapids Road location was 0.45 millirem (4.5 microsievert) per year, which is less than 5 percent of 10 millirem (100-microsievert) per year standard in [40 CFR 61](#), Subpart H.

#### **4.2.3.3 Maximum Dose to Non-U.S. Department of Energy Workers at the Hanford Site**

DOE has recently allowed private businesses to locate their activities and personnel on some regions of the Hanford Site. The EPA Region 10 Office and the WDOH provided guidance to RL that, when demonstrating compliance with 40 CFR 61 standards, it should evaluate potential doses to non-DOE employees who work at facilities within the Hanford Site but who are not under direct DOE control. This has created the need to calculate a maximum dose for an onsite individual who is employed by a non-DOE business and works within the boundary of the Hanford Site.

Doses to members of the public employed at non-DOE facilities at locations outside access-controlled areas on the Hanford Site (those requiring DOE-access authorization for entry) were evaluated in the 2014 EPA air emissions report (DOE/RL-2013-12) as possible MEIs. These locations included the Columbia Generating Station operated by Energy Northwest and the Laser Interferometer Gravitational Wave Observatory operated by the University of California (Figure 4.2). The non-DOE worker dose due to stack emissions from these facilities was calculated using the CAP-88 computer code assuming full-time occupancy because EPA guidance does not currently allow for adjustment of such doses to account for less than full-time occupancy. Even assuming an employee is continuously present, the estimated doses to non-DOE onsite workers in 2014 were lower than the 0.28 millirem (2.8 microsievert) per year dose calculated with CAP-88 to an offsite MEI at Horn Rapids Road. Combined stack emissions and diffuse/fugitive emissions dose for the Columbia Generating Station was 0.26 millirem (2.6 microsievert) per year, and for the Laser Interferometer Gravitational Wave Observatory was 0.36 millirem (3.6 microsievert) per year ([DOE/RL-2015-12](#)).

#### **4.2.4 Special Case Dose Estimates**

The exposure assumptions used to calculate the dose to the MEI were selected to provide a scenario yielding a reasonable upper bound dose estimate. The MEI dose calculations are based on measurements of radionuclide releases from stack emissions (air pathways) and differences between downstream and upstream radionuclide concentrations in the Columbia River (water pathways), followed by modeling of environmental transport related to a number of different exposure pathways (Figure 4.3). Exposure pathways using other radionuclide measurements also exist that could have resulted in radiological exposures. Two such scenarios include 1) an outdoor recreationalist who consumed meat from contaminated wildlife that migrated from the Hanford Site, and 2) an individual who drank water from one of four DOE-owned water treatment facilities at the Hanford Site. The potential doses resulting from these scenarios are examined in the following sections.

##### **4.2.4.1 Outdoor Recreationalist Dose**

Wildlife has access to Hanford Site areas that are contaminated with radioactive materials and have the potential to acquire radioactive contamination and migrate offsite. Wildlife sampling was conducted at the Hanford Site to estimate radionuclide tissue concentrations in animals from the site that could potentially have been hunted offsite.

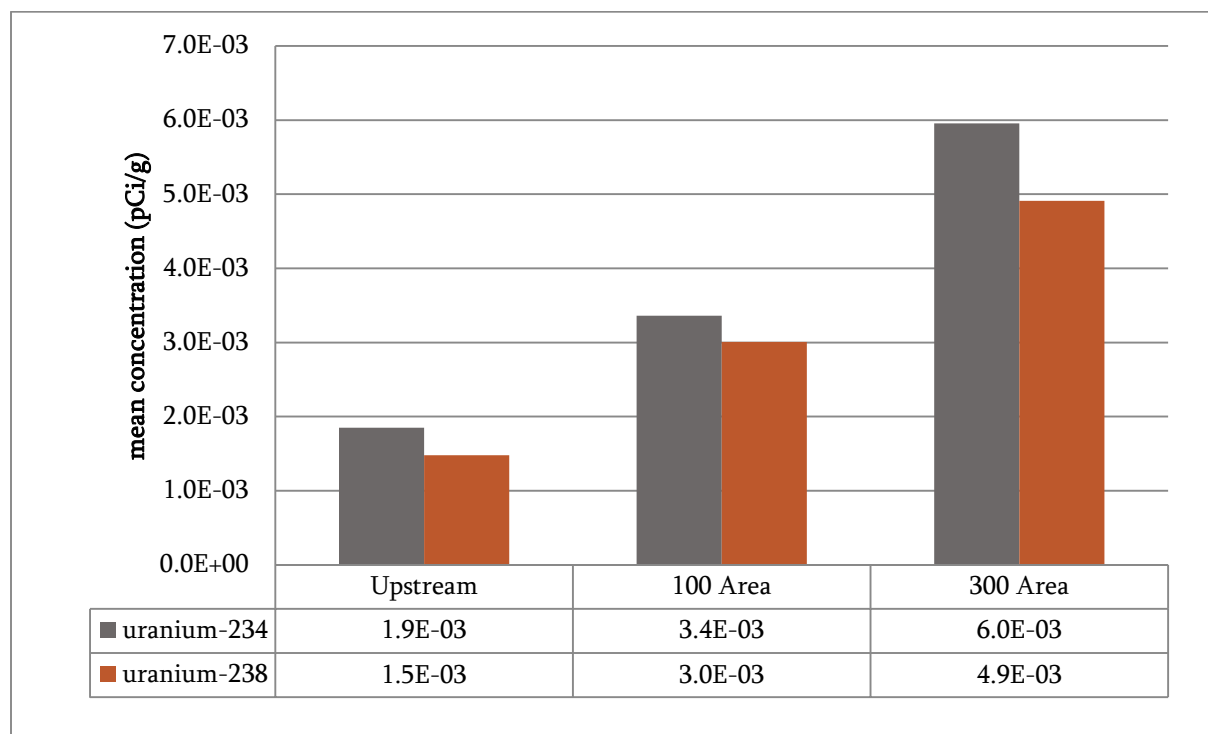
Gamma-emitting radionuclides were analyzed in muscle tissue samples collected in 2014 from mule deer, elk, and quail. In addition to muscle tissue, bone samples were collected from these three animals, and liver samples were collected from mule deer and elk. For estimating dose from ingestion of game meat, radionuclide concentrations in muscle tissue are most applicable. Five muscle tissue samples were available in 2014 for mule deer, two for elk, and nine for quail. The only radionuclide detected in the muscle tissue of mule deer, elk, or quail was potassium-40, a naturally occurring primordial radioisotope

not of Hanford Site origin. Both isotopic plutonium and gamma-emitting radionuclides were analyzed in five liver samples from mule deer and two liver samples from elk. Again, potassium-40 was the only radionuclide detected.

Fillet tissue samples were obtained from bass and carp in the 100 Area, 300 Area, and Desert Aire/Vantage (upstream) regions of the Columbia River and analyzed for gamma-emitting radionuclides, tritium, strontium-90, and isotopes of uranium. Additionally, fillet tissue samples from bass were collected in the Hanford Slough/Townsite (downstream) region. A total of 28 fillet samples were collected in July and August 2014. Detected radionuclides in fillet samples were limited to potassium-40, uranium-234, uranium-235, and uranium-238. Although, naturally occurring radionuclides like potassium-40 and uranium isotopes are associated with Hanford Site operations.

Only a single sample with isotopic uranium results is available at each location for bass fillets from the Desert Aire/Vantage (upstream) region, 100 Area, and 300 Area of the Columbia River. Although uranium isotopes were not detected in upstream and 100 Area bass fillet samples, both uranium-234 and uranium-238 were detected in the 300 Area sample. Three to four carp fillet samples were also available from these three regions. Uranium-234 and uranium-238 were detected in all these samples, and as shown in Figure 4.9, concentrations of both isotopes increase in carp fillet samples from upstream through the 100 Area and 300 Area.

**Figure 4.9** Isotopic Uranium Concentrations in Carp Fillets from Upstream, 100 Area and 300 Areas



The average measured fillet concentrations of uranium-234 in the 300 Area samples is approximately 3.5 times higher than the uranium-234 fish tissue concentration of 0.0017 pCi/g ( $6.3 \times 10^{-5}$  Bq/g) modeled in [GENII Version 2.10 \(PNNL-14583\)](#) from the difference in upstream and downstream uranium-234 concentrations. Similarly, the average measured fillet concentrations of uranium-238 in the 300 Area samples is approximately 2.5 times higher than the modeled uranium-238 fish tissue concentration of 0.0020 pCi/g ( $7.5 \times 10^{-5}$  Bq/g).



Although the measured uranium-234 and uranium-238 values in the carp fillet samples are higher than the levels modeled to be attributable to Hanford Site releases, the radiation dose received from consumption of fish fillets with these isotopic uranium concentrations would be negligible.

Assuming annual fish consumption of 88 pounds (40 kilograms) for a MEI (see Table D.4), the annual radiation dose related to fish ingestion for fish that contains 0.0060 pCi/g [ $2.2 \times 10^{-4}$  Bq/g] of uranium-234 and 0.0049 pCi/g [ $1.8 \times 10^{-4}$  Bq/g] of uranium-238 is estimated to be 0.078 millirem (0.78 microsievert) per year.

This dose estimate was derived using a uranium-234 ingestion dose factor of  $1.8 \times 10^{-4}$  millirem/pCi ( $4.9 \times 10^{-2}$  microsievert/Bq) and a uranium-238 ingestion dose factor of  $1.8 \times 10^{-4}$  millirem/pCi ( $4.9 \times 10^{-2}$  microsievert/Bq) from ICRP Publication 72 ([ICRP 1996](#), *Age-dependent Doses to the Members of the Public from Intake of Radionuclides – Part 5 Compilation of Ingestion and Inhalation Coefficients*) in the following manner using uranium-234 as an example:

$0.0060 \text{ pCi uranium-234/g} \times 40 \text{ kg} \times 1,000 \text{ g/kg} \times 1.8 \times 10^{-4} \text{ millirem/pCi} =$   
0.043 millirem (0.43 microsievert) per year.

#### 4.2.4.2 Hanford Site Drinking Water Dose

Drinking water was sampled and analyzed for tritium, strontium-90, gross alpha radiation, and gross beta radiation during 2014 in accordance with applicable regulations ([40 CFR 141](#), “National Primary Drinking Water Regulations”); water samples were collected from the 100-K Area, 200-West Area, and two sources in the 400 Area. The water supply for the 100-K and 200-West Areas is the Columbia River, whereas the primary and backup water supplies for the 400 Area are groundwater wells (see Section 7.1).

All 100-K, 200 Area, and 400 Area drinking water gross alpha radiation concentrations measured during 2014 were below the applicable drinking water standard of 15 pCi/L. Gross beta radiation groundwater standards are published as dose-based levels (millirem or microsievert per year) rather than radiation concentrations. Tritium and strontium-90 are both man-made soluble beta radiation emitters; there are also naturally occurring beta emitters in the uranium, actinium, and thorium decay series. Potential onsite drinking water dose from Hanford-related beta-emitting radionuclides is addressed by evaluating the drinking water data for tritium and strontium-90.

Strontium-90 was analyzed in one sample from each of the four drinking water sources in 2014, and was not identified above detection limits in any drinking water sample. Tritium was analyzed in one sample from both the 100-K and 200-West Areas and was not detected in either sample. Tritium was detected in all four drinking water samples collected from the primary drinking water sources for the 400 Area (well P-16) and in the single sample from backup well P-14. Based on the four quarterly samples from the primary well, the annual average 400 Area drinking water tritium concentration was 1,130 pCi/L (42 Bq/L). Assuming a consumption rate of 0.26 gallon (1 liter) per day for 250 working days at the FFTF in the 400 Area, the potential annual worker dose in 2014 would be approximately 0.019 millirem (0.19 microsievert). A single tritium sample was also collected from Well P-14 in the 400 Area, where a value of 11,500 pCi/L was reported. Based on this single measurement, an annual worker drinking water dose for water from this backup supply well would be 0.19 millirem (1.9 microsievert). These estimates are well below EPA’s drinking water dose limit of 4 millirem (40 microsievert) per year for beta-emitting radionuclides in public drinking water supplies.

The dose estimates were derived using a tritium ingestion dose factor of  $6.7 \times 10^{-8}$  millirem/pCi ( $1.8 \times 10^{-5}$  microsievert/Bq) from ICRP Report 72 ([ICRP 1996](#)) in the following manner:

$1,130 \text{ pCi tritium/L} \times 1 \text{ L/day} \times 250 \text{ d/year} \times 6.7 \times 10^{-8} \text{ millirem/pCi} = 0.019 \text{ millirem/year}$ .

#### 4.2.5 Doses from Non-U.S. Department of Energy Sources

Doses from non-DOE sources were not quantified in 2014 because the MEI dose of 0.33 millirem (3.3 microsievert) per year from DOE-related sources (Section 4.2.1) was far below the threshold of 25 millirem (250 microsievert) per year at which the contribution of non-DOE sources must be included. [DOE O 458.1](#), Chg. 2; paragraph 4.e.(1)(c) states that dose evaluations to demonstrate compliance with the public dose limit must include:

- The dose to members of the public from DOE-related exposure sources only, if the projected DOE-related dose to the representative person or MEI is 25 millirem (250 millisievert) in a year or less. If the DOE-related dose is greater than 25 millirem (250 millisievert) in a year, the dose to members of the public must include major non-DOE sources of exposure and dose from DOE-related sources.

Before it was superseded by the release of [DOE O 458.1](#) in 2011, DOE O 5400.5, Chg 2, provided the applicable requirements for radiation protection of members of the public. Chapter II, Paragraph 7, of DOE O 5400.5, Chg 2, has a reporting requirement for a combined dose due to DOE and other manmade sources. Therefore, Hanford Site environmental reports prior to 2011 routinely evaluated dose contributions from various non-DOE industrial sources of radiation exposure on or near the Hanford Site. These included a commercial, low-level radioactive waste burial ground at the Hanford Site operated by US Ecology; a nuclear power-generating station at the Hanford Site operated by Energy Northwest; a nuclear-fuel production plant operated near the site by AREVA NP, Inc.; a commercial, low-level radioactive waste treatment facility operated near the site by Perma-Fix Northwest, Inc.; and a commercial decontamination facility operated near the site by PN Services (Figure 4.2). The total individual dose from non-DOE source activities in 2010 was conservatively estimated at about 0.004 millirem (0.04 microsievert) per year. PNNL-20548, *Hanford Site Environmental Report for Calendar Year 2010* is online at [http://msa.hanford.gov/files.cfm/2010\\_pnnl-20548\\_env-report.pdf](http://msa.hanford.gov/files.cfm/2010_pnnl-20548_env-report.pdf).

#### 4.2.6 Dose to Non-Human Biota

Dose assessments for non-human biota evaluate the potential for exposures from Columbia River sediment and water and exposures associated with West Lake. Upper estimates of the radiological dose to aquatic organisms were made in accordance with the [DOE O 458.1](#), Chg. 2, interim requirement for management and control of liquid discharges. The current dose limit for aquatic animal organisms is 1 rad (10 milligray) per day. Rad is a unit of absorbed dose of ionizing radiation equal to an energy of 100 ergs per gram of irradiated material. In addition to the dose limit for aquatic organisms there is a proposed dose limit for riparian or terrestrial wildlife is 0.1 rad (1 milligray) per day.

Concentration guides for assessing doses to biota are very different from the DOE-derived concentration standards used to assess radiological doses to humans. A tiered approach is used to estimate radiological doses to aquatic and terrestrial biota. This method uses the RESidual RADioactive (RESRAD)-BIOTA computer code ([DOE/EH-0676](#), *User's Guide, Version 1. RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation*; [DOE/STD-1153-2002](#), *A Graded Approach for Evaluating*

*Radiation Doses to Aquatic and Terrestrial Biota*) to compare radionuclide concentrations measured by routine monitoring programs to a set of biota concentration guides.

Biota concentration guides are the water or sediment concentrations of a radionuclide that would produce 1 rad (10 milligray) per day for aquatic biota or 0.1 rad (1 milligray) per day for riparian or terrestrial wildlife. For samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to the dose limit. If the sum of fractions exceeds 1.0, then the dose limit has been exceeded. If the initial estimated screening value (Tier 1) exceeds the guideline (sum of fractions more than 1.0), additional screening calculations are performed (Tier 2 or Tier 3) to evaluate more accurately exposure of the biota to the radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure. Biota-dose screening assessments were conducted using surveillance data collected in 2014 from on and around the Hanford Site. The results from 2013 are provided for comparison.

Researchers used the RESRAD-BIOTA computer code to evaluate potential effects on biota from the maximum concentrations of radionuclides measured in Columbia River sediment and water as tabulated in Appendix C. The detected radionuclides evaluated across all locations in the Columbia River sediment and water biota dose assessment are carbon-14, cesium-137, plutonium-239/240, strontium-90, technetium-99, tritium, uranium-234, uranium-235, and uranium-238. Most of the locations located on the Columbia River had samples collected from riverbank springs or seeps that carry groundwater contaminants into the Columbia River. Concentrations in springs or seeps are greater than those observed in the river water, and therefore, the dose assessment results for these discrete areas of elevated concentrations are protective relative to the potential for impacts on populations of biota in the Columbia River. The results of the screening calculations listed in Table 4.4 show the concentrations in all Columbia River sediment and water samples passed the Tier 1 screen and indicate that the calculated doses were below dose limits (sum of fractions less than one). Except for the 100-K Area most of the estimated dose is associated with uranium isotopes, which are the key radionuclides for the biota dose assessment. The sum of fractions tends to be greater at locations where uranium water concentrations were estimated from sediment (and not measured). In general, the dose estimates for 2014 were similar to those calculated in 2013.

At the 100-K Area, the estimated biota dose in 2014 was less than the acceptable limit. In contrast, the estimated biota dose in 2013 was about 3.5 times the acceptable limit. Nearly 100 percent of these estimated doses were from carbon-14 to the riparian animal through the water pathway. Carbon-14 has been detected at the 100-K Area springs in 2012 (57.3 pCi/L), 2013 (2,150 pCi/L), and 2014 (414 pCi/L). The maximum concentration measured in 2013 was nearly 40 times greater than that measured in 2012. Further documentation of the Columbia River biota dose calculations is provided in Appendix D.

**Table 4.4. Estimated Doses to Biota associated with Columbia River Sediment and Water**  
(Using RESRAD-BIOTA<sup>a</sup> Computer Code)

Location	Media Sampled for Key Radionuclides <sup>c</sup>	Tier 1 Screen Sum of Fractions <sup>b</sup>		2014 Pass or Fail
		2013	2014	
Priest Rapids Dam	Sediment	0.25	0.26	Pass
100-B Area	Water	<0.01	<0.01	Pass
100-K Area	Water	3.5	0.68	Pass
100-N Area	Water	0.16	0.05	Pass
100-D Area	Sediment, Water	0.03	0.02	Pass
Locke Island	Sediment	0.26	0.27	Pass
White Bluffs Slough	Sediment	0.16	0.23	Pass
100-F Area	Sediment, Water	0.11	0.10	Pass
Hanford Townsite	Sediment, Water	0.54	0.17	Pass
Savage Island	Sediment	0.15	0.13	Pass
300 Area Spring	Water	0.47	0.36	Pass
McNary Dam	Sediment	0.28	0.28	Pass

<sup>a</sup> A screening method to estimate radiological doses to aquatic and riparian biota.

<sup>b</sup> The biota dose assessment requires concentration data for both sediment and water. If one of these media is not measured then it is estimated by using the default water to sediment partition coefficient. If water was measured then sediment was estimated from water and if sediment was measured then water was estimated from sediment. In some cases where both sediment and water were measured a radionuclide was only measured in one medium (e.g., tritium in water) and the concentration for that radionuclide in the other medium would be estimated. Please see Appendix D for the details on what was measured.

<sup>c</sup> A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening (Tier 2 or Tier 3) is required. The sum of fractions has been rounded to two figures with a maximum of two decimal points. Maximum concentrations and the Biota Concentration Guides are presented in Appendix D.

Biota dose calculations also were completed for West Lake, which is located on the Central Plateau of the Hanford Site. West Lake is a vernal pool or ephemeral wetland that fills with water during the winter and generally becomes smaller or dries up entirely in other seasons. West Lake is part of the 200 Area Unplanned Release Waste Group Operable Unit (200-UR-1 Operable Unit), and is planned for supplemental characterization ([DOE/RL-2009-121](#), *Sampling and Analysis Plan for the West Lake Site*). The results of these planned investigations will be presented in the appropriate CERCLA remedial action document for the 216-N-8 waste site. In parallel with these planned CERCLA studies, this program has been collecting sediment data annually. In addition, other media (water and biota) have been collected from West Lake on a less regular schedule. Both sediment and water samples were collected in 2014 and data tabulated (Appendix C, Tables C.2, C.3, and C.4).

The results of the 2014 screening calculations listed in Table 4.5 show the West Lake sediment and water concentrations failed the Tier 1 and Tier 2 screens. The Tier 1 screen was based on the maximum concentration, and the Tier 2 screen was based on the average concentrations of two water samples. The estimated biota dose for Tiers 1 and 2 was almost entirely due to the measured concentration of uranium in water and the assumed potential for uptake from water to aquatic biota using a default bioaccumulation factor.

The RESRAD-BIOTA default bioaccumulation factor for uranium isotopes from water to aquatic biota is 1,000. This means that the concentration in tissues would be 1,000 times that measured in water. Site-specific data from West Lake support a much lower uranium bioaccumulation factor. Aquatic biota (only brine flies have been sampled, and they are also the most relevant organisms) and water were sampled concurrently in 2000 and 2007 ([PNNL-13487](#), *Hanford Site Environmental Report for Calendar Year 2000*; [DOE/RL-2007-50](#), *Central Plateau Ecological Risk Assessment Data Package Report*).

The maximum concentration of any of the uranium isotopes in brine flies was 0.77 pCi/g for uranium-233/234 in 2007. The minimum uranium-233/234 water concentration was 940 pCi/L in 2007. The bioaccumulation factor is calculated by dividing the biota concentration (in pCi/g) by the water concentration (in pCi/ml). Therefore, the maximum bioaccumulation factor for uranium would be less than one. A bioaccumulation factor of one was used for the Tier 3 biota dose calculation as a somewhat protective measure of site-specific uranium uptake into the food chain. The Tier 3 biota dose calculations resulted in sum of fractions less than one, indicating that the calculated doses were below dose limits related to the biota concentration guides. This result is similar to those calculated for 2012, but the 2014 doses are about 10 times greater than those calculated for 2013 (Table 4.5). The reason is that the maximum concentrations in West Lake pond water samples have also varied quite widely. Isotopic uranium is typically detected in West Lake pond water. The last three years of concentrations were—2012 (uranium-234 at 3,850 pCi/L, uranium-235 at 147 pCi/L, uranium-238 at 3650 pCi/L); 2013 (uranium-234 at 256 pCi/L, uranium-235 at 13.8 pCi/L, uranium-238 at 250 pCi/L); and 2014 (uranium-234 at 6,580 pCi/L, uranium-235 at 248 pCi/L, uranium-238 at 6,380 pCi/L). The maximum concentration measured in 2014 was about 25 times greater than that measured in 2013. Further documentation of the West Lake biota dose calculations, including the Tier 3 Biota Concentration Guides, is provided in Appendix D.

**Table 4.5. Estimated Doses to Biota Associated with West Lake**  
(Using RESRAD-BIOTA<sup>a</sup> Computer Code)

Tier	Exposure Assumptions	Sum of Fractions <sup>b</sup>		2014 Pass or Fail
		2013 <sup>c</sup>	2014	
1	Maximum Sediment, Water Concentration and Default Bioaccumulation	2.5	62	Fail
2	Average Sediment, Water Concentration and Default Bioaccumulation	1.3	31	Fail
3	Average Sediment, Water Concentration and Site-specific Bioaccumulation	0.05	0.34	Pass

<sup>a</sup> A screening method to estimate radiological doses to aquatic and riparian biota.

<sup>b</sup> A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening (Tier 2 or Tier 3) is required.

<sup>c</sup> Doses presented in the 2013 annual report incorrectly omitted the maximum concentrations of isotopic uranium from pond water. The doses presented in this column reflect the corrected 2013 biota dose.

#### 4.2.7 Radiological Dose in Perspective

Scientific studies (National Research Council 2006, [Health Risks from Exposure to Low Levels of Ionizing Radiation, Phase 2](#)) [National Research Council 2006]) have been performed to estimate the possible risk from exposure to low levels of radiation. These studies provide information to government and scientific

organizations for use in recommending radiological dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation actually has been confirmed by the scientific community, regulatory agencies cautiously assume that the probability of these types of health effects occurring due to exposure to low doses (down to zero dose) is the same per unit dose as the health effects observed after an exposure to much higher doses (e.g., in atomic bomb survivors, individuals receiving medical exposure, or, historically, painters of radium dials). This concept is known as the “linear no-threshold” hypothesis. Under these assumptions, public exposure to radiation from current Hanford Site releases, exposure to natural background radiation (which is hundreds of times greater), and exposure to very high levels of radiation each increases an individual’s probability or chance of developing a detrimental health effect (primarily cancer) proportional to the dose received.

Scientists do not fully agree on how to translate the available epidemiological data on health effects from high radiological doses into the numerical probability (risk) of detrimental effects from low radiological doses ([UNSCEAR 2012](#), *Biological Mechanisms of Radiation Actions at Low Doses*). Some scientific studies have indicated that low radiological doses may result in beneficial rather than adverse effects (Calabrese 2009, “The road to linearity: why linearity at low doses became the basis for carcinogen risk assessment”). Because cancer is a common disease in the general population and may be attributable to many other causes besides radiation (e.g., genetic defects, natural and man-made chemicals, and natural biochemical reactions in the body), some scientists doubt that the risk from low-level radiation exposure can ever be conclusively proven. In developing *Clean Air Act* regulations, EPA used a probability of approximately 4 per 10 million ( $4 \times 10^{-7}$ ) for the risk of developing a fatal cancer after receiving a dose of 1 millirem (10 microsievert) ([EPA/520/1-89-005](#), *Risk Assessments Methodology Environmental Impact Statement NESHAPS for Radionuclides Background Information Document – Volume I*). Additional data ([National Research Council 2006](#)) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time. Guidance from the Interagency Steering Committee on Radiation Standards (*A Method for Estimating Radiation Risk from TEDE*, [ISCORS 2002](#)) recommends that agencies assign a risk factor of 6 per 10 million ( $6 \times 10^{-7}$ ) for developing a fatal cancer after receiving a dose of 1 millirem (10 microsievert).

One approach for providing perspective on calculated risks related to low-dose radiation exposures is to compare them to risks involved in other typical activities. Table 4.6 compares the estimated risks from various radiological doses to the risks of some activities encountered in everyday life.

**Table 4.6. Estimated Risk from Various Activities and Exposures**

Activity or Exposure Per Year	Risk of Fatality
Home accidents	$100 \times 10^{-6}$ (a)
Firearms (sporting accidents)	$10 \times 10^{-6}$ (a)
Flying as an airline passenger (cross-country roundtrip – accidents)	$8 \times 10^{-6}$ (a)
Recreational boating (accidents)	$6 \times 10^{-6}$ (a)
Riding or driving 300 miles (483 kilometers) in a passenger vehicle	$2 \times 10^{-6}$ (a)
Natural background radiological dose (310 millirem [3,100 $\mu$ Sv]) for 70 year	0 to $13,000 \times 10^{-6}$ (a)
Dose of 1 millirem (10 microsievert) for 70 years	0 to $40 \times 10^{-6}$ (a)
Flying as an airline passenger (cross-country roundtrip – radiation)	0 to $6 \times 10^{-6}$ (b)
Dose to the hypothetical, maximally exposed individual (2014 dose rate) of 0.33 millirem (3.3 microsievert) per year living near the Hanford Site for 70 years	0 to $2 \times 10^{-7}$ (b)

<sup>a</sup> Real actuarial values.<sup>b</sup> Upper bound calculated using  $6 \times 10^{-7}$  risk of developing a fatal cancer after receiving a dose of 1 millirem (10 microsievert) (ISCORS 2002).

### 4.3 Radiological Clearance of Hanford Site Property

*JW DeMers*

Principal requirements for the control and clearance of DOE property containing residual radioactivity are found in [DOE O 458.1](#), Chg. 2. These requirements are designed to ensure the following:

- ⊗ Property is evaluated, radiologically characterized—and where appropriate—decontaminated before release
- ⊗ Residual radioactivity level in property to be released is as near background levels as reasonably practicable, as determined through DOE's as low as reasonably achievable (ALARA) process requirements, and authorized limits
- ⊗ All property releases are appropriately certified, verified, documented, and reported; public participation needs are addressed; and processes are in place to maintain appropriate records.

The site contractors transitioned from DOE O 5400.5, Chg. 2, to the new order, [DOE O 458.1](#), Chg. 2.

#### 4.3.1 Radiological Clearance for Potentially Contaminated Personal Property with Hard-to-Detect Radionuclides

In the process of performing environmental remediation or related support activities, Hanford Site contractors encounter a wide variety of contaminated personal property, including consumables, office items, tools and equipment, and debris. Over 10,000 items of personal property were unconditionally released from radiological areas on the Hanford Site; however, the majority of the items did not leave the Hanford Site. The personal property items primarily consisted of small items such as flashlights, hard hats, radios, cameras, pens, pencils, respiratory protection, radiological control instruments, and industrial hygiene instruments. All of these items met [DOE O 458.1](#) release criteria, and therefore, did not require additional radiological controls post-survey.

DOE issued a moratorium in January 2000 prohibiting the release of volume-contaminated metals, and subsequently suspended the release of metals for recycling purposes from DOE radiological areas in July 2000. As a result, no volume of contaminated metals or metals for recycling purposes were released from Hanford in 2014.

Final disposition of potentially contaminated personal property with hard-to-detect radionuclides depends on whether the property is considered radiologically contaminated, and whether the disposal of such



property is subject to CERCLA requirements. Radiologically contaminated property is disposed at ERDF if subject to CERCLA requirements, and if not, at the CWC in the 200-West Area. Personal property that has contamination levels below approved DOE control and release guidelines ([DOE O 458.1](#)) are considered for release if the property can be reused. Hanford Site contractors routinely encounter a wide variety of radionuclide mixtures ranging from essentially pure plutonium to fission and activation products. Included in these fission and activation products are low-energy beta emitters, such as carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155 that are difficult or impossible to detect with routine field-survey methods (i.e., hard-to-detect radionuclides).

Traditionally, field detectable or easy-to-detect radionuclides have been used as an analog for the entire mixture of radionuclides encountered during work activities. The control and release criteria ([DOE O 458.1](#)) have been adjusted downward to account for the portion of the activity that is not detectable by field survey methods. As the ratio of hard-to-detect radionuclides to easy-to-detect radionuclides increases, the criteria are reduced to a point where the adjusted limits are difficult or impossible to verify with field survey instruments. Decades of radioactive decay have reduced the contributions of easy-to-detect radionuclides to such low levels that current control and release methodologies are no longer sufficient for verifying that contaminant levels comply with the existing, approved DOE property release guidelines in [DOE O 458.1](#).

Accordingly, in May 2006, a request to DOE was submitted by WCH (DOE contractor for the River Corridor Closure Contract) to increase the release criteria (authorized limits) for hard-to-detect radionuclides. The requested authorized limits would apply only to beta-gamma surface contamination on potentially contaminated equipment and materials, and exclude volumetric contamination (contamination that is distributed throughout the volume of the property), contamination in or on persons, unrestricted release of metals, and alpha-surface contamination. Detailed radiological analyses were performed to demonstrate these authorized limits would be protective of human health and the environment. Based on these analyses, the authorized limits would result in a dose of less than 1 millirem (10 microsievert) in any year to the MEI and a collective dose of less than 10 person-rem (0.1 person-sievert) to any exposed population. These authorized limits (Table 4.7) were reviewed by RL and HQ personnel and approved for use by WCH in May 2007. In 2008, RL provided conditional approval to CHPRC and Fluor Hanford, Inc., to use these hard-to-detect authorized limits. In addition to this request, in 2013 CHPRC requested and was approved an authorized limit to apply the general beta-gamma limits to the low energy beta emitter, plutonium-241, (1,000 dpm/100 cm<sup>2</sup> removable limit and 5,000 dpm/100 cm<sup>2</sup> total contamination limit). In June 2009, WRPS submitted a request to ORP for approval to use these hard-to-detect authorized limits. ORP provided conditional approval for this request in June 2009. MSA submitted a request to RL in October 2009 for approval to use these hard-to-detect authorized limits. RL provided conditional approval for this request in November 2009.

*Table 4.7. Approved Release Criteria (Authorized Limits) for Select Hard-to-Detect Radionuclides<sup>a</sup> for Residual Beta-Gamma Surface Contamination*

Average	Maximum	Removable
50,000 dpm/100 cm <sup>2</sup>	150,000 dpm/100 cm <sup>2</sup>	10,000 dpm/100 cm <sup>2</sup>

<sup>a</sup> Carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155.  
DPM = disintegrations per minute.

### 4.3.2 Granular Activated Carbon for Offsite Shipment and Regeneration Radiological Clearance

Carbon tetrachloride was found in the unconfined aquifer beneath the 200 West Area in the mid-1980s. Groundwater monitoring indicated the carbon tetrachloride plume was widespread, and concentrations were increasing. An expedited response action was initiated in 1992 to extract carbon tetrachloride from the vadose zone in the 200-ZP-2 Operable Unit, currently designated as the 200-PW-1 Operable Unit, in the 200 West Area. The 200-PW-1 Operable Unit soil-vapor extraction system includes vapor-phase granular activated carbon canisters to remove carbon tetrachloride from the extracted vapors prior to discharge. This facility was in full operation by 1995.

Workers installed a groundwater pump-and-treat system in 1996 in a second operable unit (200-ZP-1 Operable Unit) to treat contaminated groundwater in the unconfined aquifer. The system includes an air-stripping unit that volatilizes carbon tetrachloride in the groundwater and then discharges the carbon tetrachloride vapors through granular activated carbon canisters that are identical to the large, carbon-steel granular activated carbon canisters in the 200-PW-1 Operable Unit soil-vapor extraction system.

Each of these systems uses granular activated carbon canisters to capture the volatile organic compounds removed during the extraction process. When a granular activated carbon canister has reached volatile organic compound saturation, it is removed from the system, and the granular activated carbon is prepared for shipment to an offsite facility for regeneration and reuse. Regeneration of the granular activated carbon requires heating it in a hearth furnace to remove the captured volatile organic compounds.

Based on past Hanford Site activities, and the results of characterization sampling, this granular activated carbon could contain residual radioactivity. Characterization sampling results were used to determine specific radionuclides of concern for this residual radioactivity. For any potential residual radioactivity, [DOE O 458.1](#), Chg. 2 requires that the residual radioactivity not exceed established guidelines or that radiological release criteria (i.e., authorized limits) be developed and submitted to the applicable DOE field office. Following review by RL and HQ personnel in October 2008, approved authorized limits for offsite shipment and regeneration of granular activated carbon was approved for use by CHPRC.

In anticipation of placing the new 200-West Area Pump and Treat facility online, increasing the volume of spent granular activated carbon being sent offsite, a request to modify the authorized limits was made by CHPRC and approved by DOE in October 2010 (Table 4.8). This modification to the authorized limits does not change the expected dose to the public.

Approximately 196,577 pounds (89,166 kilograms) of granular activated carbon was shipped offsite in 2014 for regeneration under these approved modified authorized limits.

*Table 4.8. Approved Modified Authorized Limits for Offsite Shipment and Regeneration of Granular Activated Carbon*

Radionuclide	Authorized Limit (pCi/g)
Americium-241	29
Carbon-14	3,000
Cesium-137	80
Cobalt-60	21

*Table 4.8. Approved Modified Authorized Limits for Offsite Shipment and Regeneration of Granular Activated Carbon*

<b>Radionuclide</b>	<b>Authorized Limit (pCi/g)</b>
Europium-152	40
Europium-154	40
Europium-155	700
Iodine-129	50
Neptunium-237	50
Nickel-63	100
Plutonium-238	26
Plutonium-239	24
Plutonium-240	24
Protactinium-231	10
Selenium-79	2,000
Strontium-90	100
Technetium-99	500
Thorium-232 plus progeny	6
Tritium	300,000
Uranium-234	100
Uranium-235	100
Uranium-238 plus short-lived progeny	100

### 4.3.3 Tri-Cities Development Council (TRIDEC) Land Conveyance

The [DOE O 458.1](#), Authorized Limits for the radiological release of the proposed land conveyance to TRIDEC were approved in December 2013. In 2014, field work was completed, and sample and survey results determined that the authorized limits were met. An Independent Verification contractor, Oak Ridge Associated Universities, has completed independent verification field and close out activities.

## 5.0 Environmental Restoration and Waste Management

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Environmental restoration and waste management activities continued on the Hanford Site during 2014. The following sections describe ongoing Hanford Site River Corridor closure, cleanup, remediation, facility decommissioning, waste management operations, underground waste storage tank status, construction of the WTP and its associated facilities, and research activities related to waste cleanup.

### 5.1 Cleanup and Remediation Activities

The following sections describe ongoing cleanup and remediation activities at the Hanford Site

#### 5.1.1 River Corridor Closure

*JA Lerch*

The 220-square-mile River Corridor includes the Hanford Site 100 Area and 300 Area, which border the Columbia River. The River Corridor includes nine deactivated plutonium-production reactors, numerous support facilities, and liquid- and solid-waste disposal sites. DOE's focus is to complete source cleanup actions in the 100 and 300 Areas with the following principal goals:

- ⊗ Deactivate, decontaminate, decommission, and demolish excess facilities
- ⊗ Place former production reactors in an interim safe and stable condition
- ⊗ Remediate liquid- and solid-waste disposal sites
- ⊗ Meet all regulatory requirements
- ⊗ Determine the adequacy of the current cleanup criteria in protecting human health and the environment
- ⊗ Prepare the River Corridor for transition to the DOE-RL long-term stewardship program (surveillance and maintenance).

The Tri-Party Agencies agreed in 1991 to a strategy to apply available funding to actual cleanup rather than spending available resources on extensive characterization and risk assessment activities. Waste site cleanup under interim action RODs were initiated in the 100 and 300 Areas during the mid-1990s and continue today within the River Corridor. As the interim actions are completed, associated geographical areas are transitioned into the RL long-term stewardship program. Through 2014, transitions have been completed for 153 of the 220 square miles of the River Corridor.

In parallel with continued cleanup activities, the remedial investigation/feasibility study (RI/FS) process is being implemented for six decision areas of the River Corridor (100-B/C, 100-K, 100-N, 100-D/H, 100-F/IU-2/IU-6, and 300 Area) to integrate the interim actions and establish final cleanup decisions for source and groundwater operable units. Final action RODs were issued in November 2013 ([DOE/EPA/Ecology 2013](#)) for the 300 decision area and in September 2014 ([DOE/EPA 2014](#)) for the 100-F/IU-2/IU-6 decision area. Completion of RI/FS reports, public review of proposed actions, and development of RODs for the remaining four decision areas are anticipated to be complete between 2015 and 2017.

#### 5.1.2 100 Area

This section describes ongoing cleanup and remediation activities in the 100 Area.

### 5.1.2.1 100-B/C, 100-D, 100-F, 100-K, 100-H, and 100-N Areas Waste Sites

*DG Saueressig*

The 100 Area waste sites vary in complexity and waste type. Typical waste sites include waste burial grounds, liquid effluent waste sites, burn pits, retired septic systems, piping systems, and miscellaneous waste sites. Full-scale remediation of waste sites in the 100 Areas began in 1996 with the primary focus on waste sites receiving liquid waste because those sites generally contained significant quantities of contaminants and served as potential sources for groundwater contamination. In 2014 the 100 Area remediation activities were completed for 100-B/C, 100-D, 100-H, 100-N, and IU-2/6 Areas. Remediation activities focused on hexavalent chromium release sites, pipeline sites and miscellaneous waste sites. Due to the high mobility associated with past hexavalent chromium releases, excavation to groundwater is often necessary to ensure complete remediation of these sites.

Miscellaneous waste sites vary in the nature and extent of contamination and are generally smaller-size areas when compared to hexavalent chromium release sites. Sampling requirements for determining if a miscellaneous waste site requires cleanup or complies with post-cleanup goals can vary significantly from one waste site to another. The interim action RODs for 100 Area waste sites and the *Action Memorandum for General Hanford Site Decommissioning Activities* ([DOE/RL-2010-22](#)) authorize remediation activities. Waste generated from the cleanup of waste sites is disposed at ERDF in the 200 Area. This centralized disposal facility is the primary disposal pathway, but other disposal options are available if the material does not meet the waste acceptance criteria for the facility.

A total of 884,500 tons (802,400 metric tons) of contaminated soil and debris from 100 Area remediation activities were disposed at ERDF in 2014. Quantities and respective locations are as follows:

- ⊗ 117,500 tons (106,600 metric tons) from the 100-B/C Area
- ⊗ 478,300 tons (433,900 metric tons) from the 100-D Area
- ⊗ 206,500 tons (187,300 metric tons) from 100-H Area
- ⊗ 53,200 tons (48,300 metric tons) from the 100-N Area
- ⊗ 24,500 tons (22,200 metric tons) from the IU-2/6 Area
- ⊗ 4,500 tons (4,100 metric tons) for miscellaneous restoration activities in the 100 Areas.

### 5.1.2.2 100-K Basins

*BM Barnes and JW McKibben*

The 100-K Area remediation activities included facility demolition, waste site remediation, cleanout of the 100-K West Basin, and groundwater pump-and-treat operations. The K West Basin is the only remaining operating nuclear facility. The K West Basin is undergoing cleanout that involves removing radioactive contaminated sludge and debris as a precursor to facility deactivation and demolition. For nearly 30 years, the basins stored 2,300 tons (2,100 metric tons) of N Reactor spent fuel and a small quantity of slightly irradiated single-pass reactor fuel from other Hanford Site reactors. In October 2004, the major cleanup effort to remove the fuel from the K East and K West Basins was completed.

This fuel corroded during storage and the fuel washing and packaging process left behind approximately 989 cubic feet (28 cubic meters) of sludge. The sludge is currently stored in underwater containers in the K West Basin for subsequent removal and disposition. The project's CERCLA remedial design documentation will describe the means of sludge treatment and location of the national repository for sludge disposal. The sludge for subsequent removal and disposition includes the K West Basin knock-out-

pot sludge, K West Basin settler tube sludge, and K East Basin floor and pit sludge. The K West Basin fuel cleaning system transferred sludge generated from the cleaning of fuel to either knock-out-pots or settler tanks. Knock-out-pots collect particles greater than 0.02 inch (500 microns) in size by using either a downstream strainer or an internal screen. Settler tanks, a series of horizontal tubes downstream of the knock-out-pots, allow particles less than 0.02 inch (500 microns) to settle and not be recirculated. The basin floor and pit sludge is a non-homogenous mixture of debris that includes windblown sand and environmental particulates; concrete fragments from the basin walls; corrosion products from fuel canisters and fuel racks; fuel cladding pieces; tiny pieces of corroded uranium (uranium oxides, hydrates, and hydrides); ion-exchange resin beads; PCBs; and fission products. Sludge has been defined as any material that is less than or equal to 0.25 inch (0.64 centimeter) in size.

#### **5.1.2.2.1 100-K Area Remediation Progress and Accomplishments (2014)**

- ⊗ Continued 105-KE Reactor Building interim safe storage activities, engineering for reactor penetration sealing and the safe storage enclosure
- ⊗ Continued construction activities on the 100-K Annex in support of sludge removal operations.
- ⊗ Continued groundwater pump-and-treat operations
- ⊗ Continued testing systems and components to be used to remove K Basins sludge at the Maintenance and Storage Facility located in the 400 Area prior to deployment to the K West Basin and its radiological environment.

#### **5.1.2.2.2 K Basins Progress on Defense Nuclear Facilities Safety Board Recommendations**

*RA Quintero*

In a letter dated April 23, 2014 ([DNFSB 2014a](#)), to the DOE-RL manager, *Board Closes the Remaining Issue Concerning the Preliminary Design and Safety Basis for Phase I of the Sludge Treatment Project (STP) Richland Operations Office (RL)*, the Defense Nuclear Facilities Safety Board (DNFSB) closed the Hanford Site, K-Basin Closure Sludge Treatment Project, a previously identified issue concerning safety instrumented systems.

In a letter dated May 2, 2014 ([DNFSB 2014b](#)), to the DOE-RL manager, *Board Summary of Sludge Treatment Project Final Design and Safety Basis*, the DNFSB reiterated its closure of the aforementioned issue for the Hanford Site, K-Basin Closure Sludge Treatment Project, as well as a previously identified issue concerning Non-Bounding Spray Leak Consequence Analysis as reported in their *Report to Congress on the Status of Significant Unresolved Technical Differences between the Board and the Department of Energy on Issues Concerning the Design and Construction of DOE's Defense Nuclear Facilities*, dated December 26, 2013 ([DNFSB 2013](#)).

By issuing the *Report to Congress on the Status of Significant Safety Issues Concerning the Design and Construction of DOE's Defense Nuclear Facilities*, dated May 16, 2014 ([DNFSB 2014c](#)), and *Report to Congress on the Status of Significant Unresolved Issues with the DOE's Design and Construction Projects*, dated September 19, 2014 ([DNFSB 2014d](#)), the DNFSB resolved all previously identified issues for the Hanford Site, K-Basin Closure Sludge Treatment Project.

### 5.1.3 200 Area – Central Plateau

PA Burke

The Central Plateau is a 75-square-mile (194-square-kilometer) region near the center of the Hanford Site, which includes the area designated in [DOE/EIS-0222-F](#) and ROD ([64 FR 61615](#)) as the Industrial-Exclusive Area, a rectangular area of about 20 square miles (52 square kilometers) in the center of the Central Plateau. The Industrial-Exclusive Area contains the 200-East and 200-West Areas, used primarily for Hanford Site nuclear fuel processing and waste management and disposal activities. The Central Plateau also encompasses the CERCLA 200 Area NPL site. The Central Plateau has a large physical inventory of chemical processing and support facilities, tank systems, liquid- and solid-waste disposal and storage facilities, utility systems, administrative facilities, and groundwater monitoring wells.

The *Hanford Site Cleanup Completion Framework* ([DOE/RL-2009-10](#)) defines the path forward for cleanup at the Hanford Site. The framework document defines the main components of cleanup in two main geographic areas—the River Corridor and Central Plateau. As a result of the goals established in [DOE/RL-2009-10](#), the Tri-Party Agencies developed changes to the TPA that reflect the path forward for Central Plateau cleanup.

The Central Plateau includes two principal cleanup areas: the Inner and Outer Areas (Figure 5.1):

**Inner Area.** This area contains major nuclear fuel processing, waste management, and disposal facilities, and is defined as the final footprint area of the Hanford Site that will be dedicated to permanent waste management and containment of residual contamination. The Inner Area is anticipated to be approximately 10 square miles (26 square kilometers) and will remain under federal ownership and control for as long as potential hazards exist.

**Outer Area.** This area is defined as areas of the Central Plateau beyond the boundary of the Inner Area. Completing cleanup for the approximately 65-square-mile (168-square-kilometer) Outer Area will reduce the active footprint of cleanup for the Central Plateau to the Inner Area.

#### 5.1.3.1 Inner Area

The Inner Area (anticipated to encompass approximately 10 square miles (26 square kilometers)) is the projected final footprint region of the Hanford Site. Dedicated to waste management and residual contamination containment, it will remain under federal ownership and control as long as potential hazards exist. Operable units within the Inner Area include those described in the following subsections.

##### 5.1.3.1.1 200-PW-1, 200-PW-3, 200-PW-6, and 200-CW-5 Operable Units

This operable unit group includes 22 waste sites located in the 200 East and 200 West Areas that are contaminated with plutonium or cesium from processing activities at PFP and the Plutonium Uranium Extraction (PUREX) Plant. Specific sites are listed in the *Hanford Federal Facility Agreement and Consent Order Action Plan* ([Ecology/EPA/DOE 1989b](#)), [Appendix C](#). At EPA's request, the Tri-Party Agencies agreed to retain the 200-PW-1, 200-PW-3, 200-PW-6 Operable Unit group and the 200-CW-5 Operable Unit and consolidate them into a single decision (Table 5.1).



Table 5.1. Central Plateau Operable Unit Structure

New Operable Unit Group	Description	Predecessor Operable Units		Lead Regulatory Agency
Inner Area				
200-PW-1/3/6, 200-CW-5	Plutonium-contaminated soil sites located near the PFP and cesium-contaminated sites near the Plutonium Uranium Extraction Plant (PUREX)	No change		EPA
200-WA-1 and 200-BC-1	Soil waste sites located in the 200 West Inner Area that are not included in the 200-SW-2, 200-CR-1, 200-PW-1, 200-PW-6, 200-CW-5, and 200-IS-1 Operable Units; Soil waste sites in the BC Cribs and Trenches	200-BC-1 200-LW-1/2 200-MG-1/2 200-MW-1 200-PW-2/4	200-SC-1 200-TW-1/2 200-UR-1 200-UW-1	EPA
200-EA-1	200-East Inner Area that are not included in the 200-SW-2, 200-CB-1, 200-CP-1, and 200-PW-3 Operable Units	200-CS-1 200-IS-1 200-LW-1/2 200-MG-1/2	200-MW-1 200-PW-2/4 200-SC-1 200-TW-1/2 200-UR-1	Ecology
200-IS-1	Selected pipelines, diversion boxes, etc., in the Inner Area			Ecology
200-SW-2	Solid waste burial grounds and waste sites in the footprint of the burial grounds	200-CW-1 200-MG-1/2	200-SW-2	Ecology
200-DV-1	Selected soil waste sites in the Inner Area with deep vadose zone contamination	200-TW-1/2	200-PW-5	Ecology
200-CB-1	B Plant Canyon; associated waste sites	200-IS-1 200-MG-1/2 200-MW-1	200-PW-2/4 200-UR-1	Ecology
200-CP-1	PUREX Canyon; Associated waste sites	200-IS-1 200-MG-1/2	200-MW-1 200-UR-1	Ecology
200-CR-1	REDOX Canyon; associated waste sites	200-IS-1 200-MG-1/2	200-UR-1	EPA
Outer Area				
200-OA-1 200-CW-1 200-CW-3	Sites located in the Outer Area	200-CS-1 200-CW-1 200-CW-3 200-IS-1 200-MG-1/2	200-MW-1 200-SW-2 200-UR-1 200-UW-1	EPA

The Record of Decision Hanford 200 Area Superfund Site 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units ([DOE/EPA/Ecology 2011](#)) was issued in December 2011. The selected remedy in the ROD addresses soils and subsurface disposal structures contaminated primarily with plutonium and cesium, two settling tanks, and associated pipelines. The remove, treat, and dispose approach for contaminated soil and debris will be used to address plutonium contaminated soils and subsurface structures, and consists of: 1) removing a portion of contaminated soil, structures, settling tanks, and

associated debris; 2) treating these removed wastes as required to meet disposal requirements at ERDF (see Section 5.4.3.7) or waste acceptance criteria for offsite disposal at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico; and 3) disposing at ERDF or WIPP. The 200-CW-5 Operable Unit, also known as the Z-Ditches, will use the remove, treat, and dispose approach to excavate contaminated soils and dispose at ERDF or the WIPP, as appropriate.

Three of the six 200-PW-1 waste sites, also known as the High-Salt Waste Group, will use the remove, treat, and dispose approach to excavate the highest concentrations of contaminated soils, located up to 2 feet (0.6 meters) below the bottom of the disposal structure, and dispose at ERDF or the WIPP, as appropriate. An evapotranspiration barrier will be constructed over the remaining waste in these waste sites. **200-PW-3 Operable Unit.** This operable unit, also known as the Cesium-137 Waste Group, will require additional backfill for three of the five waste sites to achieve coverage of at least 15.0 foot (4.57 meter) depth. Contamination at the other two waste sites is deeper than 15.0 feet (4.57 meters) from the ground surface and will not require additional backfill.

**200-PW-6 Operable Unit.** This operable unit and three of the six 200-PW-1 waste sites, also known as the Low-Salt Waste Group, will use the remove, treat, and dispose approach to excavate a significant portion, approximately 90 percent, of the contaminated soils to a depth of 33 feet (10 meters) below ground surface, and dispose at ERDF or WIPP, as appropriate. An evapotranspiration barrier will be constructed over the remaining waste in these waste sites. A soil vapor extraction system is being used to remove and treat carbon tetrachloride contamination at waste sites in the High-Salt Waste Group and will continue to be used until vadose zone cleanup levels are met. Soil covers will be used to provide coverage to a depth of at least 15.0 feet (4.57 meters) over cesium-contaminated soils. This consists of maintaining or enhancing the existing soil cover with additional backfill.

Institutional controls and long-term monitoring will be required for waste sites in the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units where waste is left in place and unrestricted land use is precluded.

#### **5.1.3.1.2 200-WA-1/200-BC-1 Operable Unit (200-West Inner Area)**

This operable unit group includes soil waste sites located in the BC Cribs and Trenches and soil waste sites in the Inner Area portion of the 200-West Area not included in the 200-CR-1, 200-CW-5, 200-IS-1, 200-PW-1, 200-PW-6, and 200-SW-2 Operable Units. Specific sites are listed in the TPA Action Plan ([Ecology/EPA/DOE 1989b](#)), [Appendix C](#). Additional sites may be added to the 200-WA-1/200-BC-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). The *Remedial Investigation/Feasibility Study Work Plan 200-WA-1 and 200-BC-1 Operable Units* ([DOE/RL-2010-49](#)) was issued in December 2011. In addition, DOE obtained approval of the *216-U-8 Crib and 216-U-12 Vadose Zone Characterization Sampling and Analysis Plan* ([DOE/RL-2009-94](#)), which supports the 200-WA-1 Operable Unit remedial investigation.

#### **5.1.3.1.3 200-EA-1 Operable Unit (200-East Inner Area)**

This operable unit consolidates the remaining Inner Area sites in the 200-East Area except for the environmental media underlying tank farm waste management areas (WMA), landfills in the 200-SW-2 Operable Unit, PUREX, B Plant Canyon, and several waste sites with deep vadose zone contamination that are adjacent to WMA environmental media sites. Specific sites are listed in the TPA

Action Plan ([Ecology/EPA/DOE 1989b](#)), [Appendix C](#). Additional sites may be added to the 200-EA-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). The 200-EA-1 Operable Unit will make use of a comprehensive application of the technical cleanup principles for the Inner Area developed for the 200-WA-1 Operable Unit.

Analysis for the 200-EA-1 Operable Unit will follow the same pattern as the 200-WA-1 Operable Unit and will utilize the same technical basis documents and comprehensive alternatives evaluation to clearly demonstrate how selected remedies for each fit within the framework of impacts from the entire Inner Area. The 200-EA-1 work plan has not been initiated.

#### **5.1.3.1.4 200-IS-1 Operable Unit**

This operable unit includes select inactive waste transfer pipelines and pipeline components in the 200-IS-1 Operable Unit and soil waste sites in the Inner Area portion of the 200-East Area that are not included in the canyon area operable units or in the tank farm WMAs. Specific sites are listed in the TPA Action Plan ([Ecology/EPA/DOE 1989b](#)), [Appendix C](#).

The Tri-Party Agencies agreed to use a coordinated CERCLA remedial action and RCRA corrective action process for cleanup decisions in the pipelines operable unit group. The *200-IS-1 Operable Unit Pipeline System Waste Sites RFI/CMS/RI/FS Work Plan* ([DOE/RL-2010-114](#)) was issued in September 2011.

#### **5.1.3.1.5 200-SW-2 Operable Unit (Burial Grounds)**

This operable unit includes 24 landfills located in the 200-East and 200-West Areas. Three soil waste sites located within the boundary of one of the burial grounds were added to the 200-SW-2 Operable Unit during restructuring. Specific sites are listed in the TPA Action Plan ([Ecology/EPA/DOE 1989b](#)), [Appendix C](#). Portions of the burial grounds listed in the RCRA Permit (WA7890008967) include TSD facilities. DOE is working with Ecology to remove unused areas from the permit scope.

The Tri-Party Agencies agreed to use a coordinated CERCLA remedial action and RCRA corrective action process for cleanup decisions in the 200-SW-2 Operable Unit. The *200-SW-2 Radioactive Landfills Group Operable Unit RCRA RFI/CMS/RI/FS Work Plan* ([DOE/RL-2004-60](#)) was issued in March 2015.

#### **5.1.3.1.6 200-DV-1 Operable Unit (Deep Vadose Zone)**

This operable unit includes 43 soil waste sites located in the Inner Area. The sites in this operable unit were previously located in the 200-TW-1/2 and 200-PW-5 Operable Units. Specific sites are listed in the *TPA Action Plan* ([Ecology/EPA/DOE 1989b](#)), [Appendix C](#). The *Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-DV-1 Operable Unit*, [DOE/RL-2011-102](#), Draft A, was submitted to the Washington State Department of Ecology for review on March 18, 2015. The *Characterization Sampling and Analysis Plan for the 200-DV-1 Operable Unit*, [DOE/RL-2011-104](#), was issued on January 17, 2012. The *Long-Range Deep Vadose Zone Program Plan* ([DOE/RL-2010-89](#)), issued in October 2010, summarizes the state of knowledge about contaminant cleanup challenges faced by the deep vadose zone beneath the Central Plateau and the approach to solving those challenges.

**5.1.3.1.7 200-CB-1 Operable Unit (B Plant Canyon)**

This operable unit includes the B Plant Canyon Building (221-B) and the Waste Encapsulation Storage Facility (WESF), along with exterior ventilation system components for each structure (e.g., HEPA filters and sand filter) and 17 soil waste sites within the vicinity. Specific sites are listed in the TPA Action Plan ([Ecology/EPA/DOE. 1989b](#), [Appendix C](#)). Additional sites may be added to the 200-CB-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). Sites near the B Plant Canyon currently assigned to the 200-IS-1 Operable Unit may be reassigned to the 200-CB-1 Operable Unit, pending the outcome of discussions among the Tri-Party Agencies. Cesium and strontium capsules located in the WESF are not included in the scope of the 200-CB-1 Operable Unit.

**5.1.3.1.8 200-CU-1 Operable Unit (U Plant Canyon)**

This operable unit includes the U Plant Canyon Building (221-U) and other structures included in the ROD for the U Plant Canyon ([DOE/EPA/Ecology](#), *Record of Decision 221-U Facility [Canyon Disposition Initiative] Hanford Site Washington*). The U Plant Canyon Disposition Initiative is a pilot project for disposition of the five canyon buildings in the 200-East and 200-West Areas. Implementation of the selected remedial action (close in place – partially demolished structure) began in 2009.

**5.1.3.1.9 200-CP-1 Operable Unit (PUREX Canyon)**

This operable unit includes the PUREX Canyon Building (202-A), PUREX Storage Tunnels (218-E-15 and 218-E-16), exterior components of the ventilation system for each structure (e.g., deep bed filters), and 20 soil waste sites in the vicinity. Specific sites are listed in the TPA Action Plan ([Ecology/EPA/DOE. 1989b](#), [Appendix C](#)). Additional sites may be added to the 200-CP-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). Sites near the PUREX Canyon currently assigned to the 200-IS-1 Operable Unit may be reassigned to the 200-CP-1 Operable Unit, pending the outcome of discussions among the Tri-Party Agencies. The 200-CP-1 work plan has not been initiated.

**5.1.3.1.10 200-CR-1 Operable Unit (REDOX Canyon)**

This operable unit includes the REDOX Canyon Building (202-S), exterior components of the ventilation system (e.g., filters), and 12 soil waste sites located in the vicinity. Specific sites are listed in the TPA Action Plan ([Ecology/EPA/DOE 1989b](#), [Appendix C](#)). Additional sites may be added to the 200-CR-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). Sites near the REDOX Canyon Building currently assigned to the 200-IS-1 Operable Unit may be reassigned to the 200-CR-1 Operable Unit, pending the outcome of discussions among the Tri-Party Agencies. The 200-CR-1 work plan has not been initiated.

**5.1.3.2 Outer Area**

The Outer Area is defined as all areas of the Central Plateau beyond the boundary of the Inner Area. The Outer Area covers approximately 65 square miles (168 square kilometers) and contains more than 90 waste sites and structures scattered throughout the largely undisturbed sagebrush-steppe habitat. Most of the waste sites in the Outer Area are small near-surface sites that will be removed for treatment as needed for onsite disposal or sampled to confirm that no additional action is required, apart from implementing appropriate institutional controls. The largest components of Outer Area remediation are

ponds where cooling water and chemical sewer effluents were discharged and the BC Control Area where surface contamination was spread through animal intrusion.

#### **5.1.3.2.1 200-OA-1, 200-CW-1, and 200-CW-3 Operable Units (Outer Area)**

Soil waste sites in the Outer Area requiring cleanup are assigned to one of the following three operable units:

**200-CW-1 Operable Unit.** Contains ponds that were used for discharging large volumes of cooling water and other effluents with low levels of contamination or that were only potentially contaminated. There are 14 sites in the 200-CW-1 Operable Unit, including eight ponds and associated sewer lines, control structures, and unplanned releases.

**200-CW-3 Operable Unit.** Contains 16 sites that were associated with operating the 200 North Area, a small complex initially used for temporary storage of spent nuclear fuel and later for storing miscellaneous materials and rail cars. The soil waste sites (trenches, small ponds, septic tanks, and sewer lines) were cleaned up as part of interim actions conducted from 2005 through 2010.

**200-OA-1 Operable Unit.** Contains the remaining soil waste sites in the Outer Area that require cleanup under CERCLA, currently totaling 63 sites (debris and solid waste dumping areas, small liquid discharge sites, septic and sewer system components, and unplanned releases). Additional sites could be added as cleanup progresses and sites are discovered, or as existing non-CERCLA sites are reclassified.

The 200-OA-1, 200-CW-1, and 200-CW-3 Operable Unit group incorporates soil waste sites from several previous operable units. The *200-CW-3 Operable Unit Interim Remedial Action Report* ([DOE/RL-2011-58](#)) was issued in September 2011. The summary of waste site remediation activities, cleanup verification processes, and cost information will support developing a final remedial action for the Outer Area of the Hanford 200 Area NPL site.

#### **5.1.3.2.2 Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill (NRDWL)**

The NRDWL and SWL are located in the Outer Area and are not included in the operable units described above. The NRDWL is a RCRA-permitted disposal facility for dangerous waste generated at the Hanford Site that was not contaminated with radioactive materials. The NRDWL received dangerous waste from 1975 through 1985, as well as asbestos waste through 1988, and sanitary solid waste during 1976. The SWL is a non-RCRA solid waste landfill south of the NRDWL. The SWL received non-dangerous and nonradioactive solid waste, including paper, construction debris, asbestos, and lunchroom waste from 1973 through March 1996. The SWL also received up to 1.3 million gallons (5 million liters) of sewage and 100,000 gallons (380,000 liters) of garage wash water.

Because the NRDWL is a RCRA-permitted TSD site, closure is being managed in accordance with [WAC 173-303](#). The Solid Waste Landfill is regulated under [WAC 173-350](#).

### **5.1.4 300 Area**

#### *DG Saueressig and CP Strand*

Beginning in 2002, the 300-FF-2 Operable Unit interim ROD ([EPA/ROD/R10-01-119](#)) authorized remediation activities for the 300-FF-2 Operable Unit. Today, remediation activities continue under the 300-FF-2 final ROD ([DOE/EPA/Ecology 2013](#)) issued in November 2013, which authorizes remediation activities and the alternative remediation method of enhanced attenuation of uranium using sequestration in the vadose zone, periodically rewetted zone, and the top of the aquifer. In 2014, remediation focused



on the 300-FF-2 Operable Unit waste sites, where sampling was performed to determine whether suspect waste sites exceeded cleanup objectives; confirm that cleanup objectives were met; and conduct physical excavation operations; sort and segregate waste; sample, treat, and dispose of waste; and backfill and revegetate the affected sites.

Waste generated from the cleanup of waste sites in the 300-F-2 Operable Unit was disposed at the ERDF, located on the Central Plateau, and other EPA-approved disposal facilities. In 2014, approximately 489,000 tons (436,600 metric tons) of contaminated soil from the 300-FF-2 Operable Unit were disposed at the ERDF. In addition, the 340 Building remediation and 340 Vault removal were completed, and final below-grade demolition of the 309 Plutonium Recycle Test Reactor continued. Remedial actions have been initiated on all remaining waste sites south of Apple Street in the 300 Area.

The 618-10 Burial Ground (Figure 5.1), located just west of Route 4 South, was operated from 1954 to 1963. It is approximately 5.2 acres (2.1 hectares) in size. The 618-11 Burial Ground, located close to the Energy Northwest Columbia Generating Station, operated from 1962 through 1967 and is approximately 8.6 acres (3.5 hectares) in size. Both burial grounds received waste, including transuranic material, from the 300 Area laboratory facilities. The burial grounds consist of multiple trenches, vertical pipe units, and caissons. The 618-11 Burial Ground contains trenches, vertical pipe units and four caissons. Remediation of the 618-11 Burial Ground will commence after the 618-10 Burial Ground remediation is completed.



*Figure 5.1. 618-10 Burial Ground*

Waste burial grounds require cleanup, but also present a significant health and safety risk to workers because of incomplete waste disposal records and the potential for discovering unknown material from past disposal practices. This unknown material may require further characterization. Characterization is critical to ensure worker safety and proper management of waste for potential treatment and disposal. When characterizing material to verify that limits and controls identified in approved work authorization documents are adequate for the work scope, additional time and planning is required to ensure proper protective gear is used in the field when unknown material is discovered. If work authorization documents do not adequately cover the material discovered, work is stopped until the documents can be revised and work can be safely restarted. Based on the characterization results, additional waste treatment may be required before disposal.

Remediation of the 618-10 Burial Ground trenches began in April 2011 and continued through 2014. The 2014 activities focused on burial ground trenches (Figure 5.2). Future activities will include remediation of vertical pipe units that consist of the following three configurations:

- ⊗ Carbon steel pipes up to 15-feet (4.6-meters) long and 10 to 24 inches (25 to 61-centimeters) in diameter.
- ⊗ Corrugated steel pipes up to 15-feet (4.6-meters) long and 14 inches (36 centimeters) in diameter.
- ⊗ Drums 14.4-feet (4.4-meters) long, 22-inches (56-centimeters) in diameter, and vertical pipe units constructed from 55-gallon (209-liter) drums.
- ⊗ These drum style vertical pipe units (VPU) were constructed by welding five 55-gallon (209-liter) bottomless drums together end-to-end and burying them vertically. The VPUs are generally open to the soil at the bottom and closed at the top with a concrete cover. The current remediation planned for the corrugated style and drum style VPUs will involve installation of a 48-inch (122-centimeter) steel over-casing around each vertical pipe unit. Each VPU will be augured to size-reduce it, its contents, and the soil within the over-casing. The material will be mixed with water, amended water, or flowable grout prior to retrieval from the over-casing. The material will then be removed, stabilized as necessary, and packaged for either storage or disposal depending on the radiological content of the material. The current remediation plan for the carbon steel VPUs involves exposing small sections of the VPU, covering it in a flowable grout, and processing it with a shear. The material will then be removed and packaged either for storage or disposal depending on the radiological content of the material.



Simulated VPUs were constructed and buried in preparation for the method testing.



Material in a simulated drum style VPU is augured during method testing.



The project team evaluating the simulated waste after being augured.

*Figure 5.2. 618-10 Proof-of-Concept Testing*

## 5.2 Facility Decommissioning Activities

This section provides information regarding the transition of Hanford Site facilities from stabilization to surveillance and maintenance and eventual decommissioning. Decommissioning activities include the interim safe storage of plutonium production reactors and deactivation and decommissioning of facilities in the 100, 200, 300, and 400 Areas, and ancillary reactor facilities.



### 5.2.1 100 Area

#### *DG Saueressig and CP Strand*

Deactivation, decontamination, decommissioning, and demolition activities in the 100 Area during 2014 included demolition actions at the 100-B, 100-D, and 100-N Areas. The activities were conducted as non-time-critical removal actions under CERCLA. Listed below are the 100 Area facilities demolished in 2014.

- ⊗ 183-D Water Treatment Plant (Figure 5.3)
- ⊗ 151-B Primary Electrical Substation
- ⊗ 181-N Cable Float Barriers
- ⊗ M0-474 (mobile office).



Figure 5.3. 183-D Water Treatment Plant

### 5.2.2 200 Area – Central Plateau

Central Plateau facilities include buildings and waste sites in the 200 East, 200 West, and 200 North Areas, as well as those on the adjoining Rattlesnake Unit (Fitzner/Eberhardt Arid Lands Ecology Reserve). The transition toward decommissioning encompasses surveillance, maintenance, and deactivation activities.

#### 5.2.2.1 Plutonium Finishing Plant Decommissioning Progress

##### *WG Cox*

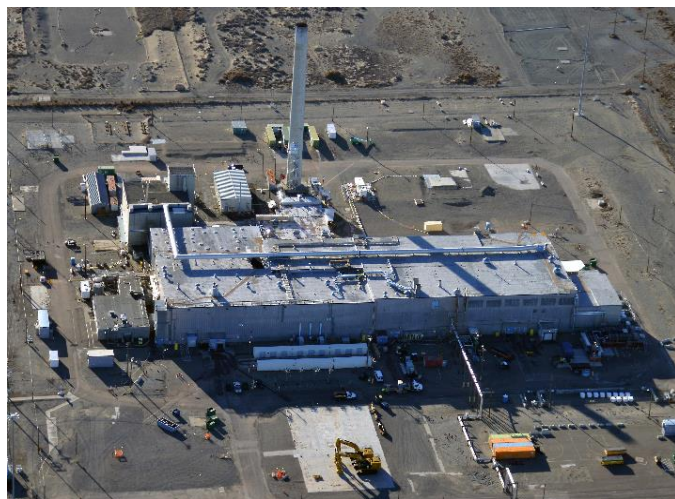


Figure 5.4. Plutonium Finishing Plant

The PFP began processing plutonium nitrate solutions into metallic plutonium during 1949 for shipment to nuclear weapons-production facilities. Operation of this plant continued into the late 1980s. DOE issued a shutdown order for PFP in 1990 and, in 1996, authorized the deactivation and transition of plutonium-processing portions of the facility in preparation for decommissioning.

All special nuclear materials and stored fuel elements have been removed from the plant, and security was downgraded by the end of 2009. The removal and disposal of process equipment, chemicals, glove boxes, and hoods

from the buildings began in 2009 and continued through 2014. The following sections describe the significant accomplishments at PFP during 2014 (Figure 5.4).

##### 5.2.2.1.1 Plutonium Finishing Plant Complex

During 2014, the 270-Z and 2704-Z buildings were demolished, and six mobile offices were removed from the complex.

**5.2.2.1.2 234-5Z, Plutonium Finishing Plant**

Removal of plutonium-contaminated process equipment continued, with a particular focus on removing gloveboxes, associated piping, and ductwork. The total gloveboxes removed to date is now 94 percent complete. The following removals were completed in 2014:

- ⊗ Removed 21 gloveboxes – 94 percent of all PFP glove boxes and hoods
- ⊗ Removed 580 linear feet of asbestos for a total of 18,071 feet (75 percent complete)
- ⊗ Removed 667 linear feet of E4 ducting in 234-5Z duct level for a total of 1,479 feet (18 percent complete).

**5.2.2.1.3 236-Z, Plutonium Reclamation Facility (PRF)**

- ⊗ Removed, size reduced, and dispositioned 53 pencil tank units (88 percent complete).

**5.2.2.2 Canyon Disposition Initiative**

*BJ Dixon*

The Canyon Disposition Initiative was created to investigate the potential for using the five former chemical separations facilities (B Plant, T Plant, U Plant, PUREX Plant, and REDOX Plant) in the 200 Areas as disposal facilities for Hanford Site remediation waste rather than demolishing these canyon buildings. The U Plant was selected as the pilot project for the Canyon Disposition Initiative.

The remaining canyon buildings are to be addressed on a case-by-case basis, building on previous canyon disposition work.

Planning and sampling activities to support preparation of a CERCLA feasibility study for implementing the Canyon Disposition Initiative at U Plant began in the mid-1990s. In fall 2005, EPA issued a ROD ([DOE/EPA/Ecology 2005](#)), with a remedy that calls for the process equipment already in U Plant to be consolidated into the belowground plant process cells, and for the cells, two lower galleries, and other void spaces to be filled with grout. The exterior walls and roof would then be collapsed in place, and the site would be covered with an engineered barrier.

Implementation of the selected alternative began in 2009 for the 221-U Facility. By October 2011, the equipment consolidation phase had been completed, and facility voids below the canyon deck level (process cells, hot pipe trench, piping and electrical galleries, drain header, process sewer, and ventilation tunnel and ducts) were filled with grout in accordance with the *Remedial Design/Remedial Action Work Plan for the 221-U Facility* ([DOE/RL-2006-21](#)). The 221-U Plant facility actions were limited to surveillance and maintenance during 2014.

### 5.2.3 300 Area

#### CP Strand

Deactivation, decontamination, decommissioning, and demolition activities in the 300 Area (Figure 5.5) continued to focus on removing physical barriers to perform remedial actions in the 300-FF-2 Operable Unit. These activities were conducted as non-time-critical removal actions under CERCLA in accordance with *Action Memorandum #1 for the 300 Area Facilities* ([DOE/EPA 2005](#)), *Action Memorandum #2 for the 300 Area Facilities* ([DOE/EPA 2006a](#)), and *Action Memorandum #3 for the 300 Area Facilities* ([DOE/EPA 2006b](#)).

Additionally, [DOE/RL-2010-22](#) authorized deactivation, decontamination, decommissioning, and demolition activities for several other 300 Area facilities.



Figure 5.5. 300 Area

During decommissioning and decontamination activities at the 324 Building in late 2009, a breach in the Radiochemical Engineering B-Cell floor liner was noted in the bottom of a sump. Radiological dose measurements of approximately 14,000 rad/hour were observed at the failure location, indicating a possible release occurred during past operations from the 324 Building. Casings containing closed-end push probes were installed in November 2010 under B-Cell at the northern corner of the 324 Building. Dose measurements taken from these probes showed peak radiation readings of 8,900 rad/hour, confirming a significant source term from within B-Cell had been released to the soil column beneath the 324 Building. Additional probes to greater depths, and reviews of down-gradient monitoring wells, confirmed that contamination had not come into contact with the groundwater. Characterization sampling of the contaminated soils has been performed, and ongoing engineering evaluations are being used to develop a retrieval methodology that is protective of both workers and the environment. In November 2014, six additional push probes were installed under B-Cell along the west footing. Higher peak radiation readings of 12,700 rad/hour were observed. This new information is being considered as the 324 Building remedial design advances.

Decommissioning efforts in 2014 included significant progress on continuing to remove the below-grade portions of the 309 Plutonium Recycle Test Reactor (Figure 5.6). The 340 Waste Neutralization Facility vault was successfully lifted and transported to ERDF for disposal. With the exception of the ongoing work at the 309 below-grade structure, all remaining surplus 300 Area facilities were demolished in 2014.



The 300 Area buildings and structures demolished in 2014 are as follows:

- ⊗ 309 Plutonium Recycle Test Reactor Core
- ⊗ 310 Retention Transfer System
- ⊗ 320 Boiler Annex (slab)
- ⊗ 340 Vault
- ⊗ 342 Lift Station Complex
- ⊗ 351 Electrical Substation (B3S4)
- ⊗ 352-F Switch Station (C3S4)
- ⊗ 3730 Gamma Irradiation Facility  
(below-grade)
- ⊗ 3790 Central Badging
- ⊗ MO-745 (mobile office)
- ⊗ MO-767 (mobile office)
- ⊗ MO-827 (mobile office)



Figure 5.6. 309 Plutonium Recycle Test Reactor Demolition

## 5.2.4 400 Area

*DR Turlington*

This section provides information on the Fast Flux Test Facility.

### 5.2.4.1 Fast Flux Test Facility

FFTF is a formerly operating 400-megawatt (thermal) liquid-metal cooled (sodium) research and test reactor located in the 400 Area (Figure 5.7). Built in the late 1970s, the original mission of the facility was to develop and test advanced fuels and materials, and to serve as a prototype facility for future Liquid Metal Fast Breeder Reactor Programs. Other missions were also pursued. FFTF operated from April 1982 to April 1992 and provided the nuclear industry with significant advances



Figure 5.7. Fast Flux Test Facility

in fuel performance, medical isotope production, material performance, and passive and active safety systems testing. The reactor was placed in a standby mode in December 1993. After multiple studies, a decision was made to complete facility deactivation, including removing all nuclear fuel, draining the sodium systems, and deactivating systems and equipment to place the facility in a low-cost, long-term surveillance and maintenance condition, the facility deactivation was completed in June 2009. FFTF remains in a long-term surveillance and maintenance condition, and routine surveillances are performed on an annual basis.

The FFTF decommissioning was included in [DOE/EIS-0391](#), issued on November 12, 2012; and the supplement analysis ([DOE/EIS-0391D-SA-01](#)) issued in February 2012, which concluded there were no substantial changes. The preferred action for the FFTF is entombment, which would remove all above-

grade structures, including the reactor building. The below-grade structures, the reactor vessel, piping, and other components would remain in place and be filled with grout to immobilize the remaining radioactive and hazardous constituents. Waste generated from these activities would be disposed at IDF, with an engineered modified RCRA Subtitle C barrier constructed over the filled area. Remote-handled special components would be processed at Idaho National Laboratory and returned to Hanford. Bulk sodium inventories would be processed at Hanford for use in the WTP. DOE issued the final record of decision on FFTF decommissioning on December 13, 2013 ([78 FR 75913](#)).

## 5.3 Waste Management Activities

This section provides information regarding Hanford Site liquid and solid waste management.

### 5.3.1 Waste Classifications

*WE Toebe*

Hanford Site cleanup operations result in the generation of solid wastes that must be evaluated for proper management. Solid wastes are reviewed against procedures in [WAC 173-303-070](#)(3), “Designation of Dangerous Waste,” and are classified as dangerous when the criteria for this classification are met. The radionuclides in solid waste are exempt from evaluation under [WAC 173-303-070](#)(3), but are subject to evaluation and categorization as transuranic, HLW, or LLW under the [AEA](#). Wastes that contain constituents regulated under both [WAC 173-303](#) and the [AEA](#) are classified as mixed wastes.

Radioactive and/or mixed wastes are managed in several ways. HLW is stored in large underground single-shell and double-shell tanks. LLW typically is stored in tanks or containers. The method used to store LLW depends on the source, composition, and waste concentration. Transuranic waste is stored in vaults, in storage buildings, on aboveground storage pads, and underground pending future retrieval. The DOE *Hanford Site Annual Dangerous Waste Report* lists the dangerous and mixed wastes that are generated, treated, and disposed OF on site or shipped off site. Dangerous and mixed wastes are treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site is shipped off site for treatment and/or disposal. Some types of dangerous waste, such as used lead-acid batteries and aerosol products (e.g., spray paint), are shipped off site for recycling.

Waste that does not contain hazardous or radioactive substances is non-regulated waste. Historically, non-regulated waste generated at the Hanford Site was disposed onsite. Beginning in 1999, non-regulated waste (e.g., refuse and drummed nonhazardous waste) has been disposed at municipal or commercial solid waste disposal facilities. Since 1996, medical waste has been shipped to a commercial medical waste treatment and disposal facility. Non-regulated waste originates at several areas across the Hanford Site. Examples include construction debris, office trash, cafeteria waste, and packaging materials. Other materials and items classified as non-dangerous waste include solidified filter backwash and sludge from the treatment of Columbia River water, failed and broken equipment and tools, air filters, uncontaminated used gloves and other clothing, and certain chemical precipitates (i.e., oxalates). Non-regulated demolition waste from 100 Area decommissioning projects was buried in situ (in place) or in designated disposal locations on the Hanford Site.

### 5.3.2 Solid Waste Inventories

*JF Berger and DE Nester*

The Solid Waste Information and Tracking System is a computer database used to track a portion of mixed and radioactive waste at the Hanford Site, primarily non-CERCLA containerized waste managed by CHPRC, MSA, and WRPS. The database does not include all waste from WCH, ERDF, or any PNNL wastes. The database also does not include high-level radioactive waste volumes managed at Hanford Site tank farms.

Quantities for both mixed and radioactive wastes generated onsite or received from offsite sources and disposed at the Hanford Site, as tracked by the Solid Waste Information and Tracking System database, are shown in Tables 5.2 and 5.3. Quantities of dangerous waste shipped offsite, as tracked by the database, are shown in Table 5.4. Hanford Site solid waste management is discussed in Section 5.3.3.

*Table 5.2. Solid Waste<sup>a</sup> Quantities Generated on the Hanford Site*

Waste Category		2009	2010	2011	2012	2013	2014
Mixed	Tons	281	286	522	305	206	140
	Metric tons	255	260	474	277	187	127
Radioactive	Tons	696	725	4,022	343	513	572
	Metric tons	631	658	3,649	311	465	519

<sup>a</sup> Solid waste includes containerized liquid waste.

*Table 5.3. Solid Waste<sup>a</sup> Quantities Received on the Hanford Site from Offsite Sources*

Waste Category		2009	2010	2011	2012	2013	2014
Mixed <sup>b</sup>	Tons	257	152	320	66	36.5	38.4
	Metric tons	233	138	290	60	33	35
Radioactive <sup>b</sup>	Tons	196	388	257	82	62.8	57
	Metric tons	178	352	233	74	60	52

<sup>a</sup> Solid waste includes containerized liquid waste. Solid waste quantities do not include U.S. Navy reactor compartments.

<sup>b</sup> Total includes Hanford Site-generated waste treated by an offsite contractor and returned as newly generated waste. Includes both low-level radioactive and transuranic waste.

*Table 5.4. Dangerous Waste<sup>a</sup> Quantities Shipped Off the Hanford Site*

Waste Category		2009	2010	2011	2012	2013	2014
Containerized (DW Only)	Tons	47	55	53	18	65.4	103
	Metric tons	42.6 <sup>b</sup>	49.9 <sup>b</sup>	48 <sup>b</sup>	16.3 <sup>b</sup>	59.3 <sup>b</sup>	93.4 <sup>b</sup>
Containerized (MW Only)	Tons	79	37	43	91	50.6	33.7
	Metric Tons	71.7 <sup>c</sup>	33.6 <sup>c</sup>	39 <sup>c</sup>	82.5 <sup>c</sup>	45.9 <sup>c</sup>	30.6 <sup>c</sup>
Bulk Solids (DW Only)	Tons	3.8	20	26	3	—	22.1
	Metric tons	3.5	18.1	23.6	2.7	—	20.1
Bulk Solids (Non-Rad/Non-DW)	Tons	79	210	120	17	—	—
	Metric tons	71.7	191	108.9	15.4	—	—
Bulk Liquids (DW Only)	Tons	2	—	—	—	—	22
	Metric tons	1.8	—	—	—	—	20
Bulk Liquids (Non-Rad/Non-DW)	Tons	—	—	—	—	—	—
	Metric tons	—	—	—	—	—	—
<b>Totals</b>	<b>Tons</b>	<b>211</b>	<b>322</b>	<b>242</b>	<b>129</b>	<b>116</b>	<b>181</b>
	<b>Metric tons</b>	<b>191</b>	<b>292</b>	<b>220</b>	<b>117</b>	<b>105</b>	<b>164</b>

<sup>a</sup> Does not include Toxic Substances Control Act waste.<sup>b</sup> Dangerous waste (DW) only.<sup>c</sup> Mixed waste (radioactive and dangerous).

### 5.3.3 Solid Waste Management

LC Petersen

Solid waste management includes treatment, storage, and disposal of solid waste produced during Hanford Site operations or received from offsite sources authorized by DOE to ship waste to the site.

These facilities are operated and maintained in accordance with state and federal regulations and facility permits. The following sections describe specific waste management locations at the Hanford Site.

#### 5.3.3.1 Central Waste Complex

LC Petersen

The CWC, a solid waste storage facility located in the 200 West Area (Figure 5.8), operates under interim status standards specified in the RCRA Permit (WA7890008967), CWC Part A Form. CWC receives waste from the Hanford Site and offsite sources authorized by DOE to ship waste to the site for treatment, storage, and disposal; however, the majority of waste received at the CWC is generated from ongoing cleanup, research, and development activities at the Hanford Site.

Waste types include low-level, mixed low-level, transuranic, and PCB radioactive. The CWC can store as much as 735,000 cubic feet (20,800 cubic meters) of waste, which is an adequate capacity to store the projected volumes of generated waste from the activities identified above, assuming on-schedule treatment and disposal of the stored waste. An outside storage area was constructed in 2007 to store large containers of suspect transuranic waste from waste retrieval operations. The volume of waste currently stored in the CWC Outside Storage Areas is 195,400



Figure 5.8. Central Waste Complex



cubic feet (5,534 cubic meters), and the volume of waste stored at CWC at the end of 2014 totaled approximately 310,800 cubic feet (8,802 cubic meters).

### 5.3.3.2 Waste Receiving and Processing (WRAP) Facility

*LC Petersen*

The WRAP Facility (Figure 5.9) began operating in 1997 with the mission to analyze, characterize, and prepare drums and boxes of low-level, mixed, and transuranic wastes for disposal. The 52,000-square-foot (4,800-square-meter) facility, along with two 21,500-square-foot (2,000-square-meter) storage buildings, are located north of the CWC in the 200West Area. The WRAP Facility is operating under interim status standards specified in the RCRA Permit (WA7890008967), WRAP Facility Part A Form.



*Figure 5.9. Waste Receiving and Processing Facility*

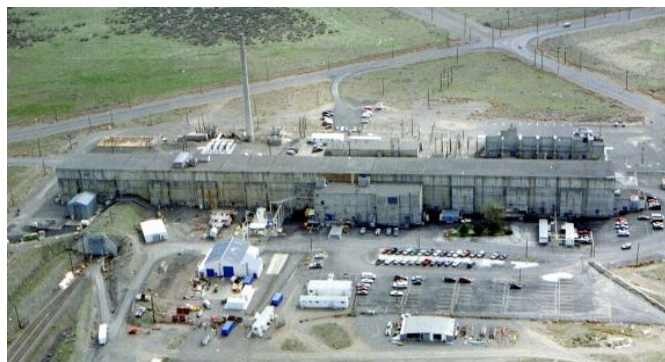
Waste destined for the WRAP Facility includes stored waste as well as newly generated waste from current Hanford Site cleanup activities. The waste consists primarily of contaminated cloth, paper, rubber, metal, and plastic (i.e., debris). Processed waste that qualifies as low-level radioactive waste and meets disposal requirements is buried at the Hanford Site. Low-level radioactive waste not meeting burial requirements is processed at the WRAP Facility for onsite burial or prepared for future treatment at other onsite or offsite TSD facilities. Waste determined to be transuranic is certified and packaged for shipment to the WIPP for disposal.

In response to budget constraints, actions were taken in late 2011 and 2012 to place the WRAP Facility into a layup status until future funding is available to restart the facility. The layup actions during the interim period maintain facility safety, environmental compliance, and operational viability to enhance the transition to operational status at the end of the layup period.

### 5.3.3.3 T Plant Complex

*LC Petersen*

The T Plant Complex (Figure 5.10) is located in the 200 West Area and provides solid waste treatment, storage, and decontamination services for the Hanford Site and offsite facilities. The T Plant Complex is operating under interim status standards specified in the RCRA Permit (WA7890008967), T Plant Complex Part A Form.



*Figure 5.10. T Plant Complex*

### 5.3.3.4 Canister Storage Building (CSB)

LC Petersen

The CSB (Figure 5.11) is a large, 42,000-square-foot (3,906-square-meter) facility located in the 200-East Area. The facility stores about 2,300 tons (2,086 metric tons) of spent nuclear fuel packaged in approximately 400 multi-canister overpacks from the 100-K Basins, 100-N Reactor, and T Plant. The multi-canister overpacks are stored in 220 carbon steel tubes in a below-grade concrete vault. The irradiated fuel was cleaned, packaged, dried, and relocated to the CSB beginning in 2004 to provide safe interim storage in a consolidated location, allowing for cleanup of older facilities, which reduces the cleanup footprint of the Hanford Site and risk. The CSB has a design life of 40 years, and will safely store the multi-canister overpacks until they are permanently placed in a National Repository.



Figure 5.11. Canister Storage Building & Interim Storage Area

Adjacent to the CSB is the Interim Storage Area, which also contains spent nuclear fuel packaged in various containers. This spent nuclear fuel will be subsequently repackaged and sent to a National Repository.

### 5.3.3.5 Low-Level Burial Grounds (LLBG)

LC Petersen and DE Nester

The low-level burial grounds consist of eight separate burial grounds. Two are located in the 200 East Area, and six are located in the 200 West Area. These burial grounds are regulated under the AEA. Two of the burial grounds are used for disposal of LLW and mixed waste (i.e., low-level radioactive waste with a dangerous waste component regulated by [WAC 173-303](#)). The 218-W-5 Burial Ground, located in the 200 West Area, contains Trenches 31 and 34. The 218-E-12B Burial Ground, located in the 200 East Area, contains Trench 94. Trench 94 is dedicated for disposal of defueled U.S. Navy reactor compartments. Trenches that contain mixed LLW are regulated under RCRA. Five burial grounds in the 200 West Area were used to dispose of LLW and/or retrievable storage of transuranic waste, as were portions of the 218-E-12B Burial Ground. The 218-W-6 Burial Ground has never received waste. The LLBGs are operating under interim status standards specified in the RCRA Permit (WA7890008967), Low-Level Burial Grounds Part A Form. In addition, the LLBGs are included in [DOE/RL-2004-60, 200-SW-1 Nonradioactive Landfills Group and 200-SW-2 Radioactive Landfills Group Operable Units Remedial Investigation/Feasibility Study Work Plan](#).

#### 5.3.3.5.1 Low-Level Waste Burial Ground 218-W-5, Trenches 31 and 34

Trenches 31 and 34 (Figure 5.12) are rectangular landfills with approximate base dimensions of 250 by 100 feet (76 by 30 meters), with a variable depth of 30 to 40 feet (9 to 12 meters). These trenches comply with [WAC 173-303](#) requirements for double liners and leachate removal/collection systems.

These lined disposal units were originally designated for mixed LLW. Disposal of LLW in the unlined trenches ceased June 23, 2004. Since that date, Trenches 31 and 34 have accepted LLW and mixed LLW for disposal. Disposal in Trench 31 began in May 2005, and disposal in Trench 34 began in September 1999. The first operational layer of waste packages have been covered with compacted gravel and soil, and the covering of the second waste layer has been initiated for Trenches 31 and 34.

Trench 31 is filled to approximately 50 percent of waste capacity, with approximately 193,675 cubic feet (5,674 cubic meters) of waste in 3,300 waste packages. In 2014, a total of 6,568 cubic feet (186 cubic meters) of waste was disposed of in Trench 31. Trench 34 is filled to approximately 82 percent of waste capacity, with approximately 200,349 cubic feet (5,171 cubic meters) of waste in 5,290 waste packages.

In 2014, no waste was disposed of in Trench 34.



Figure 5.12. LLBG Trenches 31 and 34

#### 5.3.3.5.2 Low-Level Waste Burial Ground, Trench 94

The LLBG Trench 94 (Figure 5.13) received two defueled U.S. Navy reactor compartments in 2014. The total number of reactor compartments received into Trench 94 (218-E-12B Burial Ground) to date is 127. All U.S. Navy reactor compartments shipped to the Hanford Site for disposal originated from decommissioned defueled nuclear-powered submarines or cruisers. Decommissioned submarine reactor compartments are approximately 33 feet (10 meters) in diameter, 47 feet (14.3 meters) long, and weigh between 1,000 and 1,500 tons (900 and 1,400 metric tons). Decommissioned cruiser reactor compartments are approximately 33 feet (10 meters) in diameter, 42 feet (12.8 meters) high, and weigh approximately 1,500 tons (1,362 metric tons).



Figure 5.13. LLBG Trench 94

#### 5.3.3.6 Waste Encapsulation and Storage Facility (WESF)

*DJ Watson*

The WESF (Figure 5.14), located in the 200 East Area, was constructed in 1970 and 1971 on the west end of B Plant and became operational in 1974. The WESF is operating under interim status standards specified in the RCRA Permit (WA7890008967), WESF Part A Form. The WESF is a storage-only unit for strontium and cesium encapsulated salts in double-containment stainless-steel capsules in underwater pool cells; and does not generate regulated waste. The water provides cooling and shielding for the capsules that are considered sealed sources.



Figure 5.14 Waste Encapsulation and Storage Facility

The mission of the WESF was encapsulation and storage of cesium chloride and strontium fluoride salts that had been separated from the Hanford Site's high-level radioactive tank waste. The facility is a two-story, 20,000-square-foot (1,860-square-meter) building, 157 feet (48 meters) long, and 40 feet (12 meters) high. The facility is constructed of steel-reinforced concrete and partitioned into seven hot cells, a hot cell service area, operating areas, building service areas, and a pool cell area. The hot cells are labeled A through G, and activities within the hot cells are performed remotely using manipulators. Waste and drum load-out can be performed in Hot Cell A. Hot Cells B through E are pending stabilization until final closure. Of these, only Hot Cells F and G remain active for supporting cesium and strontium capsule storage. The operating areas and other building service areas associated with the hot cells provide areas for instrumentation monitoring, utility support, or manipulator repair as required.



### 5.3.3.7 Integrated Disposal Facility (IDF)

LC Petersen

The IDF (Figure 5.15) is located in the south-central part of the 200 East Area, and is a new, unused landfill that is not actively operating. The landfill is an expandable RCRA hazardous waste-compliant unit (i.e., a double high-density polyethylene-lined trench with leachate collection and a leak detection system). The IDF operates in accordance with the RCRA Permit. The landfill is divided lengthwise (north to south) into two distinct cells: the east cell is for disposal of low-level radioactive waste (non-RCRA permitted), and the west cell is for disposal of low-level mixed waste (radioactive and RCRA-regulated hazardous waste). The IDF has a process design capacity of 2.89 million cubic feet (82,000 cubic meters). The IDF is referenced in [DOE/EIS-0391](#) as a future disposal option for Hanford Site wastes.



Figure 5.15. Integrated Disposal Facility

### 5.3.3.8 Environmental Restoration Disposal Facility (ERDF)

MA Casbon

ERDF (Figure 5.16) is the largest disposal facility in the DOE cleanup complex. The massive landfill located near the 200-West Area is regulated by the EPA; and covers 107 acres at the base of the disposal trench – roughly the same area as 52 football fields – and currently has a capacity of 18 million tons (16.3 million metric tons). The facility began operations in July 1996 and serves as the central disposal site for contaminated waste removed during Hanford Site cleanup operations conducted under



Figure 5.16. Environmental Restoration Disposal Facility

CERCLA regulations. The total available expansion area of the ERDF site was authorized in a 1995 ROD ([EPA/ROD/R10-95/100](#), *Record of Decision Hanford 200 Area*) to cover as much as 1.6 square miles (4.1 square kilometers). To provide a barrier to prevent contaminant migration from the in ground facility, ERDF is constructed to RCRA Subtitle C minimum technology requirements, which includes a double liner and leachate collection system ([40 CFR 264.301](#), Subpart N, “Landfills”). Remediation waste disposed in the facility includes soil, rubble, or other solid waste materials contaminated with hazardous, low-level radioactive, or mixed (combined hazardous and radioactive) LLW.

Designed to be expanded as needed, ERDF consists of disposal areas called cells. Each pair of cells is 70 feet (21 meters) deep, 500 feet (152 meters) wide and 1,000 (305 meters) feet long at the base. There are currently 10 cells at ERDF. Cells 1 through 8 can each hold 2.8 million tons (2.5 million metric tons) of material per pair of cells. Super Cells 9 and 10 can each hold 3.0 million tons (2.7 metric tons).

As each pair of cells reaches capacity, an interim cover is installed to prevent the infiltration of water. Cells 1 through 4 are full with an interim cover, Cells 5 and 6 are being filled and near operational capacity, Cells 7 and 8 are over half-full, and disposal in Super Cells 9 and 10 continues. A permanent cap will be placed over the facility when Hanford cleanup is completed.

The DOE and its contractors have disposed of 17 million tons (14.5 million metric tons) of contaminated material at the ERDF since the facility began operations in 1996. The disposal record is a measure of the tremendous amount of progress being made at the Hanford Site. The majority of cleanup waste at ERDF comes from the 220-square-mile River Corridor, located along the banks of the Columbia River. The low-level waste consists mainly of soil contaminated by the effluent of Hanford's nine plutonium production reactors, which operated from 1943-1987, as well as contaminated rubble from building demolition. In addition, ERDF also receives cleanup waste from other Hanford contractors.

### 5.3.4 Liquid Waste Management

*DJ Watson*

Facilities are operated on the Hanford Site to store, treat, reduce, and dispose of various types of liquid effluent generated by site cleanup activities. These facilities are operated and maintained in accordance with state and federal regulations, and facility permits.

#### 5.3.4.1 200 Area Effluent Treatment Facility (ETF)

The 200 Area ETF (Figure 5.17, on the left) is located in the 200 East Area. The 200 Area ETF stores and treats liquid effluent to remove toxic metals, radionuclides, and ammonia, in addition to destroying organic compounds. The treatment process constitutes best available technology and includes pH adjustment; filtration; ultraviolet light and peroxide oxidation to destroy organic compounds; reverse osmosis to remove dissolved solids; and ion exchange to remove the last traces of contaminants. The facility began operating in December 1995 and has a maximum treatment capacity of



*Figure 5.17. 200 Area Effluent Treatment Facility and Liquid Effluent Retention Facility*

150 gallons (570 liters) per minute. The 200 Area ETF operates in accordance with the RCRA Permit.

The effluent discharges are managed in accordance with limitations set forth in the State Waste Discharge Permit [ST-4500](#) and the 200 Area ETF Delisting Petition approval conditions. The treated effluent is stored in tanks, sampled and analyzed, and discharged via a dedicated pipeline to the State-Approved Land Disposal Site (also known as the 616-A Crib). This disposal site is located just north of the 200 West Area and is an underground drain field. The percolation rates for the field have been established by site testing and evaluation of soil characteristics. Tritium in the liquid effluent from the ETF cannot be practically removed. The location of the disposal site maximizes the time for migration of tritium to the Columbia River to allow for radioactive decay (the half-life of tritium is 12.35 years).



The volume of wastewater treated and disposed in 2014 was approximately 1.19 million gallons (4.5 million liters). This wastewater was primarily process condensate from the 242-A Evaporator. The 200 Area ETF was not operating for most of the year due to a failed heat exchanger. A new replacement heat exchanger was procured and is pending receipt and installation.

#### **5.3.4.2 Liquid Effluent Retention Facility (LERF)**

The LERF (Figure 5.17, on the right) is located in the 200 East Area, and operates in accordance with the RCRA Permit. The LERF consists of three RCRA-compliant surface impoundments used to store process condensate from the 242-A Evaporator, groundwater from various operable unit pump-and-treat systems, leachate from ERDF and from LLBG Trenches 31 and 34, and other aqueous waste. The LERF provides a steady flow and consistent pH for the 200 Area ETF feed. Each basin has a maximum capacity of 7.8 million gallons (29.5 million liters) and is constructed of two flexible, high-density polyethylene membrane liners. A system is provided to detect, collect, and remove leachate from between the primary and secondary liners. Beneath the secondary liner is a soil and bentonite clay barrier, should both the primary and secondary liners fail. Each basin has a floating membrane cover constructed of very low-density polyethylene to keep out windblown soil and weeds and minimize evaporation of small amounts of organic compounds and tritium that may be present in the basin contents. The facility began operating in April 1994 and receives liquid waste resulting from cleanup activities regulated by both RCRA and CERCLA. Historically, RCRA and CERCLA wastewaters were segregated in the surface basins and processed with different disposal destinations; however, this became unnecessary after the ROD for ERDF was amended in 2007 to allow receipt of all RCRA and CERCLA waste ([DOE 2007](#), *Amended Record of Decision for the Environmental Restoration Disposal Facility*). Segregation of RCRA and CERCLA wastewater is no longer required in the LERF basins.

The volume of wastewater received for the LERF basin storage in 2014 was approximately 3.57 million gallons (13.5 million liters). The majority of wastewater received at the LERF was pipeline-transported CERCLA-regulated leachate from ERDF, totaling approximately 1.8 million gallons (6.81 million liters). The other major contributor to wastewater received into LERF was approximately 1.37 million gallons (5.19 million liters) of process condensate from the 242-A Evaporator. Approximately 0.38 million gallons (1.44 million liters) of wastewater was received by tanker trucks from various other facilities. The volume of wastewater being stored in the LERF at the end of 2014 was approximately 13.4 million gallons (50.7 million liters).

### 5.3.4.3 200 Area Treated Effluent Disposal Facility (TEDF)



Figure 5.18. 200 Area TEDF Pond A and B

The 200 Area TEDF (Figure 5.18), located east of the 200 East Area, is a collection and disposal system for non-RCRA waste streams. The individual waste streams must be treated or otherwise comply with best available technology and all known available and reasonable treatment methods in accordance with “Submission of Plans and Reports for Construction of Wastewater Facilities” ([WAC 173-240](#)), which is the responsibility of the generating facilities. Effluent discharges comply with the limitations established in State Waste Discharge Permit [ST-4502](#).

The 200 Area TEDF consists of approximately 11 miles (18 kilometers) of buried pipelines connecting three pumping stations, the 6653 Building (known as the disposal sample station) and two 5-acre (2-hectare) disposal ponds. The facility began operating in April 1995 and has a capacity of 3,400 gallons (12,900 liters) per minute. The volume of unregulated effluent disposed to this facility in 2014 was approximately 359 million gallons (1,360 million liters).

### 5.3.4.4 242-A Evaporator

#### *AL Prignano*

The 242-A Evaporator (Figure 5.19), located in the 200-East Area, concentrates dilute liquid tank waste by evaporation in accordance with the RCRA Permit. The resultant water vapor is captured, condensed, filtered, sampled, sent to the nearby LERF for storage, and then further treated at ETF. This process reduces the volume of liquid waste sent to the double-shell tanks for storage and reduces the potential need for additional tanks.

In 2014, waste volume reduction operations resumed at the 242-A Evaporator after four years of facility upgrades to extend the 242-A Evaporator service life for certain systems through 2032. In 2014, the 242-A Evaporator completed processing 2.2 million gallons (8.3 million liters) of waste from the double-shell tank system, resulting in a 793,000-gallon (3,002,000-liter) reduction in tank waste volume.



Figure 5.19. 242-A Evaporator

## 5.4 Underground Waste Storage Tanks

*AL Prignano*

Hanford's 56 million gallons of highly radioactive and chemical waste is stored in 177 underground tanks until it is prepared for disposal (Figure 5.20). The tank waste is material left over from years of World War II and post-war production of nuclear weapons. The waste is stored in 149 older SSTs and 28 safer DSTs that are grouped into 18 farms in the 200 East and 200 West Areas. This section provides information about the SSTs and DSTs and activities that occurred in 2014 related to their operation and closure.

In 2014, an independent assessment team looked into vapor exposure issues at the Hanford Tank Farms as part of the WRPS commitment to eliminate or reduce worker exposure to chemical vapors. WRPS is implementing the recommendations from that assessment.

*Figure 5.20. 200 Area Tank Farms Aerial Overview*





### 5.4.1 Single-Shell Tank (SST) System

The SST system includes 149 tanks that were constructed between 1943 and 1964 to store mixed waste generated on the Hanford Site; 67 of the tanks are assumed to have leaked over 1 million gallons. Pumpable liquids in the SSTs were transferred to the newer and safer DSTs several years ago under the Interim Stabilization Program to help prevent additional environmental releases. The SST system is undergoing closure and operates under interim status standards specified in the RCRA Permit, Single-Shell Tank System Part A Form.

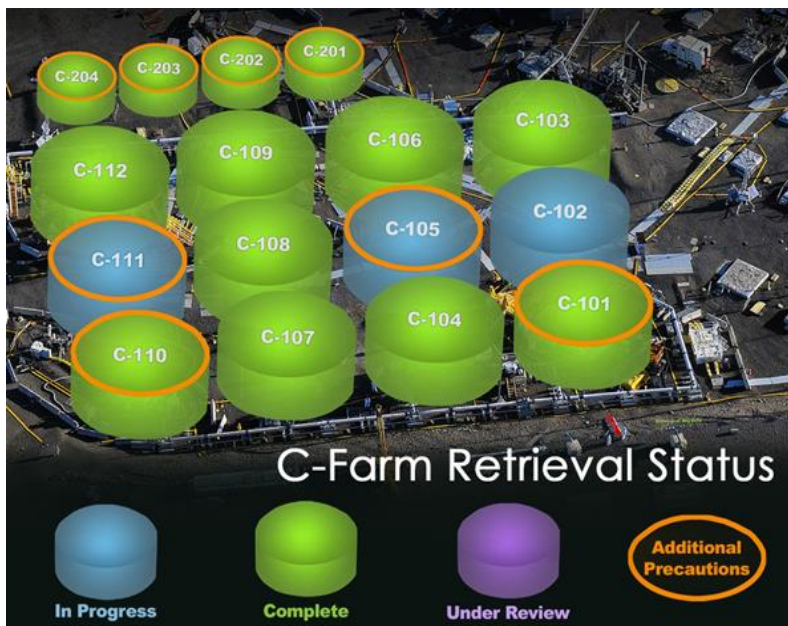


Figure 5.21. C-Farm Graphical Overlay Depicting Status of each SST

In 2014 progress continued in retrieving waste from the C Farm tanks and transferring it to newer, safer DSTs to prepare to feed tank waste to the WTP. C Farm (Figures 5.21 and 5.22) is one of 18 tanks farms located on the Hanford Site. The figure shows the retrieval status for the 16 tanks as 13 complete and 3 in progress. More than 84 percent of waste has been retrieved from tank C-102, 89 percent from tank C-112, and 95 percent of the waste from tank C-107 using the Mobile Arm Retrieval System (MARS). MARS is a robotic arm mounted on a central mast that uses powerful jets to wash down the inside of the tank and drive the waste to a central pump.



Figure 5.22. Tank Farms are Only Accessible from the Surface

### 5.4.2 Double-Shell Tank (DST) System

The DST system includes 28 DSTs (25 tanks in 200 East Area and 3 tanks in 200 West Area located in five tank farms (AN, AP, AW, AY, AZ, and SY) that were constructed between 1968 and 1986 to store mixed waste generated on the Hanford Site. The DST system is operating under interim status standards specified in the RCRA Permit (WA7890008967), Double-Shell Tank System Part A Form. One of the tanks (AY-102) is assumed to have leaked waste into the annulus. The tanks contain liquids and settled solids from past nuclear operations, including waste transfers from older SSTs. The DST system storage capacity is approximately 33 million gallons (126 million liters) of radioactive and chemical waste.

Storage space within the DST system is being managed to store waste pending treatment by the WTP and includes emergency pumping space available at all times for 1 million gallons (3.8 million liters).

Sample ports continued to be installed in ventilation exhaust ducts to directly measure flow rates from the tank waste in the ventilation outlet to address flammable gas safety concerns, including installing sample ports in ventilation exhaust to directly measure gases from the tank waste in the tank ventilation outlet.

At the end of 2014, there were 26.6 million gallons (101 million liters) of waste in the DSTs. Quantities of liquid waste generated in 2014 and stored in underground storage tanks are provided in the *Hanford Site Annual Dangerous Waste Report Calendar Year 2014* ([DOE/RL-2015-13](#)). Table 5.5 summarizes the liquid waste generated and stored from 2009 through 2014 in underground storage tanks.

**Table 5.5. Tank Farm System Quantities of Liquid Waste<sup>a</sup> Generated and Stored<sup>b</sup>**

Type of Waste	Units	2009	2010	2011	2012	2013	2014
DSTs year-end volume <sup>c</sup>	Gallons	25,971	25,835	25,948	26,580	26,733	26,575
	Liters	98,311	97,796	98,224	98,000	101,195	100,597
242-A Evaporator volume evaporated	Gallons	960	548	0	0	0	793
	Liters	3,634	2,074	0	0	0	3,002
Single-Shell Tanks volume pumped <sup>d</sup>	Gallons	102	240	560	238	70	262
	Liters	386	909	2,120	900	263	991

<sup>a</sup> Quantity of liquid waste is defined as liquid waste sent to double-shell underground storage tanks during these years, rounded to the nearest 1,000; and does not include containerized (e.g., barreled) waste included in the solid waste category.

<sup>b</sup> Multiply volumes shown by 1,000.

<sup>c</sup> Includes other miscellaneous additions or reductions, e.g., dilution and flush waters and corrosion controls, not represented elsewhere on this chart

<sup>d</sup> Volume includes dilution or flush water.

### 5.4.3 Underground Waste Storage Tanks and Associated Facilities Progress on Defense Nuclear Facilities Safety Board (DNFSB)

*JM Garcia*

Throughout 2014, ORP and its contractors met with and provided information to the DNFSB and its technical staff to resolve concerns regarding Hanford Site underground storage tank farm projects.

The following issues were addressed:

- ⊗ Tank 241-AY-102 and DST tank integrity
- ⊗ DST space management
- ⊗ SST level changes
- ⊗ 242-A Evaporator
- ⊗ Tank Farms Ventilation Systems.

*Defense Nuclear Facilities Safety Board Recommendation 2012-2*

On September 28, 2012, the DNFSB issued Recommendation [2012-2](#), *Hanford Tank Farms Flammable Gas Safety Strategy*. The DNFSB's recommendation documented their position that DOE needs to upgrade the DST ventilation systems and other instrumentation systems used for safety-related functions at the Hanford tank farms.

On June 6, 2013, DOE delivered the *Implementation Plan for Recommendation 2012-2* ([DOE 2013a](#)) to the DNFSB. Implementation Plan actions completed and provided to the DNFSB included:

- ⊗ Action 1-1 and 4-1, implementation of the DOE-approved Documented Safety Analysis and associated Technical Safety Requirements for DST primary tank ventilation systems, completed March 2013.
- ⊗ Action 1-3, a feasibility study for inspecting the condition and integrity of DST primary ventilation ductwork between the tank and flow monitoring locations, completed August 2014.
- ⊗ Action 2-1, installation and testing of flow meters in selected DST ventilation exhausts to evaluate instrument performance, completed January 2014.
- ⊗ Action 4-2, demonstration of current capabilities to recover from a loss of ventilation, completed February 2014.

Work will continue in 2015 to evaluate potential means to reduce the inventory of retained flammable gases in DSTs in a controlled manner. Action 2-2, installation of safety significant instrumentation for real-time monitoring of the ventilation exhaust flow from each DST, is the current focal project of 2012-2. Once complete, the selected air flow meter will be installed and used to monitor DST ventilation exhaust flow in real time.

In addition, DOE is evaluating Action 1-2, development of a streamlined approach to implement the planned improvements for upgrading the DST primary tank ventilation systems to meet safety significant requirements. All related information for Recommendation 2012-2, is available on the DNFSB website at <http://www.dnfsb.gov/board-activities/recommendations/hanford-tank-farms-flammable-gas-safety-strategy>.

#### 5.4.4 Vadose Zone Program

*SJ Eberlein*

The Vadose Zone Program is responsible for implementing the Tank Farm RCRA Corrective Action Program through field characterization, laboratory analyses, technical analyses, risk assessment for past tank leaks, and installation of interim measures that will reduce the threat from contaminants until permanent solutions can be found. Results of vadose zone investigations and interim measures conducted the first 10 years of the project, are documented in the *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas* ([DOE/ORP-2008-01](#)). In 2014, *Draft A of the Phase 2 RCRA Facility Investigation Report for Waste Management Area C* ([RPP-RPT-58339](#)) was produced to provide additional results of investigations conducted in Waste Management Area C to support the determination of need for corrective measures.

Field characterization efforts in 2014 continued in the 200-West Area in support of the *200 West Area Tank Farms Interim Measures Investigation Work Plan* ([RPP-PLAN-53808](#)). Additional efforts were initiated in the Waste Management Area A-AX to support the *Field Sampling and Analysis Plan for Soil Samples at Waste Management Area A-AX* ([RPP-PLAN-57332](#)). Monitoring was also conducted at the two interim surface barriers (one covers a portion of the 241-T Tank and one covers all the



241-TY Tank Farm). These two surface barriers cover areas where soil has been contaminated due to past leaks from tanks or tank associated equipment. They reduce water infiltration through the contaminated soil.

#### 5.4.4.1 Direct-Push Boreholes and Sampling

Direct-push technology using a hydraulic hammer unit to evaluate subsurface contamination in the vadose zone continued to be used in TX Tank Farm during 2014, and was deployed in Waste Management Area A-AX. Four direct push boreholes were placed in TX Tank Farm, in addition to the eight direct-push boreholes placed in 2013. Each borehole was logged for moisture and gamma-emitting radionuclides, then a companion borehole was placed next to the first borehole, and soils samples were obtained at selected depths. During decommissioning of the logging boreholes, deep electrodes were placed to support future electrical resistivity work. In September 2014, the *Vadose Zone Characterization Report for 241-TX Tank Farm* ([RPP-RPT-57964](#)) documented the results of these field efforts. In Waste Management Area A-AX, eight direct-push boreholes were placed and logged for moisture and gamma-emitting radionuclides. During decommissioning of the logging boreholes, deep electrodes were placed to support future electrical resistivity work. Sampling in Waste Management Area A-AX will be initiated in 2015, and additional direct pushes are planned.

#### 5.4.4.2 Surface Geophysical Exploration

Surface geophysical exploration is a combination of surface-deployed geophysical techniques, including pole-to-pole electrical resistivity, electro-magnetic induction, magnetic gradiometry, and ground-penetrating radar, to help define the presence and distribution of buried infrastructure so that those features can be considered during resistivity data analysis. The depth to which the resistivity measurements interrogate the subsurface is determined by the distance between electrode pairs (the farther apart, the deeper the interrogation). Resistivity is an indirect measure of several subsurface phenomena (e.g., moisture distribution, saline contaminants, and soil texture). The greater the depth of interrogation, the lower the resolution of the analysis. In 2014, ground-penetrating radar information was collected in Waste Management A-AX to support planned field activities. Electrical resistivity data were reported in 2014 in the *Three-Dimensional Surface Geophysical Exploration of the U Tank Farm* ([RPP-RPT-56430](#)) and the *Three-Dimensional Surface Geophysical Exploration of the 200-Series Tanks at the 241-C Tank Farm* ([RPP-RPT-56760](#)).

#### 5.4.4.3 Interim Surface Barriers

The effectiveness of the T Tank Farm interim surface barrier at reducing infiltration is assessed through a barrier-monitoring program ([PNNL-16538](#), *T Tank Farm Interim Surface Barrier Demonstration – Vadose Zone Monitoring Plan*). Pre-barrier data were collected and a monitoring report for FY 2007 was issued in January 2008 ([PNNL-17306](#), *T Tank Farm Interim Surface Barrier Demonstration – Vadose Zone Monitoring FY07 Report*). Barrier monitoring continued during 2014, with information being reported annually. The barriers are resulting in slow drying of the vadose zone as water is diverted, which normally would recharge the surface. Two interim barriers were previously designed to be placed over most of the tanks in the SX Tank Farm. Modified asphalt was selected as the impermeable surface, and an evapotranspiration basin will be located south of the SX Tank Farm to redirect any runoff back to the atmosphere. The design and monitoring plan was approved by Ecology for future construction.

#### 5.4.4.4 Interim Measures Pore Water Extraction Test

A proof of principle test for pore water extraction was initiated in 2013 and was completed in 2014 under the *200 West Area Tank Farms Interim Measures Investigation Work Plan* ([RPP-PLAN-53808](#)). The test used the direct-push unit to place small diameter boreholes into the soil south of SX Tank Farm.

A vacuum system was used to extract potentially contaminated pore water from the soil. Additional testing has been proposed, but a decision as to whether the testing will be conducted has not been reached at this time. Information on this test is presented in the *Pore-Water Extraction Proof-of-Principle Field Test Report* ([RPP-RPT-56596](#)).

### 5.5 Waste Treatment and Immobilization Plant (WTP)

BA Walker

The WTP (Figure 5.23, July 2014) is being built on 65 acres (26 hectares) in the 200 East Area to treat radioactive and hazardous waste stored in 177 underground tanks located on the Central Plateau. The WTP comprises four major facilities (Pretreatment Facility, High-Level Waste [HLW] Vitrification Facility, Low-Activity Waste [LAW] Vitrification Facility, and Analytical Laboratory) along with support buildings and associated infrastructure (Balance of Facilities). Construction of the WTP is managed in accordance with the RCRA Permit.



Figure 5.23. Waste Treatment and Immobilization Plant

Two major achievements for 2014 included resuming production engineering at the HLW Vitrification Facility and completing conceptual design of the option to feed low-activity waste directly to the LAW Vitrification Facility. The latter achievement, referred to as Direct Feed LAW, supports the DOE Framework for cleanup of Hanford tank wastes as soon as practicable. A description of the WTP facilities and the progress at each facility in 2014 is provided below:

**Pretreatment Facility:** The Pretreatment (PT) Facility is where waste is received from the tank farms and separated into low-activity and high-level waste streams for transport to the LAW and HLW facilities for processing. In 2014, work continued to resolve the remaining technical issues that have impacted design and construction at the PT Facility since 2012. Significant progress on the technical issues was made in 2014 with the construction of the Full-Scale Vessel Testing platform. By the end of the 2014, testing at the new facility had begun on the mixing system for the pulse-jet mixers that will be used to ensure adequate mixing of waste within the waste process vessels at the PT Facility.

**HLW Vitrification Facility:** The HLW Vitrification Facility is where high-level waste from the PT Facility will be combined with glass-forming materials in high-temperature melters, poured into waste canisters, and allowed to cool to form a solid, immobilized glass form. The most significant accomplishment in 2014 was receiving DOE approval to resume full engineering and design of the HLW Vitrification Facility. Construction in 2014 included making 18 concrete placements, along with setting 179 tons (162 metric tons) of structural steel, and placing 1,040 feet (317 meters) of pipe and 1,696 feet (517 meters) of conduit.

**LAW Vitrification Facility:** The LAW Vitrification Facility is where low-activity waste from the PT Facility will be mixed with glass-forming materials in high-temperature melters, and poured into containers to form a solid, immobile glass form. Construction continued on interior equipment and commodities installation. Workers installed melter refractory for the two glass melters in the LAW Vitrification Facility.

**Analytical Laboratory:** Once operational, the Analytical Laboratory will process about 10,000 waste samples annually to support glass formulation and waste-form compliance. In 2014, workers completed sufficient construction and received or installed the necessary equipment to begin systemization. 'Ready for Systemization' represents a significant achievement in work progress at the Analytical Laboratory.

Emphasis in 2014 continued on facility completion efforts at the LAW Vitrification Facility and Analytical Laboratory and included placement of the standby diesel generator, which will provide emergency power to plant systems should primary power be lost.

### 5.5.1 Waste Treatment and Immobilization Plant Progress on Defense Nuclear Facilities Safety Board Recommendations

*JM Garcia*

Throughout 2014, ORP and its contractors met with and provided information to the DNFSB and its technical staff to resolve commitments and review the following WTP technical topics. The following are the two new safety issues identified in 2014:

- ⊗ Volcanic Ashfall Hazard: In an October 23, 2014, letter to DOE, the DNFSB communicated a concern that the WTP design did not include an adequate control strategy to address the most recent volcanic ashfall hazard assessment at the Hanford Site.
- ⊗ Unanalyzed Melter Accidents: In a December 5, 2014, letter to DOE, the DNFSB communicated a concern with the proposed nuclear safety control strategy for the HLW Vitrification Facility melter and associated support systems and their ability to adequately protect the public and facility workers.

Resolution of both these new issues is ongoing, with the latest status provided to Boards staff April 7 - 9, 2015. In addition, the following issues were closed in 2014:

LAW Vitrification Facility, Analytical Laboratory, and Balance of Facilities instrumentation and control system design. The DNFSB raised a number of issues regarding the design of the instrumentation and control systems at the WTP in their letter of May 5, 2011. In response, DOE directed the contractor to implement [DOE-STD-1195-2011](#), *Design of Safety Significant Safety Instrumented Systems Used at DOE Non-Reactor Nuclear Facilities*. Revised hazard analysis and control selection process improvements were implemented. The DNFSB stated these actions adequately address the concern and the issue was closed, as noted in the DNFSB's December 9, 2014, letter to DOE.

#### **5.5.1.1 Defense Nuclear Facility Safety Board Recommendation 2010-2**

On January 28, 2014, the DNFSB closed [Recommendation 2010-2](#) citing DOE's new technical approach to resolving safety-related pulsejet mixing issues. Since 2010, DOE has developed an entirely new approach, which was presented to the DNFSB in a briefing dated September 11, 2013. Based on this new approach the DNFSB concluded that the recommendations to [Recommendation 2010-2](#) were no longer relevant.

#### **5.5.1.2 Defense Nuclear Facilities Safety Board Recommendation 2011-1**

The DNFSB issued [Recommendation 2011-1](#), *Safety Culture at the WTP* on June 9, 2011. The DOE Office of Health, Safety and Security (HSS) conducted a follow-on assessment review in December 2013 through January 2014 on the WTP safety culture. The follow-on review was similar to the 2011 independent oversight review conducted of the safety culture for WTP, based on the January 30, 2012, letter to the DNFSB, in which the senior advisor to the DOE Office of Environmental Management (EM) committed to having HSS conduct a WTP safety culture progress assessment approximately 12 to 18 months from the issuance of the HSS [WTP Safety Culture 2012 Report \(DOE 2012\)](#). The final report was transmitted on June 17, 2014, by the DOE Office of Independent Enterprise Assessments (OEA), which replaced HSS in May 2014.

On September 11, 2014, ORP completed its part of [Action 2-12 of the DOE Implementation Plan for DNFSB Recommendation 2011-1](#) (DOE 2013b) by transmitting a letter to EM-1, containing the Safety Culture Sustainment Plans for ORP and its prime contractors. EM-1 transmitted all EM site proposed plans to the DNFSB on November 13, 2014. The sustainment plans included actions in response to the OEA report mentioned above.

All related information for Recommendation 2011-1, is available on the DNFSB website at:

<http://www.dnfsb.gov/board-activities/recommendations/safety-culture-waste-treatment-and-immobilization-plant>.

#### **5.5.1.3 Pretreatment Facility – Hydrogen in Piping and Ancillary Vessels**

During 2014, WTP executed new processes and procedures for conducting piping analyses in accordance with the qualitative and deterministic risk assessment processes. Hydrogen gas generated by the highly radioactive wastes to be processed in the WTP can be trapped and accumulate over time at high points within piping systems. For process piping that is less than or equal to four inches in diameter ( $\leq 4$  inches outer diameter), the project has developed a 'quantitative' risk analysis (QRA) technique to model hydrogen explosions and help inform the design of WTP piping systems. The QRA is used to evaluate WTP piping to ensure it satisfies American Society of Mechanical Engineers (ASME) Code B31.3-1996, *Process Piping*, design requirements and will withstand the strains caused by hydrogen explosions without rupturing for the life of the plant. The QRA model, supported by years of full-scale representative testing, has been independently verified by a 12-person panel of industry experts, the Independent Review Team. QRA will be used for design purposes only, for piping  $\leq 4$  inch, to determine it will satisfy the design



requirements of ASME B31.3. Piping larger than 4 inches in diameter and ancillary vessels (such as pulse jet mixer bodies and breakpots) will also be evaluated to make sure they satisfy the ASME B31.3 requirements using engineering analysis other than QRA.

In September 2014, the project proposed using a deterministic method to perform the nuclear safety analysis of hydrogen events in WTP piping and ancillary vessels. The project plans to develop a conservative model to support deterministic conclusions on the adequacy of WTP design features and selected safety systems to accommodate hydrogen in piping and ancillary vessels events. The safety classification of controls will be determined from the results of the consequence analysis, consistent with accepted guidance in standard [DOE-STD-3009-94](#). ORP acknowledged the pursuit of the proposed methodology but withheld endorsement of the deterministic approach until the safety analysis process could demonstrate a defensible basis for addressing hydrogen in piping and ancillary vessels. DNFSB staff have been briefed on the proposed process.

## 5.6 Long-Term Stewardship

*Raja Ranade*

The MSA Long-Term Stewardship (LTS) Program activities in 2014 focused on integrating the WCH draft transition and turnover packages and managing stewardship responsibilities for geographic areas previously transitioned to the MSA. Transition and turnover packages were completed in 2014 for the 105-C,



Figure 5.24. Surveillance of 105-F Building

105-D, 105-DR, 105-H, and 105-N/109-N reactor buildings. The package describes activities that led to placing the reactors into interim safe storage configuration (ISS). The ISS is a process of demolishing all but the shield walls surrounding the reactor core, removing or stabilizing all loose contamination within the facility, and placing a new roof on the remaining structure. Access to the structure is provided for surveillance and maintenance work. Access doorways are welded shut, and all other openings in the shield walls are sealed to prevent intrusions and the release of radioactive materials.

Surveillance of these facilities is conducted every five years. MSA conducted a structural and radiologic assessment and inspection of temperature and flood level sensors located inside the 105-F Building in October 2014. The surveillance involved grinding off the door weld to enter the building. Radiological, biological, and physical safety conditions were evaluated before assessment teams entered the 105-F Building. The assessment teams found no change in conditions from the previous surveillance. MSA also conducted annual external surveillance of all LTS Program-managed ISS reactor buildings. Other stewardship activities included assessment of institutional controls at the LTS-managed waste sites and areas. Figure 5.24 shows a welder grinding the door weld off, and instrument technicians checking the temperature monitors inside 105-F.

## 5.7 Scientific and Technical Contributions to Hanford Site Cleanup

*MD Freshley and RA Peterson*

PNNL scientific and technical contributions to cleanup at the Hanford Site were focused on applied science, technology development and maturation, and basic science contributions. These contributions were funded through the DOE EM Office of Soil and Groundwater Remediation, RL, CH2M, DOE EM Office of Tank Waste Management, ORP, WRPS, and BNI. The contributions included performing scientific and technical evaluations and reviews and developing and advancing new technologies to address site cleanup challenges. The 2014 contributions to Hanford Site cleanup are provided below.

**Waste Processing.** Conducted fundamental engineering development to support resolution of the mixing issues associated with WTP, including working with BNI to identify necessary and sufficient testing to demonstrate single high solids vessel full-scale mixing. In addition, PNNL provided leadership in resolution of technical issues associated with criticality and flammable gas control within the WTP.

**Improve the Immobilization of Low-Activity Waste and High-Activity Waste.** In collaboration with WRPS and the Savannah River Site, cast stone was evaluated as technology to treat low-activity waste at the Hanford Site. In addition, researchers have teamed with Savannah River National Laboratory, Catholic University, and the Missouri University of Science and Technology to develop new glass formulations capable of significantly reducing the volume of both low-activity waste glass and high-activity waste glass.

**Speciation of Technetium in Tank Waste.** Researchers continued an effort to identify the speciation of technetium in tank wastes. Under normal processing conditions, technetium is usually present as the pertechnetate ion. However, a significant portion of the technetium in Hanford waste tanks is present as a complexed soluble species. Work identified several candidate complexes that may be present in tank wastes. These complexes will be further explored during 2015.

**Deep Vadose Zone Applied Field Research Initiative.** The Deep Vadose Zone Applied Field Research Initiative (AFRI) focused on improving best practices to enhance current baseline remediation technologies being deployed at the Hanford Site, conducting high-impact research to define alternatives to the current baseline, and develop next-generation solutions. The AFRI is 1) developing and implementing systems-based characterization and monitoring of contaminant sources and residual vadose zone contamination, 2) understanding the processes controlling the behavior, transport, and fate of contaminants in the environment to provide defensible decision support for risk-informed endpoints, and 3) developing transformational approaches to reduce contaminant mass flux to groundwater.

PNNL contributed to improving best practices by incremental technology maturation in the following areas:

- ⊗ Applied understanding of microbial communities to optimize performance of the fluidized bed reactor for treating carbon tetrachloride and nitrate, resulting in uninterrupted operation of the system and more efficient contaminant removal.
- ⊗ Tested performance of new sorbent materials for removal of iodine-129 for pump and treat systems ([PNNL-23730](#); PNNL-23669). Tested sorbent materials using groundwater collected from a 200-West Area well. The results showed that several inorganic composites performed to specification. Further testing is needed for scale-up and to engineer appropriate forms of the composite materials for deployment in the pump-and-treat system.



- ⊗ Generated scale-up information for gas-phase treatment of uranium in the vadose zone using ammonia gas ([PNNL-23699](#)). Laboratory experiments were conducted to support calculations for field-scale treatment using ammonia gas, quantify field-scale advective and diffusive transport in unsaturated sediments, and evaluate pore-water chemistry changes with ammonia delivery. Gas-phase treatment of the vadose zone was shown to be amenable to monitoring using electrical geophysical methods.
- ⊗ Continued monitoring the soil desiccation treatability test in the Central Plateau, showing expected rewetting, and redistribution of moisture in the vadose zone ([PNNL-23731](#)).
- ⊗ Initiated summary of performance monitoring for the Prototype Hanford Barrier. Over two decades (from 1944 to 2013) of performance monitoring data have been collected, but not reviewed and summarized. Completed data processing and analysis as well as quality assurance documentation; the report will be issued in 2015.
- ⊗ Completed technical review of groundwater monitoring plans to identify opportunities to streamline operations and reduce overall cost. The panel assembled for the review decreased efforts by more than 50 percent by establishing monitoring requirements driven by technical objectives, knowledge of plume behavior, and integration with remedial actions.

PNNL continued investigating the 100-OL-1 Operable Unit to address residual contamination from farms and orchards that used lead and arsenic as pesticides. These farms and orchards existed on the Hanford Site before operations began. During FY 2014, a pilot study was conducted to evaluate field-portable x-ray fluorescence equipment, demonstrating that it operates within quality assurance criteria for analytical measurements used in remediation decisions ([DOE/RL-2014-38](#), [PNNL-23868](#)). This result led to revision of the work plan for the Operable Unit.

PNNL reduced technical risks and uncertainty through high-impact technology development in the following areas:

- ⊗ Developed guidance for transition, closure of pump-and-treat systems. It is often difficult to identify pathways to transition pump-and-treat systems to alternative remediation strategies. A structured approach was developed to assess pump-and-treat performance for optimization, transition, or closure. Guidance was provided on the steps for evaluating an endpoint for pump-and-treat operations for systems with diminishing returns.
- ⊗ Conducted laboratory experiments to evaluate extension of gas-phase remediation to technetium-99 in the vadose zone ([PNNL-23665](#)). The laboratory experiments were used to examine changes in technetium-99 mobility in vadose zone sediments, suggesting that a combination of hydrogen sulfide and ammonia gas could provide a viable remedial approach.
- ⊗ Released a computer code for inversion of very large data sets from subsurface electrical geophysics ([PNNL-23783](#)). The publically released code (E4D) is useful for inverting subsurface characterization of tank farms and includes capabilities for explicitly modeling and removing the effects of metallic infrastructure. The code meets NQA-1 quality assurance requirements for safety software.

PNNL undertook a number of applied science investigations, as described below:

- ⊗ Developed a robust conceptual model for uranium in the Central Plateau vadose zone with varying waste chemistry. The conceptual model describes how uranium was distributed in the vadose zone during disposal, how it has continued to migrate, and how it is strongly influenced by geochemical reactions ([PNNL-23666](#)).
- ⊗ Investigated the biogeochemistry of iodine in Hanford groundwater, including speciation analysis to define the composition and characterization to determine how microbial communities are impacted by iodine-129. These studies will provide a technical basis for in situ remediation or natural attenuation of iodine-129.
- ⊗ The Deep Vadose Zone AFRI led a multi-national laboratory effort to identify research and development needed to successfully define and apply risk-informed remediation approaches for complex sites (DOE 2014a). Research topics were proposed in characterization and conceptual model development, predictions of site conditions, remediation approaches, monitoring, and remediation decision support.

**Advanced Simulation Capability for Environmental Management (ASCEM).** The project continued enhancing capabilities in the ASCEM toolset and initiated a supporting analysis of WMA C closure performance assessment. ASCEM is being developed as a workflow for understanding and predicting contaminant fate and transport in natural and engineered systems. The capability includes modular and open source toolsets that facilitate integrated approaches to modeling and site characterization and enable robust and standardized assessments of performance and risk for DOE EM cleanup and closure activities.

## 6.0 Air Monitoring

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*CJ Perkins, DJ Rokkan*

The purpose of Hanford Site air monitoring programs is to ensure the protection of environmental and public health for the air pathway. Air quality is monitored using stack sampling at the sources and ambient air monitoring at receptor locations. The specific objectives are to measure airborne radionuclides and chemicals in order to calculate the doses to humans, plants, and animals. Measured and calculated results are compared with DOE, EPA, and/or WDOH standards. This report presents the results of the 2014 measurements.

### 6.1 Air Emissions

*DJ Rokkan*

Hanford Site contractors monitor airborne emissions from site facilities to determine compliance with state and federal regulatory requirements as well as to assess the effectiveness of emission control equipment and pollution management practices. Measuring devices quantify most facility emission flows, while other emission flows are calculated using process information or the fan manufacturers' specifications. Most facility radioactive air emission units are actively ventilated stacks that are sampled either continuously or periodically. Airborne emissions with a potential to contain radioactive materials at prescribed threshold levels are measured for gross alpha and gross beta concentrations and, as warranted, specific radionuclides. Nonradioactive constituents and parameters are monitored directly, sampled and analyzed, or estimated based on inventory usage.

Emission data are documented in this and other reports, all of which are available to the public. For example, DOE annually submits to EPA and the WDOH a report of Hanford Site radionuclide air emissions (e.g., [DOE/RL-2015-12](#)) in compliance with [40 CFR 61](#), Subpart H and with [WAC 246-247](#).

#### 6.1.1 Radioactive Airborne Emissions

Small quantities of particulate and volatilized forms of radionuclides are emitted to the environment through state and federally permitted radioactive emission point sources (i.e., stacks). Tritium (i.e., hydrogen-3), strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, and americium-241 are the isotopes most commonly measured in the emissions. Emission points are monitored continuously if they have the potential to exceed 1 percent of the standard for public dose, which is 10 millirem (100 microsievert) per year.

Distinguishing Hanford Site-produced radionuclides in the environment is challenging because concentrations of emissions from site stacks are comparable to widespread background concentrations of radionuclides that originated from historical atmospheric nuclear weapons testing. Gross alpha and gross beta concentrations in stack emissions are, on average, equivalent to concentrations in the environment, including concentrations at distant locations upwind of the Hanford Site. Radioactive emissions decreased on the Hanford Site largely because the production and processing of nuclear materials ceased.

The continuous monitoring of radioactive emissions from facilities requires analyzing samples collected at points of discharge to the environment, usually a stack. Samples are analyzed for gross alpha and gross beta as well as for selected radionuclides. Specific radionuclides are selected for sampling, analysis, and reporting based on an evaluation of the hypothetical maximum potential of emissions of known

radionuclide inventories in a facility or an outside activity occurring under normal operating conditions, with the calculated effect of pollution-abatement equipment removed, sampling criteria provided in contractor environmental compliance manuals, and the potential of each radionuclide to contribute to the public dose. Continuous air monitoring systems with alarms also are used at selected emission points where the potential exists for radioactive emissions to exceed normal operating ranges to levels that require immediate personnel alert.

Radioactive emission points are located on the Hanford Site in the 100, 200, 300, 400, and 600 Areas. The prime sources of emissions and the number of emission points by operating area are as follow:

- ⊗ In the 100 Areas, three radioactive emission points were active. Emissions originated from the 100-K West Fuel Storage Basin, which in previous years contained irradiated nuclear fuel, and from the Cold Vacuum Drying Facility (CVDF).
- ⊗ In the 200 Areas, 37 radioactive emission points were active. The primary locations of these emission points were the PFP, T Plant, B Plant, WESF, underground tanks storing high-level radioactive waste, a waste evaporator, the WRAP Facility, the 222-S Laboratory, and the PUREX Plant.
- ⊗ In the 300 Area, four radioactive emission points were active. The primary sources of these emissions were laboratories and research facilities, including the 324 Waste Technology Engineering Laboratory, 325 Applied Chemistry Laboratory, and 331 Life Sciences Laboratory.
- ⊗ In the 400 Area, three radioactive emission points were active. The sources of these emissions are three facilities that have been shut down: FFTF, Maintenance and Storage Facility, and the Fuels and Materials Examination Facility.
- ⊗ In the 600 Area, two radioactive emission points were active at WSCF where low-level radiological and chemical analyses were performed on various types of samples (e.g., particulate air filters, liquids, soil, and vegetation).

Air emission data collected in 2014 were comparable to those collected in 2013. Table 6.1 summarizes Hanford Site radioactive airborne emissions in 2014.

**Table 6.1. Hanford Site Radioactive Airborne Emissions**

Radionuclide	Half-Life	2014 Releases, Ci <sup>a</sup>				
		100 Area	200-East Area	200-West Area	300 Area	400 Area
Actinium-227	21.6 years	NA	NA	NA	$3.3 \times 10^{-10}$	NA
Alpha (gross)	NA	$3.6 \times 10^{-6}$	$9.7 \times 10^{-7}$	$2.8 \times 10^{-5}$	$4.9 \times 10^{-8}$	NA
Americium-241	432.2 years	$1.5 \times 10^{-6}$	$2.4 \times 10^{-8}$	$3.6 \times 10^{-6}$	$2.3 \times 10^{-10}$	NA
Americium-243	7,380 years	NA	NA	NA	$8.5 \times 10^{-8}$	NA
Beta (gross)	NA	$1.3 \times 10^{-5}$	$1.1 \times 10^{-4}$	$1.1 \times 10^{-5}$	$3.3 \times 10^{-6}$	NA
Cesium-134	2.1 years	NM	NM	NM	NM	NM
Cesium-137	30 years	$5.5 \times 10^{-7}$	$3.7 \times 10^{-5}$	$2.1 \times 10^{-7}$	$1.6 \times 10^{-6}$	$4.3 \times 10^{-7}$ (b)
Curium-243/-244	29.1 years	NA	NA	NA	ND	NA
Europium-152	13.5 years	NM	NM	NM	$1.6 \times 10^{-9}$	NA
Europium-154	8.6 years	$3.7 \times 10^{-10}$	NM	NM	$5.5 \times 10^{-9}$	NA
Gadolinium-153	240.4 days	NA	NA	NA	$1.0 \times 10^{-10}$	NA
Iodine-129	16,000,000 years	NA	$9.8 \times 10^{-4}$	NA	NA	NA
Krypton-85	10.7 years	NA	NA	NA	$5.6 \times 10^{-7}$	NA

Table 6.1. Hanford Site Radioactive Airborne Emissions

Radionuclide	Half-Life	2014 Releases, Ci <sup>a</sup>				
		100 Area	200-East Area	200-West Area	300 Area	400 Area
Neptunium-237	2,144,000 years	NA	NA	NA	$2.9 \times 10^{-9}$	NA
Plutonium-238	87.7 years	$3.3 \times 10^{-8}$	$3.7 \times 10^{-11}$	$5.5 \times 10^{-7}$	$3.7 \times 10^{-8}$	NA
Plutonium-239/240	24,110 years	$2.6 \times 10^{-7}$	$3.3 \times 10^{-8}$	$1.3 \times 10^{-5}$	$8.5 \times 10^{-9}$	$2.0 \times 10^{-7}$ <sup>(c)</sup>
Plutonium-241	14.4 years	$1.1 \times 10^{-6}$	ND	$4.7 \times 10^{-6}$	$3.9 \times 10^{-7}$	NA
Protactinium-231	32,760 years	NA	ND	NA	NA	NA
Radium-226	1,600 years	NA	NA	NA	$4.8 \times 10^{-10}$	NA
Radon-220	55.6 seconds	NA	NA	NA	$7.5 \times 10^{+1}$	NA
Radon-222	3.8 days	NA	NA	NA	$2.4 \times 10^{-2}$	NA
Sodium-22	2.6 years	NA	NA	NA	NA	$1.4 \times 10^{-9}$ <sup>(d)</sup>
Strontium-90	29.1 years	$2.8 \times 10^{-7}$	$9.3 \times 10^{-5}$	$3.9 \times 10^{-7}$	$5.8 \times 10^{-7}$	NA
Technetium-99	211,100 years	NA	NA	NA	$4.1 \times 10^{-6}$	NA
Tritium (elemental)	12.3 years	NA	NA	NA	$3.1 \times 10^{+2}$	NA
Tritium (tritiated water vapor)	12.3 years	NA	NA	NA	$3.1 \times 10^{+2}$	$1.8 \times 10^{-3}$
Uranium-232	68.9 years	NA	NA	NA	$5.3 \times 10^{-9}$	NA
Uranium-233	159,200 years	NA	NA	NA	$1.8 \times 10^{-8}$	NA
Yttrium-90	1.5 seconds	NA	$9.3 \times 10^{-5}$	NA	NA	NA

<sup>a</sup> To convert to the International System of Units; multiply pCi/g by 0.037 to obtain Bq/g.<sup>b</sup> This release value derives from data on gross beta emissions from 400 Area stacks.<sup>c</sup> This release value derives from data on gross alpha emissions from 400 Area stacks.<sup>d</sup> Calculated from estimated residual sodium inventory remaining in FFTF primary coolant piping.

NA = Not applicable.

ND = Not detected (i.e., either the radionuclide was not detected in any sample during the year or the average of all the measurements for that given radionuclide or type of radioactivity made during the year was below background levels).

NM = Not measured.

### 6.1.2 Criteria and Toxic Air Pollutants

Criteria and toxic air pollutants emitted from chemical-processing and electricity-generating engines fueled by petroleum are monitored when activities are known to release pollutants of concern, such as particulate matter, sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead. Total annual releases of these constituents are reported in accordance with the air quality standards established in [WAC 173-400](#), *General Regulations for Air Pollution Sources*. Based on the quantities of petroleum fuel consumed at Hanford Site power plants, emissions were calculated using EPA-approved formulas ([AP-42](#), *Compilation of Air Pollutant Emission Factors*, Volume I: *Stationary Point and Area Sources*). Table 6.2 summarizes the Hanford Site emissions of nonradioactive criteria and toxic air pollutants discharged to the atmosphere.

*Table 6.2. Hanford Site Criteria and Toxic Air Pollutant Emissions*

Constituent	2014 Releases	
	lb	kg
<b>Criteria Pollutants</b>		
Particulate matter-total	0	0
Particulate matter-10	2,000	907
Particulate matter-2.5	0	0
Lead	0	0
Nitrogen oxides	32,000	14,515
Sulfur oxides	0	0
Carbon monoxide	20,000	9,072
Volatile organic compounds	10,000	4,536
Ammonia	6,000	2,722
<b>Toxic Air Pollutants</b>		
Acetic acid	1	0.45
Acetone	2	0.91
Benzene	1	0.45
Carbon tetrachloride	200	2.7
Chloroform	2	0.45
Dichloromethane	11	5.0
1,1,1-Trichloroethane	2	0.91
Trichlorofluoromethane	1	0.45

## 6.2 Ambient Air Monitoring

*CJ Perkins*

Atmospheric releases of radioactive materials from Hanford Site facilities and operations to the surrounding region are potential sources of exposure to humans. Radioactive constituents in air are monitored at Hanford Site facilities and operations, at locations away from site facilities, and offsite around the site perimeter as well as in nearby and distant communities. Information about these ambient air-monitoring efforts, including detailed descriptions of air sampling and analysis techniques, is provided in RL's environmental monitoring plan ([DOE/RL-91-50](#)).

Comparing measured radionuclide concentrations from locations on and around the Hanford Site to concentrations measured at upwind locations assumed to be uninfluenced by Hanford Site operations provides an evaluation of the impact of radionuclide air emissions from the Hanford Site on surrounding ambient air.

### 6.2.1 Hanford Site Ambient Air Monitoring

A network of continuously operating samplers at 63 locations across the Hanford Site was used during 2014 to monitor radioactive airborne materials in air near Hanford Site facilities and operations (Table 6.3). Most air samplers were located at or within approximately 1,640 feet (500 meters) of sites and facilities having the potential for, or a history of, environmental releases. The samplers were primarily located in the prevailing downwind direction. Samples were collected according to a schedule established before the 2014 monitoring year. Airborne particle samples were collected at each location by drawing air through a cellulose filter. The filters were collected biweekly, field-surveyed for gross radioactivity, held



for at least 5 days, and then analyzed for gross alpha and beta activity. The 5-day holding period is necessary to allow for the decay of naturally occurring, short-lived radionuclides that would otherwise obscure the detection of longer-lived radionuclides associated with emissions from nuclear facilities. The gross radioactivity measurements were used to indicate changes in trends in the onsite facility environment.

For most specific radionuclide analyses, the amount of radioactive material collected on a single filter during a 2-week period was too small to be measured accurately. The individual samples collected during the year at each location were combined into semiannual, location-specific, composite samples (Table 6.3) to increase the accuracy of the analysis. Composite samples were routinely analyzed for gamma-emitting isotopes, strontium-90, uranium-234, uranium-235, plutonium-238, uranium-238, and plutonium-239/240. Americium-241 and plutonium-241 were analyzed at locations associated with spent nuclear fuel processing.

Figure 6.1 shows the annual average air concentrations of selected radionuclides in the 100, 200, and 600 Areas compared to EPA concentration values and air concentrations measured in distant communities. The EPA concentration values for environmental compliance ([40 CFR 61](#), Appendix E, Table 2) are dose-based reference values used as indices of performance. The concentration values are concentrations that would result in a dose of 10 millirem (100 microsievert) per year under conditions of continuous exposure. The 2014 data indicate a large degree of variability by location. Air samples collected from locations at or directly adjacent to Hanford Site facilities had higher radionuclide concentrations than samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which are much less than EPA concentration values but greater than those measured offsite. The data also show that concentrations of certain radionuclides were higher and widely variable within different Hanford Site operational areas. Appendix C, Table C.5 shows the annual average and maximum concentrations of radionuclides in air samples collected near Hanford Site facilities and operations during 2014.

Air monitoring was conducted only through April 2014 at the 100-N Area deactivation, decommission, decontamination and demolition (D4) project. All radionuclides of concern were below analytical detection limits.

Ambient air was monitored in 2014 at six locations in the 100-K Area, and analytical results showed radionuclide concentrations at or below typical Hanford Site levels. Uranium-234 and uranium-238 were detected in approximately 17 percent of the samples, and tritium was detected in approximately 30 percent of the samples. All other radionuclides of concern were below analytical detection limits.

Air sampling was conducted at 21 locations in the 200 East Area during 2014. Generally, radionuclide levels measured in the 2014 air composite samples were similar to those measured in previous years. Uranium-234 and uranium-238 were detected in approximately 30 percent of the samples. All other radionuclides of concern were below analytical detection limits.

Air sampling was conducted at 23 locations in the 200 West Area during 2014. Radionuclide levels measured were similar to results for previous years. Uranium-234 and uranium-238 were detected in approximately 25 percent of the samples. Plutonium-239/240 was detected in approximately 10 percent of the samples. Noteworthy for the second consecutive year (2014) was that there were no elevated

plutonium-239/240 concentrations at air-sampling location N165, located near the 216-Z-9 Trench (see Figure 6.2).

Air sampling in support of the 300 Area D4 and Field Remediation project continued in 2014. Uranium-234 and uranium-238 were detected in 85 percent of the samples at levels similar to those measured in previous years.

Air sampling was conducted at five locations at ERDF (200 West Area). Radionuclide levels measured at this site were similar to typical Hanford Site levels. Uranium-234 and uranium-238 were detected in 10 percent of the samples, and all other radionuclides of concern were below analytical detection limits.

Air monitoring was conducted at four locations at the 618-10 Burial Ground Project (north of the 300 Area). The analytical results showed that plutonium-239/240 was detected in 75 percent of the samples, and uranium-234, uranium-238, and americium-241 were detected in approximately 38 percent of the samples. During the second-half of 2014, one air monitoring result from one station located at the 618-10 Burial Ground project was greater than 10 percent of EPA's concentration values ([40 CFR 61](#), Appendix E, Table 2) and was reported to EPA and WDOH. Plutonium-239/240 at station N548 was elevated, and no contributing cause was specifically identified. Similar results were reported at this location during 2011 and 2012 (see Figure 6.3).

**Table 6.3. Hanford Site Monitoring Locations and Analyses for Ambient Air Monitoring Samples**

Site/Project	Number of Samplers	EDP Code	Analyses	
			Bi-Weekly	Composite
100-K Area	6	N476, N534, N535, N575, N576 <sup>a</sup> , N578	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238, americium-241
100-N Area D4 Project	3	N102, N103, N106	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238, americium-241
200-East Area	17	N019, N158, N498, N499, N957, N967, N968, N969, N970, N972, N973, N976, N977, N978, N984 <sup>a</sup> , N985, N999	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238
Canister Storage Building (200-East Area)	2	N480, N481	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238
Integrated Disposal Facility (200-East Area)	2	N532, N559	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238
200-West Area	23	N155, N161, N165 <sup>a</sup> , N168, N200, N304, N433, N441, N442, N449, N456, N457, N554, N555, N956, N963, N964, N965, N966, N974, N975, N987, N994	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238
300 Area D4 and Field Remediation Project <sup>b</sup>	2	N557, N130	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238
Environmental Restoration Disposal Facility	5	N482 <sup>a</sup> , N168, N517, N518, N963	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238
600 Area (WYE Barricade)	1	N981 <sup>a</sup>	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238
618-10 Burial Ground	4	N548 <sup>a</sup> , N549, N579, N580	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/240, uranium-234/-235/-238

<sup>a</sup>. Collocated sampling location with Washington State Department of Health.<sup>b</sup>. Offsite air sampling station(s) provide supplemental air monitoring data. See Table 6.4 for a listing of locations.

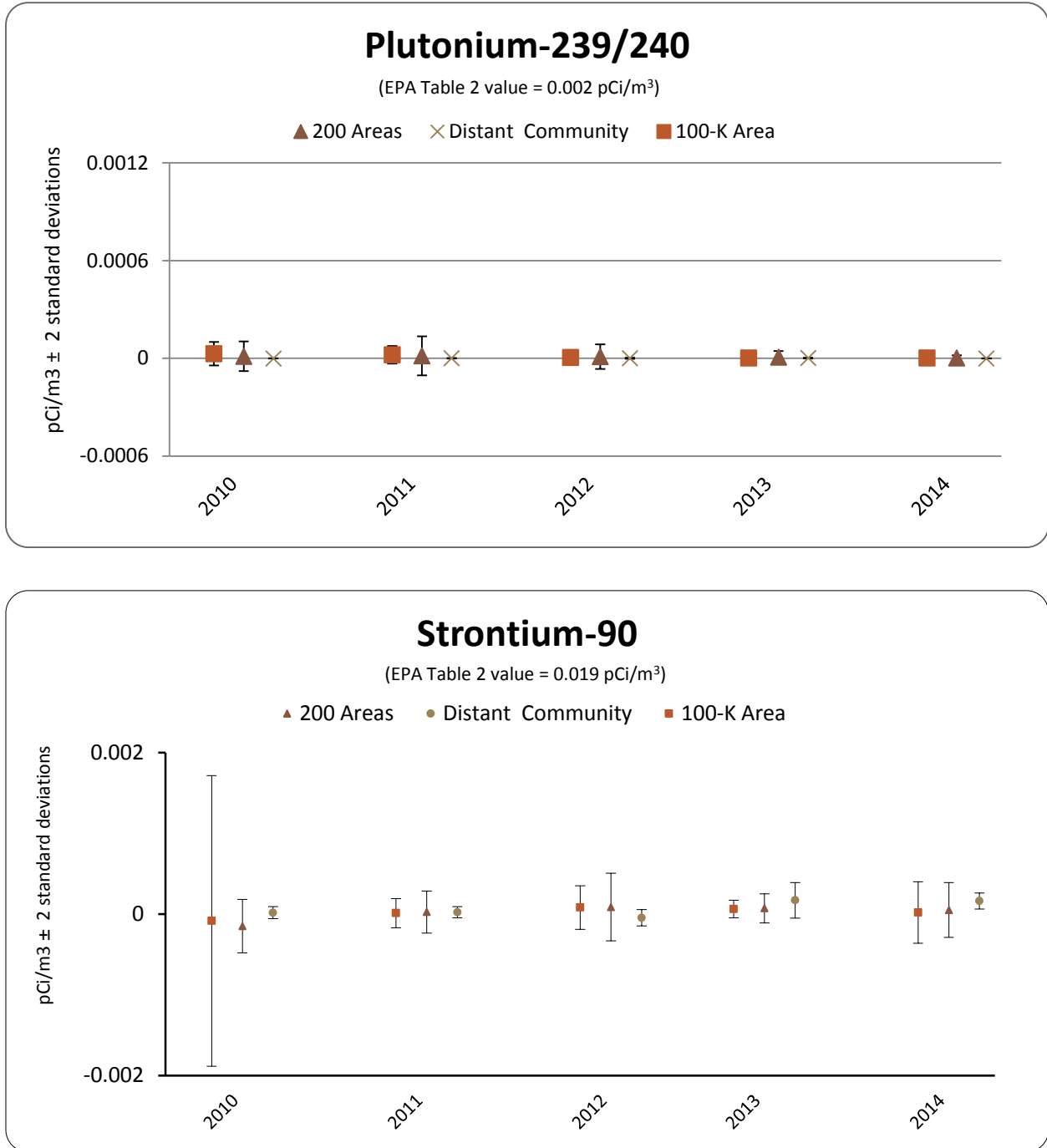
D4 = deactivation, decommission, decontamination and demolition.

EDP = Environmental data point code = sampler location code.

GEA = Gamma energy analysis.

**Figure 6.1.** Hanford Site Average Radionuclide Concentrations in Ambient Air Samples Compared to Distant Community Samples

Because of figure scale, some uncertainties (error bars) are concealed by the point symbol. KBC = K Basins Closure Project.



**Figure 6.1** Hanford Site Average Radionuclide Concentrations in Ambient Air Samples Compared to Distant Community Samples (Cont.)

Because of figure scale, some uncertainties (error bars) are concealed by the point symbol. KBC = K Basins Closure Project.

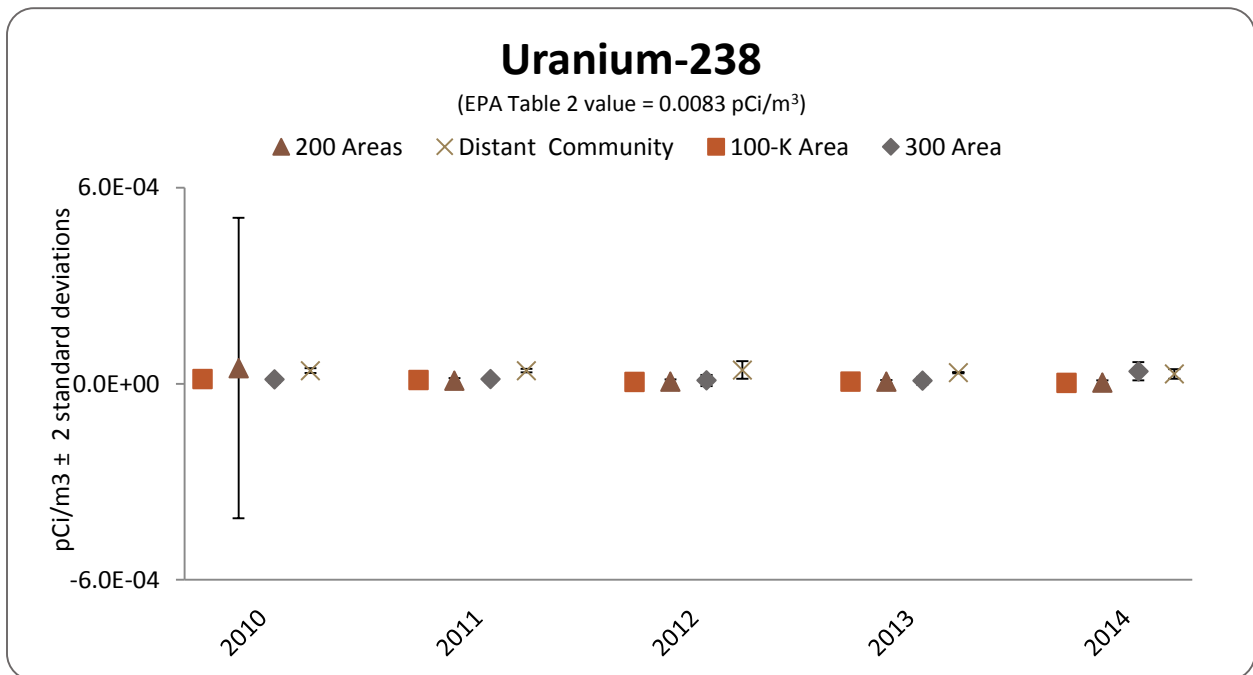
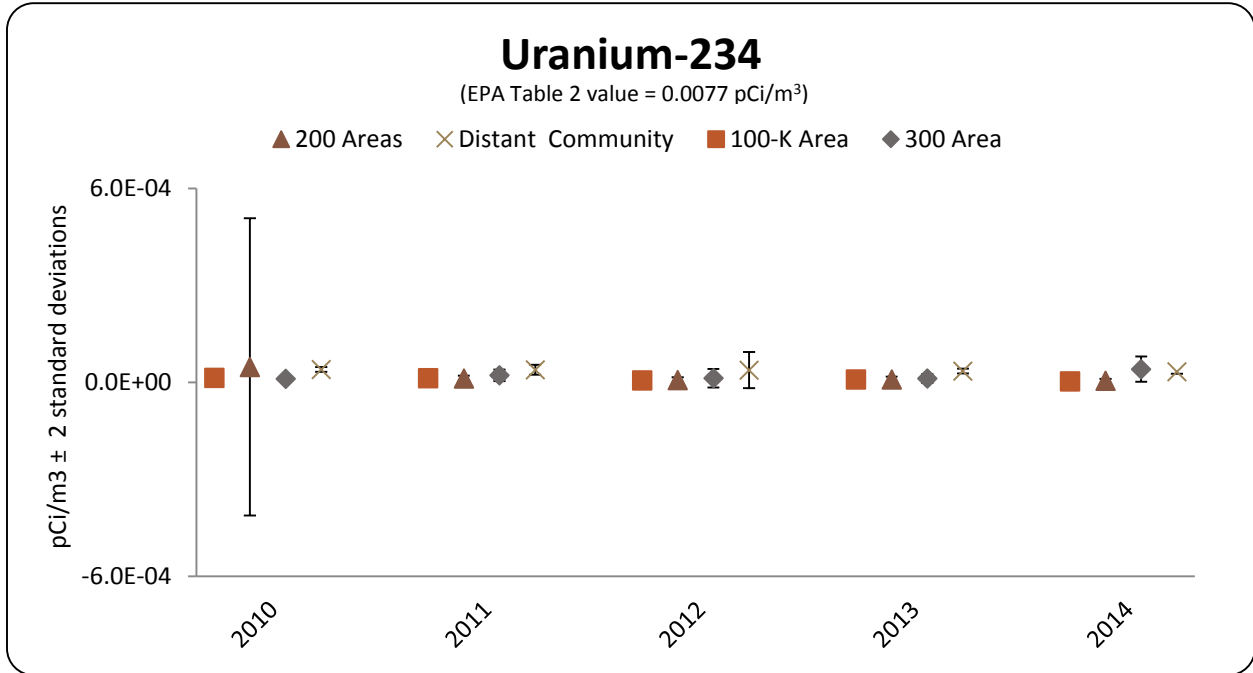


Figure 6.2. Plutonium-239/240 Air Concentrations at 216-Z-9 Trench

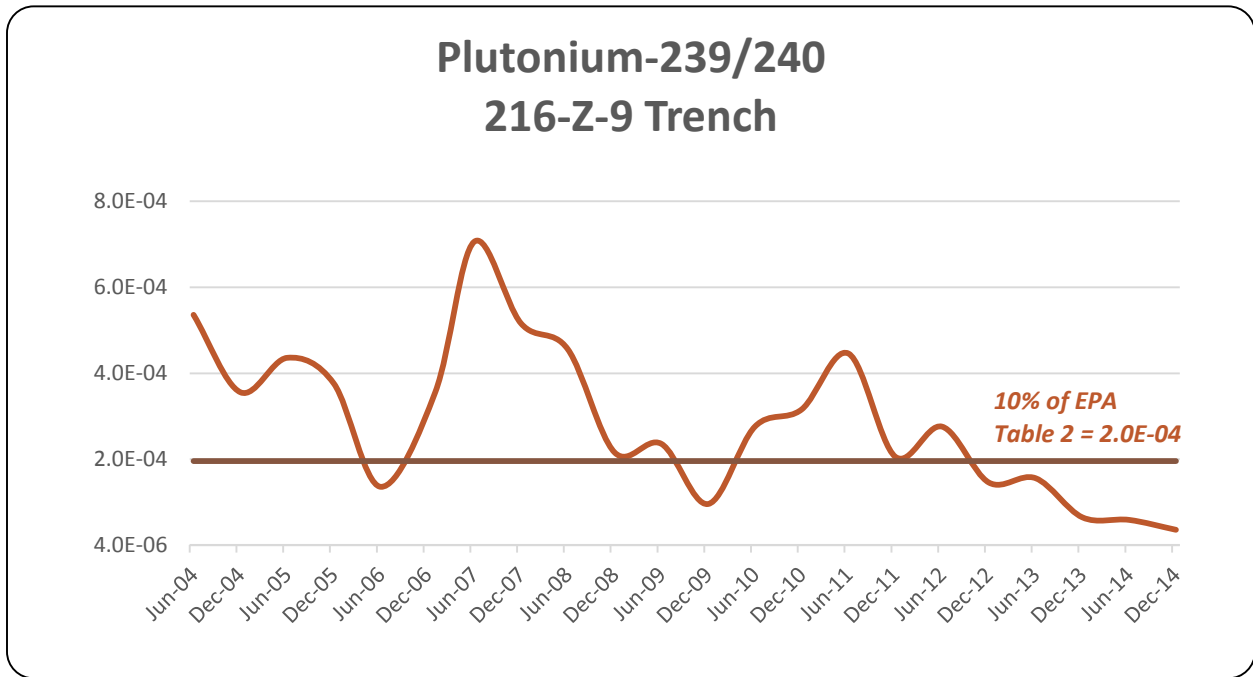
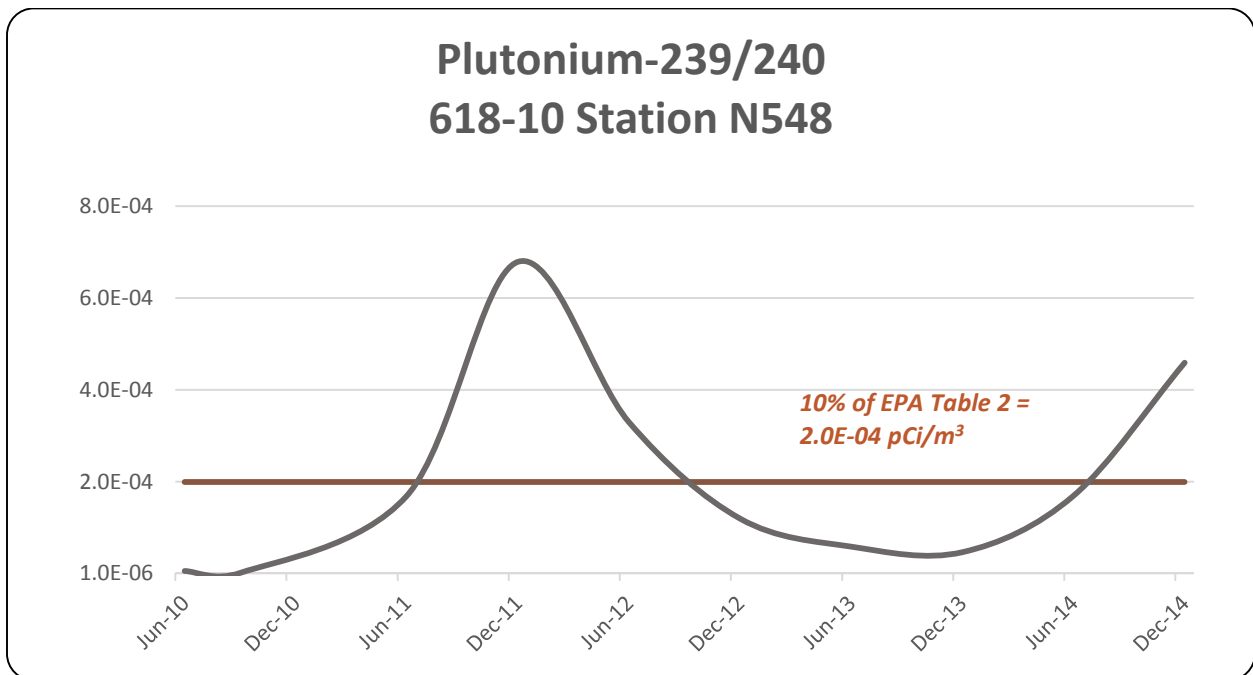


Figure 6.3. Plutonium-239/240 Air Concentrations at 618-10 Station N548





## 6.2.2 Hanford Site and Offsite Ambient Air Monitoring

Airborne radionuclide samples were collected in 2014 by 40 continuously operating samplers at or in the vicinity of the Hanford Site. The sampling stations were grouped into four location classifications:

1) Hanford Site (21 stations), 2) perimeter (11 stations), 3) nearby Hanford Site communities (7 stations), and 4) distant community (1 station) (Figure 6.4 and Table C.6, Appendix C). Hanford Site air samplers were located primarily around major operational areas to maximize the capability to detect radiological contaminants resulting from site operations. Perimeter samplers were located around the site boundary with emphasis on the prevailing downwind directions to the south and east. Samplers located in Basin City, Benton City, Kennewick, Mattawa, Othello, Pasco, and Richland, Washington, provided data for the nearest population centers. A sampler in Yakima, Washington, provided background data from a community essentially unaffected by Hanford Site operations.

### 6.2.2.1 Sampling and Analysis

Samples were collected and analyzed according to a schedule established prior to the monitoring year for offsite samples ([DOE/RL-2013-53](#), *Hanford Site Environmental Surveillance Master Sampling Schedule Calendar Year 2014*). Airborne particle samples were collected biweekly at each location by continuously drawing air through a glass-fiber filter. The filter samples were transported to an analytical laboratory and stored for at least 72 hours. The storage time allows for the decay of short-lived, naturally occurring radionuclides (e.g., radon gas decay products) that would otherwise obscure the detection of longer-lived radionuclides potentially present from Hanford Site emissions. The filters were then analyzed for gross beta radiation. Selected filters were also analyzed for gross alpha radiation. Historically, for most radionuclides, the amount of radioactive material collected on a filter during a 2-week period has been too small to analyze accurately individual radionuclides of concern. Biweekly samples were combined into semiannual composite samples to increase the sensitivity and accuracy of the analysis. The compositing procedure results in a 26-week average concentration for specific radionuclides present in the atmosphere as particulates. The composite samples were analyzed for gamma-emitting radionuclides, and most were analyzed for strontium-90, uranium-234, uranium-235, plutonium-238, uranium-238, and plutonium-239/240. Table 6.4 shows the analyses for the discrete filters and composite samples.

Atmospheric water vapor was collected for tritium analysis at 20 locations in 2014 by continuously drawing air through multi-column samplers containing adsorbent silica gel. The water-vapor samplers were exchanged every 4 weeks to prevent loss of the sample as a result of breakthrough (i.e., oversaturation). The collection efficiency of the silica gel adsorbent is discussed in *Ambient Air Sampling for Tritium-Determination of Breakthrough Volumes and Collection Efficiencies for Silica Gel Adsorbent* ([Patton et al. 1997](#)). The collected water was distilled from the silica gel and analyzed for its tritium content.

### 6.2.2.2 Monitoring Results

All sample results in 2014 showed very low radiological concentrations in air. With the exception of one sample, all radionuclide concentrations (Table C.6, Appendix C) were less than their respective EPA Table 2 concentration values. The EPA concentration values ([40 CFR 61](#), Appendix E, Table 2) are concentrations that would result in an annual dose of 10 millirem (100 microsievert) per year from airborne radiological material.

Gross alpha concentrations in the air samples collected in 2014 from Hanford Site, perimeter, and nearby Hanford Site communities were comparable to each other and slightly higher than samples from the distant community. Gross alpha concentrations in 2014 were comparable to concentrations seen in the previous 5 years.

Gross beta and gross alpha concentrations in air peaked during the fall and winter months in 2014 (Figure 6.5), repeating a pattern of natural radioactivity fluctuations (*Environmental Radioactivity from Natural, Industrial, and Military Sources* [Eisenbud 1987]). This fluctuation is seen in both Hanford Site and distant location concentrations.

During the second-half of 2014, one air monitoring result from a perimeter station located east of the Hanford Site was slightly greater than 10 percent of EPA's concentration value (40 CFR 61, Appendix E, Table 2) and was reported to EPA and WDOH. Cobalt-60 was detected at the West End of Fir Road Station, and no contributing cause was specifically identified.

Plutonium-239/240 was detected at very low levels in 2 out of 64 air samples collected in 2014. Both results were less than 1 percent of the EPA concentration value. Figure 6.6 shows that plutonium-239/240 concentrations in the air samples collected in 2014 are at levels similar to those measured in previous years. There were no plutonium-238 detects in 2014.

Uranium-234 and uranium-238 were both detected in all air samples collected in 2014 from all four location classes. Figure 6.6 shows that uranium-234 and uranium-238 concentrations were at levels similar to those measured in previous years. The maximum concentrations measured in all locations were less than one percent of the EPA concentration values for both radionuclides.

Cesium-137 was detected in one sample at less than 10 percent of the EPA concentration value.

Strontium-90 was not detected in any of the samples collected during 2014.

Figure 6.4. Ambient Air Sampling Locations

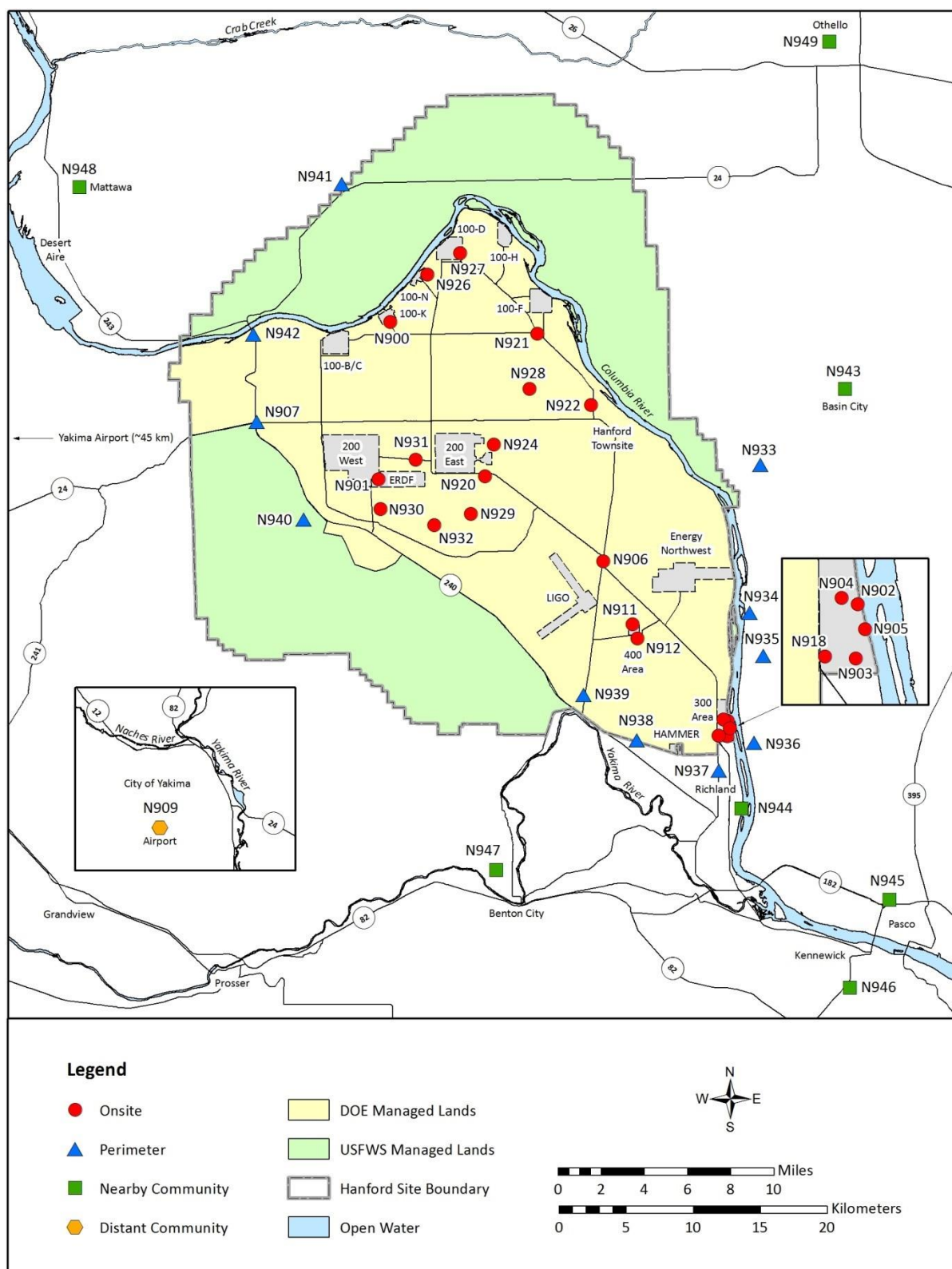


Table 6.4. Hanford Site and Offsite Ambient Air Sampling Locations and Analytes

EDP Code <sup>a</sup>	Location	Analyses		
		Bi-Weekly	Monthly <sup>b</sup>	Composite
Hanford Site				
N900	100 K Area	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N926	100 N-1325 Crib	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N927	100 D Area	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N921	100 F Met Tower	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N922	Hanford Townsite	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N928	Gable Mountain	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N920	200 ESE	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N929	S of 200-E	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N924	B Pond	Alpha, Beta		GEA, plutonium-238/-239/240, uranium-234/-235/-238
N930	Army Loop Camp	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N931	200 Tel. Exchange	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N932	SW of B/C Cribs	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N901	200 W SE	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N905	300 Water Intake <sup>c, d, e</sup>	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N903	300 South Gate <sup>e, f</sup>	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N918	300 South West <sup>e</sup>	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N904	300 Trench <sup>e</sup>	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N902	300 NE <sup>e</sup>	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240
N911	400 N	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240
N912	400 S	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240
N906	Wye Barricade <sup>c, g</sup>	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238

Table 6.4. Hanford Site and Offsite Ambient Air Sampling Locations and Analytes

EDP Code <sup>a</sup>	Location	Analyses		
		Bi-Weekly	Monthly <sup>b</sup>	Composite
Hanford Site Perimeter				
N933	Ringold Met Tower	Alpha, Beta	Tritium	GEA, plutonium-238/-239/240
N934	W End of Fir Road <sup>c, d</sup>	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N935	Dogwood Met Tower	Alpha, Beta	Tritium	GEA, strontium-90, uranium-234/-235/-238
N936	Byers Landing	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N937	Battelle Complex <sup>c, d</sup>	Alpha, Beta	Tritium	GEA, uranium-234/-235/-238
N938	Horn Rapids Substation	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240
N939	Prosser Barricade <sup>c, d</sup>	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240
N907	Yakima Barricade <sup>c</sup>	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240
N940	Rattlesnake Springs	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240
N941	Wahluke Slope	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240
N942	South End Vernita Bridge	Beta, Alpha		GEA, strontium-90, plutonium-238/-239/240
Nearby Hanford Site Communities				
N943	Basin City School	Alpha, Beta	Tritium	GEA, plutonium-238/-239/240, uranium-234/-235/-238
N944	Leslie Groves-Richland	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N945	Pasco	Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N946	Kennewick-Ely Street	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238
N947	Benton City	Beta		GEA
N948	Mattawa	Beta		GEA
N949	Othello	Beta		GEA, uranium-234/-235/-238
Distant Hanford Site Community				
N909	Yakima	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/240, uranium-234/-235/-238

<sup>a</sup>. EDP Code = Environmental data point code = sampler location code. Refer to Figure 6.2.

<sup>b</sup>. Atmospheric water vapor samples for tritium analysis are collected every 4 weeks using silica gel columns.

<sup>c</sup>. WDOH particulate air sampler also at this location.

<sup>d</sup>. WDOH tritium air sampler also at this location.

<sup>e</sup>. Data from this location is used to support 300 D4 and Field Remediation project.

<sup>f</sup>. Two tritium samples are collected from this location, one as a Quality Assurance duplicate sample.

<sup>g</sup>. Quality Assurance duplicate sample collected at this location.

GEA = Gamma energy analysis.

Figure 6.5. Gross Alpha and Beta Concentrations in Airborne Particulate Samples  
(1 pCi = 0.037 Bq)

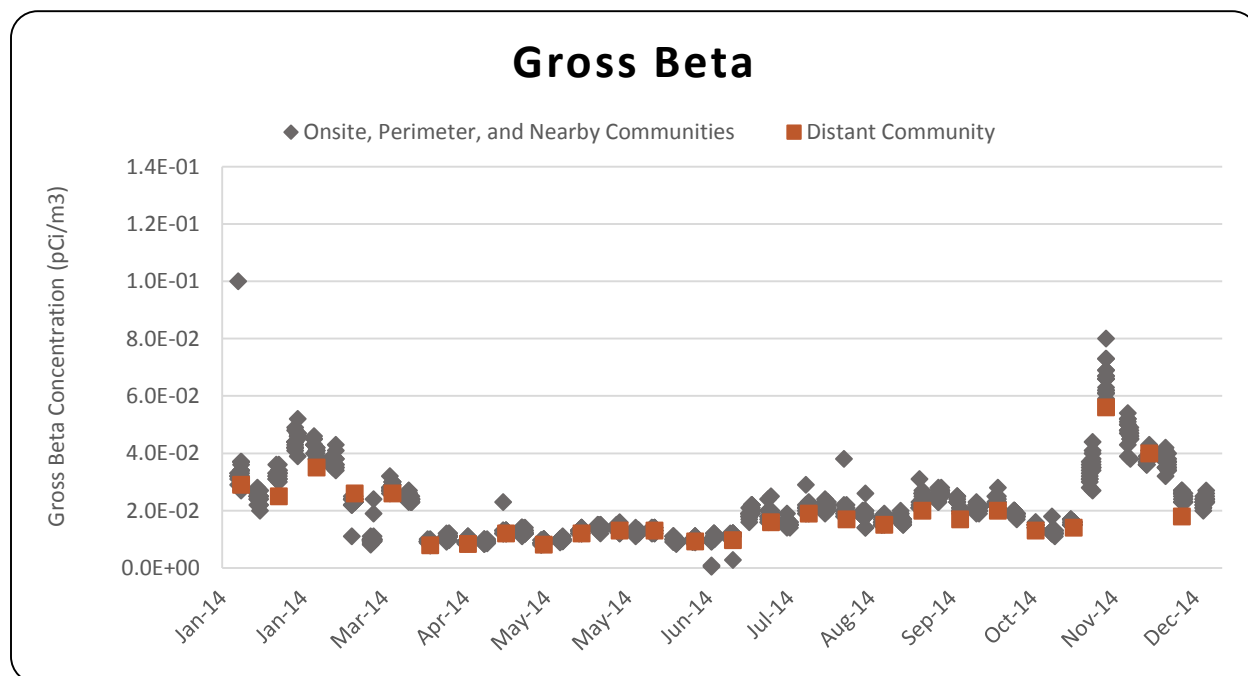
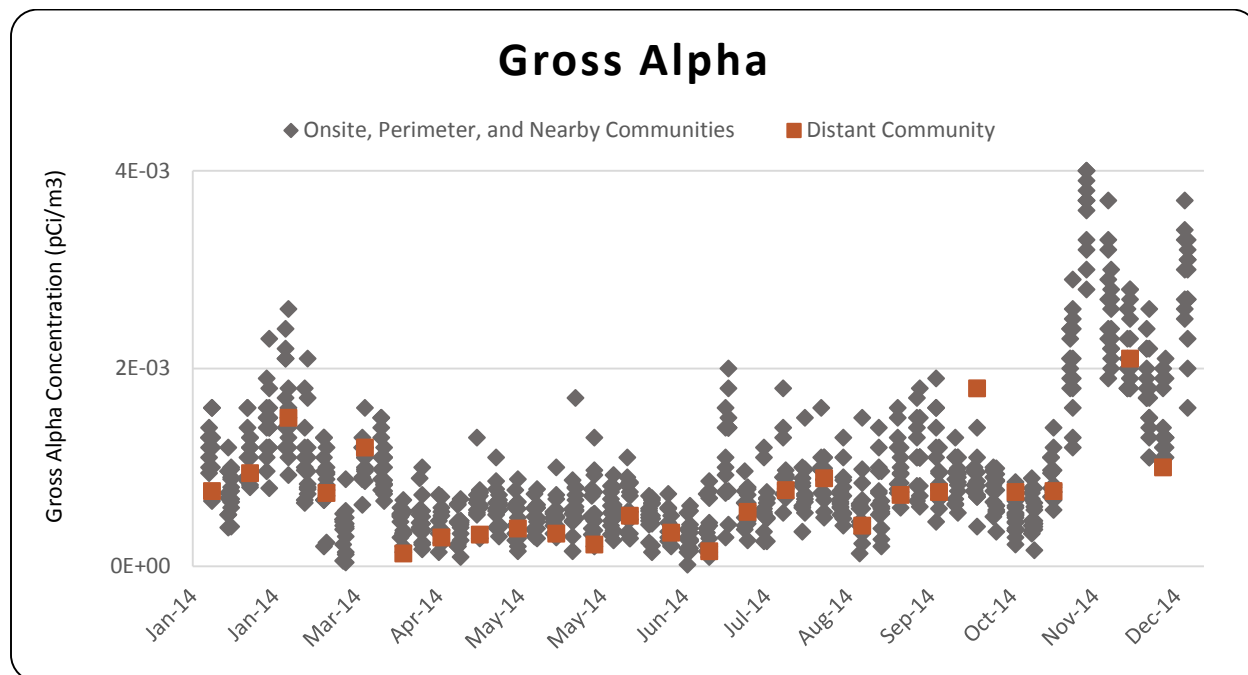




Figure 6.6. Radionuclide Concentrations in Ambient Air Samples  
(1 pCi = 0.037 Bq)

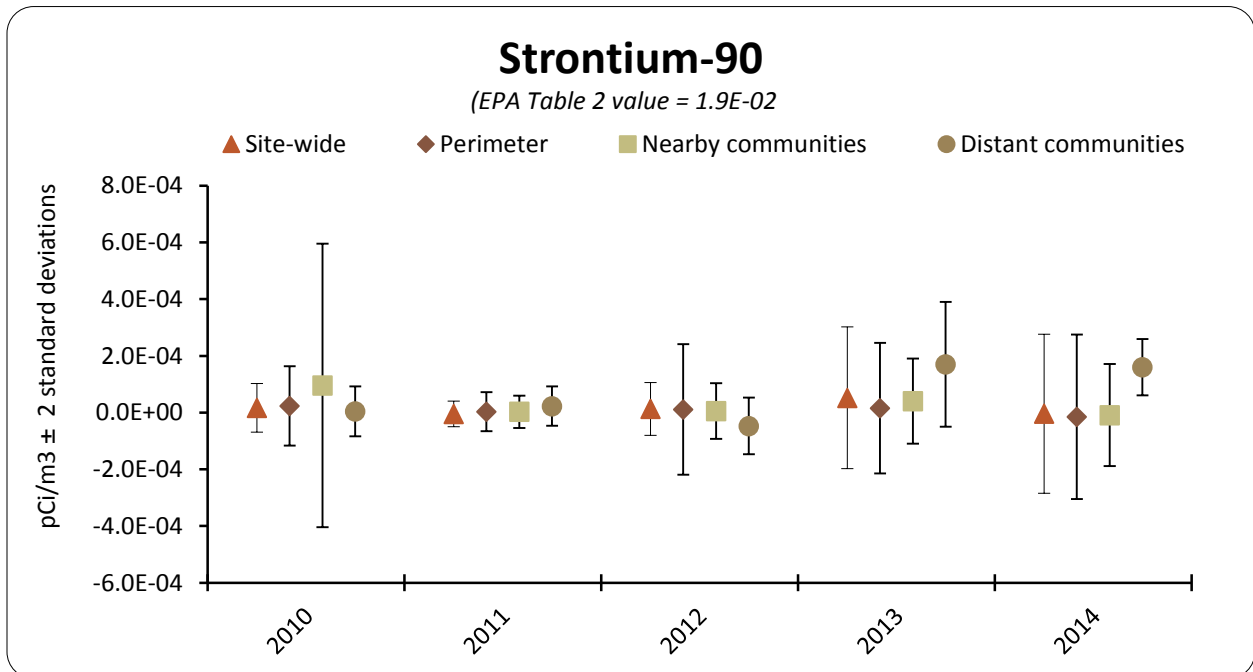
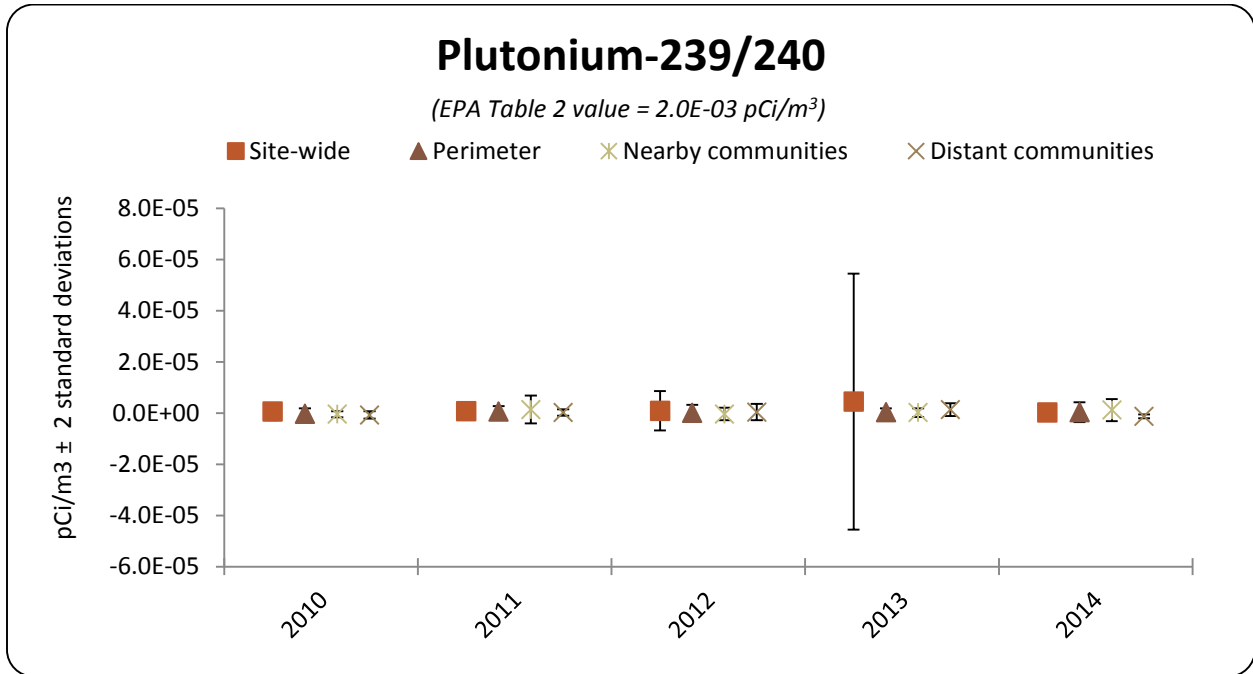


Figure 6.6. Radionuclide Concentrations in Ambient Air Samples (Cont.)  
(1 pCi = 0.037 Bq)

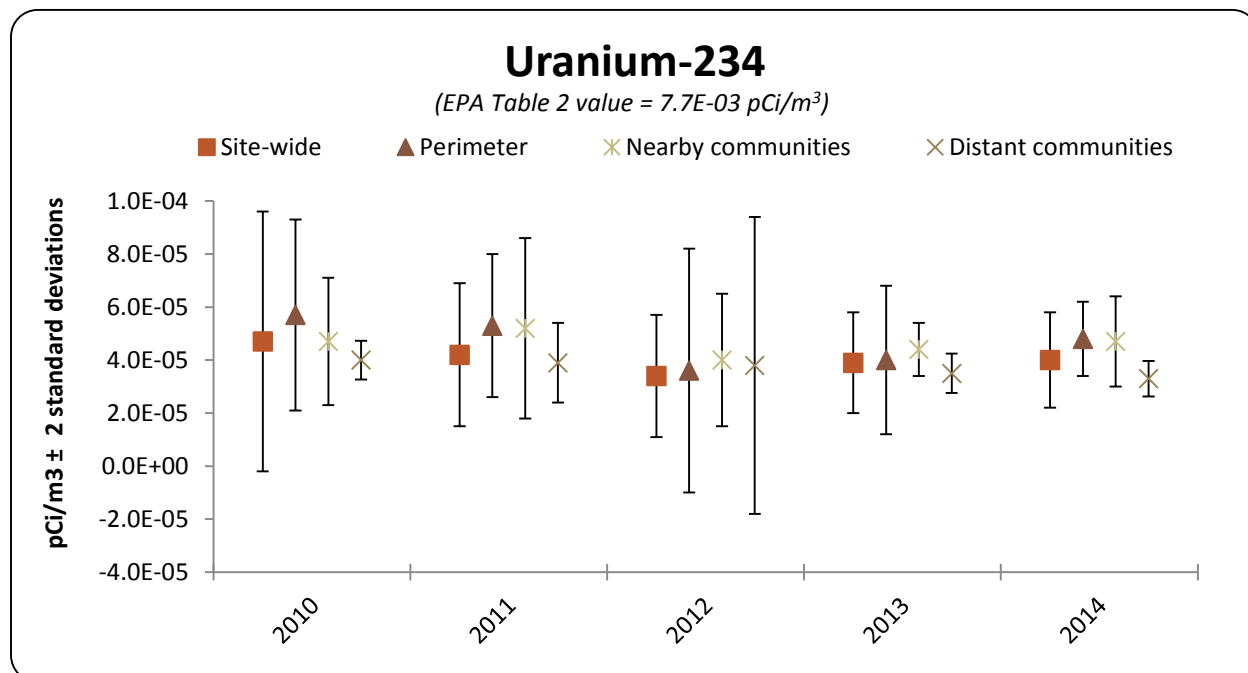
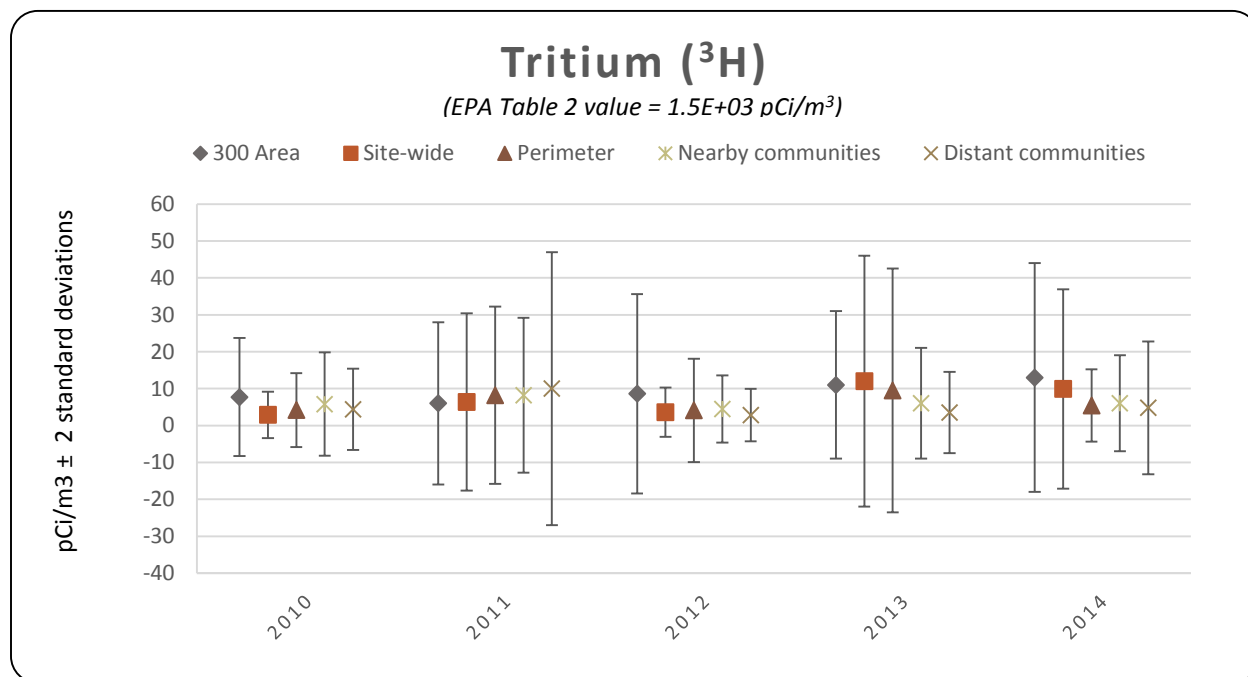
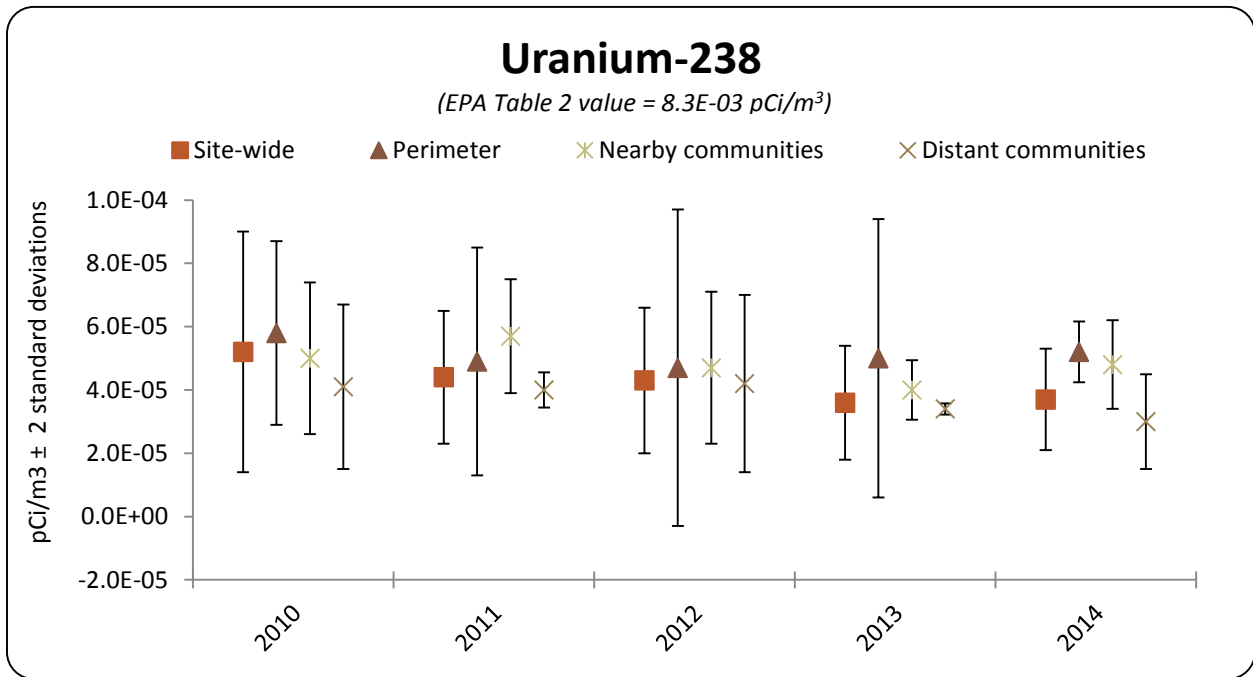


Figure 6.6. Radionuclide Concentrations in Ambient Air Samples (Cont.)  
(1 pCi = 0.037 Bq)



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## 7.0 Water Monitoring

### 7.1 Drinking Water Systems

*LE Bisping and LM Kelly*

Eight DOE-owned, contractor-operated, public water systems supply drinking water to DOE facilities on the Hanford Site (Table 7.1). MSA operates six of the public water systems; WCH operated one system through September 30, 2014, and responsibility was transferred to MSA on October 1, 2014, and CHPRC operates two systems. The city of Richland supplied water to the 300 Area, the Richland North Area, and HAMMER.

*Table 7.1. Drinking Water Systems*

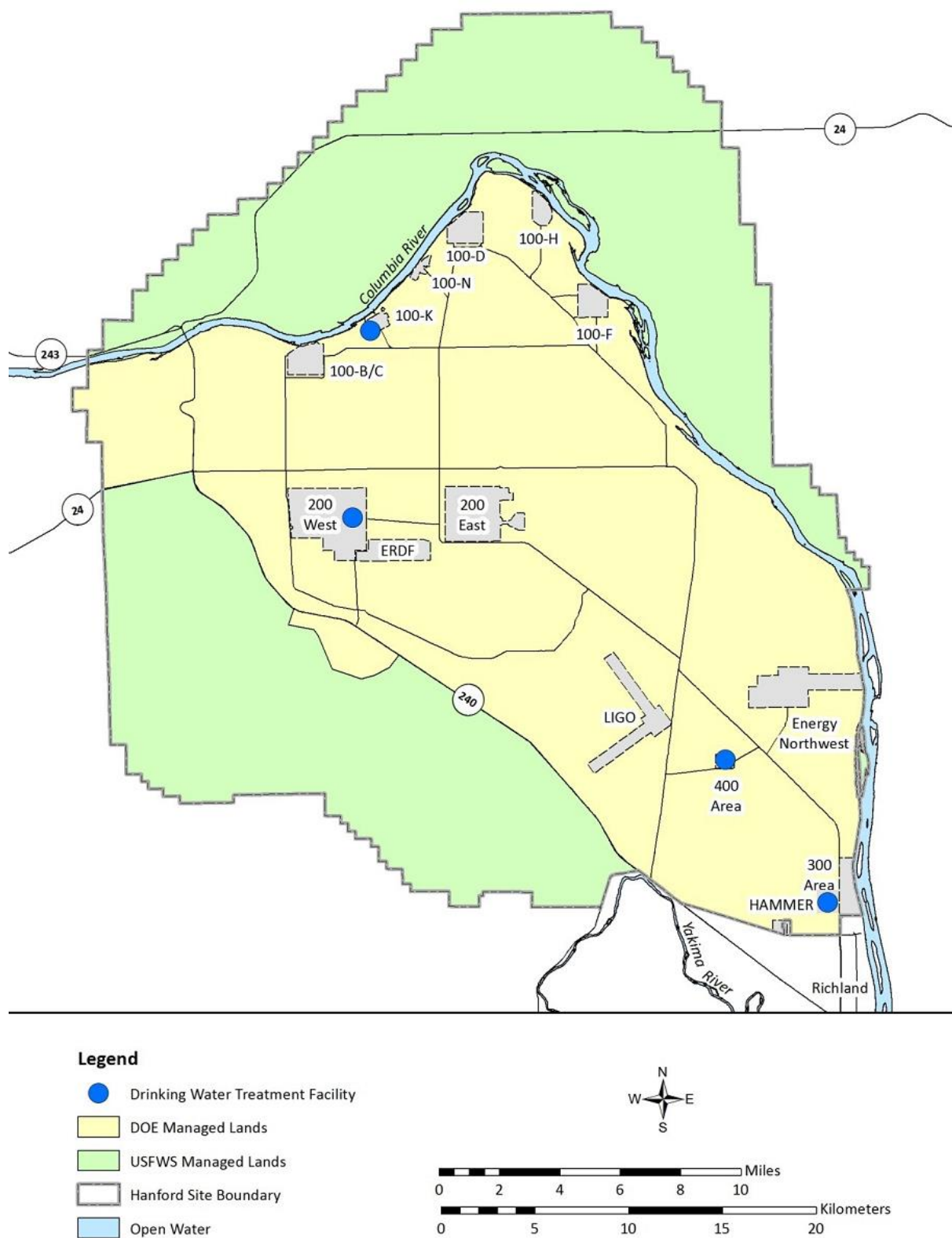
Public Water System	Water Source	Operator
100-K Area	Columbia River	CHPRC
200 West Area	Columbia River	MSA
251 Substation	Trucked Water from 283-W Water Treatment Plant	MSA
Wye Barricade	Trucked Water from 283-W Water Treatment Plant	MSA
Yakima Barricade	Trucked Water from 283-W Water Treatment Plant	MSA
300 Area	City of Richland (Columbia River and Wells)	WCH/MSA <sup>a</sup>
400 Area	400 Area Groundwater Wells	CHPRC
609 Fire Station	Trucked Water from Water Treatment Plant 283-W Water Treatment Plant	MSA

<sup>a</sup> WCH operated water system until responsibility shifted 10/1/14 to MSA.

#### 7.1.1 Drinking Water Treatment Facilities

Source water was treated at four DOE-owned water treatment facilities in the 100-K, 200 West, 300 and 400 Areas (Figure 7.1). All facilities treated the water with a form of chlorine to ensure adequate disinfection prior to distribution. The source of supply water for the 100-K Area and 200 West Area facilities was the Columbia River. The 100-K Area water treatment plant (189-K) employed membrane filtration, a pressure-driven process, and coagulation to remove particulate matter and microbial pathogens from the water. The 200 West water treatment plant (283-W) used conventional filtration treatment, which is a series of processes including coagulation, flocculation, sedimentation, and filtration that together achieved substantial particulate removal. The city of Richland supplied water to the 300 Area booster pumping station 385, where sodium hypochlorite was added as necessary prior to distribution to 300 Area consumers. The 400 Area source of supply was groundwater provided from one of three wells. The 400 Area primary supply well 499-S1-8J (P-16) was the source of drinking water for all of 2014. Emergency backup wells 499-S0-8 (P-14) and 499-S0-7 (P-15) did not supply water to 400 Area consumers during the reporting period.

Figure 7.1. Drinking Water Treatment Facilities





### 7.1.2 Monitoring

Samples at 100-K, 200 West, and 400 Area drinking water treatment facilities were collected monthly and analyzed quarterly or annually for radiological contaminants. All were samples of treated water collected before the water was distributed for general use. DOE contractor personnel did not routinely monitor drinking water in the 300 Area, Richland North Area, and HAMMER for radiological contaminants. However, Public Safety and Resource Protection personnel routinely collected water samples from the Columbia River at the city of Richland river water intake. The Columbia River is a major source of the city of Richland's drinking water. The radiological analytical results for these river water samples are summarized in this section and tabulated in Appendix D. The city of Richland monitors its water for radiological and chemical contaminants as well as for general water quality. Because it is a community water system, city officials are required to annually report monitoring results and characterize the risks (if any) from exposure to contaminants in the water in what is known as a Consumer Confidence Report. The annual water quality report is mailed to all utility consumers as an insert with a monthly utility bill, and is available on the city of Richland website at <https://www.ci.richland.wa.us/DocumentCenter/View/8643/>.

### 7.1.3 Radiological Results

Scientists conducted radiological monitoring of drinking water at one DOE-owned pump and three water treatment facilities. In addition, routine chemical, physical, and microbiological monitoring of Hanford Site drinking water was performed. Individual water systems operated by MSA, CHPRC, and WCH (Table 7.1) performed process monitoring (including chemical and physical sampling) at the water treatment plants and distribution systems to determine compliance with applicable regulations.

[WAC 246-290](#) requires that all drinking water analytical results be reported routinely to the WDOH. Radiological results for Hanford Site drinking water samples are reported to the state through this annual environmental report. The contractor responsible for operating the water system provides process-monitoring reports directly to the state each month. Chemical, physical, and microbiological data are reported to the state directly by the state-accredited laboratory performing the analyses, as well as to MSA; however, the reports are not published.

With the exception of the 300 Area drinking water system, all DOE-owned Hanford Site systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels during 2014. A monthly total coliform sample was inadvertently missed in the 300 Area that resulted in a monitoring violation. Contaminant concentrations measured during the year were similar to those observed in recent years as described in the annual Hanford Site environmental reports for 2012 ([DOE/RL-2013-18](#)) and 2013 ([DOE/RL-2013-47](#)).

Environmental assessment personnel collected drinking water samples for radiological analysis, which were analyzed for gross alpha, gross beta, tritium, and strontium-90 (Table 7.2). The maximum amount of beta-gamma radiation from manmade radionuclides allowed in drinking water by Washington State and EPA is an annual average concentration that will not produce an annual dose equivalent to the whole body or any internal organ greater than 4 millirem (0.04 millisievert). Maximum contaminant levels for gross alpha (excluding radon and uranium) are 15 pCi/L (0.56 Bq/L). The maximum allowable annual average limit for tritium is 20,000 pCi/L (740 Bq/L) ([40 CFR 141](#) and [WAC 246-290](#)). These concentrations are assumed to produce a total body or organ dose of 4 millirem (0.04 millisievert) per year.

If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any internal organ must not exceed 4 millirem (0.04 millisievert).

Annual average concentrations of all monitored radionuclides in Hanford Site drinking water in 2014 were below state and federal maximum allowable contaminant levels (Table 7.2). The gross alpha, gross beta, tritium, and strontium-90 results from the two facilities where drinking water was obtained from the Columbia River were all below minimum detectable concentration (i.e., concentrations were too low to measure). The 400 Area source of drinking water for 2014 was well 499-S1-8J (P-16). Gross beta and tritium were found in all 400 Area water samples, but were still below the maximum allowable contaminant level. Gross alpha and strontium-90 were not detected in 400 Area water samples.

**Table 7.2. Drinking Water Annual Average Concentrations of Selected Radiological Constituents**

Constituent	Systems	Samples Analyzed at	Annual Average <sup>a</sup>	Standard
		Each Location	(pCi/L) <sup>b</sup>	
Gross alpha <sup>c</sup>	100-K Area	4 <sup>d</sup>	-0.434 ± 1.794	15 <sup>e, f</sup>
	200 West Area	4 <sup>d</sup>	-0.846 ± 1.124	
	400 Area	4 <sup>d</sup>	-0.278 ± 1.273	
Gross beta <sup>c</sup>	100-K Area	4 <sup>d</sup>	0.799 ± 3.500	50 <sup>f</sup>
	200 West Area	4 <sup>d</sup>	0.298 ± 2.161	
	400 Area	4	6.973 ± 2.770	
Tritium <sup>g</sup>	100-K Area	1 <sup>d</sup>	-84.8 ± 357	20,000 <sup>f</sup>
	200 West Area	1 <sup>d</sup>	165 ± 382	
	400 Area	4	1130 ± 384	
Strontium-90 <sup>g</sup>	100-K Area	1 <sup>d</sup>	-0.058 ± 0.991	8 <sup>e, f</sup>
	200 West Area	1 <sup>d</sup>	0.772 ± 1.15	
	400 Area	1 <sup>d</sup>	-0.945 ± 0.954	

<sup>a</sup> Annual average is ± 2 times the standard deviation, unless only one sample analyzed in which case it is the single result ± total propagated analytical error.

<sup>b</sup> Multiply pCi/L by 0.037 to convert to Bq/L.

<sup>c</sup> Gross alpha samples were collected and analyzed quarterly. Gross beta samples were collected monthly, composited, and analyzed quarterly.

<sup>d</sup> Analytical results are below the minimum detectable concentration.

<sup>e</sup> [WAC 246-290.](#)

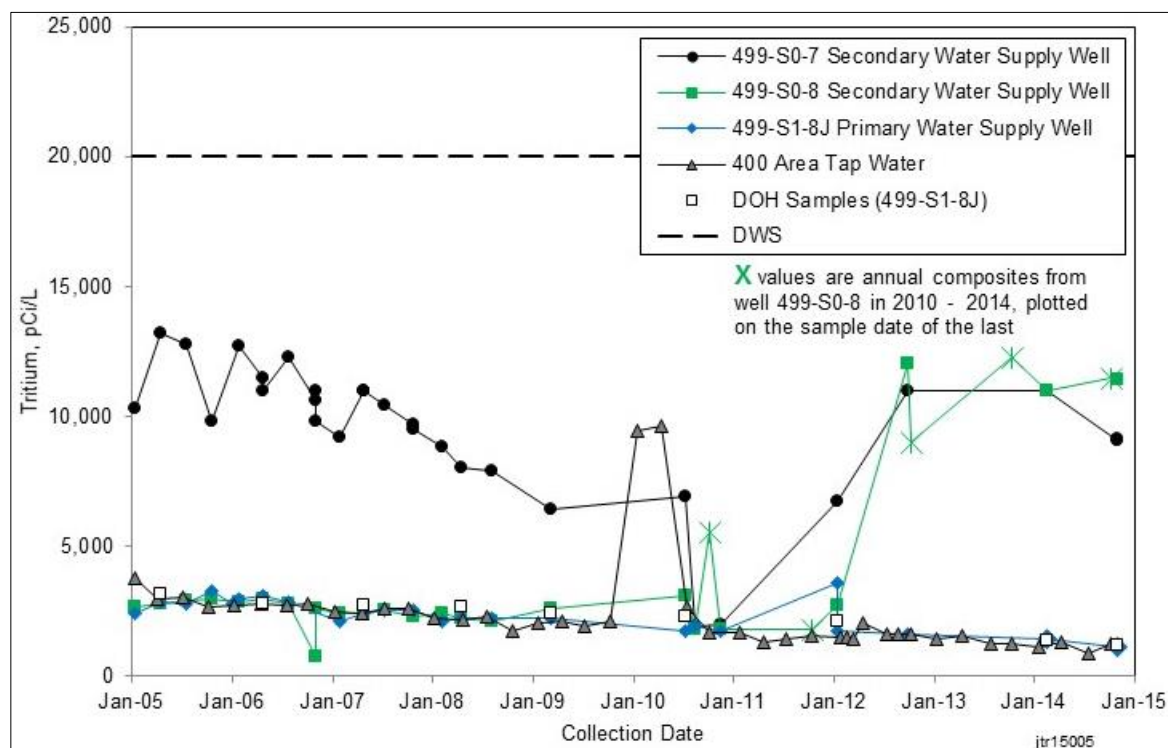
<sup>f</sup> [40 CFR 141.](#)

<sup>g</sup> Samples were collected quarterly, composited, and analyzed annually, with the exception of the 400 Area tritium analyses. In the 400 Area, tritium samples were collected and analyzed quarterly.

Soil and Groundwater Remediation Project personnel collected and analyzed raw (untreated) water samples from all three 400 Area drinking water wells (one primary well and two backup wells). A tritium plume originating in the 200-East Area and extending under the 400 Area historically has affected tritium concentrations in all the 400 Area drinking water wells (Table 7.3; Figure 7.2). In addition, Environmental Assessment personnel collected raw (untreated) water samples from 400 Area drinking water backup well 499-S0-8 (P-14). Samples were collected quarterly, composited for a single annual tritium analysis (11,500 ± 2,270 pCi/L), and fell below the 20,000-pCi/L (740-Bq/L) state and federal annual average drinking water standards.

**Table 7.3. Tritium Concentrations in Hanford Site 400 Area Drinking Water Wells***Reported concentration  $\pm 2$  total propagated analytical error*

Sampling Date	Primary Drinking Water Well 499-S1-8J (P-16) (pCi/L) <sup>a</sup>	Backup Drinking Water Well 499-S0-8 (P-14) (pCi/L) <sup>a</sup>	Backup Drinking Water Well 499-S0-7 (P-15) (pCi/L) <sup>a</sup>
February 12, 2014	1,400 $\pm$ 373	11,000 $\pm$ 2,346	11,000 $\pm$ 2,176
October 30, 2014	1,140 $\pm$ 200	11,400 $\pm$ 2,230	9,095 $\pm$ 127 <sup>b</sup>

<sup>a</sup> Multiply pCi/L by 0.037 to convert to Bq/L.<sup>b</sup> Two samples collected on 10/30/2014, annual average  $\pm 2$  times the standard deviation.**Figure 7.2. 400 Area Tritium Concentrations in Drinking Water***(Multiply pCi/L by 0.037 to convert to Bq/L)*

## 7.2 Columbia River Surface Water

ME Hoefer

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the concentrations of radiological, inorganic, and organic compounds in the aquatic environment that may be attributed to the Hanford Site. Surface-water bodies monitored included the Columbia River, Hanford Site ponds, and offsite irrigation sources (Figure 7.3). Aquatic sediment monitoring was conducted for the Columbia River and one Hanford Site pond. Tables 7.4 and 7.5 summarize the sampling locations, types, and frequencies, as well as sample analyses included in surface-

water and sediment monitoring. This section describes the monitoring efforts and summarizes the results for these aquatic environments.

Figure 7.3. Surface-Water and Sediment Sampling Locations

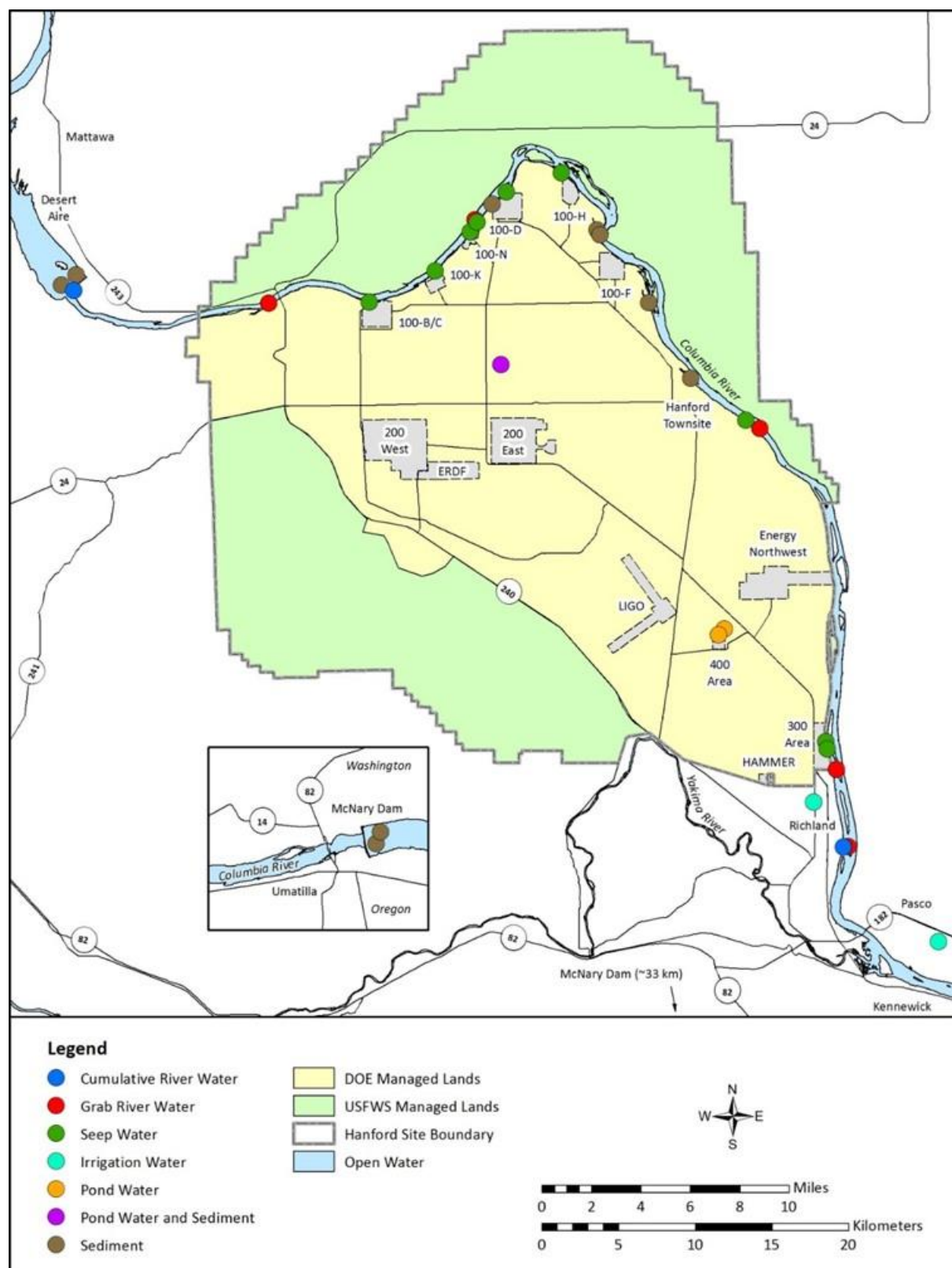


Table 7.4. Surface-Water Monitoring

Location	Sample Type	Frequency	Analyses
<b>Columbia River – Radiological</b>			
Priest Rapids Dam and Richland Pump House	Cumulative	Monthly Composite	Low tritium <sup>a</sup> , strontium-90, technetium-99, uranium-234, -235, -238
	Particulate (filter)	Monthly Continuous <sup>b</sup>	Gamma energy analyses
		Quarterly Continuous <sup>c</sup>	plutonium-238,-239/240
	Soluble (resin)	Monthly Continuous <sup>b</sup>	Gamma energy analyses
		Quarterly Continuous <sup>c</sup>	plutonium-238,-239/240
Vernita Bridge	Grab (transects)	Annually	Gamma energy analyses, low tritium <sup>a</sup> , strontium-90, uranium-234, -235, -238, plutonium-238,-239/240, technetium-99
Richland	Grab (transects)	Annually	Gamma energy analyses, low tritium <sup>a</sup> , strontium-90, uranium-234, -235, -238, plutonium-238,-239/240, technetium-99
100-N, 300 Areas, and Hanford Townsite	Grab (transects)	Annually	Gamma energy analyses, low tritium <sup>a</sup> , strontium-90, uranium-234, -235, -238
<b>Columbia River - Inorganics and Organics</b>			
Vernita Bridge	Grab (transects)	Annually	Anions, mercury, metals (filtered and unfiltered)
	Grab (transects)	Annually	Volatile organic compounds
Richland	Grab (transects)	Annually	Anions, mercury, metals (filtered and unfiltered)
	Grab (transects)	Annually	Volatile organic compounds
100-N, 300 Area, and Hanford Townsite	Grab (transects)	Annually	Anions, metals (filtered and unfiltered)
<b>Onsite Ponds</b>			
West Lake Seep	Grab	Annually	Tritium, uranium-234, -235, -238
West Lake Water	Grab	Annually	Tritium, uranium-234, -235, -238
Fast Flux Test Facility Pond	Grab	Quarterly	Alpha, beta, tritium, gamma energy analyses
<b>Offsite Irrigation Water</b>			
Riverview Irrigation Canal	Grab	3/year	Alpha, beta, low tritium <sup>1</sup> , strontium-90, gamma energy analyses
Horn Rapids	Grab	3/year	Alpha, beta, low tritium <sup>1</sup> , strontium-90, gamma energy analyses

<sup>a</sup> Low-level tritium analysis (10-pCi/L detection limit).<sup>b</sup> River water was sampled for 2 weeks by continuous flow through a filter and resin column, and multiple samples were composited monthly for analyses.<sup>c</sup> River water was sampled for 2 weeks by continuous flow through a filter and resin column, and multiple samples were composited quarterly for analyses.

Table 7.5. Columbia River Sediment

Location <sup>a</sup>	Frequency	Analyses
Priest Rapids Dam (2 locations near the dam)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium <sup>b</sup> , isotopic plutonium <sup>c</sup> metals, mercury, strontium-90, and total organic carbon
Hanford Reach <sup>d</sup>	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium <sup>b</sup> , isotopic plutonium <sup>c</sup> , metals, mercury, strontium-90, and total organic carbon
Priest Rapids Dam (2 locations near the dam)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium <sup>b</sup> , isotopic plutonium <sup>c</sup> , metals, mercury, strontium-90, and total organic carbon
Contiguous Hanford Reach Islands (Locke and Savage)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium <sup>b</sup> , isotopic plutonium <sup>c</sup> , metals, mercury, and strontium-90

<sup>a</sup> Refer to Figure 7.3.<sup>b</sup> Uranium-234, uranium-235, and uranium-238.<sup>c</sup> Plutonium-238 and plutonium-239/240.<sup>d</sup> Hanford Reach consists of sediment collected in the 100-F Slough, Hanford Slough, and White Bluffs Slough.

The Columbia River is one of the largest rivers in the continental U.S. in terms of total flow and is the dominant surface-water body at the Hanford Site. The original selection of the Hanford Site for plutonium production was based partly on the abundant water supply offered by the river. The river flows through the northern portion of the Hanford Site and forms part of the eastern boundary of the site. The river is used as a source of drinking water for Hanford Site facilities and communities downstream of the Hanford Site. Water removed from the river immediately downstream of the Hanford Site also is used for irrigation in Benton and Franklin counties. In addition, the Hanford Reach of the Columbia River is used for a variety of recreational activities, including hunting, fishing, boating, wakeboarding, waterskiing, and swimming.

Originating in the Rocky Mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of approximately 260,000 square miles (670,000 square kilometers) before discharging to the Pacific Ocean. Three dams in Canada and 11 dams in the United States regulate the flow of the river; four of these dams are downstream of the Hanford Site. Priest Rapids Dam is the nearest upstream dam, and McNary Dam is the nearest downstream dam to the Hanford Site.

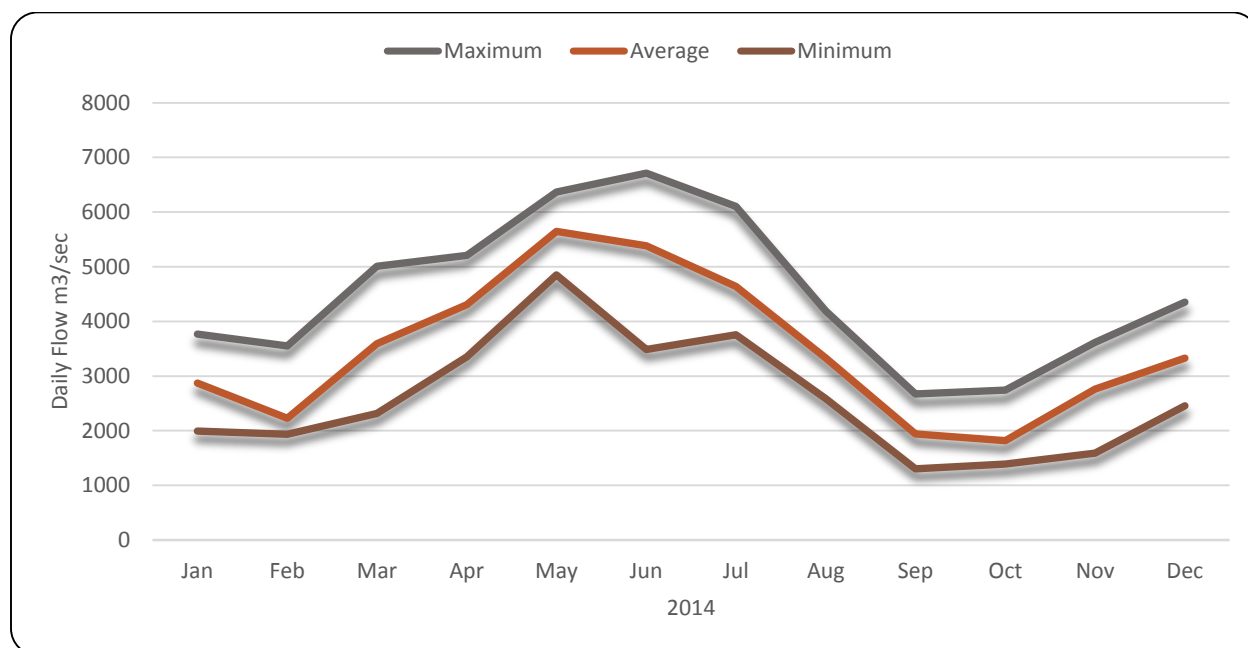
The Hanford Reach of the Columbia River extends from Priest Rapids Dam downstream to the head of Lake Wallula, created by McNary Dam, near the city of Richland. The Hanford Reach is the last free-flowing stretch of the Columbia River. River flow through the Hanford Reach is controlled primarily by operations at upstream dams, which over the course of the year causes water levels to fluctuate significantly. Figure 7.4 shows the maximum, average, and minimum flow rates of the Columbia River at Priest Rapids Dam for 2014. The annual average flow of the Columbia River downstream of Priest Rapids Dam was approximately 124,149 cubic feet (3,516 cubic meters) per second, which was slightly above the 10-year average annual flow rate of 115,831 cubic feet (3,280 cubic meters) per second (U.S. Geological Survey [[USGS 2013](#)]), *USGS Water-Data Report for 2013, 12472800 Columbia River Below Priest Rapids Dam, WA*). The highest monthly average flow rate occurred during May (199,492 cubic feet [5,649 cubic meters] per second) (Figure 7.4). The lowest monthly average flow rate occurred during October (64,070 cubic feet [1,814 cubic meters] per second), based on mean daily flows. Daily average flow rates



varied from 45,900 to 237,020 cubic feet (1,300 to 6,712 cubic meters) per second in 2014. Because of fluctuation in discharges, the depth of the river varies significantly. The river stage (river water surface elevation) may change along the Hanford Reach by up to 10 feet (3 meters) within a few hours. Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately one-half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam. The relative distance of each area from Priest Rapids Dam, and the width of the river, vary from approximately 980 to 3,300 feet (300 to 1,000 meters) as it passes through the Hanford Site.

**Figure 7.4. Columbia River Flow Rates at Priest Rapids Dam**

*(Multiply  $m^3/sec$  by 35.31 to obtain  $ft^3/sec$ )*



### 7.2.1 Monitoring

Columbia River water samples were collected from fixed-location monitoring stations at Priest Rapids Dam and at the city of Richland in 2014 and analyzed for radionuclides. Cross-river transects near Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the city of Richland were analyzed for radionuclides, metals, and inorganic and organic compounds (Figure 7.3). Samples were collected upstream of the Hanford Site at Priest Rapids Dam and Vernita Bridge to provide data from locations unaffected by Hanford Site operations. Samples were collected from all other locations, including a municipal drinking water supply and points of withdrawal for irrigation water downstream of the Hanford Site, to identify any increase in contaminant concentrations attributable to the site.

The sampling of irrigation water systems is discussed in Section 7.6.

The fixed-location monitoring stations at Priest Rapids Dam and the city of Richland consist of an automated sampler and a continuous flow system. The automated samplers were used to obtain unfiltered samples of Columbia River water (cumulative samples), which were composited for a period of 14 days. The samplers collect water at set intervals of time (e.g., 1 hour) and set incremental volumes (e.g., 55 mL). These bi-weekly samples were combined into monthly and quarterly composite samples for radiological

analyses (Table 7.4). The continuous flow system was used to collect particulate and soluble constituents in Columbia River water by passing water through a filter and then through a resin column. Filter and resin samples were exchanged approximately every 14 days and were combined into quarterly composite samples for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in [DOE/RL-91-50, Rev. 6A](#).

Radionuclides of interest were selected for analyses based on the following criteria:

- ⊗ Their presence in historical effluent discharges from Hanford Site facilities or in groundwater underlying the Hanford Site near the Columbia River
- ⊗ Their importance in determining water quality, and in determining compliance with applicable water quality standards
- ⊗ Their importance in key pathway-specific exposure dose assumption calculations based on 95th percentile of drinking water ingestion rate of 3.1 L/day for 350 days/year ([EPA/600/R-09/052F](#), Table ES-1).

Constituents of interest in Columbia River water samples collected at Priest Rapids Dam and the city of Richland included gamma-emitting radionuclides, tritium, strontium-90, technetium-99, uranium-234, uranium-235, plutonium-238, uranium-238, and plutonium-239/240. Gamma-energy analysis provides the capability to detect numerous specific radionuclides. Analytical detection levels (defined as the laboratory-reported minimum detectable concentration) for all radionuclides were less than or equal to 10 percent of their respective Washington State water quality criteria levels (Appendix C). Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, with alpha at a 5 percent significance level.

Transect sampling (i.e., a series of samples collected along a line across the Columbia River) was initiated because of findings of a special study conducted in the late 1980s ([PNL-8531, Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pump House](#)). The study concluded that, under certain flow conditions, contaminants entering the Columbia River from the Hanford Site are not completely mixed when sampled at routine monitoring stations located downriver. Incomplete mixing results in a conservative bias in the data generated using the routine, single-point sampling system at the city of Richland drinking water intake. Transect sampling allows cross-river concentration profiles to be determined to provide information over a larger portion of the Hanford Site shoreline where the highest contaminant concentrations of concern would be expected.

In 2014, four to five evenly spaced cross-river transect samples were obtained. The city of Richland, Vernita Bridge, 100-N Area, Hanford Townsite, and 300 Area locations were all sampled annually in 2014 during late summer when river flows were low, which provides the highest probability of detecting Hanford Site contaminants carried by groundwater to the Columbia River.

Columbia River transect water samples collected during 2014 were analyzed for radiological, inorganic, and organic contaminants (Table 7.4). Specific metals and anions were selected for analyses following reviews of existing surface-water and groundwater data, various RI/FS work plans, and preliminary Hanford Site risk assessments ([DOE/RL-92-67, Final Remedial Investigation/Feasibility Study-Environmental Assessment Report for the 1100-EM-1 Operable Unit, Hanford](#); [WCH-380, Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington](#)). Metals analyses included both unfiltered and filtered samples.

## 7.2.2 Radiological Results

**Fixed-Location Samples.** Results of radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the city of Richland in 2014, and for the previous 5 years, are summarized in Appendix C, Table C.6. With the exception of isotopic uranium concentrations, all individual radiological contaminant concentrations measured in Columbia River water during 2014 were less than 1/25 of the DOE-derived concentration guides (Appendix D). Uranium-234 and uranium-238 concentrations were less than 1/15 of DOE-derived concentration guidelines. The DOE-derived concentration guides are based on a 100-millirem (1-milliseivert) per year standard; dividing by 25 allows for more direct comparison to the 4-millirem (0.04-milliseivert) per year drinking water standards and Washington State ambient surface-water quality criteria ([40 CFR 141](#); [WAC 173-201A](#); Appendix D).

Radionuclide concentrations monitored in Columbia River water were low throughout 2014.

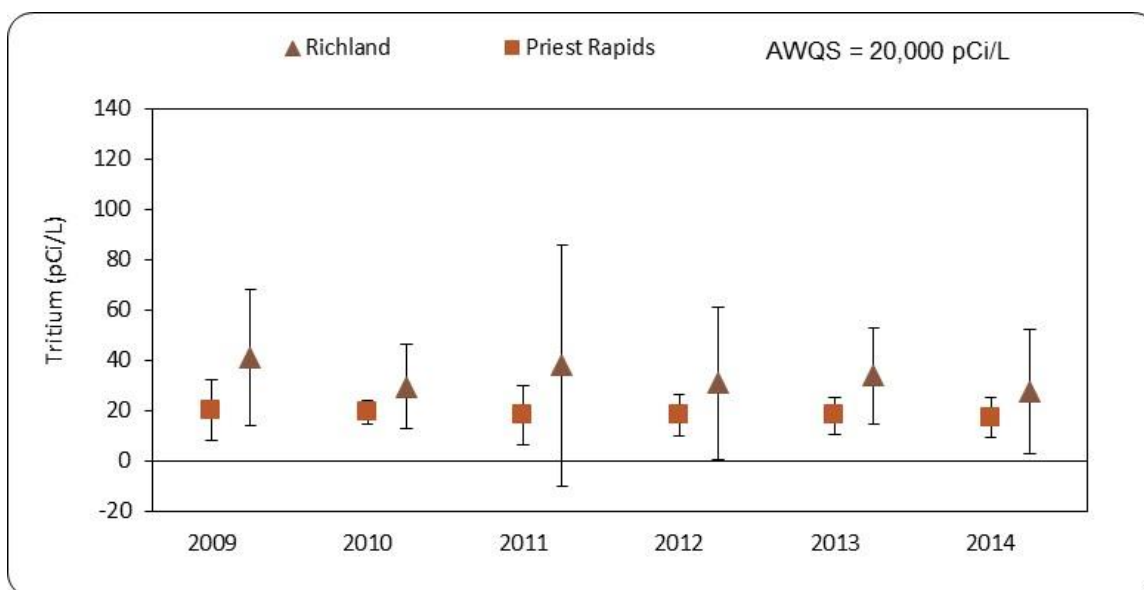
Tritium, uranium-234, and uranium-238 were consistently measured in river water at levels greater than their reported minimum detectable concentrations. Uranium-235 was occasionally detected, but all values were near the minimum detectable concentrations. Concentrations of all other radionuclides were typically less than the minimum detectable concentrations.

The 2014 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years (Figure 7.5). Statistical analyses indicated that monthly tritium concentrations in river water samples at the city of Richland were slightly higher than concentrations in samples from Priest Rapids Dam. Average tritium concentrations in Columbia River water collected at the city of Richland were 0.14 percent of the Washington State ambient surface-water quality criterion of 20,000 Ci/L (740 Bq/L).

*Figure 7.5. Tritium Annual Average Concentrations in Columbia River Water Upstream and Downstream of Hanford Site*

*( $\pm X$  standard deviations, AWQS = ambient water quality standard)*

*Washington State ambient water quality standard for tritium is 20,000 pCi/L (740 Bq/L)*

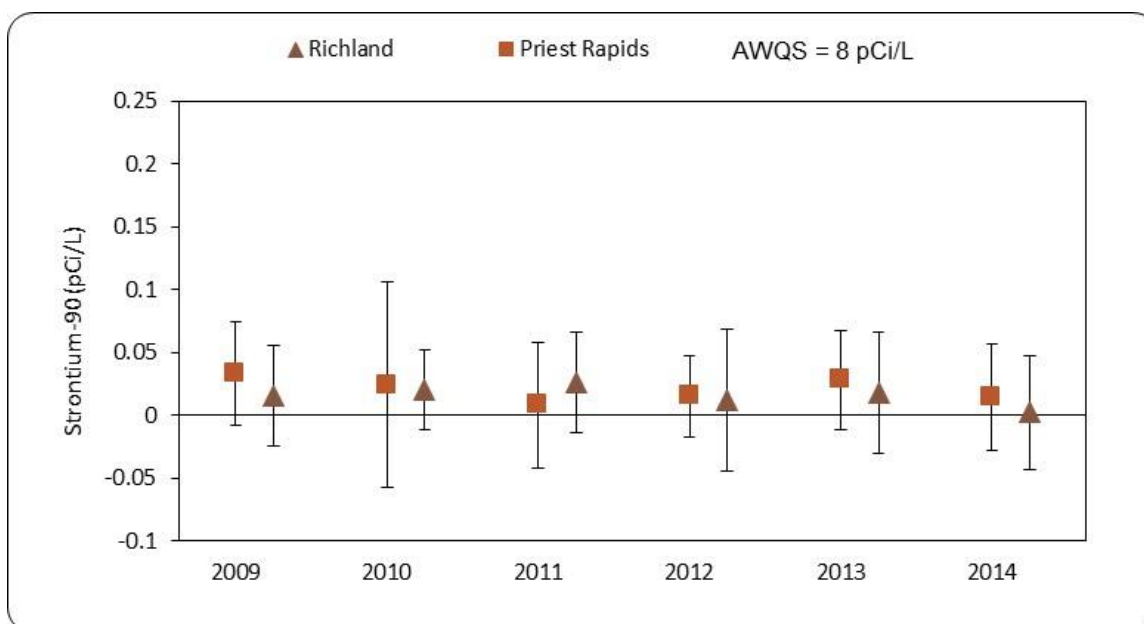


The Hanford Site source of tritium entering the river is from groundwater upwelling and shoreline seepage. Although representative of river water used by the city of Richland for drinking water (first municipal water source downstream from the Hanford Site), tritium concentrations measured at the city of Richland shoreline tend to be elevated when compared to average tritium concentrations across the river at this location. This bias is attributable to a groundwater plume originating from the 200 East Area entering the river along the portion of shoreline extending from the Hanford Townsite downstream to the 300 Area. The plume is not completely mixed within the Columbia River at the city of Richland because of the close proximity to the city's water intake structure. Sampling along cross-river transects at the city of Richland during 2014 confirmed the existence of a concentration gradient in the river under certain flow conditions. It is discussed in this section. The extent to which samples taken at the city of Richland drinking water intake overestimate the average tritium concentrations in the Columbia River at this location is variable and appears to be related to the flow rate of the river just before and during sample collection.

Average strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2014 were similar to those reported in previous years (Figure 7.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Area. Some of the highest strontium-90 levels that have been found in Hanford Site groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Although strontium-90 concentrations at Priest Rapids Dam and the city of Richland were below minimum detection limits (0.06 pCi/L), low levels were still statistically compared to show differences. Priest Rapids Dam had a maximum concentration of 0.040 pCi/L (0.0019 Bq/L), and the city of Richland intake had a maximum concentration of 0.056 pCi/L (0.0015 Bq/L). Average strontium-90 concentrations in Columbia River water at the city of Richland were less than 0.03 percent of the Washington State ambient surface-water quality criterion (8 pCi/L [0.30 Bq/L]) while those at Priest Rapids measured 0.19 percent on average.

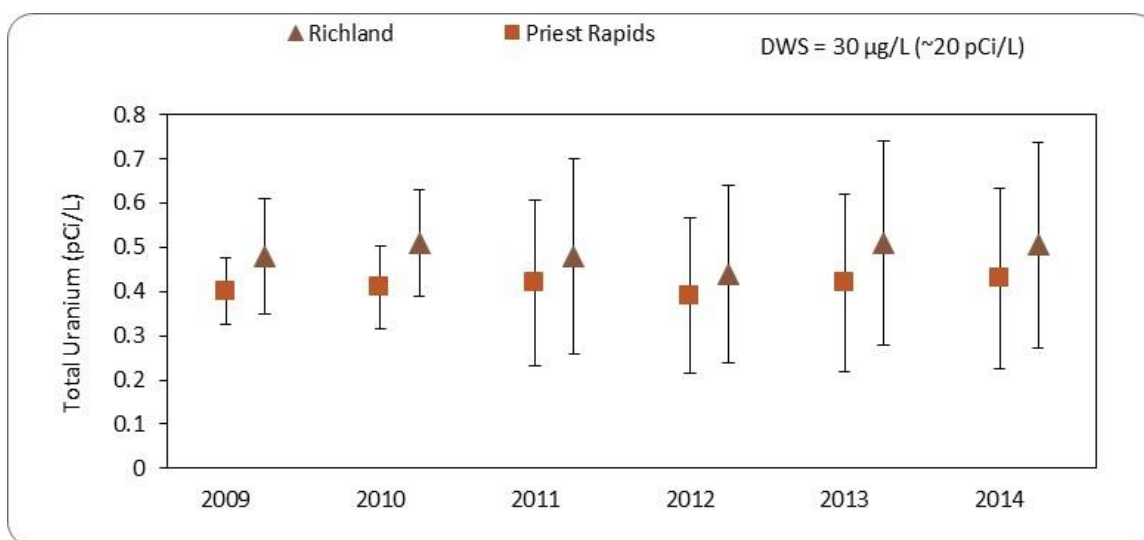
*Figure 7.6. Strontium-90 Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site*

*( $\pm 2$  standard deviations, AWQS = ambient water quality standard)*



Annual average uranium-234 and uranium-238 concentrations measured in water samples collected upstream and downstream of the Hanford Site in 2014 were similar to those observed during recent years (Figure 7.7). Average monthly uranium concentrations measured at Priest Rapids Dam (0.42 pCi/L total Uranium) in 2014 were slightly lower than those averages measured at the city of Richland (0.50 pCi/L total Uranium). Uranium is present in the groundwater beneath the 300 Area as a result of past Hanford Site operations, and it has been detected at elevated levels in shoreline springs at the 300 Area in the past (Section 7.4; [PNNL-13692](#), *Survey of Radiological and Chemical Contaminants in the Near-Shore Environment at the Hanford Site 300 Area*; and [PNNL-16805](#), *Investigation of the Hyporheic Zone at the 300 Area, Hanford Site*). There is no Washington State ambient surface-water quality criterion directly applicable to uranium; however, total uranium levels in the river during 2014 were well below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L], Appendix D).

**Figure 7.7. Uranium Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site**  
( $\pm 2$  standard deviations; DWS = drinking water standard)

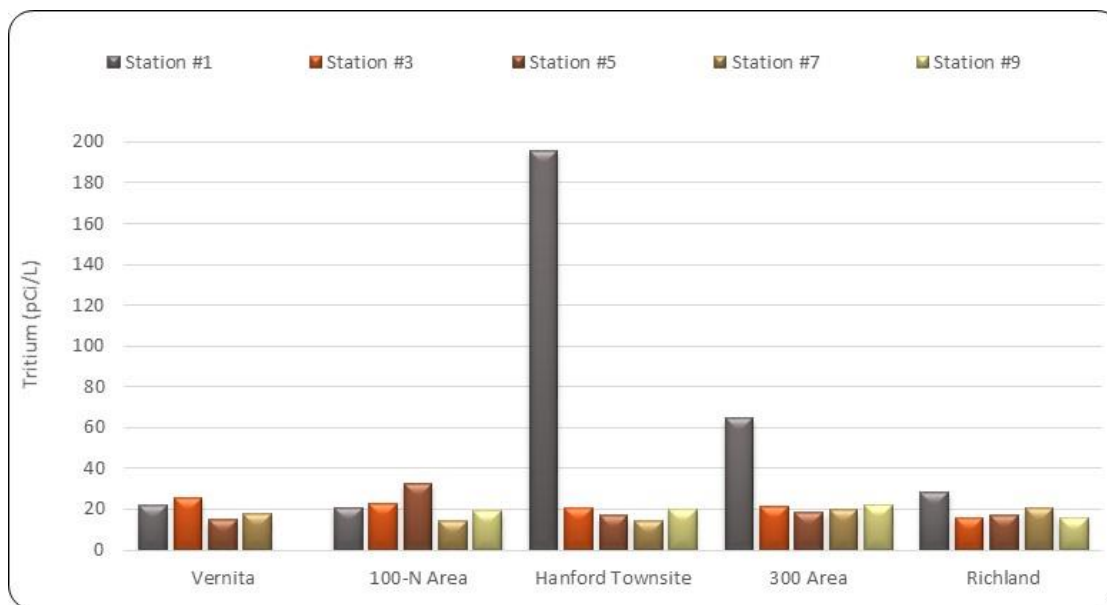


Plutonium-238 and plutonium-239/240 concentrations for river water samples at the city of Richland in 2014 were reported as undetected by the analytical laboratory. All concentrations and detection limits were well below the DOE-derived concentration guide of 30 pCi/L (1.1 Bq/L). No Washington State ambient surface-water quality criterion exists for plutonium-239/240. Plutonium concentrations at Priest Rapids Dam were not statistically compared with the city of Richland because upstream and downstream concentrations were less than the reported minimum detectable concentrations. However, the Priest Rapids Dam data did have a single Plutonium-238 detection of 0.0002 pCi/L (7.4E-06 Bq/L).

**Columbia River Transect Samples.** Radiological results from samples collected along Columbia River transects near Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the city of Richland are presented in Appendix C. Sampling locations were documented using a hand-held global positioning system. Station 1 at each transect is located along the Benton County shoreline while the highest station number for each transect is along the Grant-Franklin County shoreline. Radionuclides consistently measured at concentrations greater than the minimum detectable activity included tritium, uranium-234, and uranium-238. Uranium-235 was detected occasionally, and most levels were near the minimum

detectable concentrations. All measured concentrations of these radionuclides were less than the applicable Washington State ambient surface-water quality criteria and the EPA drinking water standards. Tritium concentrations measured along Columbia River transects at Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the city of Richland during 2014 are depicted in Figure 7.8. The Vernita Bridge transect is the most upstream location. The 100-N Area, Hanford Townsite, 300 Area, and the city of Richland transects have higher tritium concentrations near the Hanford Site shore (Benton County) when comparing levels to the opposite shoreline. The presence of a tritium concentration gradient in the Columbia River at the city of Richland supports previous studies showing that contaminants in the 200 Areas groundwater plume entering the river at, and upstream of, the 300 Area are not completely merged within the river water at the city of Richland. The gradient is most pronounced during periods of relatively low river flow. Historically, the average tritium concentration measured along the city of Richland transect has been less than that measured in monthly composited samples from the fixed-location monitoring station in the city of Richland, illustrating the conservative bias (i.e., highest estimate) of the fixed-location monitoring station. This also was true with samples collected in 2014 as the Richland transect results had a maximum of  $28.5 \pm 7.16$  pCi/L ( $1.05 \pm 0.26$  Bq/L), and the fixed monitoring station had a maximum result of  $62.9 \pm 9.65$  pCi/L ( $2.33 \pm 0.36$  Bq/L). The highest tritium concentration measured in cross-river transect water was  $196 \pm 67$  pCi/L ( $7.25 \pm 2.48$  Bq/L) at the Hanford Townsite. Slightly elevated conductivity results for the 2014 transect water samples collected at the 100-N Area and 300 Area indicate there was only limited mixing of groundwater into the river at the time of sample collection.

Figure 7.8. Tritium Concentrations in Cross-River Transect Water Samples (Hanford Reach, Columbia River)



Strontium-90 concentrations in Hanford Reach river water for transect samples collected in 2014 were similar to upstream reference concentrations for most locations. The maximum strontium-90 concentration was  $0.054 \pm 0.038$  pCi/L ( $0.0020 \pm 0.0014$  Bq/L) from a sample collected along the Hanford Townsite transect. The average strontium-90 concentrations found during sampling at the city of Richland transect were similar to those measured in monthly composite samples at the Richland Pumphouse and at Priest Rapids Dam.



Uranium concentrations in all transect samples collected during 2014 were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]). Uranium-234 and uranium-238 concentrations were highest in the water sample collected near the 300 Area shoreline (300 Area-1 HRM 43.1), which measured 0.55 µg/L (0.37 pCi/L) for uranium-234 and 0.44 µg/L (0.29 pCi/L) for uranium-238.

Uranium isotopes measured in the 300 Area riverbank seep water samples were higher than those reported at the 300 Area-1 HRM 43.1 and other transect location concentrations and are associated with its presence in groundwater as elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of former uranium fuel fabrication facilities and inactive waste sites.

Average strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2014 were similar to those reported in previous years (Figure 7.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Area. Some of the highest strontium-90 levels that have been found in Hanford Site groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Although strontium-90 concentrations at Priest Rapids Dam and the city of Richland were below minimum detection limits (0.06 pCi/L), low levels were still statistically compared to show differences. Priest Rapids Dam had a maximum concentration of 0.040 pCi/L (0.0019 Bq/L) and the city of Richland intake had a maximum concentration of 0.056 pCi/L (0.0015 Bq/L), respectively. Average strontium-90 concentrations in Columbia River water at the city of Richland were less than 0.03 percent of the Washington State ambient surface-water quality criterion (8 pCi/L [0.30 Bq/L]) while those at Priest Rapids measured 0.19 percent on average.

### 7.2.3 Inorganic and Organic Chemical Results

Inorganic and organic water quality data were compiled in 2014 for the Columbia River. A number of the parameters measured have no regulatory limits, but they are useful as indicators of water quality and contaminants of Hanford Site origin. Potential sources of pollutants not associated with the Hanford Site include irrigation return water; groundwater seepage associated with extensive irrigation north and east of the Columbia River; and industrial, agricultural, and mining effluent introduced upstream of the Hanford Site.

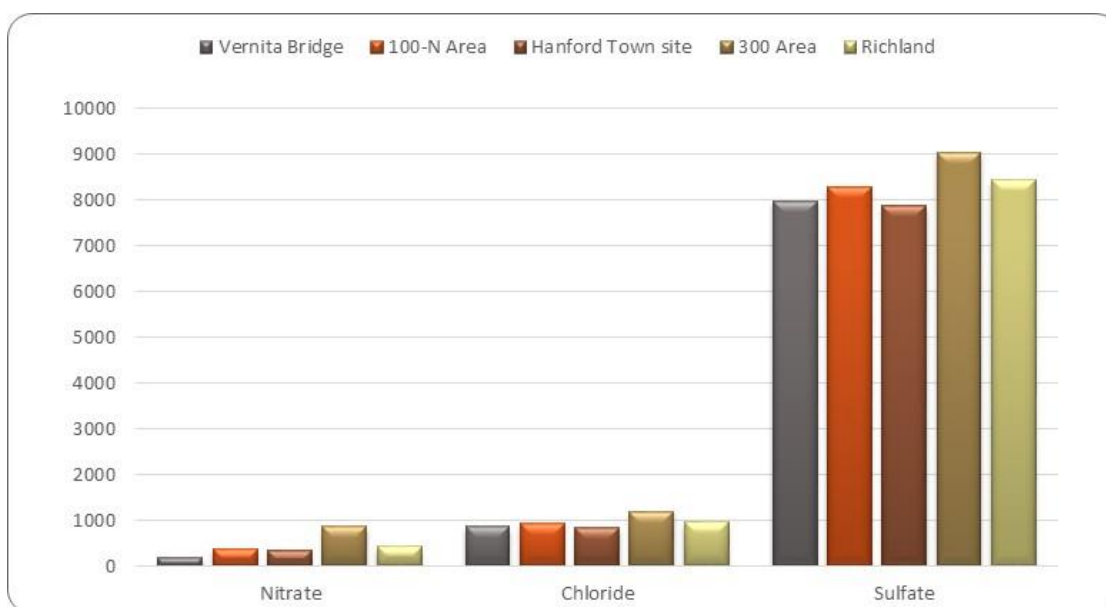
The metals and anions concentrations observed in river water were similar to those observed in the past and remain below regulatory limits. Metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Copper, nickel, uranium, and zinc were detected in most samples. All dissolved metal concentrations in river water were less than the Washington State ambient surface-water quality criteria for the protection of aquatic life (Appendix C, Table C.8).

Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent ([WAC 173-201A](#)). Increased water hardness (i.e., primarily higher concentrations of calcium and magnesium ions) can reduce the toxicity of some metals by limiting their absorption into aquatic organisms. Criteria for Columbia River water were calculated using a total hardness of 66 mg/L as calcium carbonate, the lowest value based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge ([USGS-12472900](#), *Columbia River At Vernita Bridge, Near Priest Rapids Dam, WA*) and the city of Richland in recent years.

For samples collected on the cross-river transects, there were no reportable detections of nitrites. Concentrations of nitrate, chloride, and sulfate were slightly elevated near the 300 Area in comparison to

other transect locations (Figure 7.9). In many cases, the highest anion concentrations were found in samples collected along the Grant-Franklin County shoreline. These elevated results likely resulted from groundwater seepage associated with extensive irrigation north and east of the Columbia River. Nitrate contamination of some Franklin County groundwater has been documented by *Nitrate Concentrations in Ground Water of the Central Columbia Plateau* (USGS 1995), and is associated with high fertilizer and water usage in agricultural areas. Numerous wells in western Franklin County exceed the EPA maximum contaminant level for nitrate (40 CFR 141, *Water Quality in the Central Columbia Plateau, Washington and Idaho, 1992-95* [USGS Circular 1144]). Average annual concentrations of chloride and sulfate were similar at the city of Richland transect when compared with Vernita Bridge transect results. The highest concentrations of nitrates were measured at the 300 Area-1 HRM 43.1 transect; however, the 100-N, Hanford Townsite, and Richland Pumphouse transects also had detections of nitrate in 2014. Additional anion analysis of fluoride in Columbia River transect collections resulted in reportable concentrations ( $>33 \mu\text{g/L}$ ) of fluoride in all samples; however, these results were less than required detection limits ( $500 \mu\text{g/L}$ ) per DOE guidelines. When compared to concentrations since 2008, the overall average has dropped from  $122 \mu\text{g/L}$  to  $75 \mu\text{g/L}$  in transect samples.

Figure 7.9. Selected Anion Concentrations in Columbia River Transect Samples



Concentrations of chromium (reported in Appendix C) in the Hanford Reach are of interest because groundwater contaminated with chromium above the ambient water quality criterion intersects the Columbia River at several Hanford Site locations. All river transect filtered water samples for 2014 had chromium concentrations below the minimum detectable concentration.

### 7.3 Columbia River Sediment

ME Hoefer

During peak operating years at the Hanford Site, large amounts of effluents associated with reactor operations were discharged to the Columbia River. Some constituents in these effluents may have become associated with particulate matter that accumulated in riverbed sediment, particularly in slack-water areas and in the reservoirs behind the dams located downstream of the Hanford Site. The majority of short-

lived radioactive constituents have decayed away, but some longer-lived radionuclides, such as isotopes of cesium, plutonium, strontium, and uranium are still detectable. Fluctuations in the river flow from the operations of upriver hydroelectric dams, annual spring high river flows, and occasional floods have resulted in re-suspension, relocation, and subsequent re-deposition of sediment. Upper-layer sediment in the Columbia River downstream of the Hanford Site contains low concentrations of radionuclides, metals of Hanford Site origin, and radionuclides from worldwide atmospheric fallout, as well as metals and other nonradioactive contaminants from mining and agricultural activities (*Simultaneously Extracted Metals/Acid-Volatile Sulfide and Total Metals in Surface Sediment from the Hanford Reach of the Columbia River and the Lower Snake River* [PNNL-13417], *Summary of Radiological Monitoring of Columbia and Snake River Sediment, 1988 through 2004* [PNNL-16990]). Periodic sediment sampling confirms that concentrations are low, and that no significant changes in concentrations have occurred. The accumulation of radioactive materials in sediment can lead to human exposure from ingestion of aquatic organisms associated with the sediment or sediment re-suspension into drinking water supplies. Sediment with accumulated radioactive materials can be an external radiation source, irradiating people who are fishing, wading, swimming, sunbathing, or participating in other recreational activities associated with the river or shoreline (*Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* [DOE/EH-0173T]). Sediment contaminant concentrations are also used to model potential pathway exposures to riparian (e.g., raccoon, coyote) and aquatic receptors (e.g., fish, benthic organisms) and to establish DOE guidelines for organisms within the Hanford Reach.

Several studies have been conducted to investigate the difference in sediment grain-size composition and total organic carbon content at routine Columbia River monitoring sites and the effect of grain size and organic content in measured contaminant concentrations (PNNL-13417). Physical and chemical sediment characteristics were found to be highly variable among monitoring sites along the Columbia River. Samples containing the highest percentage of silts, clays, and total organic carbon were generally collected from the reservoir behind Priest Rapids Dam upstream of the site, the Hanford and White Bluffs Slough on the Hanford Reach, and downstream of the site in the reservoir pool located above McNary Dam.

### 7.3.1 Monitoring

Samples of the surface layer of Columbia River sediment were collected at depths of 0 to 6.3 inches (0 to 16 centimeters) from 10 river locations that were predominantly submerged (some Hanford Reach sampling locations may not be submerged during an extremely low-river stage). Sampling locations were documented using a handheld global positioning system. Surface sediment was collected using a clamshell-style sediment dredge sampler (Petite Ponar), capturing several years of integrated deposits, including various sediment grains. Estimated average sediment deposition rates of 0.28 inch (0.723 centimeter) per year for Priest Rapids Dam and 0.89 inch (2.25 centimeters) per year for McNary Dam (*An Investigation of the Origin of  $^{152}\text{Eu}$  in Columbia River Sediments*, Gibbons 2000). Assuming a maximum sediment sampling depth of 6.3 inches (16 centimeters) with the Petite Ponar dredge, the samples may integrate up to approximately 22 years at Priest Rapids Dam and 7 years at McNary Dam. Sediment deposition rates have not been estimated for the slough areas along the Hanford Reach. Samples were collected upstream of Hanford Site facilities from the Priest Rapids Dam reservoir (the nearest upstream impoundment) to provide data from an area unaffected by site operations. Samples were collected downstream of the Hanford Site above McNary Dam (the nearest downstream impoundment) to identify any increase in contaminant concentrations. Any increases in contaminant concentrations found

in sediment above McNary Dam compared to those found above Priest Rapids Dam do not necessarily reflect a Hanford Site source. The confluences of the Columbia River with the Yakima, Snake, and Walla Walla rivers lie between the Hanford Site and McNary Dam. Several towns, irrigation water returns, and factories in these drainages, as well as atmospheric nuclear fallout, also may contribute to the contaminant load found in McNary Dam sediment. Sediment samples also were collected at 100-D Spring 102-1, 100-F Slough, Hanford Slough, White Bluffs Slough, and locations adjacent to Locke and Savage islands located along the Hanford Reach of the Columbia River from slack-water areas where fine-grained material is known to deposit.

Monitoring sites in the reservoirs behind McNary and Priest Rapids dams consisted of two stations spaced approximately equidistant on a transect line crossing the Columbia River; the samples were collected near the boat-exclusion buoys immediately upstream of each dam. One location was sampled at the 100-D Spring (seep) 102-1 location and an additional from the 100-F Slough. The White Bluffs Slough monitoring site consisted of two sampling locations; however, only one sampling location was sampled successfully in 2014 due to rock and aquatic vegetation inclusions in the collection process. One sample was collected at a location in Hanford Slough and two additional samples from locations adjacent to the islands.

### **7.3.2 Radiological Results**

All sediment samples were analyzed for gamma-emitting radionuclides, anions, hexavalent chromium, strontium-90, uranium-234, uranium-235, plutonium-238, uranium-238, plutonium-239/240, metals, mercury, and total organic carbon ([DOE/RL-91-50](#)). The specific analytes selected for sediment samples were based on findings of previous Columbia River sediment investigations, reviews of past effluent contaminants discharged from site facilities, and reviews of contaminant concentrations observed in Hanford Site groundwater monitoring wells near the Columbia River. No federal or state freshwater sediment criteria are available to assess the sediment quality of the Columbia River. Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2014 included cesium-137, uranium-234, uranium-235, uranium-238, plutonium-239/240, and decay products from naturally occurring radionuclides. The concentrations of all other radionuclides, including strontium-90, were below the reported minimum detectable concentrations for most samples.

Cesium-137 and plutonium isotopes exist in worldwide fallout as well as in effluent from past Hanford Site operations. Uranium isotopes occur naturally in the environment and have been present in past releases of Hanford Site effluent. Analytical results for 2014 showed similar concentrations of cesium-137 at both Priest Rapids and McNary dam sediment collection locations. These concentrations were slightly elevated when compared to Hanford Reach sediment collection location results (Figure 7.10). Plutonium-239/240 sediment results mirrored cesium-137 data as Priest Rapids and McNary dam locations had higher concentrations reported than sediment results along the Hanford Reach (Figure 7.11).

Figure 7.10. Cesium-137 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment

(Upper and lower bars represent maximum and minimum values; these values may be similar to the average and may not be visible)

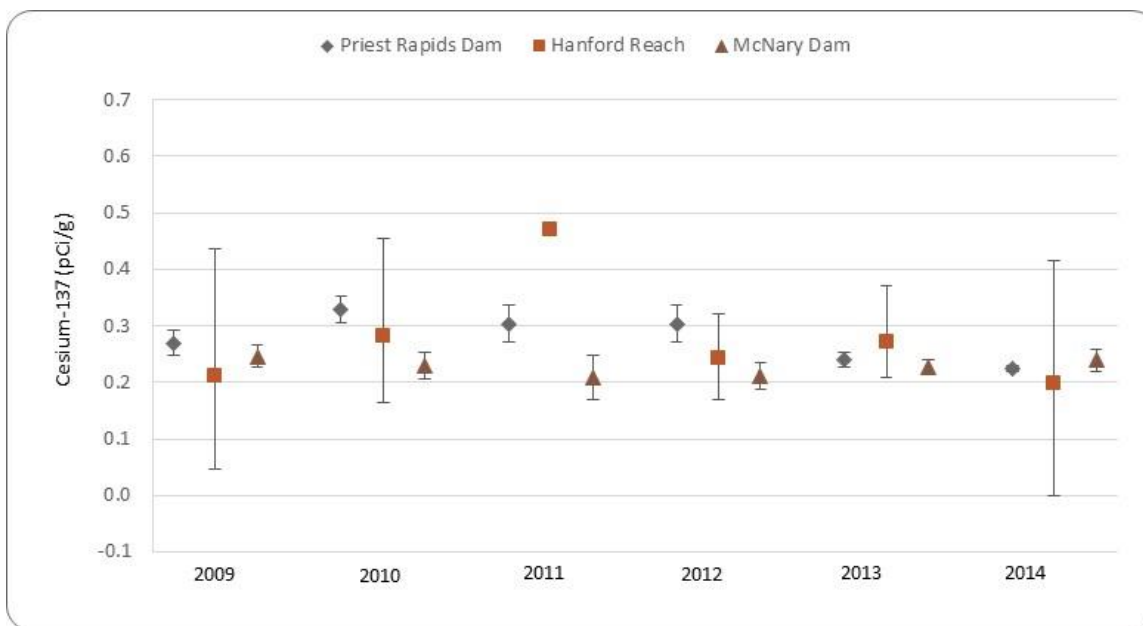
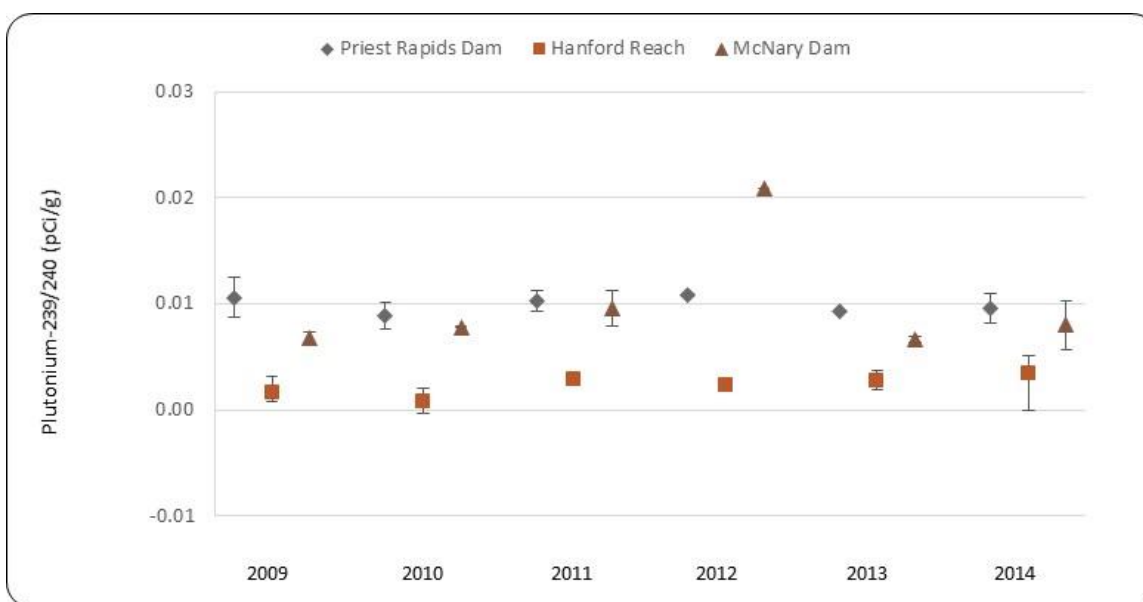


Figure 7.11. Plutonium 239/240 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment

(Upper and lower bars represent maximum and minimum values; these values may be similar to the average and may not be visible)



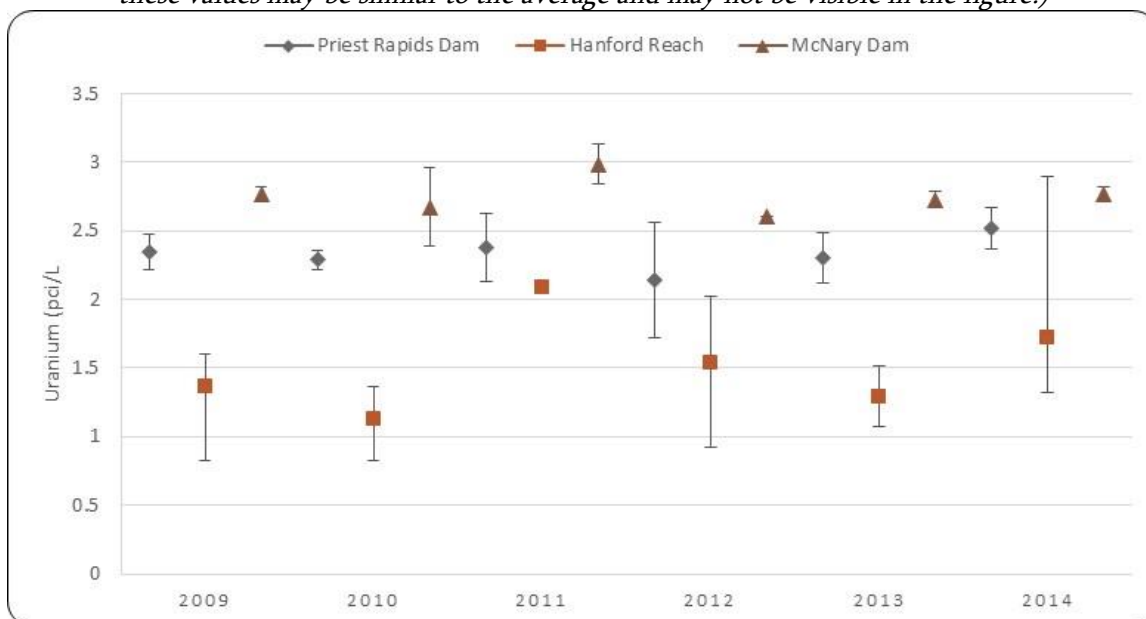
Uranium-234 concentrations were slightly elevated in the Hanford Reach, McNary Dam, Priest Rapids Dam, and White Bluffs Slough samples in 2014 as compared to values measured in the previous 5 years.

Other radionuclide concentrations reported in river sediment were similar to those reported for previous years, and there were no obvious differences between locations.

Priest Rapids and McNary dam sediment also had elevated total uranium results in comparison to Hanford Reach locations in 2014. Hanford Reach averaged 1.7 pCi/g while Priest Rapids and McNary dam concentrations averaged 2.5 pCi/g and 2.8 pCi/g respectively (Figure 7.12).

**Figure 7.12. Uranium Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment**

*(Upper and lower bars represent maximum and minimum values; these values may be similar to the average and may not be visible in the figure.)*



The values for cesium-137 at the White Bluffs Slough were slightly elevated compared to Priest Rapids Dam and all other sediment collection locations but lower than elevated values measured in 2009 through 2013. Previous studies of sediment from the White Bluffs Slough detected elevated concentrations of cesium-137. The average, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (2009 through 2014) are presented in Figures 7.10, 7.11, and 7.12.

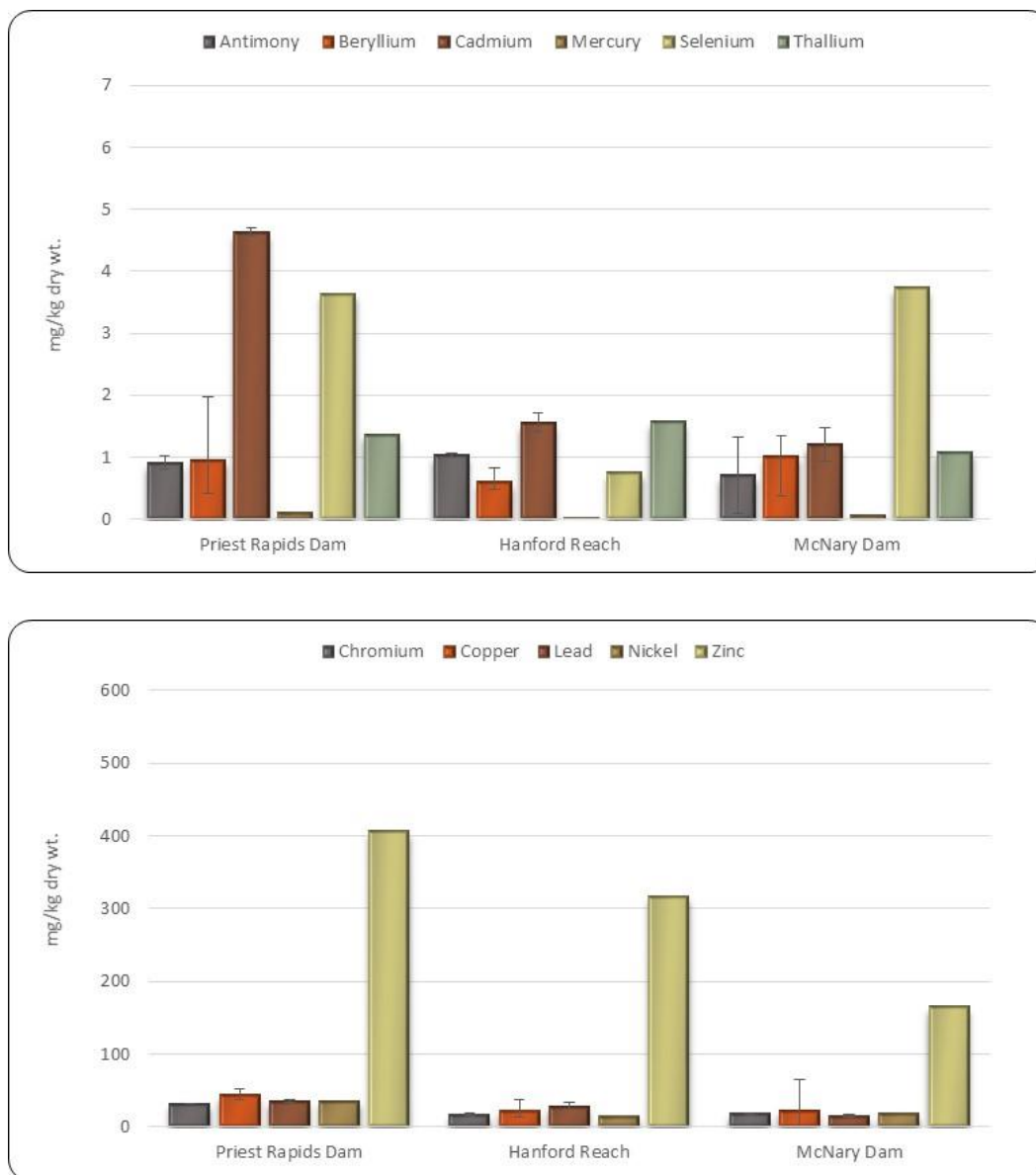
### 7.3.3 Chemical Results

Detectable amounts of most metals were found in all river sediment samples (Figure 7.13). Maximum and average concentrations of cadmium, copper, mercury, nickel, and selenium were higher for sediment collected in the reservoir upstream of Priest Rapids Dam than in sediment from either the Hanford Reach or McNary Dam. Arsenic, lead, silver, and zinc concentrations were detected at higher rates in White Bluffs sediment in comparison to all other sediment collection locations. Currently, there are no Washington State freshwater sediment quality criteria to compare with the measured values.



**Figure 7.13. Selected Metals Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (Washington and Oregon)**

*(Upper and lower bars represent maximum and minimum values; these values may be similar to the average and may not be visible.)*



## 7.4 Columbia River Seep Water

ME Hoefer

In 2014, samples of Columbia River seep water and one associated shoreline sediment sample were collected along the Hanford Reach (Figure 7.3) and analyzed to determine the potential impact of radiological, inorganic, and organic contaminants from the Hanford Site on the public and the aquatic environment. Various radiological analyses were performed on selected seeps following reviews of existing surface-water and groundwater data, multiple RI/FS work plans, and preliminary Hanford Site

risk assessments ([DOE/RL-92-67; WCH-380](#)). Specific analyses performed on samples collected from each location are listed in Tables 7.6 and 7.7.

**Table 7.6. Columbia River Seep Monitoring**

Location <sup>a</sup>	Sample Type	Sampling Frequency	Analyses
100-B Area	Grab	Annually	Anions, metals (filtered and unfiltered), strontium-90, tritium
100-D Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, technitium-99, uranium-234, -235, -238 <sup>b</sup>
100-F Area	Grab	Annually	Anions, metals (filtered and unfiltered), strontium-90, tritium
100-H Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, technitium-99, tritium
100-K Area	Grab	Annually	Alpha, anions, beta, carbon-14, metals (filtered and unfiltered), strontium-90, technitium-99, tritium, VOA
100-N Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, TPH, tritium
300 Area	Grab	Annually	Alpha, anions, beta, tritium, uranium-234, -235, -238 <sup>b</sup> , VOA
Hanford Townsite	Grab	Annually	Alpha, anions, beta, iodine-129, tritium

<sup>a</sup> Refer to Figure 7.3.

<sup>b</sup> Analyzed by alpha spectrometry (alpha energy analysis).

VOA = Volatile organic analyses

**Table 7.7. Columbia Riverbank Seeps Concentration Ranges for Selected Metals and Anions in Water Monitoring Samples, Hanford Site**

2010-2014 Analyte*	Ambient- Water Quality Criterion Level <sup>a</sup>	Sample Location							
		100B Area	100D Area	100F Area	100H Area	100K Area	100N Area	Hanford Townsite	300 Area
DISSOLVED METALS ((µG/L) <sup>e</sup>									
Antimony	N/A	0.095 –	0.136 –	0.0988 –	0.188 –	0.0179 –	0.165 –	0.168 –	0.149 –
		3.5	2.72	0.128	0.392	0.238	0.201	0.341	0.447
Arsenic	190	0.867 –	0.486 –	1.93 –	0.342 –	0.385 –	1.92 –	1.89 –	1.15 –
		5	7.44	2.74	3.15	7.11	26.9	4.01	6.27
Cadmium	0.59	0.00396 –	0.0105 –	0.0074 –	0.00513 –	0.00827 –	0.009 –	0.00726 –	0.0129 –
		0.109	0.0191	0.0275	0.0375	0.0254	0.0246	0.0248	0.0316
Chromium	10 <sup>b</sup>	3.97 –	1.51 –	5.88 –	3.08 –	0.787 –	4.0 –	0.524 –	0.47 –
		14.9	35.4	15.5	33.7	63.4	8.26	2.42	3.3
Copper	6	0.203 –	0.344 –	0.23 –	0.396 –	0.332 –	0.244 –	0.404 –	0.309 –
		1.57	1.46	0.583	1.47	1.25	1.61	0.701	0.678
Lead	1.1	0.174 –	0.00869 –	0.0508 –	0.118 –	0.118 –	0.0896 –	0.0762 –	0.0999 –
		1.41	0.421	0.224	0.179	0.361	0.269	0.217	0.376
Nickel	83	0.342 –	0.295 –	0.118 –	0.231 –	0.244 –	0.934 –	0.216 –	0.167 –
		2.1	3.82	2.61	2.66	2.61	2.75	0.915	3.03

**Table 7.7. Columbia Riverbank Seeps Concentration Ranges for Selected Metals and Anions in Water Monitoring Samples, Hanford Site**

2010-2014 Analyte*	Ambient- Water Quality Criterion Level <sup>a</sup>	Sample Location							
		100B Area	100D Area	100F Area	100H Area	100K Area	100N Area	Hanford Townsite	300 Area
Thallium	N/A	0.00283 – 0.024	0.00983 – 0.023	0.001 – 0.45	0.00582 – 0.0121	0.00615 – 0.0158	0.00276 – 0.00699	0.00316 – 0.0157	0.00616 – 0.0185
Zinc	55	0.433 – 16.7	1.46 – 8.91	1.02 – 1.56	0.68 – 4.86	1.09 – 3.8	1.16 – 54.9	0.734 – 1.89	1.06 – 3.47
<b>Number of Detects</b>		<b>9</b>	<b>9</b>	<b>4</b>	<b>9</b>	<b>7</b>	<b>7</b>	<b>9</b>	<b>12</b>
<b>TOTAL RECOVERABLE METALS (µG/L)<sup>e</sup></b>									
Chromium	96 <sup>c</sup>	2.22 – 253	1.53 – 35.5	10.5 – 58.8	3.22 – 37.9	1.01 – 64.6	2.16 – 9.9	0.686 – 6.83	0.655 – 9.14
Mercury	0.012	0.00022 – 0.00676 <sup>f</sup>	0.000748 – 0.0422	0.00217 – 0.0601 <sup>g</sup>	0.000524 – 0.0317 <sup>h</sup>	0.000436 – 0.0124 <sup>i</sup>	0.000766 – 0.00528 <sup>j</sup>	0.000571 – 0.00686	0.000916 – 0.0215
Selenium	5	0.671 – 1.26	0.208 – 2.04	1.46 – 1.96	0.339 – 1.31	0.795 – 1.38	0.754 – 0.913	0.383 – 1.65	0.423 – 3.91
<b>Number of Detects</b>		<b>11</b>	<b>9</b>	<b>4</b>	<b>9</b>	<b>7</b>	<b>9</b>	<b>9</b>	<b>12</b>
<b>ANIONS (mg/L)<sup>e</sup></b>									
Nitrate	45 <sup>d</sup>	3.22 – 6.77	0.726 – 26.1	23.8 – 38.5	2.47 – 16.5	0.775 – 23.7	1.81 – 16.7	4.83 – 21.7	11.6 – 26.9
<b>Number of Samples</b>		<b>10</b>	<b>9</b>	<b>4</b>	<b>9</b>	<b>7</b>	<b>8</b>	<b>11</b>	<b>19</b>

\*Analytical testing methods changed and minimum detectable concentrations varied as a result.  
<sup>a</sup> Ambient water quality criteria values or chronic toxicity unless otherwise noted. (WAC 173-201A-240)  
<sup>b</sup> Value for hexavalent chromium.  
<sup>c</sup> Value for trivalent chromium.  
<sup>d</sup> DWS (WAC 246-290)  
<sup>e</sup> Values shown are minimum concentrations minus maximum reported concentrations.  
<sup>f</sup> 7 samples analyzed.  
<sup>g</sup> 3 samples analyzed.  
<sup>h</sup> 7 samples analyzed.  
<sup>i</sup> 5 samples analyzed.  
<sup>j</sup> 4 samples analyzed.  
N/A = Not available.

#### 7.4.1 Seep Water Monitoring

Columbia River seeps were documented along the Hanford Reach long before Hanford Site operations began during World War II (*Underground Water Supply of the Region about White Bluffs and Hanford* [Jenkins 1922]).

The Columbia River is the discharge area for the unconfined aquifer underlying the Hanford Site. Groundwater provides a means for transporting Hanford Site-associated contaminants (via leaching) from past waste disposal practices to the Columbia River (DOE/RL-92-12, *Sampling and Analysis of 100 Area Springs*, Rev. 1; PNL-5289, *Investigation of Groundwater Seepage from the Hanford Shoreline of the Columbia River*; PNL-7500, *1988 Hanford Riverbank Springs Characterization Report*;

[WHC-SD-EN-TI-006](#), *Hydrologic and Geologic Data Available for the Region North of Gable Mountain, Hanford Site, Washington*). Contaminated groundwater enters the Columbia River through surface and subsurface discharge. Discharge zones, located above the water level of the river, are identified in this report as Columbia River seeps. Routine monitoring of riverbank seeps offers the opportunity to characterize the quality of groundwater being discharged to the river and assess the potential human and ecological risk associated with the seep water. In addition, contaminants in groundwater near the Columbia River are monitored using shoreline groundwater-sampling tubes (aquifer tubes) (Section 7.5; [BHI-01153](#), *Aquifer Sampling Tube Completion Report: 100 Area and Hanford Townsite Shorelines*; [PNNL-14444](#), *Aquifer Sampling Tube Results for Fiscal Year 2003*; [PNNL-16805](#), *Investigation of the Hyporheic Zone at the Hanford Site*; [PNNL-16894](#), *Investigation of the Strontium-90 Contaminant Plume along the Shoreline of the Columbia River at the 100-N Area of the Hanford Site*; [SGW-41497](#), *Aquifer Tube Optimization Evaluation*).

During the early 1980s, researchers walked a 41-mile (66-kilometer) stretch of the Benton County shoreline of the Hanford Reach and identified 115 seeps ([PNL-5289](#)). These researchers reported that the predominant areas of riverbank seeps at that time were near the 100-N Area, Hanford Townsite, and the 300 Area.

In recent years, it has become increasingly difficult to locate riverbank seeps in the 100-N Area and other locations along the Hanford Reach. Declining water table elevations, a consequence of the end of 100-N Reactor operations and other ongoing site remediation, have reduced discharges from the seeps in and around the 100-N Area. The presence of Columbia River seeps also vary with river stage (river-water surface elevation). The water table near the Hanford Reach is strongly influenced by river-stage fluctuations. The river stage in the Hanford Reach is controlled by upriver conditions and operations at upriver dams. As river levels fluctuate, groundwater levels change, which cause the presence of seeps in the Hanford Reach to vary. At the 300 Area, the river stage is also influenced by the elevation of the McNary Dam pool.

Columbia River water moves into the Hanford Site aquifer as the river stage rises (bank storage) and then discharges from the aquifer in the form of riverbank seeps as the river stage falls. Following an extended period of low river flow, groundwater discharge zones above the water level of the river may cease to exist when the level of the aquifer comes into equilibrium with the river level. Thus, seeps are most readily identified immediately following a decline in river stage.

Bank storage of river water affects the contaminant concentration of the seeps. Columbia River seep water discharged immediately following a river stage decline generally consists of river water or a mixture of river water and groundwater. The percentage of groundwater in a seep water discharge increases over time following a drop in the river stage. Measuring conductivity of the seep water discharge provides an indicator of the extent of bank storage. Hanford Site groundwater has higher conductivity readings than Columbia River water. The conductivity of river water typically ranges between approximately 130 and 150 microsiemens per centimeter ( $\mu\text{S}/\text{cm}$ ).

The effect of bank storage on groundwater discharges and contaminant concentration variations in aquifer thickness, porosity, and plume concentrations make it difficult to estimate accurately the proportion of contaminated groundwater discharging via seeps to the Columbia River within the Hanford Reach. Studies of riverbank seeps conducted during 1983 ([PNL-5289](#)); 1988 ([PNL-7500](#)); and 1991 ([DOE/RL-92-12](#); [WHC-EP-0609](#), *Riverbank Seepage of Groundwater Along the 100 Areas Shoreline*,

Hanford Site); and results of near-shore studies in 1997 ([PNNL-11933](#), *Survey of Radiological Contaminants in the Near-Shore Environment at the Hanford Site 100-N Reactor Area*) and 2001 ([PNNL-13692](#)) noted that discharges from the seeps had localized effects on Columbia River contaminant concentrations only. Beginning in 2011, river-stage specified local quality control guidelines were administered for the seep monitoring efforts following the process and findings described in [WCH-380](#). These guidelines help precision and accuracy of the seep monitoring efforts by reducing variability across space and time associated with fluctuating river stages and the influence of bank storage.

## 7.4.2 Monitoring Results

Routine monitoring of selected Columbia River seeps was initiated in 1988. Currently, seep water samples are collected for contaminant monitoring, and dose calculations and contaminant trends ([DOE/RL-91-50, Rev. 6A](#)). Table 7.6 summarizes the sampling locations and frequencies, as well as sample types and analyses included in Columbia River seep monitoring during 2014. This section describes the monitoring efforts and summarizes results for these aquatic environments. Analytes of interest for samples from seeps were selected based on the findings of previous investigations, reviews of contaminant concentrations observed in nearby groundwater monitoring wells, and results of preliminary risk assessments. Sampling is conducted annually when river flows are low, typically in late summer to early fall to help minimize the effect of bank storage.

All samples collected were analyzed for tritium. Water samples from selected seeps were analyzed for anions, carbon-14, metals, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, and volatile organic compounds. Only unfiltered samples were analyzed, except for metals analyses, in which case both filtered and unfiltered samples were analyzed (Table 7.6).

### 7.4.2.1 Radiological Results

Contaminants of Hanford Site origin continued to be detected in 2014 in water from riverbank seeps entering the Columbia River along the Hanford Site. Gross alpha, gross beta, carbon-14, strontium-90, tritium, and total uranium (uranium-234, uranium-235, and uranium-238) were detected in seep water samples. Carbon-14 levels measured in a 100-K Area riverbank seep decreased in comparison to those measured in 2013 (approximately 5 times lower). In Fall 2014, carbon-14 results exceeded DOE biota concentrations with a measurement of ~2,200 pCi/L (609 pCi/L established RESRAD riparian guideline). As a result, conditions will continue to be monitored throughout the 2015 calendar year.

Gross alpha results for the 300 Area DR 42-2 riverbank seep had a detection ( $66 \pm 7.2$  pCi/L) that exceeded both DOE-derived standards (30 pCi/L) and the Washington State ambient water quality criteria (15 pCi/L) ([DOE O 458.1](#)).

Gross beta detections occurred in 100-K, 100-D, Hanford Townsite and 300 Area seeps during 2014. Detectable concentrations in riverbank seep water at those locations were elevated compared to maximum gross beta concentrations in irrigation water collected from the Horn Rapids Battelle Sporting Complex and Riverview collection locations. The highest gross beta concentration was measured in the Hanford Spring 28-2 riverbank seep ( $47 \pm 4.5$  pCi/L [ $1.8 \pm 0.14$  Bq/L]), which was 94 percent of the Washington State ambient surface water quality criterion of 50 pCi/L (1.85 Bq/L) ([WAC 173-201A](#); [40 CFR 141](#)).

Tritium concentrations varied widely with location. The highest tritium concentration measured in riverbank seeps was near the Hanford Townsite ( $20,800 \pm 4,100$  pCi/L [ $666 \pm 131$  Bq/L]), which exceeded

the Washington State ambient surface water quality criterion of 20,000 pCi/L (740 Bq/L) ([WAC 173-201A; 40 CFR 141](#)). Tritium results at the Hanford Townsite did not exceed DOE-derived standards for riparian life (265,000,000 pCi/L). Tritium concentrations in most riverbank seep water samples were higher when compared to maximum concentrations in 2014 Columbia River fixed-station locations at Priest Rapids Dam and the city of Richland and Columbia River transect station locations. The maximum seep concentration reported was from a sample collected in the Hanford Townsite area (20,800 pCi/L  $\pm$  766 pCi/L). Overall, results in 2014 were comparable to the previous 5 years of concentrations reported in riverbank seeps.

All water samples from riverbank seeps were analyzed for strontium-90. The highest strontium-90 concentration detected in shoreline spring water was in the 100-N Area (13  $\pm$  2.0 pCi/L [0.49  $\pm$  0.076 Bq/L]), which was approximately 1 percent of the DOE-Derived Concentration Guide ([DOE O 458.1, Radiation Protection of the Public and the Environment](#)) of 1,000 pCi/L (37 Bq/L). Historically, groundwater in the 100-N Area has had the highest strontium-90 levels measured at Hanford. The 2014 seep water result at 100-N was about a third less than the 2013 reported concentrations and was within the typical range for this area.

A water sample from a riverbank seep in the Hanford Townsite area was collected in 2014 and submitted to a laboratory for iodine-129 analysis using an ultra-trace method. The water sampled during 2014 from the Hanford Townsite riverbank seep was a non-detect for iodine-129. The Washington State surface water quality criterion for I-129 is 1 pCi/L (0.037 Bq/L) (Appendix D), and the DOE-biota concentration guide standards for aquatic and riparian life are 1,000,000 pCi/L and 38,400 pCi/L. From 2007 to 2010, riverbank seep water samples were analyzed with traditional gamma spectrometry, which has a higher detection limit than the ultra-trace method. All samples analyzed for iodine-129 in 2007 to 2010 were below the detection limit of 1 pCi/L (0.037 Bq/L).

Uranium isotopes were monitored in riverbank seep water samples from the 100-D Area and the 300 Area. The highest concentrations of uranium were found in the 300 Area seep water collected at DR 42-2 riverbank seep. This location is down gradient from the retired 300 Area process trenches. The uranium concentrations in this seep water sample were slightly higher (37 pCi/L  $\pm$  1.1 pCi/L uranium-234; 35 pCi/L  $\pm$  1.1 pCi/L) than the EPA DWS limit of 30  $\mu$ g/L (approximately 20 pCi/L [0.74 Bq/L]). Maximum and average concentrations of uranium-234, uranium-235, and uranium-238 were slightly lower in 2014 than they were during 2009 to 2013. Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area near former uranium fuel fabrication facilities and inactive waste sites.

#### 7.4.2.2 Chemical Results

Inorganic and organic contaminants originating from the Hanford Site continued to be detected in water from riverbank seeps entering the Columbia River. Metals and anions of interest (chloride, nitrate, and sulfate) were detected in seep water. Concentrations of volatile organic compounds were near or below the analytical laboratory's required detection limits in all samples.

Table 7.7 presents concentration ranges of selected metals and anions measured in riverbank seep water during 2009 through 2014. For most locations, the 2014 sample results were similar to those previously reported ([PNL-19455, Hanford Site Environmental Report for Calendar Year 2009](#)). Nitrate concentrations for 2014 were highest in seep water samples from the 100-F Area. Dissolved chromium



concentrations in riverbank seeps for 2014 were highest in the 100-D Area. Hanford Site groundwater monitoring results for 2014 indicated contaminant concentrations at shoreline areas near the discharge locations for the 100-K area seeps were greatest (see Section 8, Groundwater Monitoring).

The Washington State ambient surface water quality criteria for copper, lead, nickel, and zinc are total-hardness dependent ([WAC 173-201A](#); Appendix D). For comparison purposes, the minimum value of 66-mg/L calcium carbonate for 2006 through 2007 water samples collected by the U.S. Geological Survey near the Vernita Bridge were used. Concentrations of most metals measured in water collected from seeps along the Hanford Site shoreline during 2009 through 2014 were below the Washington State ambient surface water chronic toxicity levels ([WAC 173-201A](#)). However, for 2009 through 2014, the maximum concentrations of dissolved chromium in riverbank seep water from the 100-B, 100-D, 100-F, 100-H, and 100-K Areas were above the Washington State ambient surface water acute toxicity levels ([WAC 173-201A](#)). Concentrations from the 100-B Area were the only samples collected having results above the Washington State ambient surface water chronic toxicity levels. All other dissolved chromium results for 2014 were below the Washington State ambient surface water acute and chronic toxicity levels.

Arsenic concentrations in riverbank seep water were well below the Washington State ambient surface water chronic toxicity level. A sample collected in the 100-H area (11.5 µg/L or 0.012 mg/L) slightly exceeded the EPA limit of 0.01 mg/L for the protection of human health for the consumption of water and organisms. This EPA value is 19,000 times lower than the Washington State chronic toxicity standard ([40 CFR 141](#)). Nitrate concentrations at all riverbank seep locations were below the EPA drinking water standard of 45 mg/L.

### 7.4.3 Sediment Monitoring

Beginning in the 1990s, periodic studies were conducted to collect and analyze sediment from riverbank seeps in the 100 Areas and the 300 Area ([DOE/RL-92-12](#); [WHC-EP-0609](#); [WHC-SD-EN-TI-125](#), *Sampling and Analysis of the 300-FF-5 Operable Unit Springs and Near Shore Sediments and River Water*; [WHC-SD-EN-TI-198](#), *100 Area Columbia River Sediment Sampling*). Routine sampling of sediment from riverbank seeps began during 1993 at the Hanford Townsite and the 300 Area. Sampling of riverbank seeps sediment in the 100-B, 100-K, and 100-F Areas began during 1995; and the 100-H Area was added in 2004. However, Hanford Site releases in these areas are best monitored using seep water samples as compared to sediment samples. As such, only one sediment sample was collected from a riverbank seep in the 100-D Area (100-D Spring 102-1) in 2014 (Table 7.8).

**Table 7.8. Columbia Riverbank Sediment Sampling**

Location <sup>a</sup>	Frequency	Analyses
100-D Area	Annually	Anions, Cr+6, gamma energy analysis, uranium-234, -235, -238 <sup>b</sup> , plutonium-289, -239/240, metals, mercury, strontium-90, and total organic carbon

<sup>a</sup> Refer to Figure 7.8.

<sup>b</sup> Analyzed by alpha spectrometry (alpha energy analysis).

#### 7.4.3.1 Radiological Results

Results for the 2014 shoreline seep sediment samples were similar to those observed in Columbia River sediment. Cesium-137 and uranium isotopes were the only radionuclides reported above the minimum

detectable concentrations. Appendix C, Table C.10, compares radionuclide and total organic carbon concentrations in Columbia River sediment near the Hanford Site collected from 2009 through 2014.

#### 7.4.3.2 Metals Results

Concentrations of metals in shoreline seep sediment samples collected in 2014 were similar to concentrations in Columbia River sediment samples with the exception of chromium. Concentrations reported in 2014 for shoreline sediment collected from the 100-D Spring 102-1 had levels that were approximately twice as much as the next highest recorded concentration measured in Columbia River sediment samples. Appendix C, Table C.11, compares metal concentrations in sediment samples collected in 2014. Currently, there are no Washington State freshwater sediment quality criteria to compare with the measured values.

#### 7.4.3.3 Hexavalent Chromium Results

The 100-D Spring 102-1 area also had the highest levels of hexavalent chromium, as concentrations were almost three times higher than the maximum of all other sediment results. This is likely due to historical energy conversion when sodium dichromate was used in reactors to produce fluoride for the enrichment of uranium. The 100-D Area has two separate hexavalent chromium plumes that have been recorded, and surrounding soil and water sampling have shown elevated concentrations ([BHI-01747](#), *Results of Hexavalent Chromium Sampling Near 100-D Area Sodium Dichromate Transfer Station Railroad Tracks*). All hexavalent chromium concentrations reported are listed in Appendix C, Table C.12.

### 7.5 Pond Water and Sediment

ME Hoefler

Two Hanford Site ponds, FFTF Pond and the West Lake Pond (Figure 7.3), were sampled periodically during 2014. The ponds are accessible to migratory waterfowl, deer, and other wildlife, creating a potential biological pathway for the dispersion of contaminants. The FFTF Pond is a retired disposal site that collected process water, primarily cooling water drawn from 400 Area groundwater wells. West Lake, the only naturally occurring pond on the Hanford Site, is located north of the 200-East Area ([ARH-CD-775](#), *Geohydrologic Study of the West Lake Basin*). West Lake has not received direct effluent discharges from Hanford Site facilities, but it is influenced by precipitation and changing water table elevations. The water level in West Lake fluctuates, and the lake changes from standing water in winter and spring to dry or nearly dry in summer and fall. Radionuclides were chosen for analysis based on their presence in local groundwater and their potential to contribute to the overall radiation dose to biota that frequent the ponds.

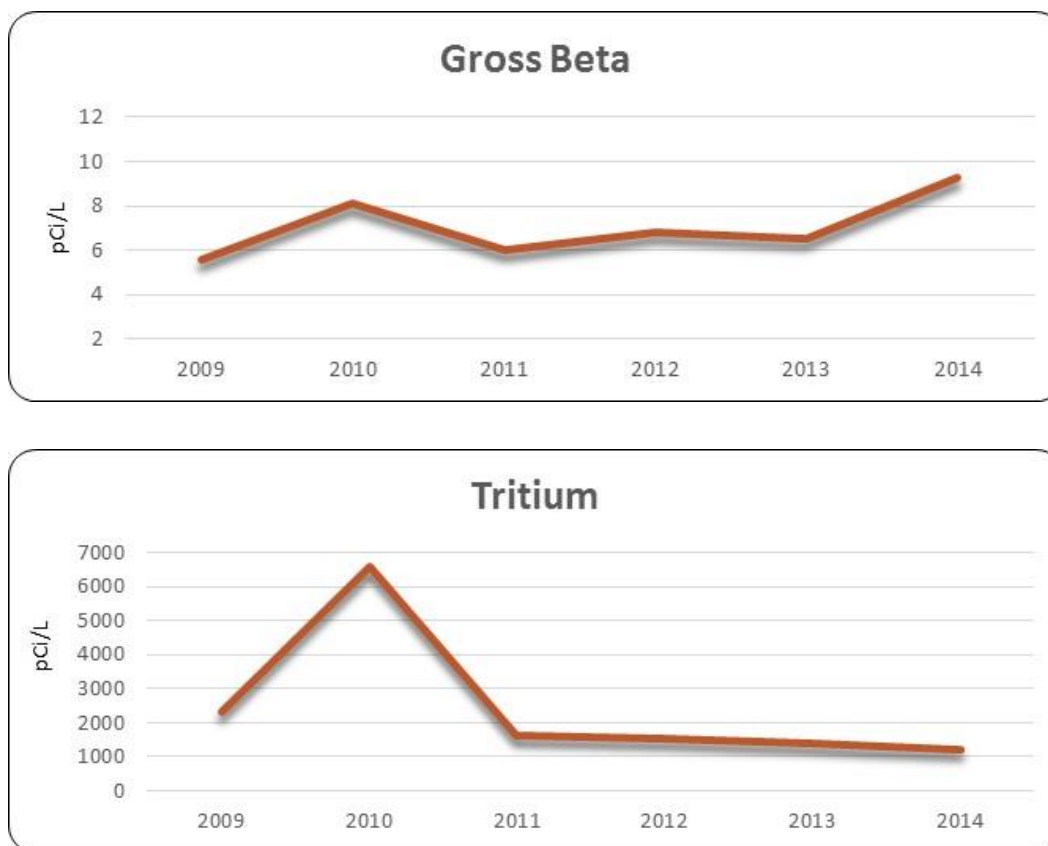
#### 7.5.1 Fast Flux Test Facility Pond Water

Grab samples were collected quarterly in 2014 from the FFTF Pond water access weir box. All water samples collected from the FFTF Pond were analyzed for gross alpha, gross beta, tritium, and gamma-emitting radionuclides.

Figure 7.14 shows the annual average gross beta and tritium concentrations in FFTF Pond water from 2009 through 2014. All samples had non-detects on gross alpha concentrations while average gross beta levels increased slightly during 2014 when compared to 2013. Tritium concentrations in FFTF Pond water were slightly lower in 2014 than they were in 2013. The sources of contaminants in the pond water are historical groundwater contaminant plumes from the 200 Areas that have migrated to wells in the

400 Area, which supplied water to facility operations. The weir box/pond area also serves as retention for surrounding storm water runoff. Radionuclide concentrations in FFTF Pond water samples collected during 2014 and in the previous 5 years are shown in Appendix C, Table C.1.

Figure 7.14. Gross Beta and Tritium in Fast Flux Test Facility Pond Water Samples



### 7.5.2 West Lake Water

Water monitoring continued at West Lake in 2014 with sampling conducted twice a year during the first and second quarters. The groundwater table in the 200-East Area has dropped in recent years (Section 8, Groundwater Monitoring), decreasing the size of West Lake, and causing the suspended sediment load to increase. West Lake seep and surface water samples collected from 2002 through 2010 were not analyzed for gross alpha, gross beta, strontium-90, technetium-99, uranium-234, uranium-235, or uranium-238 because of the high sediment load. A special study conducted in 2000 ([PNNL-13487](#), *Summary of the Hanford Site Environmental Report for Calendar Year 2000*) indicated that uranium is present in a soluble form in West Lake water. As a result, analyses of West Lake water samples for uranium-234, uranium-235, and uranium-238 were resumed in 2011.

During the first quarter of 2014, a grab sample of standing seep water was collected for analysis of uranium-234, uranium-235, and uranium-238. The uranium-234 and uranium-238 concentrations were above applicable DOE-Derived Concentration Guides ([DOE O 458.1](#)).

A grab sample of surface water was collected for analysis during the second quarter of 2014 when the lake was almost dry. The surface water collected within the footprint of West Lake was analyzed for tritium,

uranium-234, uranium-235, and uranium-238. Tritium concentrations in surface water collected from West Lake in 2014 were below the laboratory-reported required detection limit. Figure 7.14 shows the annual average concentrations of uranium-234 in West Lake surface water and West Lake seep water from 2013 and 2014. Radionuclide concentrations in the West Lake seep and surface water samples collected during 2014 and in the previous 2 years are shown in Appendix C, Tables C.3, and C.4.

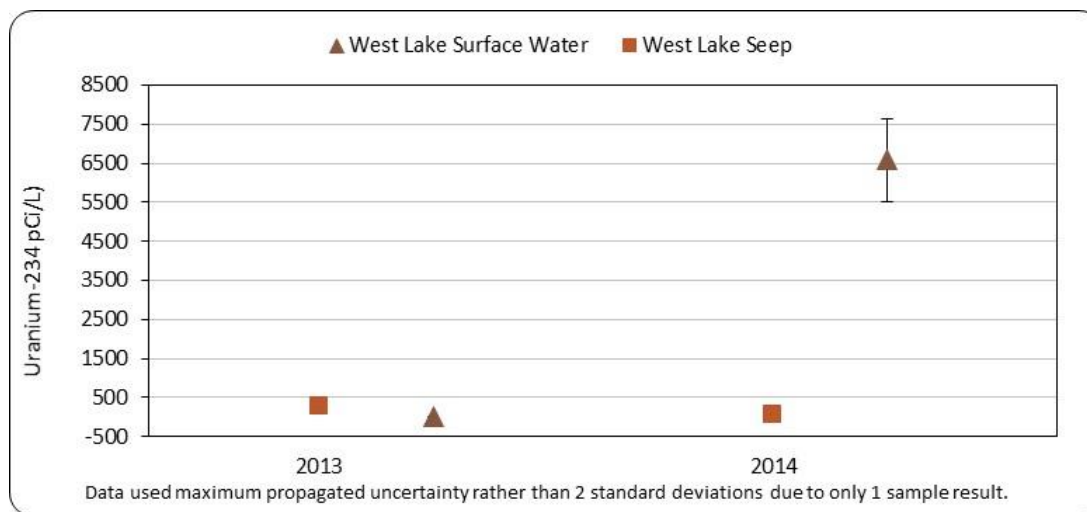
### 7.5.3 West Lake Sediment

One sediment sample was collected from West Lake during the second quarter of 2014. The sediment sample was collected from upper-layer material near the pond shoreline.

The West Lake sediment sample was analyzed for gross alpha, gross beta, cesium-137, strontium-90, uranium-234, uranium-235, uranium-238, and other gamma-emitting radionuclides. Radionuclides were chosen for analysis based on their presence in local groundwater and their potential to contribute to the overall radiation dose to biota that frequent the ponds. Detections of all radionuclides during 2014 were similar to previous measurements reported.

Uranium concentrations are most likely from naturally occurring uranium in the surrounding soil ([BNWL-1979](#), *Environmental Surveillance at Hanford for CY-1975*). Radionuclide levels from samples collected during 2014 and a summary of those collected during the previous 5 years are shown in Appendix C, Table C.2.

Figure 7.15. Uranium in West Lake Water Samples



## 7.6 Offsite Irrigation Water

ME Hoefer

As a result of public concern about the potential for Hanford Site-associated contaminants in offsite water, sampling was conducted in 2014 to document the levels of radionuclides in water used by the public. The consumption of food products irrigated with Columbia River water downstream of the site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical MEI and any other member of the public (Section 4.2.1).

**Offsite Irrigation Water Monitoring.** Water samples were collected in 2014 from an irrigation canal located east of the Columbia River and a location downstream of the Hanford Site at Riverview. Samples of the

water supply from the Horn Rapids irrigation pumping station (Figure 7.3) were collected from the irrigation valve at the Battelle sporting complex. Each location was sampled three times during the 2014 irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, strontium-90, and tritium.

**Sample Results.** Most radionuclide concentrations measured in irrigation water in 2014 were at similar levels detected in Columbia River transect water samples collected upstream of the Hanford Site. At the Horn Rapids irrigation pumping station, the tritium results were slightly higher than water collected from the Riverview irrigation system. Strontium-90 was not detected, and results were similar to concentrations measured in Horn Rapids and Riverview irrigation samples. All radionuclide concentrations were within the historical range and were less than their respective DOE-Derived Concentration Guides and Washington State ambient surface-water quality criteria ([DOE O 458.1](#); [WAC 173-201A](#); [40 CFR 141](#)).

## 7.7 Liquid Effluent

*DJ Rokkan*

Liquid effluents were discharged to ground disposal units from a few Hanford Site facilities in 2014. Only one of those waste streams is permitted for radioactive constituents; however, all are sampled and analyzed for select radioactive parameters and nonradioactive hazardous materials.

Throughout each calendar year, discharge-monitoring reports, containing contaminant data from the analysis of liquid effluent samples, are submitted to DOE, as regulated by [WAC 173-216](#), and subsequently reported to Ecology.

### 7.7.1 Radionuclide Results

The only active discharge point for radioactive liquid effluent to the ground in 2014 was the 616-A Crib, also known as the State-Approved Land Disposal Site. Table 7.9 summarizes the analysis results on this effluent discharge point for 2014.

**Table 7.9.** *Radionuclides in the 200 Area Liquid Effluent Discharged to the State Approved Land Disposal Site*

Radionuclide	Half-Life	Release, Ci <sup>a</sup>
Tritium	12.35 years	11.0
<sup>a</sup> 1 Ci = $3.7 \times 10^{10}$ Bq.		

### 7.7.2 Nonradioactive Hazardous Materials Results

Nonradioactive hazardous materials in several liquid effluent streams discharge to ground disposal units in the 100, 200, and 400 Areas. These discharges are authorized by six state-approved discharge permits ([WAC 173-216](#)), which stipulate monitoring requirements. The effluents are monitored for select materials. The EPA is notified immediately if chemicals in the liquid effluents exceed reportable quantities under CERCLA. If chemicals in effluents remain stable at predicted levels, these levels may be reported annually if EPA has approved this practice. Section 2.4.1 provides a synopsis of the state waste discharge permits.

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## 8.0 Groundwater Monitoring

*MJ Hartman*

The Hanford Site, part of DOE's nuclear weapons complex, encompasses 586 square miles (~1,500 square kilometers) along the Columbia River in southeastern Washington State. During World War II and the Cold War period (1945 to 1991), the government built a total of nine reactors for the production of plutonium and other nuclear materials.

During reactor operations, chemical and radioactive waste was released into the environment and contaminated the soil and groundwater beneath portions of the Hanford Site, mostly in the 200 East Area, 200 West Area, 300 Area, 1100 Area, and the 100 Area reactor areas along the river (e.g., 100-BC, 100-K) (Figure 8.1). Since 1989, DOE has worked to remediate this contamination. DOE developed a plan to address groundwater and vadose zone contamination in consultation with EPA and Ecology. Key elements associated with managing the Hanford Site's groundwater and vadose zone contamination are to: (1) protect the Columbia River and groundwater, (2) develop a cleanup decision process, and (3) achieve final cleanup restoring groundwater to its highest beneficial use.

Groundwater occurs in an unconfined aquifer within unconsolidated gravel and sand units. Groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge areas along the Columbia River (Figure 8.2). The flow of water divides beneath the 200 East Area, with some water flowing toward the north and some flowing southeast. Maximum concentrations of key groundwater contaminants are presented in Tables 8.1 and 8.2; time series graphs of plume area over time for the largest plumes and the combined plume footprint are shown in Figure 8.3.

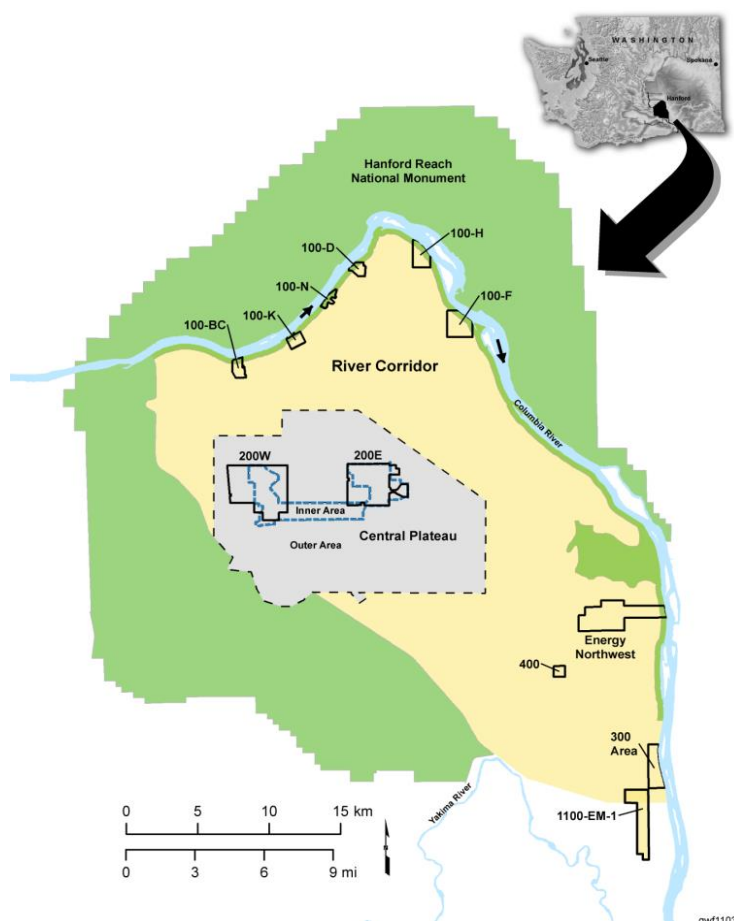
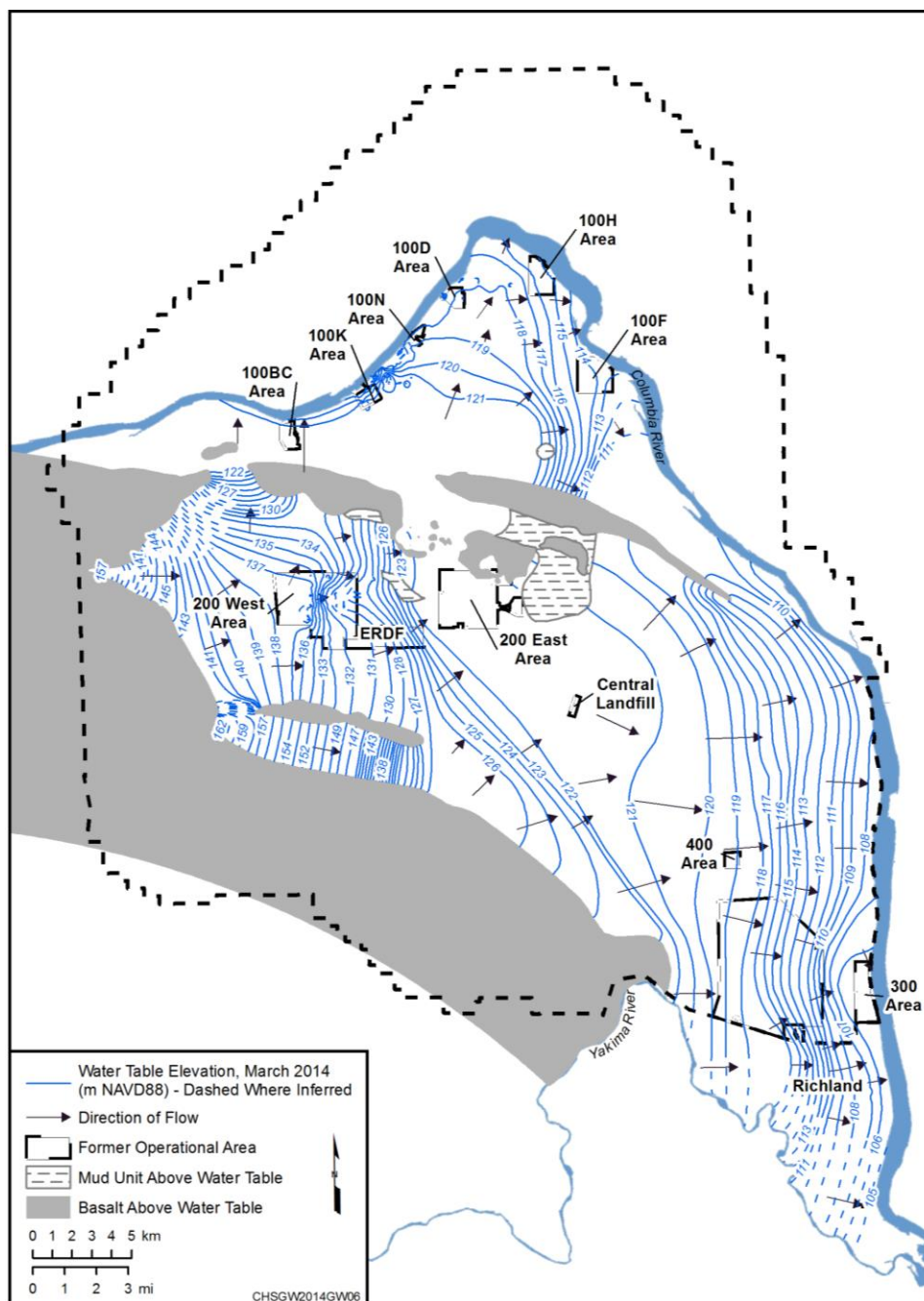


Figure 8.1. Regions of the Hanford Site

*Figure 8.2. Hanford Site 2014 Water Table and Directions of Groundwater Flow*



DOE has taken the following actions to protect the Columbia River from contaminated groundwater:

- ⊗ Ceasing discharge of all unpermitted liquids in the central Hanford Site.
- ⊗ Remediating waste sites in the 100 and 300 Areas to reduce the potential for future groundwater contamination.
- ⊗ Containing groundwater plumes and reducing the mass of primary contaminants through remedial actions such as pump-and-treat (P&T).

Table 8.1. Overview of the River Corridor Groundwater Interest Areas Contaminant Concentrations

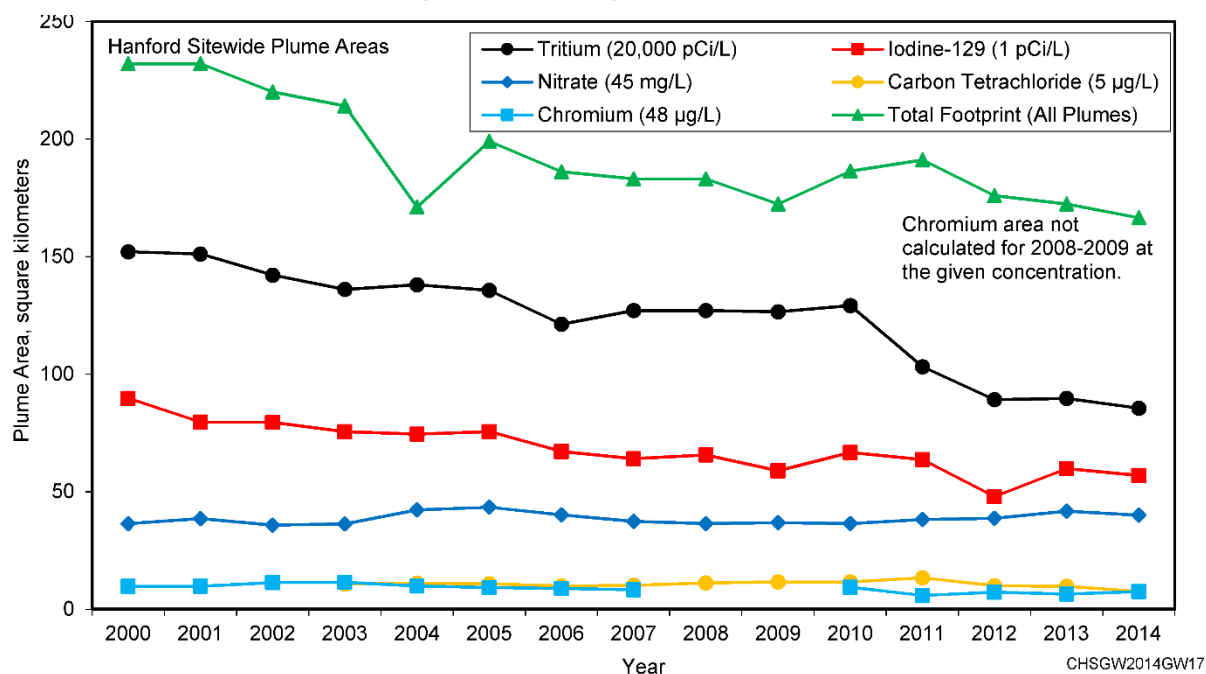
River Corridor Overview										
Area	Primary Operations	Status of Waste Site Remediation <sup>a</sup>	Status of Ground-water ROD	Groundwater Contamination: Maximum Concentration and Plume Area						
				Carbon-14	Hexavalent Chromium	Nitrate	Strontium-90	Trichloro-ethene	Tritium	Uranium
100-BC	Reactor operations -- B Reactor 1944-69; C Reactor 1952-69	93% complete	None to date	N	63 µg/L	47 mg/L	43 pCi/L	2.43 µg/L	17,000 pCi/L	9 µg/L
100-K	Reactor operations -- KE Reactor 1955-71; KW Reactor 1955-70	59% complete	Interim action P&T	14,300 pCi/L	520 µg/L	74 mg/L	231	6.8 µg/L	414,000 pCi/L	7.7 µg/L
100-N	Reactor operations -- N Reactor 1963-87	92% complete	Interim action permeable reactive barrier	52 pCi/L	181 µg/L	186 mg/L	15,500 pCi/L	N	761,000 pCi/L	6.6 µg/L
100-D & 100-H	Reactor operations -- D Reactor 1944-67; DR Reactor 1950-64; H Reactor 1949-65	87% complete	Interim action P&T	N	3,440 µg/L	53 mg/L	36.4 pCi/L	N	20,400 pCi/L	52.1 µg/L
100-F	Reactor operations -- F Reactor 1945-65; Biological experiments until 1976	98% complete	Final action MNA	N	29 µg/L	146 mg/L	144 pCi/L	15.3 µg/L	5,500 pCi/L	21.1 µg/L
300	Nuclear fuel fabrication and research -- 1940s-1960s	91% complete	Final action enhanced attenuation, MNA	N	5.6 µg/L	(b)	1.9 pCi/L	83	994,000 pCi/L	358 µg/L
1100 and Offsite	Vehicle maintenance, 1954-85; solid waste landfill --1950s- 1970	100% complete (final action ROD)	Final action MNA; goals met	N	N	(b)	N	0.71 µg/L	121 pCi/L	(b)
Standards <sup>c</sup>				2,000 pCi/L	10 µg/L	45 mg/L	8 pCi/L	5 µg/L	20,000 pCi/L	30 µg/L
Half-life (years)				5,730	N/A	N/A	28.8	N/A	12	>159,000
Mobility in subsurface				High	High to Moderate	High	Slight	Moderate	High	Moderate
Legend										
Colors indicate maximum concentration in 2014					Height of bar indicates plume area above standard (km <sup>2</sup> )					
≥1,000 x standard					>10					
≥100 x standard and <1,000 x standard					>1 and ≤ 10					
≥10 x standard and <100 x standard					>0.1 and ≤ 1					
≥Standard and <10 x standard					>0, ≤0.1					
N Not detected or not analyzed										
NOTES										
(a) Approximate percentage by number of waste sites classified as closed, interim closed, no action, rejected, or not accepted (end of 2014).										
(b) Nitrate in 300-FF-5, and nitrate and uranium in 1100-EM-1, originates from offsite sources, so plume areas and maximum concentrations are not shown										
(c) Drinking water standards for all but hexavalent chromium (aquatic standard)										
ABBREVIATIONS										
MNA Monitored natural attenuation			N/A Not applicable			ROD Record of decision			CHSGW2014GW04	

Table 8.2. Overview of Central Plateau Groundwater Interest Areas Contaminant Concentrations

Central Plateau Overview													
Area	Primary Operations	Status of Groundwater ROD	Groundwater Remedial Action	Groundwater Contamination: Maximum Concentration and Plume Area									
				Carbon Tetrachloride	Chromium	Cyanide	Iodine-129	Nitrate	Strontium-90	Trichloroethene	Technetium-99	Tritium	Uranium
200-ZP-1	T Plant (Pu separation) 1944-1956; Pu Finishing Plant: 1949-1989	Signed 2008 (final action)	Groundwater P&T and MNA: 1995-present. Soil vapor extraction 1991-2013	2,000 µg/L	186 µg/L	N	1.9 pCi/L	536 mg/L	N	8.6 µg/L	21,500 pCi/L	72,000 pCi/L	2.7 µg/L
200-UP-1	REDOX Plant (Pu separation) 1952-1967; U Plant (U recovery) 1952-1957	Signed 2012 (interim action)	U plant P&T: 1994-2011; S-SX P&T: 2012-present	See 200-ZP-1	497 µg/L	2.5 µg/L	11 pCi/L	2,270 mg/L	1.15 pCi/L	8.7 µg/L	86,500 pCi/L	280,000 pCi/L	734 µg/L
200-BP-5	B Plant Pu separation: 1945-1952; B Plant Sr and Cs recovery: 1967-1985	Expected 2016	Perched aquifer P&T test: 2011-2014	1.7 µg/L	172 µg/L	1,600 µg/L	6.05 pCi/L	1,480 mg/L	1,100 pCi/L	3.97 µg/L	42,000 pCi/L	37,000 pCi/L	4,030 µg/L
200-PO-1	PUREX Plant Pu separation: 1956-1972 and 1983-1989	Expected 2016	Vadose zone desiccation test: 2011	1.8 µg/L	167 µg/L	9.7 µg/L	6.49 pCi/L	156 mg/L	15 pCi/L	1.6 µg/L	1,840 pCi/L	510,000 pCi/L	57.8 µg/L
Standards*				5 µg/L	48 µg/L	200 µg/L	1 pCi/L	45 mg/L	8 pCi/L	5 µg/L	900 pCi/L	20,000 pCi/L	30 µg/L
Half-life (years)				N/A	N/A	N/A	16,000,000	N/A	28.8	N/A	212,000	12	>159,000
Mobility in subsurface				Multi-phase	High to Moderate	Moderate	High	High	Slight	Moderate	High	High	Moderate
Legend													
Colors indicate maximum concentration in 2014													
Height of bar indicates plume area above standard (km <sup>2</sup> )													
<div><div><div>≥100 x standard and &lt;1,000 x standard</div><div>≥10 x standard and &lt;100 x standard</div><div>≥Standard and &lt;10 x standard</div><div>N Not detected or not analyzed</div></div><div><div>&gt;10</div><div>&gt;1 and ≤10</div><div>&gt;0.1 and ≤1</div><div>&gt;0, ≤0.1</div></div></div>													
*Drinking water standards for all but hexavalent chromium (MTCA standard)													
ABBREVIATIONS													
N/A = Not applicable      P&T = pump-and-treat      ROD = record of decision      MTCA = Model Toxics Control Act													
CHSGW2014/GW05													

CHSGW2014GW05

Figure 8.3. Hanford Site Plume Areas



DOE operates an extensive groundwater monitoring program on the Hanford Site, collecting thousands of samples from hundreds of wells each year. In addition to monitoring wells, DOE monitors hundreds of sampling points near the Columbia River, known as aquifer tubes, for general information about groundwater approaching the river. DOE sampled 977 monitoring and extraction wells, and 324 aquifer tubes in 2014. Many of them were sampled multiple times, for a total of 4,654 sampling events (Figure 8.4).

Figure 8.4. 2014 Sampling Events (Wells and Aquifer Tubes)

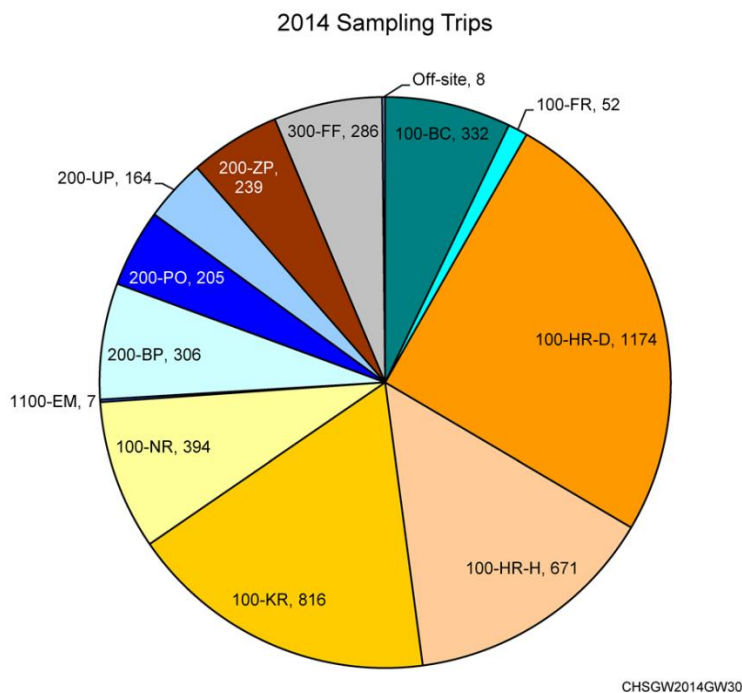
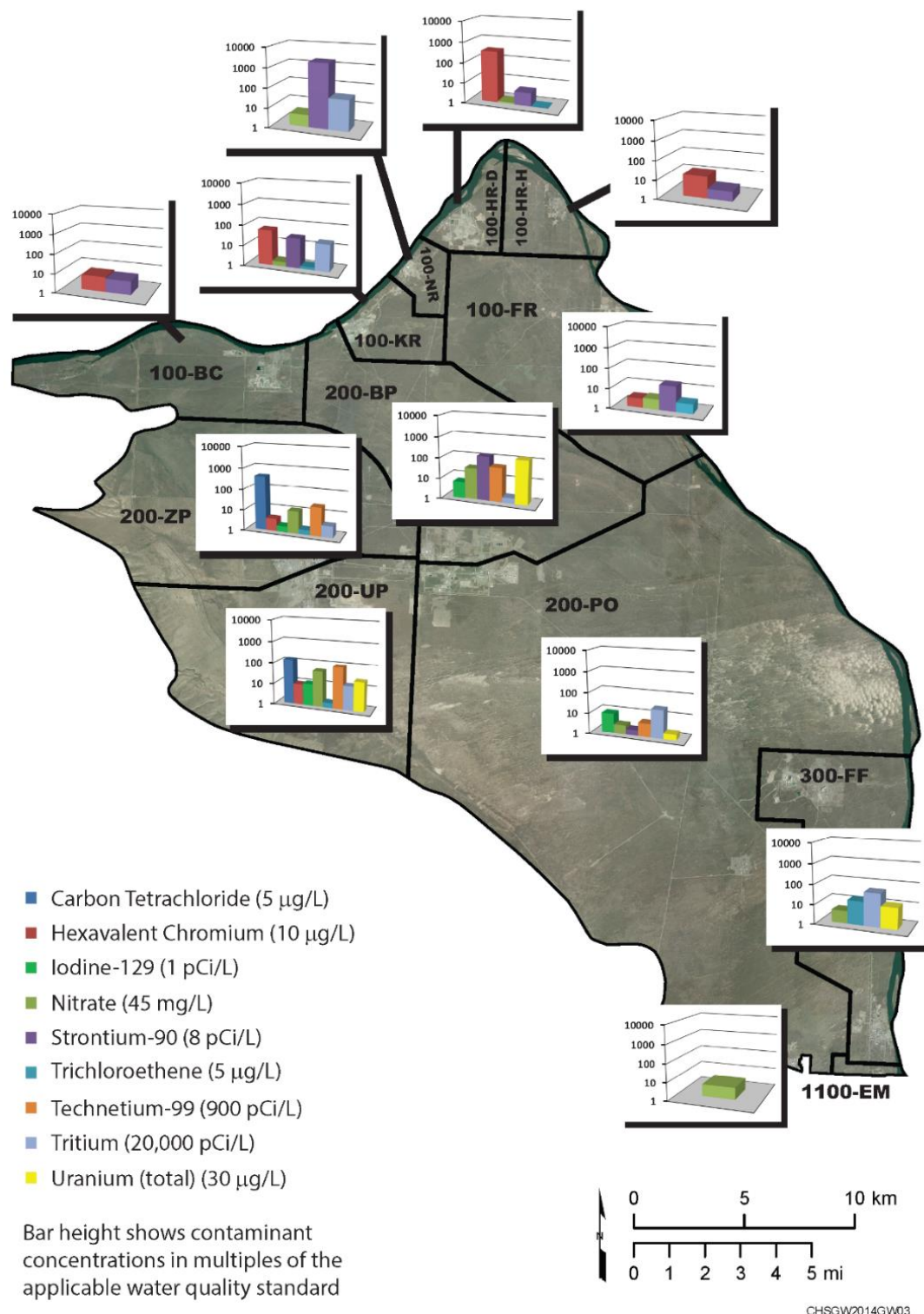




Figure 8.5 compares maximum concentrations of the major groundwater contaminants in various parts of the Site in 2014. These contaminants are discussed further in the following sections. This chapter is organized by geographic regions known as “groundwater interest areas” (Figure 8.5) within the River Corridor (100 and 300 Areas) and the Central Plateau (200 Areas).

*Figure 8.5. Exceedance Ratios of Groundwater Contaminants in 2014*





## 8.1 River Corridor

Since the 1990s, DOE has been remediating waste sites and groundwater in the River Corridor under interim action RODs. Removal of contaminated soil has reduced the potential for exposure to contaminants, including future groundwater impacts. As of the end of 2014, 89 percent of the waste sites in the River Corridor had been remediated or were classified as not needing remediation under interim action RODs, as compared to 85 percent in 2013 and 74 percent in 2012. Cleanup of the remaining sites is underway. Based on remedy performance monitoring and the reduction in length of shoreline impacted by contaminant plumes, groundwater remediation systems in 100-HR, 100-KR, and 100-NR are reducing the amount of contamination entering the Columbia River.

Table 8.1 provides a summary of the River Corridor groundwater interest areas and associated contamination plumes. In the 100 Area, groundwater contamination is related to past disposal of waste associated with water cooled nuclear reactors. The primary groundwater contaminants of concern (COC) in the 100 Area are chromium (hexavalent and total), strontium-90, nitrate, trichloroethene, and tritium (Figure 8.6). Sources of hexavalent chromium contamination included the routine disposal of reactor cooling water, which contained the corrosion inhibitor sodium dichromate, and unplanned spills and leaks of the high-concentration sodium dichromate stock solution. In the 300 Area, the groundwater COCs are uranium, tritium, nitrate, gross alpha, trichloroethene and cis-1,2-dichloroethene.

Under interim action RODs, groundwater remediation systems in the 100-HR-3 and 100-KR-4 Operable Units are limiting the amount of contamination reaching the Columbia River and reducing the mass of contaminants. The primary contaminant addressed is hexavalent chromium. The comparison concentration for inland groundwater wells is 20 µg/L. Similar to other river corridor decisions (e.g., 100-FR-3), the cleanup level for groundwater discharges to the river for the final action ROD for 100-HR-3 and 100-KR-4 is expected to be 10 µg/L, when they are completed. EPA and DOE signed a final action ROD for 100-FR waste sites and groundwater in 2014. Final action RODs previously were signed for the 300-FF-5 and 1100-EM-1 OUs. Final action RODs for the other portions of the River Corridor are expected to be developed in the next few years.

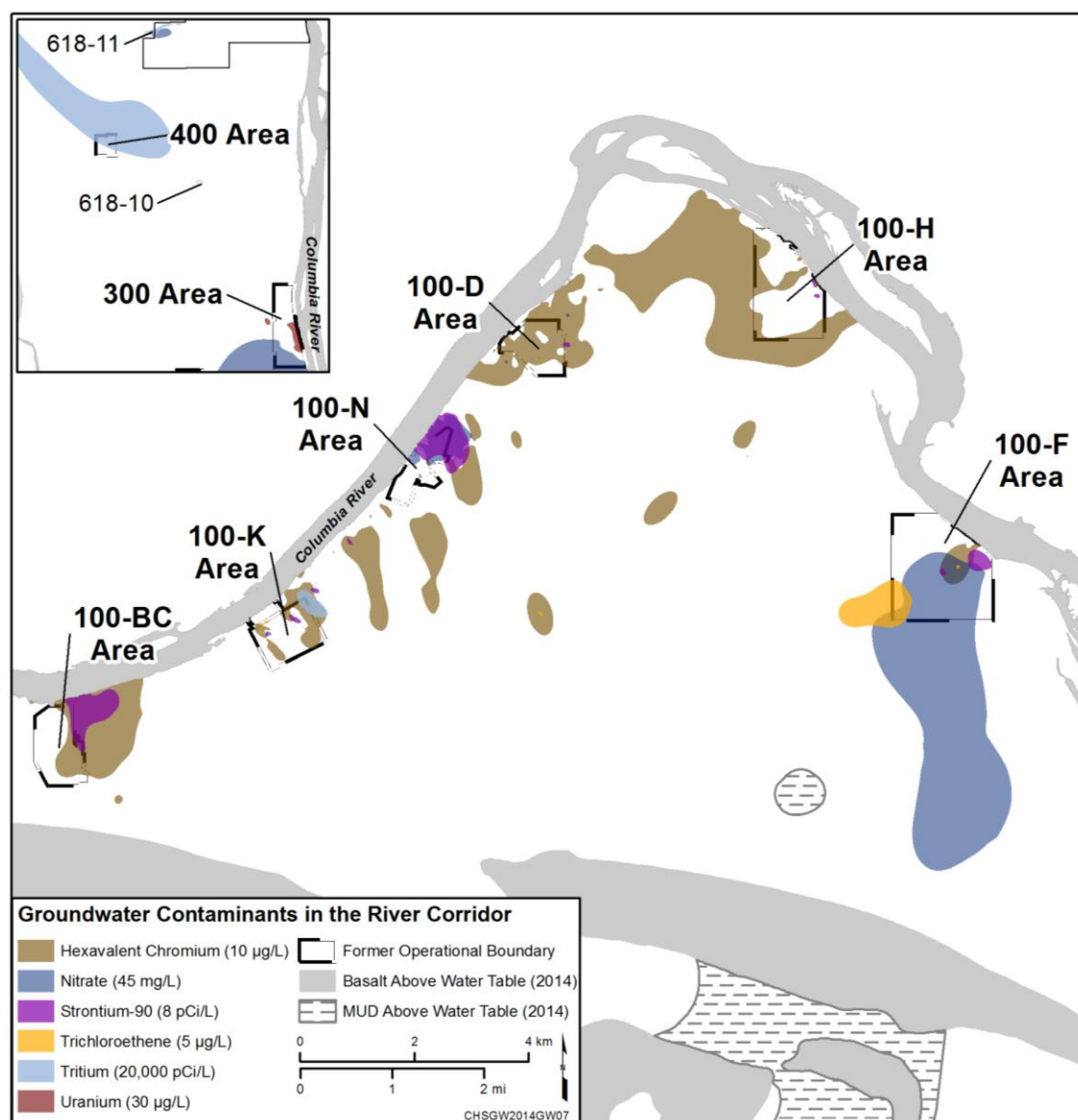
### 8.1.1 100-BC

Groundwater contaminants in 100-BC include hexavalent chromium and strontium-90. Tritium concentrations remained below the DWS in 2014. Waste sites in 100-BC have been remediated under an interim action ROD, so contaminant levels in groundwater are expected to continue to decline.

Remedial investigation (RI) studies continued in 100-BC in 2014, with additional sampling of wells and river shoreline sampling points installed in 2013. The studies, which are expected to conclude in 2016, will provide data to support remedy decisions for groundwater cleanup. This includes ongoing, intensive sampling of water in the shallow river bed to evaluate variable concentrations of hexavalent chromium, at the groundwater/surface water interface.

DOE and EPA have agreed that additional RI studies are needed to reduce uncertainties relating to (1) the completion of waste site remediation; (2) short term changes in groundwater contaminants related to waste site remediation; (3) modeling results predicting that the hexavalent chromium plume could persist for over 100 years; and (4) the level of risk associated with variable hexavalent chromium concentrations in Columbia River pore water.

Figure 8.6. Groundwater Contaminants in the River Corridor



### 8.1.2 100-KR

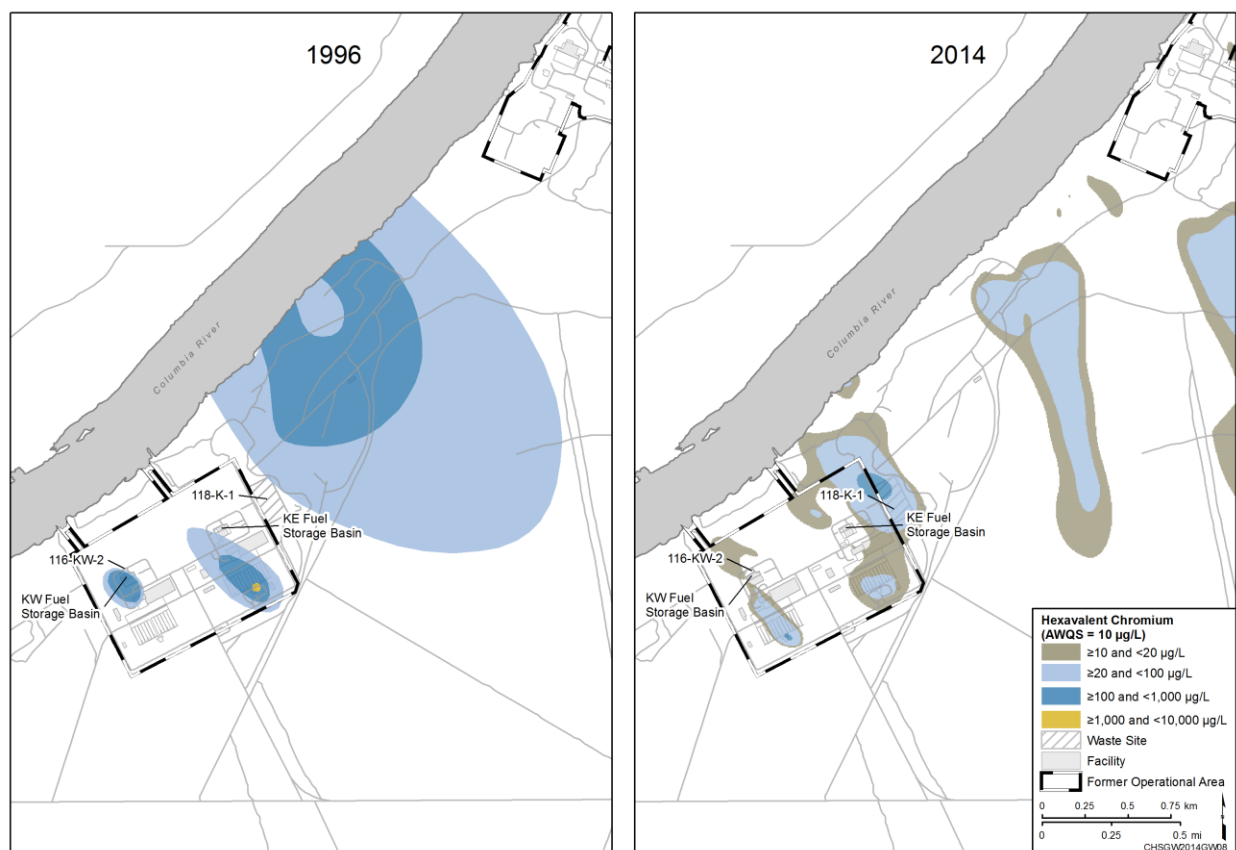
Hexavalent chromium is the primary contaminant in 100-KR groundwater. Smaller plumes of carbon 14, tritium, strontium 90, nitrate, and trichloroethene also are present. Cleanup actions for these other contaminants will be defined in an upcoming ROD. DOE has proposed additional P&T for hexavalent chromium as part of a preferred alternative for groundwater remediation. The draft RI/Feasibility Study (FS) and Proposed Plan underwent review in 2012, and DOE will incorporate the results of supplemental source characterization activities that includes drilling boreholes near the KE Fuel Storage Basin and 116-KE-3 Crib and Reverse Well. These boreholes are expected to be drilled in 2015.

Approximately 59 percent of 100-KR waste sites have been remediated or were determined not to require remediation under an interim action ROD. Three P&T systems continued to operate in 100-KR to remove hexavalent chromium from groundwater. In 2014, over 607.6 million gallons (2.3 billion liters) of groundwater was pumped from 41 extraction wells and a total of 1,757 pounds (797 kilograms) of

hexavalent chromium have been removed to date. The hexavalent chromium plume area (greater than 20 µg/L) was estimated to be 0.29 square miles (0.76 square kilometers) in 2014, a decrease from 2013. Since 2007, the plume area above 20 µg/L has decreased by approximately 70 percent, and the length of shoreline that the plume is interpreted to intersect (based on data from wells and aquifer tubes) has decreased from 7,200 feet (2,200 meters) to 660 feet (200 meters) (Figure 8.7).

For [AEA](#) purposes, DOE monitors groundwater near the KW and former KE Fuel Storage Basins, which were integral parts of each reactor building. Groundwater monitoring in 2014 did not show new groundwater impacts from the basins.

**Figure 8.7.** 100-KR Hexavalent Chromium Plume in 1996 (Before Interim Action) and 2014 (During Interim Action)



### 8.1.3 100-NR

DOE submitted a draft RI/FS report and Proposed Plan to Ecology for review in 2013. When finalized, these documents will be used to develop a ROD documenting remediation of waste sites and groundwater. Work continued in 2014 on revisions to the RI/FS report in response to Ecology comments. The major liquid waste disposal sites have been remediated, and excavation is continuing at remaining waste sites. Work is expected to be complete in 2015. Principal groundwater activities for 100-NR include RCRA monitoring and remediation of strontium-90 and total petroleum hydrocarbons. Other groundwater contaminants include nitrate and tritium. Hexavalent chromium from 100-KR has affected 100-NR groundwater in some locations.

Strontium-90, which originated at the 116-N-1 and 116-N-3 waste sites, is the primary contaminant. Strontium (including the strontium-90 isotope) substitutes for calcium in the sediment, reducing the mobility of this contaminant in the vadose zone and groundwater. As a result, the shape and size of the plume (Figure 8.8) has not changed significantly since 1996.

P&T technology, which operated from 1995 to 2006, was found to be ineffective in cleaning up strontium-90, so DOE is now applying an in situ technology called strontium-90 sequestration, using an apatite chemical solution. Under an interim action ROD, a 900 foot (170 meter) section of a permeable reactive barrier was placed along the shoreline, reducing the amount of strontium-90 migrating from groundwater into the river. Expansion of the barrier to its full 2,500 foot (760 meter) length is pending.

In 2014, RCRA monitoring continued under final status detection programs at the 1301-N, 1324-N/NA, and 1325-N facilities (waste sites 116-N-1, 120-N-1, 120-N-2, and 116-N-3). Results indicated no releases of dangerous waste constituents from the RCRA units.

#### **8.1.4 100-HR**

The 100-HR-3 Groundwater OU in the northern Hanford Site includes the 100-HR-D and 100-HR-H groundwater interest areas. Hexavalent chromium is the primary COC. Additional groundwater contaminants in 100-HR include strontium-90 and nitrate (Figure 8.6). Investigation of groundwater conditions at 100 HR greatly changed the understanding of the extent of chromium contamination since P&T began, primarily because many more wells were installed. In 1997, 110 wells and aquifer tubes were sampled, and in 2014, over 330 wells and aquifer tubes were sampled in 100-HR. The added wells and aquifer tubes identified areas of higher chromium concentrations at 100 D, in the Horn, and in the Ringold Formation upper mud unit (RUM). Even with areas of high levels of contamination being identified, the overall areal extent of the plume has decreased as a result of remediation (Figure 8.9).

The CERCLA process is underway to make final cleanup decisions for 100-HR. DOE submitted the Draft A RI/FS and Proposed Plan in 2012. In 2013 and 2014, DOE and Ecology worked through the comment resolution process, and Ecology accepted the 100-HR-3 RI/FS Report in October 2014. The Proposed Plan is expected to be available for public comment in 2015 or 2016. A ROD will then be issued that identifies the final remedial alternatives. DOE has proposed ongoing P&T as the preferred alternative for remediating hexavalent chromium in groundwater.

Approximately 87 percent of the former waste sites have been remediated or were determined not to require remediation under an interim action ROD. Remediation of waste sites continued in 2014, including 100-D-100, a major source of hexavalent chromium. Contaminated sediment was excavated down to the water table, and excavation into the top of the aquifer continues in 2015.

Two P&T systems continued to operate under an interim action ROD, removing hexavalent chromium. In 2014, 634 million gallons (2.4 billion liters) of groundwater were pumped from 74 extraction wells. A total of 4,952 pounds (2,246 kilograms) of hexavalent chromium have been removed to date. The plume area (greater than 20 µg/L) was estimated to be 1.4 square miles (3.5 square kilometers) in 2014, a decline from 2013. Since 2005 the plume has decreased in area by over 60 percent, and the length of shoreline intersected by the plume (above 20 µg/L) has been reduced from 8,200 feet (2,550 meters) to zero (Figure 8.9). The changes are a result of contaminant removal, remediation of sources, hydraulic control, and natural processes.

The former 183-H Solar Evaporation Basins (waste site 116-H-6) constitute the only RCRA site in 100-HR. The site is monitored in accordance with RCRA corrective action requirements during the post-closure period to track contaminant trends during operation of the CERCLA interim action for hexavalent chromium.

*Figure 8.8. 100-NR 2014 Strontium-90 Plume and Apatite Barrier*

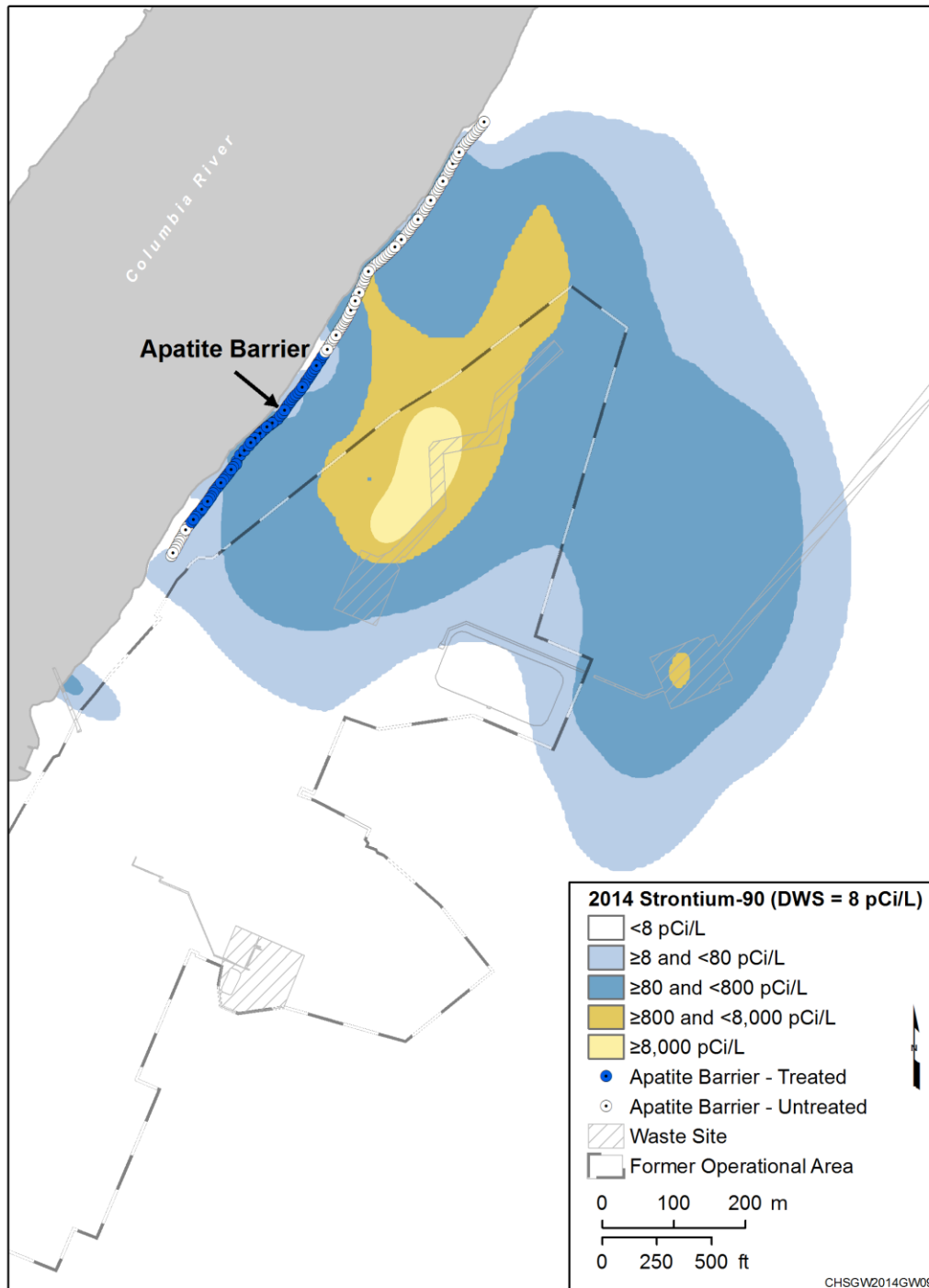
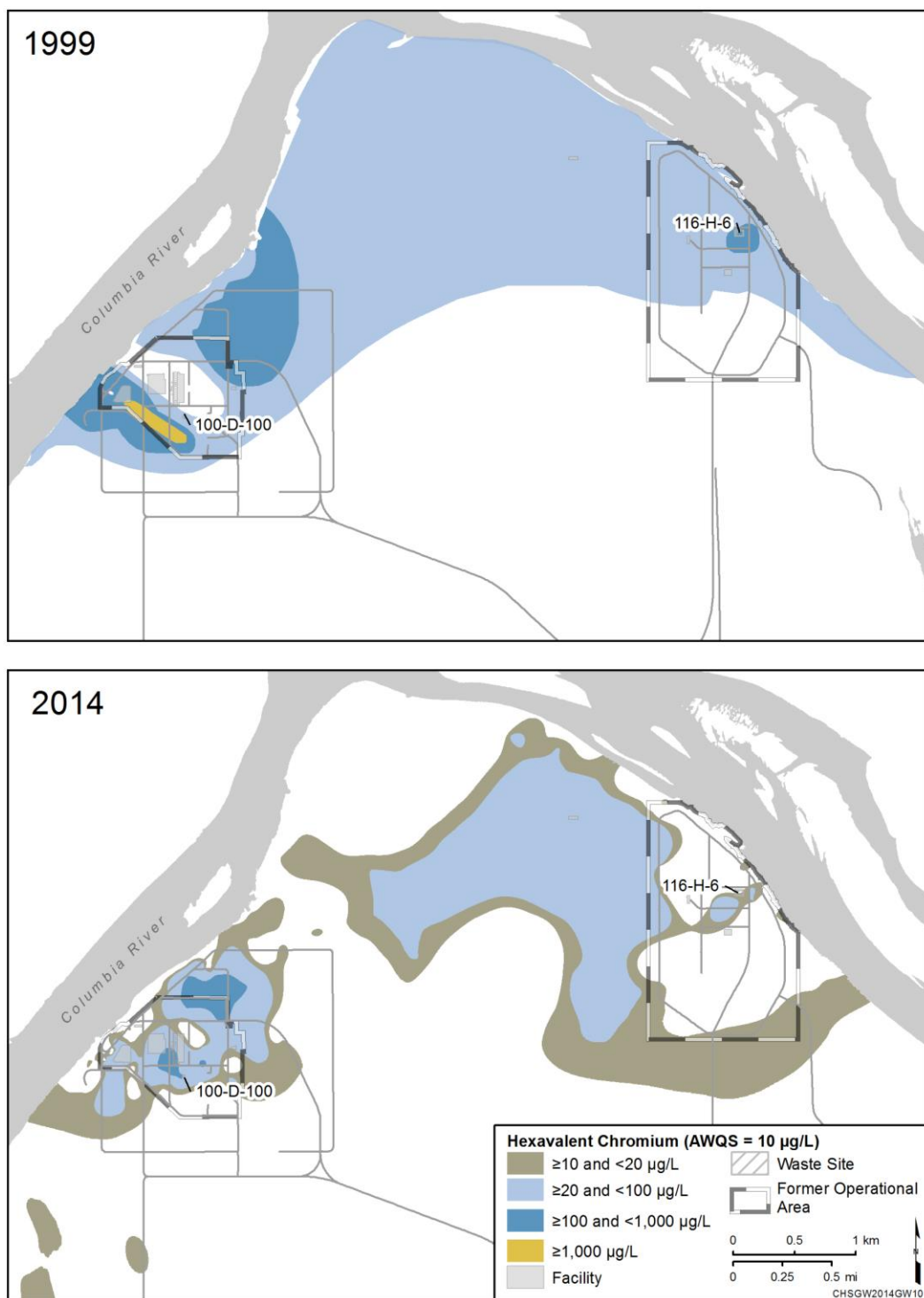


Figure 8.9. 100-HR Hexavalent Chromium Plume in 1999 (Early in Interim Action Period) and 2014 (During Interim Action)





### 8.1.5 100-FR

Groundwater contamination in 100-FR originated from disposal of solid and liquid waste associated with operation of the water-cooled F Reactor and biological experiments. Nitrate concentrations in groundwater exceed the DWS beneath much of the 100-F Area and the plume extends southward approximately 3.1 miles (5 kilometers). Smaller plumes of hexavalent chromium, strontium-90, and trichloroethene are present (Figure 8.6). Contaminant concentrations are below cleanup standards near the river and are declining.

Former 100-FR waste sites have been excavated and backfilled under an interim action ROD. In 2014, EPA and DOE signed a ROD that includes monitored natural attenuation (MNA) as the preferred alternative for 100-FR-3 OU groundwater remediation. Preparation of a work plan and sampling and analysis plan is underway.

### 8.1.6 300-FF

Three geographic regions comprise 300-FF: the 300 Area Industrial Complex; the 618-11 Burial Ground region; and a region including the 618-10 Burial Ground and 316-4 Cribs (Figure 8.6). Approximately 91 percent of the waste sites have been remediated or classified as not requiring remediation. Remediation is continuing at the remaining sites. DOE is conducting field and laboratory studies to understand and model the processes that control contaminant flux between groundwater and the Columbia River. In 2014, studies focused on seasonal water quality dynamics (including uranium and nitrate).

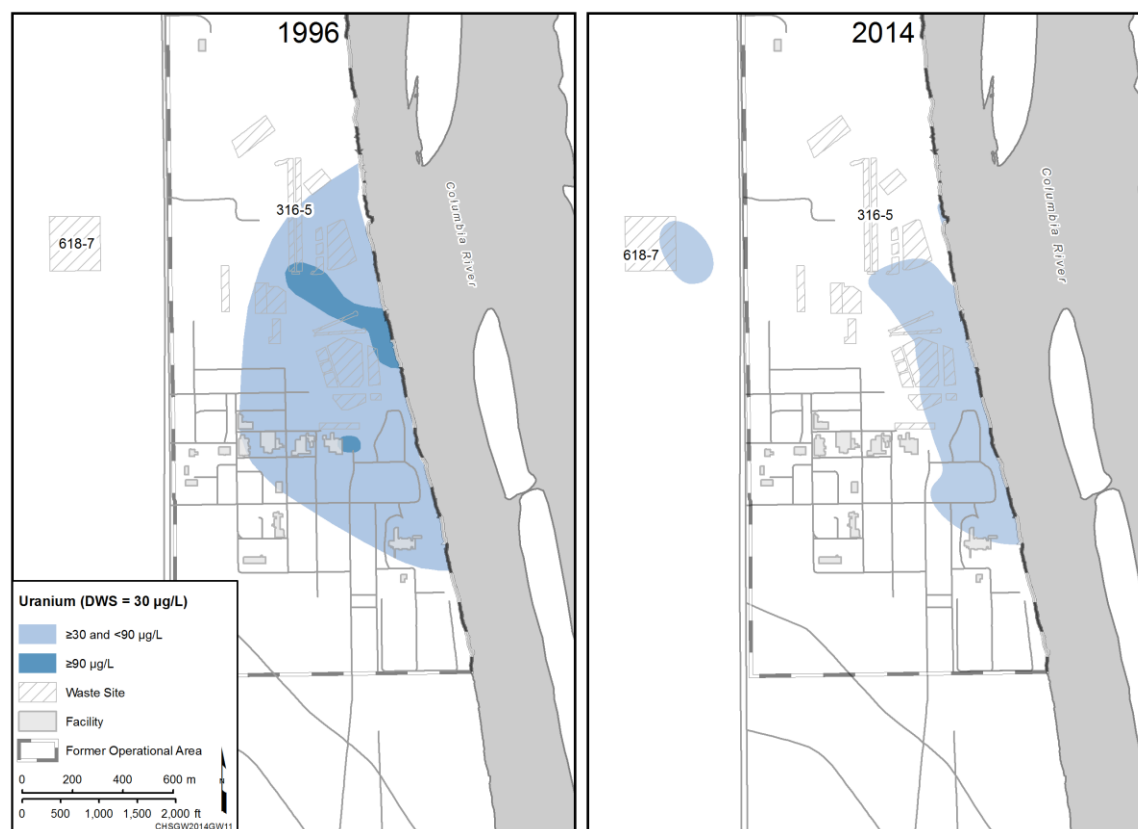
EPA and DOE signed a ROD in 2013 and the remedial design report/remedial action work plan that implements the 2013 final action ROD is anticipated to be issued in 2015. The remedial action for groundwater includes enhanced attenuation of uranium using sequestration by phosphate application. MNA is the selected remedy for other COCs: trichloroethene and cis-1,2-dichloroethene at the 300 Area Industrial Complex and tritium and nitrate at the 618-11 Burial Ground. Uranium concentrations remain above the cleanup level (30 µg/L) in groundwater in the 300 Area Industrial Complex and downgradient from the 618-7 Burial Ground (Figure 8.10). Contamination from 618-7 was mobilized by waste site remediation activities in recent years.

Trichloroethene concentrations exceeded the cleanup level (4 µg/L) in one 300-FF monitoring well and several aquifer tubes in 2014. Concentrations of nitrate above 45 mg/L are also present in groundwater beneath part of the 300 Area Industrial Complex, but these originated from sources off the Hanford Site; nitrate in the 300 Area Industrial Complex is not a COC for 300-FF.

Groundwater associated with the 618-11 Burial Ground, north of the 300 Area Industrial Complex, contains a high-concentration tritium plume originating from irradiated material in the burial ground. The waste site has not been remediated. Nitrate concentrations near the 618-11 Burial Ground also continued to exceed the cleanup level (45 mg/L).

RCRA groundwater monitoring continued at the 300 Area Process Trenches (waste site 316-5). The unit is monitored in accordance with post-closure corrective action requirements (WAC 173-303-645[11]). Uranium and cis-1,2-dichloroethene continued to exceed permit concentration limits in 2014. In accordance with the closure plan, groundwater corrective action will be addressed as part of the remediation for the CERCLA 300-FF-5 Groundwater OU.

Figure 8.10. 300-FF Uranium Plume in 1996 and 2014



### 8.1.7 1100-EM and Richland North

Remediation of the former 1100-EM-1 OU is complete and the 1100-EM-1 Groundwater OU was removed from the “National Priorities List” (40 CFR 300, Appendix B) in 1996. The selected remedy was MNA of volatile organic compounds, with institutional controls (IC) on drilling of new water supply wells. Trichloroethene is the primary COC, but concentrations have remained below the cleanup level since 2001.

Uranium concentrations in Hanford Site wells in the vicinity of DOE’s inactive Horn Rapids Landfill have increased gradually since 1996, exceeding the DWS in 2012 and dropping slightly below the standard in 2014. The presence of uranium at these locations is attributed to a plume moving northeast from an active offsite facility, AREVA NP, Inc. a nuclear fuel production facility.

DOE monitors wells in and near the north Richland well field, which is part of the municipal water supply system. Tritium concentrations are at background levels.

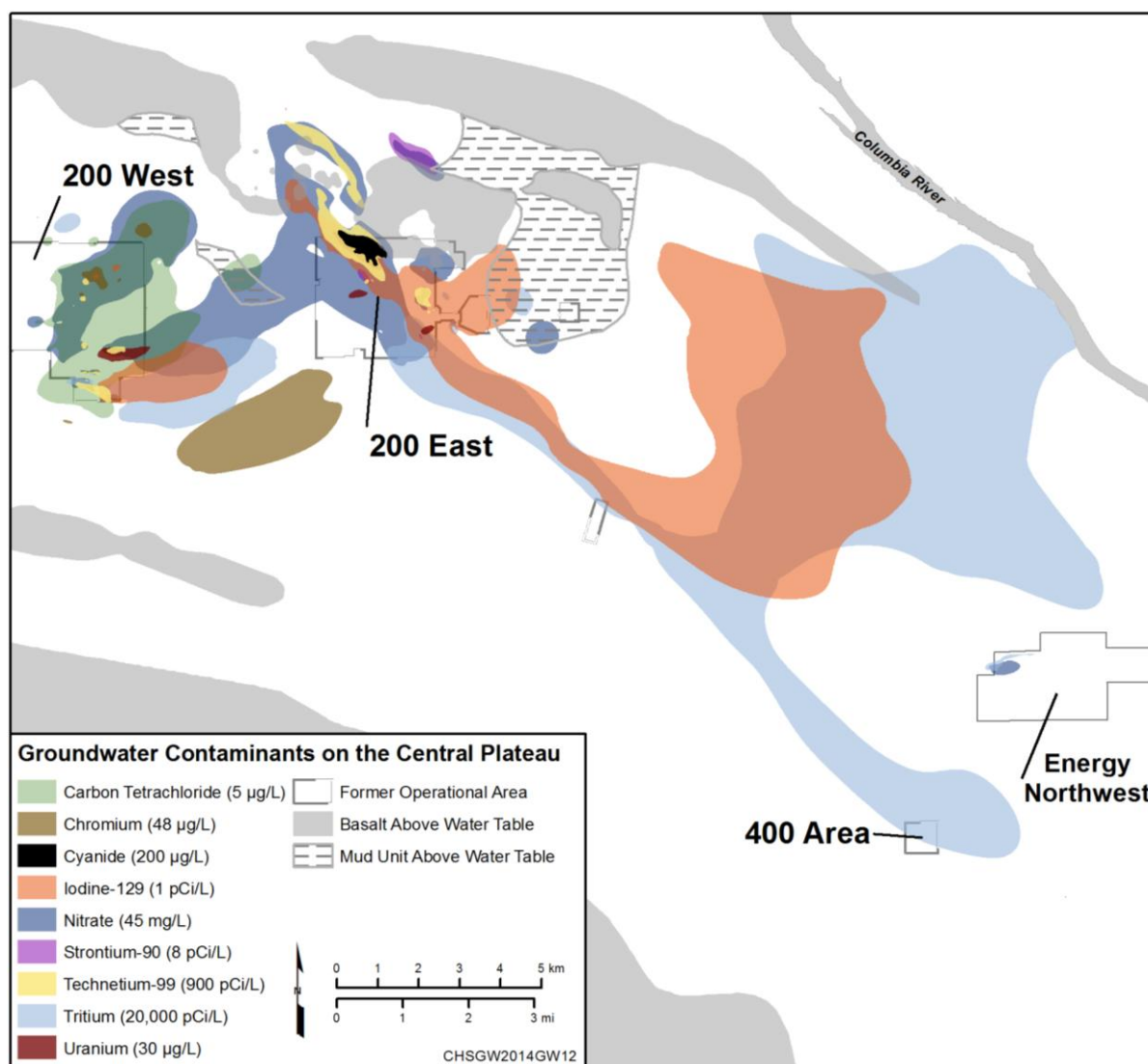
## 8.2 Central Plateau

When the Hanford Site was operating as a plutonium-production facility, irradiated fuel reprocessing, isotope recovery, and associated waste management activities occurred in the 200 East and 200 West Areas in the central portion of the Site. Ponds, cribs, and ditches used for disposal of liquid waste were primary sources of groundwater contamination. There are also seven single-shell tank WMAs in the 200 Area. Some of these tanks have leaked, contaminating the vadose zone and groundwater beneath the tanks. Contamination is still present in many parts of the thick vadose zone, and may continue to drain into the

groundwater. Remediation of the Central Plateau waste sites and vadose zone will accelerate after River Corridor remediation is complete. Meanwhile, DOE has been remediating groundwater and testing methods to remediate the deep vadose zone.

Groundwater contaminant plumes of tritium, nitrate, and iodine-129 formed when the waste discharged to ponds and cribs reached the aquifer. These contaminants form regional plumes originating on the Central Plateau. The plumes have decreased in area over the years as a result of dispersion and, in the case of tritium, radioactive decay. A large carbon tetrachloride plume originated in the PFP area of 200 West. Other groundwater contaminants in the Central Plateau include technetium-99, uranium, strontium-90, trichloroethene, hexavalent chromium, cyanide, and other dangerous waste constituents (Table 8.2 and Figure 8.11).

Figure 8.11. Groundwater Contaminants in the Central Plateau



An estimated 1,256,635 to 2,028,253 pounds (570,000 to 920,000 kilograms) of liquid wastes with carbon tetrachloride was discharged to waste sites in 200-ZP-1. Remediation has reduced the size of the high-concentration core and the overall footprint of the carbon tetrachloride plume. Combined, the final action system, the interim action system, and a soil vapor extraction system have removed a total of 221,556 pounds (100,496 kilograms) of carbon tetrachloride from the subsurface.

A P&T system at WMA S-SX in the 200-UP-1 OU, which began operating in July 2012, has removed 1.66 Ci of technetium-99, 35,891 pounds (16,280 kilograms) of nitrate, 62 pounds (28.1 kilograms) of chromium, and 551 pounds (250 kilograms) of carbon tetrachloride from groundwater.

The size of the regional tritium plume associated with 200-PO-1 has decreased from 71 to 49 square miles (185 to 79 square kilometers) since 1980, primarily as a result of radioactive decay and dispersion.

### **8.2.1 200-ZP**

Contaminant sources in 200-ZP, located in the 200 West Area, included cribs, ponds, and single-shell storage tanks. A final action ROD for 200-ZP-1 OU groundwater identified carbon tetrachloride as the primary COC. Other COCs are trichloroethene, iodine-129, technetium-99, nitrate, chromium, and tritium. Two Low-Level Waste Management Areas (LLWMA-3 and LLWMA-4) in 200-ZP are monitored under RCRA interim status, contaminant indicator parameter programs. Monitoring results showed no indication that either of these is contaminating groundwater.

RCRA assessment monitoring continued at WMA T and WMA TX-TY. Due to CERCLA remediation activities (operation of the 200 West P&T system) near WMA T, chromium concentrations are declining and the plume extents at both WMAs are shrinking.

The State-Approved Land Disposal Site (SALDS) receives treated water from the Hanford Site's Effluent Treatment Facility. It is regulated under a state waste discharge permit and has created a local tritium plume. All groundwater sampling results from the SALDS proximal wells were within permit compliance limits during 2014.

A P&T system has reduced the high-concentration core area of the carbon tetrachloride plume (Figure 8.12). The plume area above 5 µg/L was 5.1 square miles (13.1 square kilometers) in 2014, compared to 5.9 square miles (15.4 square kilometers) in 2013. In 2014, 20 extraction wells and 20 injection wells were in use and the treatment plant operated at a flow rate of 1,562 gallons per minutes (5,913 liters per minute) (71 percent of its design capacity). Additional wells were installed in 2014 that will be used to expand the extraction network. In 2014, the system processed 819 million gallons (3.1 billion liters) of groundwater and removed 6,164 pounds (2,796 kilograms) of carbon tetrachloride, 517,240 pounds (234,616 kilograms) of nitrate, and other contaminants from groundwater. Combined, the final action system, the interim action system, and a soil vapor extraction system have removed a total of 221,556 pounds (100,496 kilograms) of carbon tetrachloride from the subsurface (Figure 8.13).

Figure 8.12. 200-West Carbon Tetrachloride Plume in 1996 (Upper Part of Unconfined Aquifer) and 2014 (Including Available Vertical Interval Data)

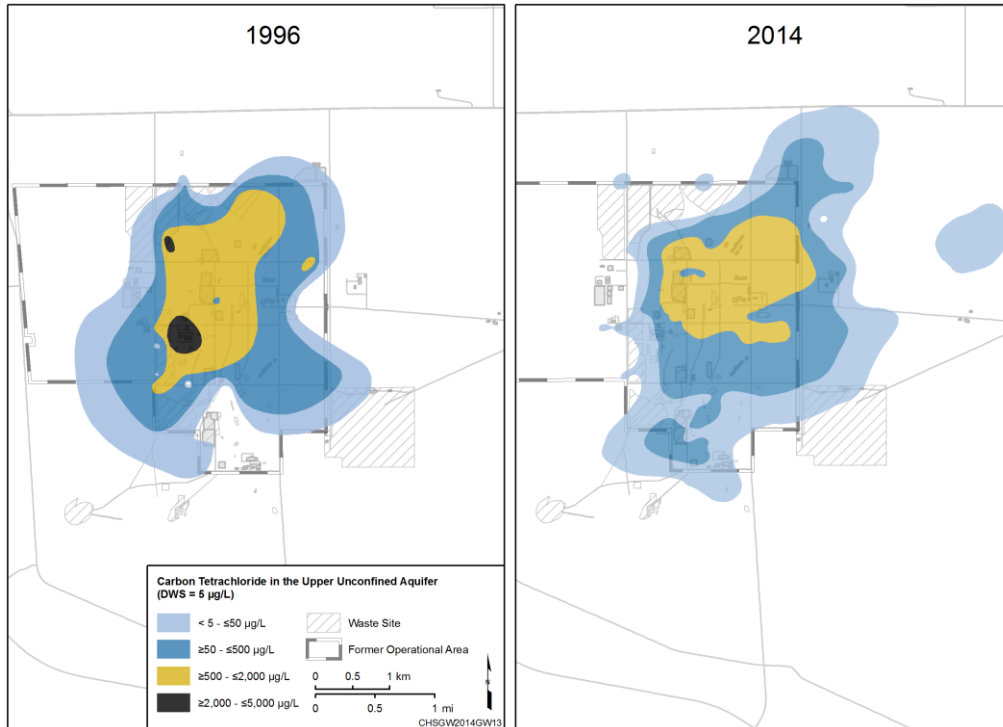
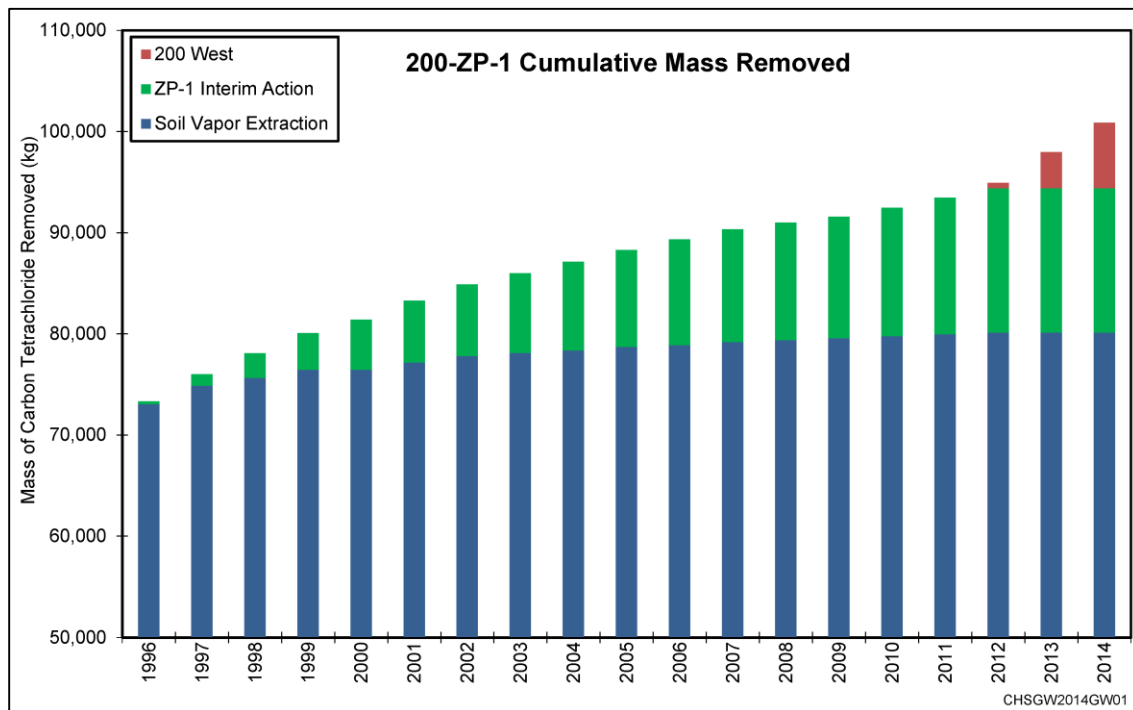


Figure 8-13. 200-ZP Carbon Tetrachloride Mass Removed by Final Pump-and-Treat, Interim Pump-and-Treat, and Soil Vapor Extraction

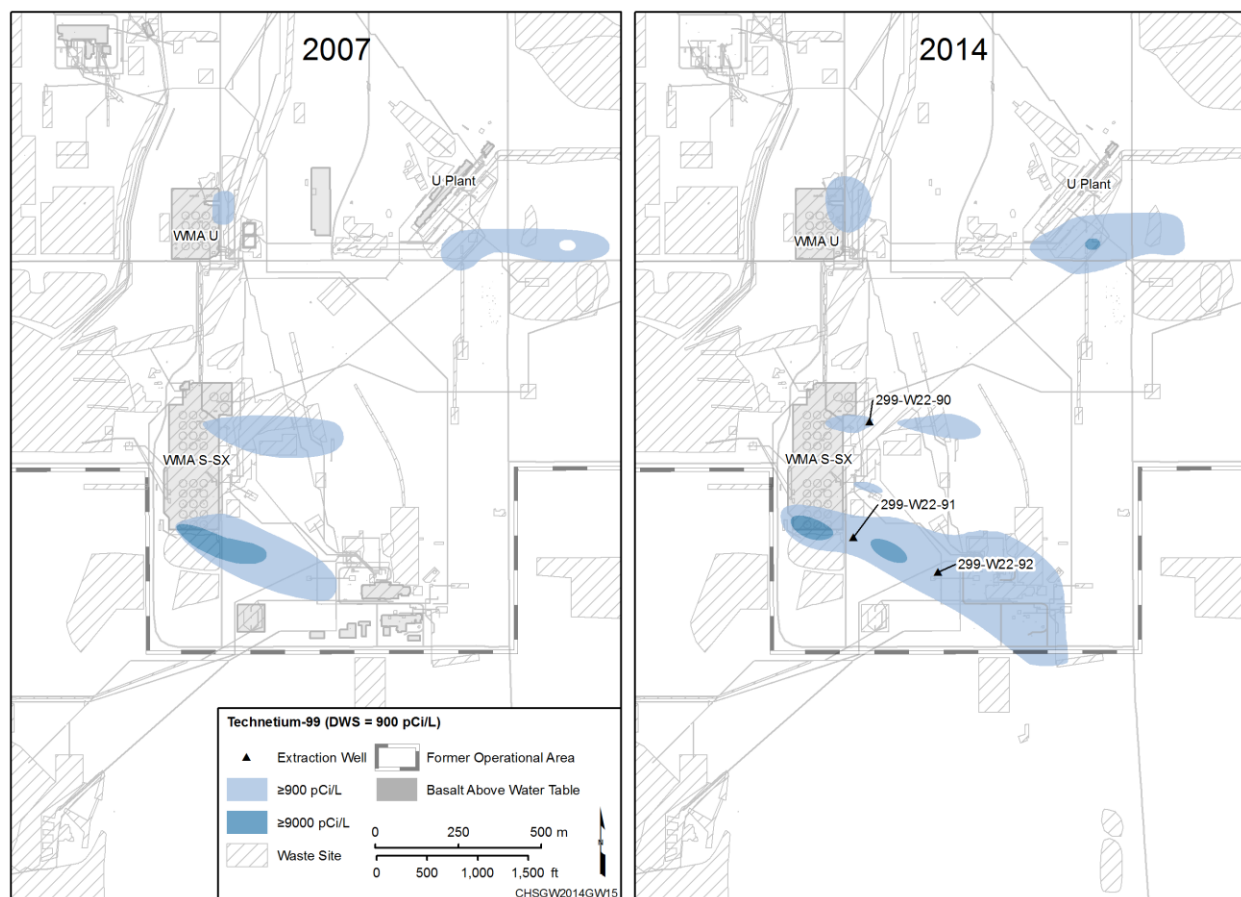


### 8.2.2 200-UP

The southern portion of the 200 West Area and adjacent areas to the east and south comprise 200-UP. Contaminant sources included cribs, ponds, and single-shell tanks. Carbon tetrachloride, technetium-99, uranium, tritium, iodine-129, nitrate, and chromium plumes are present. Carbon tetrachloride in this region originated from sources in 200-ZP. Wells near WMA S-SX monitor the highest technetium-99 concentrations on the Hanford Site, and the plume has grown in recent years (Figure 8.14). An interim action ROD addressing all of the major contaminant plumes within the 200-UP-1 OU was published in 2012. The selected remedy in the ROD consists of a combination of P&T, MNA, hydraulic containment, and institutional controls.

The P&T system at WMA S-SX began operating in July 2012. From 2012 to 2014 the system removed 1.66 Ci of technetium-99, 35,891 pounds (16,280 kilograms) of nitrate, 62 pounds (28.1 kilograms) of chromium, and 551 pounds (250 kilograms) of carbon tetrachloride from groundwater. Another part of groundwater remediation under the interim action ROD is a groundwater extraction system to remediate the uranium and technetium-99 plumes in the U Plant area. The system is currently being designed and will be constructed in 2015.

Figure 8.14. WMA S-SX Technetium-99 Plume in 2007 and 2014



RCRA monitoring in 200-UP includes interim status groundwater quality assessment monitoring at WMA S-SX and WMA U, and interim status indicator parameter evaluation monitoring at the 216-S-10 Pond and Ditch. WMA S-SX has contaminated groundwater with chromium, nitrate, and the non-RCRA



constituent technetium-99. Water levels have declined at WMA S-SX due to groundwater extraction, causing some monitoring wells to go dry sooner than they would have otherwise. One new well was installed in 2014 and four additional replacement wells are planned in 2015. Sources within WMA U have contaminated groundwater with nitrate and chromium. The groundwater beneath this tank farm is within the capture zone of a nearby extraction well. Indicator parameters did not exceed statistical comparison values at the 216-S-10 Pond and Ditch during 2014.

The Environmental Restoration Disposal Facility (ERDF) is a CERCLA disposal facility used for disposal of low-level radioactive mixed waste generated by remedial actions. The results of groundwater monitoring in 2014 continued to indicate that the facility has not impacted groundwater.

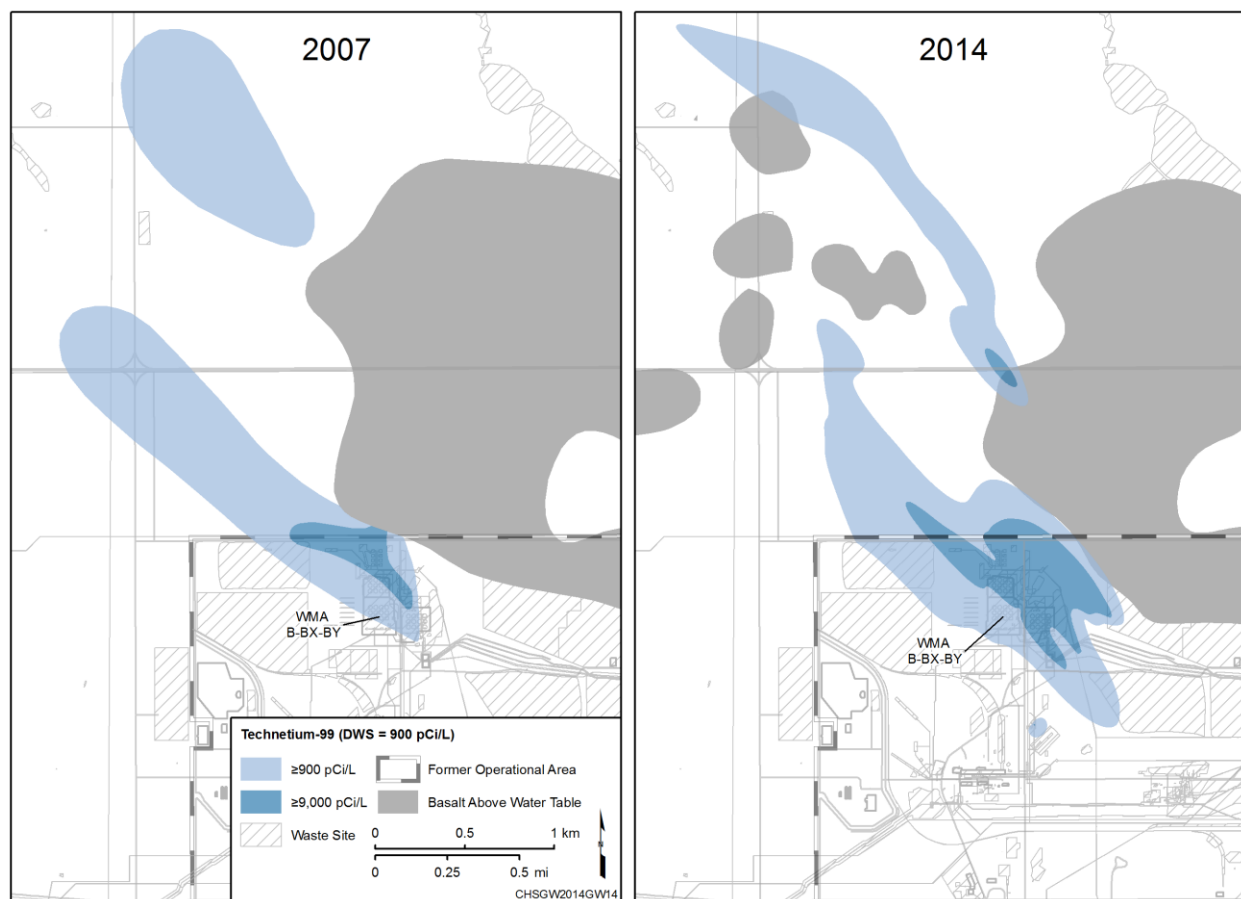
### **8.2.3 200-BP**

The 200-BP groundwater interest area includes the northern 200 East Area and the region to the northwest where mobile contaminants have migrated between Gable Mountain and Gable Butte. Most of the groundwater contamination is concentrated beneath WMA B-BX-BY and adjacent waste sites in the northwestern portion of the 200 East Area. Nitrate, iodine-129, and technetium-99 form the largest contaminant plumes. The high-concentration cores of these plumes have grown in size since 2007 due to continued drainage of contaminated water from the vadose zone into the aquifer (Figure 8.15). Smaller plumes of uranium, cyanide, strontium-90, and tritium also exceed their respective DWSs. Cesium-137 and plutonium-239/240 contamination is limited to one or two wells.

Wells in the northwestern part of 200-BP detect the highest concentrations of uranium in Hanford Site groundwater. Concentrations are even higher in a zone of perched water that lies above the water table. DOE, EPA, and Ecology signed an Action Memorandum in 2014 that directs continuing the extraction of contaminated perched water as a non-time-critical removal action under CERCLA. Approximately 117 pounds (53 kilograms) of uranium were removed from the perched zone through the end of 2014. A draft RI report for the 200-BP-5 OU was prepared in 2014, describing the nature and extent of contamination and identifying contaminants of potential concern to support a future FS. In addition, work began on the FS in late 2014.

Six RCRA sites with groundwater monitoring requirements are located in 200-BP. RCRA groundwater quality assessment monitoring at WMA B-BX-BY and WMA C indicates that the dangerous waste constituent cyanide in groundwater originated in the WMAs. Because of the continued migration of this dangerous waste constituent an additional well was installed at WMA B-BX-BY in 2014. RCRA contamination indicator parameter monitoring continued at the 216-B-63 Trench, LLWMA-1, and LLWMA-2 in 2014. Results continued to show that these units have not impacted groundwater. DOE monitors the LERF under a RCRA final status detection program. Results showed no indication that the site has affected groundwater. A new groundwater monitoring plan for LERF was implemented in 2014.

Figure 8.15. 200-BP Technetium-99 Plume in 2007 and 2014



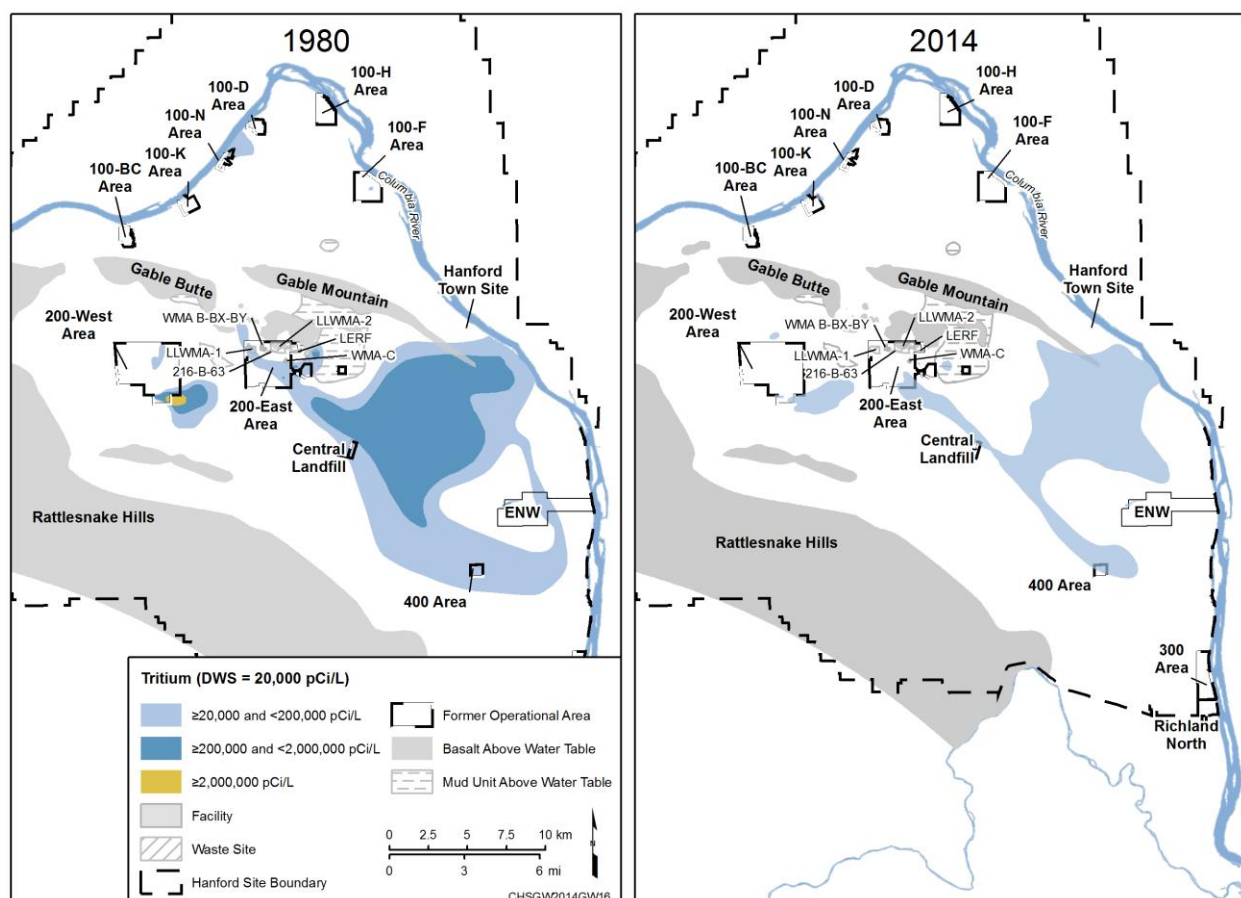
#### 8.2.4 200-PO

The southern portion of the 200 East Area and a large region of the Hanford Site to the east and southeast comprise 200-PO. Disposal of large volumes of liquid waste created regional groundwater plumes of tritium, iodine-129, and nitrate. An RI addendum report for the 200-PO-1 OU is currently being prepared to update the risk assessment based on additional groundwater data collected since the RI was completed in 2008 and 2009. In addition, work began on the FS in late 2014.

The tritium plume had an estimated area of 30.6 square miles (79.2 square kilometers) in 2014, a 5 percent decrease from 2013. The size of the regional tritium plume (Figure 8.16) from 200-PO has decreased from 71 to 31 square miles (185 to 79 square kilometers) since 1980, primarily as a result of radioactive decay and dispersion. Concentrations of tritium are declining as the groundwater plume attenuates naturally as a result of radioactive decay and dispersion. The maximum concentration has declined from over 6 million pCi/L in the 1980s to 510,000 pCi/L in 2014.

The area of the iodine-129 plume above the 1 pCi/L contour has decreased slightly over the past decade, and maximum concentrations have declined as a result of dispersion. Radioactive decay has not decreased the level of iodine-129 contamination noticeably because this isotope has a half-life of 15.7 million years. The nitrate plume covers a large area, with concentrations above background, but mostly below the DWS. Other contaminants in 200-PO include strontium-90, technetium-99, and uranium in smaller areas near their discharge sources (Figure 8.11).

Figure 8.16. Hanford Site Tritium Plumes in 1980 and 2014



In 2014, RCRA assessment monitoring continued at WMA A-AX and interim status indicator parameter programs continued at the 216-A-36B Crib, 216-A-37-1 Crib, 216-A-29 Ditch, 216-B-3 Pond, and NRDWL. One monitoring well with casing corrosion associated with WMA A-AX was decommissioned in 2013. Drilling of a replacement well started in November 2014 and will be completed in early 2015. Monitoring results from the interim status sites provided no indication of releases from these facilities to groundwater.

The IDF is an expandable, double-lined landfill that is regulated under RCRA and the AEA. It is not yet in use, and current groundwater monitoring is directed at obtaining baseline data.

The Solid Waste Landfill is regulated under Washington State solid waste handling regulations. As in previous years, some of the monitoring wells showed higher concentrations of regulated constituents than the statistically calculated background threshold values. Background threshold values exceeded during 2014 included specific conductance, nitrite, sulfate, and total organic carbon.

Three onsite water supply wells provide drinking water and serve as an emergency water supply for the 400 Area, which is in the footprint of 200-PO. Because the 400 Area is in the path of the Hanford Site-wide tritium plume, DOE routinely monitors the wells for tritium.

### 8.3 Confined Aquifers

Although most Hanford Site groundwater contamination is found in the unconfined aquifer, DOE monitors wells in deeper aquifers because of potential downward movement of contamination.

One confined aquifer occurs within sand and gravel at the base of the Ringold Formation. Carbon tetrachloride, nitrate, and technetium-99 have contaminated this unit in a portion of the 200 West Area where the upper confining unit is absent. Newer wells have been installed to monitor and remediate this contamination. The Ringold confined aquifer is the uppermost aquifer in a region east of 200 East (within portions of 200-BP and 200-PO). Iodine-129 and tritium are detected in wells at this location, but the contamination has not migrated farther to the east or southeast.

In the northern Hanford Site, fine-grained sedimentary units, informally called the RUM, confine deeper sediments in the Ringold Formation. In some parts of 100-HR this unit is contaminated with hexavalent chromium at concentrations over 100 µg/L and is being remediated by a P&T system.

Groundwater within basalt fractures and joints, interflow contacts, and sedimentary interbeds make up the upper basalt-confined aquifer system.

### 8.4 Wells

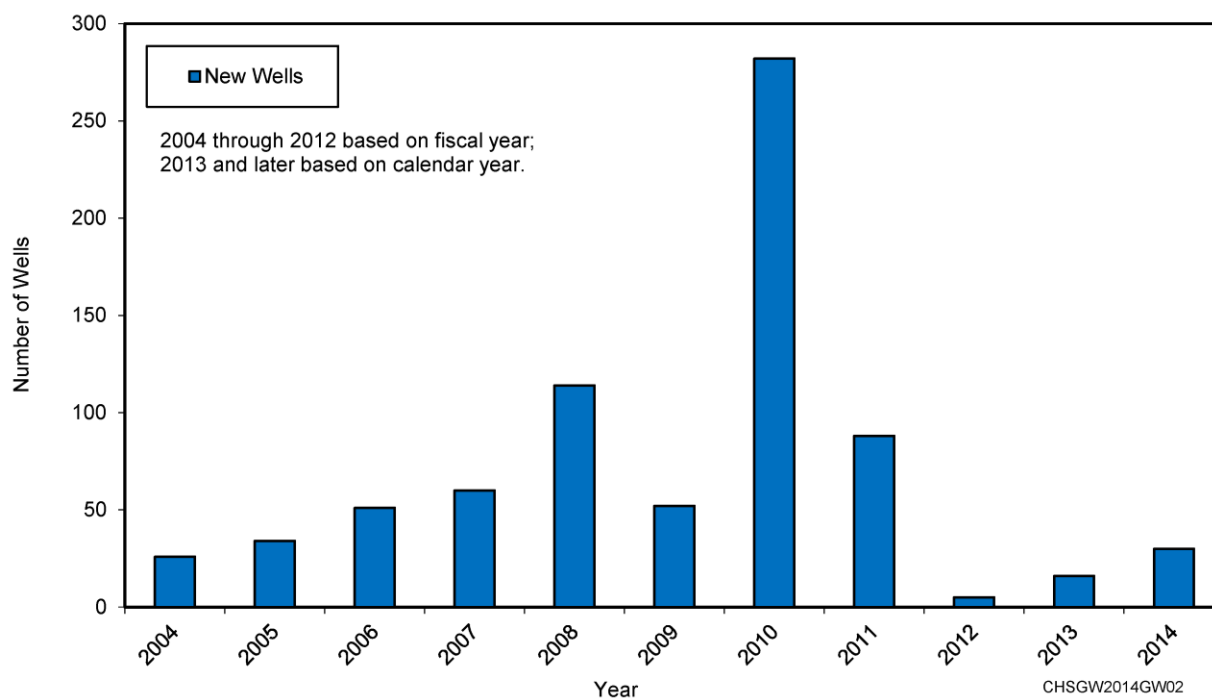
Over the lifetime of the Hanford Site, DOE has installed thousands of wells to monitor and remediate groundwater and provide geologic data. During 2014, DOE installed 30 new wells and 6 new aquifer tubes. Table 8.3 lists the new wells and aquifer tubes installed in 2014 and Figure 8.17 illustrates the number of wells installed during the past 10 years.

DOE identifies wells, boreholes, or other subsurface installations for decommissioning when they are no longer needed. This involves sealing the wells in compliance with Washington State standards for construction and maintenance of wells ([WAC 173-160](#)). Four temporary wells in 100-D Area (199-D5-155, 199-D5-156, 199-D5-157, and 199-D5-158), were decommissioned in 2014.

*Table 8.3. New Wells and Aquifer Tubes Completed in 2014*

Groundwater Interest Area	Wells	Aquifer Tubes
100-BC	8	6
100-HR-D	4	0
100-KR	6	0
200-BP	3	0
200-PO	3	0
200-UP	2	0
200-ZP	4	0
Total	30	6

Figure 8.17. New Wells Installed on the Hanford Site, 2004 to 2014



## 8.5 Additional Information

The monitoring data presented in this chapter—and information on monitoring well locations, construction details, and screened intervals—can be found through the DOE Environmental Dashboard Application at <https://ehs.hanford.gov/eda/> or on the PHOENIX website at <http://phoenix.pnnl.gov>. The data and additional groundwater monitoring details are available in the *Hanford Site Groundwater Monitoring Report for 2014* ([DOE/RL-2015-07](#)).

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## 9.0 Soil Monitoring

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*JW Wilde*

Radiological monitoring of soil is conducted at a variety of locations: on site near Hanford Site facilities and operations, on site away from facilities and operations, and off site at perimeter and distant locations and in nearby communities. Contaminant concentration data are used for the following:

- ⊗ Determine the effectiveness of effluent monitoring and controls within facilities
- ⊗ Assess the adequacy of containment at waste disposal sites
- ⊗ Detect and monitor unusual conditions
- ⊗ Provide information on long-term radionuclide contamination trends in soil at undisturbed locations.

Data obtained from onsite soil samples is used as a qualitative indicator and verification of ambient air sampling results per the WDOH Radioactive Emissions License for the Hanford Site ([FF-01](#)).

Soil samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large amount of data exist that document onsite and offsite levels of manmade radionuclides in Hanford Site soils. These data provide a baseline to which unplanned releases are compared. The Hanford Site Environmental Surveillance Master Sampling Schedule is available online at <http://www.hanford.gov/page.cfm/environmentalsurveillance>.

### 9.1 Monitoring Results

Soil monitoring provides information about long-term contamination trends and baseline environmental radionuclide activities at undisturbed locations both on and off the Hanford Site according to the Hanford Site Environmental Monitoring Plan ([DOE/RL-91-50, Rev. 6A](#)).

### 9.2 Sampling Results

Soil samples are collected near facilities and operations on the Hanford Site to detect potential migration and deposition of facility emissions and evaluate long-term trends in the environmental accumulation of radioactive materials. Soil contamination can occur as the result of direct deposition from facility emissions, resuspension and movement of contaminants from radiologically contaminated surface areas, uptake of contaminants into plants whose roots contact groundwater or below ground waste, or translocation of buried waste by intruding animals.

Soil samples were collected on or adjacent to waste disposal sites and from locations downwind and near or within the boundaries of operating facilities and remedial action sites. The number and locations of soil samples collected in 2014 are summarized in Table 9.1. Only radionuclides with concentrations consistently above analytical detection limits are discussed in this section. Soil samples from offsite locations were last collected in 2008 ([PNNL-18427](#), *Hanford Site Environmental Surveillance Data Report for Calendar Year 2008*).

*Table 9.1. Soil Sample Locations*

Number of Samples Analyzed	Operational Area (discrete samples analyzed)							Composites <sup>a, b</sup>
	ETF	200-West <sup>a</sup>	200-East <sup>a</sup>	300 <sup>a</sup>	400	600 <sup>a</sup>	ERDF	
50	3	9	8	8	1	6	1	14

<sup>a</sup> Number of samples includes one or more replicate samples.

<sup>b</sup> 41 individual soil samples from the 200 and 600 Areas were combined into 14 composite samples using a multi-incremental approach.

Individual soil samples are 2.2 pounds (1.0 kilogram), which represent a parent sample consisting of five plugs of soil; each sample is approximately 1.0 inch (2.5 centimeters) deep and 4 inches (10 centimeters) in diameter. Soil samples are sieved in the field to remove potential sample intrusions such as rocks and plant debris, and then dried in the laboratory prior to analysis to remove residual moisture. Some soil samples were analyzed as single parent samples (discrete codes), while others were composited using the following approach.

A multi-incremental sampling technique is used when collecting samples from a large given area (i.e., a decision unit). Individual samples are processed using a gridded pattern approach and combined with other samples from the decision unit to create a composite sample that represents the decision unit as a whole. This compositing limits the variability of selected environmental contaminant concentrations in a given area and reduces the amount of sampling error due to heterogeneity, while allowing for a reproducible mean concentration for the decision unit.

Soil samples were analyzed for radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides, strontium-90, uranium isotopes, and/or plutonium isotopes). The analytical results from Hanford Site soil samples were compared to concentrations of radionuclides measured in samples collected off site at various sampling locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin counties in 2008. These comparisons were used to differentiate concentrations of Hanford Site-produced contaminants from levels resulting from natural sources and worldwide fallout.

Onsite soil sampling results can be compared to the accessible soil concentrations ([WHC-SD-EN-TI-070](#), *Soil Concentration Limits for Accessible and Inaccessible Areas*) developed specifically for use at the Hanford Site. These concentration values for radionuclides were established to ensure that effective dose equivalents to the public do not exceed the established limits for any reasonable scenario, such as direct exposure, inadvertent ingestion, inhalation, and consumption of foods, including animal products. The accessible soil concentration values are based on a radiation-dose estimate scenario ([WHC-SD-EN-TI-070](#)) in which an individual would have to spend 100 hours per year in direct contact with the contaminated soil. The conservatism inherent in pathway modeling ensures the required degrees of protection are in place. These concentrations apply specifically to the Hanford Site with respect to onsite waste disposal operations, cleanup, and decontamination and decommissioning activities. A partial list of these values is provided in Table 9.2.

**Table 9.2. Accessible Soil Concentration Limits for Selected Radionuclides**  
*pCi/g<sup>a</sup> dry weight*

	<b>Cobalt- 60</b>	<b>Strontium- 90</b>	<b>Cesium- 137</b>	<b>Uranium- 234</b>	<b>Uranium- 235</b>	<b>Uranium- 238</b>	<b>Plutonium- 239/240</b>
Accessible soil <sup>b</sup> concentration limits ( <a href="#">WHC-SD-EN-TI-070</a> )	7.1	2,800	30	630	170	370	190

<sup>a</sup> To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.<sup>b</sup> Hanford Site soil that is not behind security fences.[WHC-SD-EN-TI-070](#), *Soil Concentration Limits for Accessible and Inaccessible Areas*

Some degree of variability is always associated with collecting and analyzing environmental samples; therefore, variations in sample concentrations from year to year are expected. In general, radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2014 were higher than the concentrations in samples collected farther away. The data also showed, as expected, that concentrations of certain radionuclides in 2014 were higher in different operational areas when compared to concentrations measured in distant communities in previous years. Historically, the predominant radionuclides detected were activation and fission products in the 100 Areas, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas.

Cesium-137, strontium-90, plutonium-239/240, and uranium were detected consistently in the 2014 soil samples. Concentrations of these radionuclides were elevated near and within facility boundaries when compared to historical concentrations measured offsite at distant communities. Figure 9.1 shows the average concentrations of selected radionuclides in soil samples collected during 2014 and the preceding 4 years. Some individual levels demonstrate a high degree of variability, although overall trends are stable.

Table 9.3 provides a summary of selected analytical results for near-facility soil samples collected and analyzed. The average and maximum results were reported for the major operational areas, along with comparative data for the preceding 5 years. Complete lists of radionuclide concentrations for all soil samples collected during 2014, as well as sampling location maps, are available upon request.

Results for soil samples collected in 2014 at locations in the 200-East Area, 200-West Area, 300 Area, and 600 Area were comparable to previous years. Soil samples collected in the 300 Area showed concentrations of uranium-234 and uranium-238 that were comparable to historical data, but remained higher than those measured in the 200 Area. The higher uranium levels in the 300 Area were expected because of uranium releases to the environment during past fuel-fabrication operations. Plutonium-239/240 was detected in a number of soil samples in the 200, 300, and 600 Areas. Strontium-90 was detected in the 200 and 600 Areas and were within historical concentration ranges. Cesium-137 was detected consistently at levels comparable to historical levels over the past 5 years.

There were no soil samples collected in the 100 Areas during 2014.

To comply with WDOH Notice of Construction requirements, special soil deposition sampling was implemented during 2014 around the 200 Effluent Treatment Facility and Trench 94 of the 218-E-12B waste site in the 200-East Area. Sample results from both sites showed cesium-137 concentrations comparable to values from other sample areas. Table 9.4 provides a summary of selected analytical results for samples from these sites.

A soil sample is collected annually at ERDF from a predominantly downwind sampling location. The 2014 soil sample showed slightly elevated concentrations of uranium, however, detections were comparable to levels observed in previous years at other near-facility sampling locations on the Hanford Site.

*Figure 9.1. Hanford Site Soil Samples Average Concentrations of Selected Radionuclides (2010 through 2014)*

*As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.*

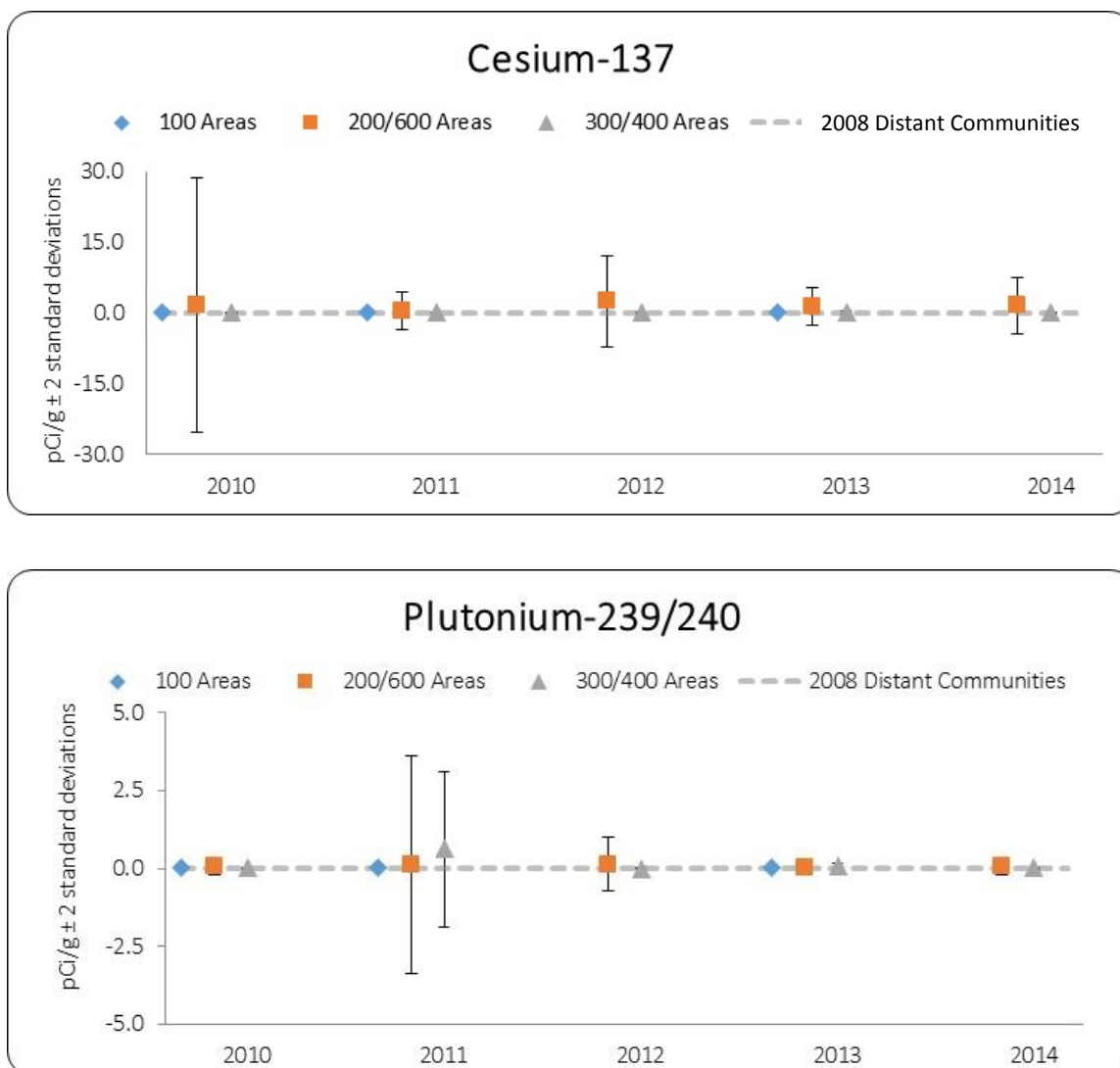
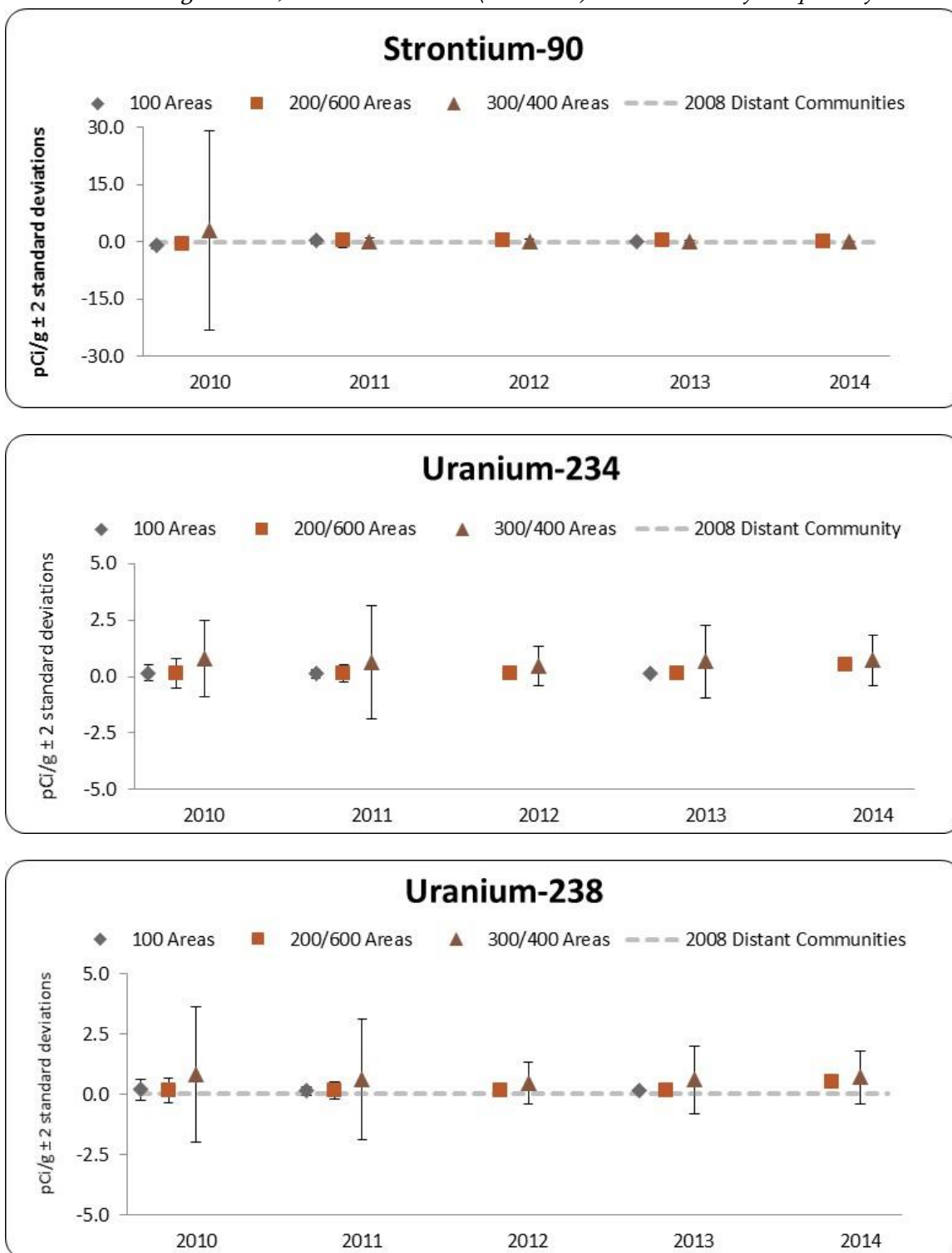


Figure 9.1. Hanford Site Soil Samples Average Concentrations of Selected Radionuclides (Cont.)  
(2010 through 2014)

As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.



**Table 9.3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples**  
(pCi/g dry weight)  
(2014 compared to previous years)

Isotope	Hanford Area	2014				2009 to 2013			
		Number of Samples	Detects	Average <sup>a,)</sup> (pCi/gm)	Maximum <sup>b</sup> (pCi/gm)	Number of Samples	Detects	Average <sup>a</sup> (pCi/gm)	Maximum <sup>b</sup> (pCi/gm)
<b>Cobalt 60</b>	100	0	0	N/A	N/A	41	4	6.5E-03 ± 4.0E-02	9.8E-02 ± 1.9E-02
	200-East	8	0	2.9E-03 ± 2.6E-02	2.9E-02 ± 2.8E-02 <sup>(c)</sup>	59	0	-1.2E-03 ± 9.8E-03	9.1E-03 ± 1.1E-02 <sup>c</sup>
	200-West	11	0	-3.2E-03 ± 1.7E-02	1.5E-02 ± 1.4E-02 <sup>(c)</sup>	102	0	-4.1E-04 ± 9.1E-03	1.3E-02 ± 1.3E-02 <sup>c</sup>
	300	8	0	4.0E-03 ± 2.3E-02	1.7E-02 ± 1.9E-02 <sup>(c)</sup>	64	0	-5.2E-04 ± 7.5E-03	9.7E-03 ± 8.5E-03 <sup>c</sup>
	400	1	0	2.3E-02 <sup>(d)</sup>	2.3E-02 ± 1.9E-02 <sup>(c)</sup>	5	0	-5.7E-04 ± 1.0E-02	5.2E-03 ± 8.6E-03 <sup>c</sup>
	600	6	0	-6.6E-03 ± 1.8E-02	8.3E-03 ± 1.1E-02 <sup>(c)</sup>	64	0	9.8E-05 ± 9.9E-03	1.4E-02 ± 1.3E-02 <sup>c</sup>
<b>Cesium 137</b>	100	0	0	N/A	N/A	41	40	2.0E-01 ± 3.7E-01	7.9E-01 ± 1.4E-01
	200-East	8	8	3.4E+00 ± 9.1E+00	1.4E+01 ± 1.2E+00	59	59	2.5E+00 ± 7.9E+00	2.0E+01 ± 2.7E+00
	200-West	11	10	8.5E-01 ± 1.5E+00	2.8E+00 ± 2.5E-01	102	101	1.2E+00 ± 2.7E+00	6.5E+00 ± 8.6E-01
	300	8	5	5.8E-02 ± 9.7E-02	1.6E-01 ± 5.1E-02	64	46	5.4E-02 ± 1.2E-01	4.1E-01 ± 6.9E-02
	400	1	1	4.0E-02 <sup>(d)</sup>	4.0E-02 ± 2.2E-02	5	5	5.5E-02 ± 7.5E-02	1.3E-01 ± 2.1E-02
	600	6	6	3.9E-01 ± 5.3E-01	7.9E-01 ± 7.1E-02	64	63	8.0E-01 ± 6.6E+00	2.7E+01 ± 3.6E+00
<b>Plutonium 238</b>	100	0	0	N/A	N/A	41	1	1.9E-03 ± 3.3E-02	4.8E-02 ± 2.9E-02
	200-East	8	0	2.7E-03 ± 5.8E-03	8.0E-03 ± 2.9E-03	59	2	5.2E-04 ± 3.4E-02	5.1E-02 ± 4.1E-02 <sup>(c)</sup>
	200-West	11	2	3.8E-03 ± 9.7E-03	1.5E-02 ± 5.4E-03	102	8	5.5E-03 ± 3.5E-02	8.0E-02 ± 4.7E-02
	300	8	0	3.7E-03 ± 2.1E-03	5.3E-03 ± 2.5E-03	64	1	-2.3E-04 ± 2.2E-02	3.2E-02 ± 4.2E-02 <sup>(c)</sup>
	400	1	0	8.0E-03 <sup>(d)</sup>	8.0E-03 ± 2.8E-03	5	0	-6.5E-03 ± 4.3E-02	1.0E-02 ± 1.3E-02 <sup>(c)</sup>
	600	6	0	6.6E-04 ± 4.0E-03	3.0E-03 ± 6.0E-03 <sup>(c)</sup>	64	3	7.4E-03 ± 9.3E-02	3.7E-01 ± 1.1E-01
<b>Plutonium 239/240</b>	100	0	0	N/A	N/A	41	13	1.2E-02 ± 1.6E-02	2.9E-02 ± 2.3E-02 <sup>(c)</sup>
	200-East	8	6	1.3E-02 ± 1.7E-02	2.9E-02 ± 7.0E-03	59	27	7.5E-02 ± 9.0E-01	3.5E+00 ± 7.7E-01
	200-West	11	10	1.3E-01 ± 3.6E-01	6.8E-01 ± 6.4E-02	102	80	1.3E-01 ± 6.1E-01	2.1E+00 ± 5.4E-01
	300	8	3	9.5E-03 ± 3.5E-02	5.4E-02 ± 7.9E-03	64	16	1.1E-02 ± 3.4E-02	9.9E-02 ± 3.1E-02
	400	1	0	2.0E-03 <sup>(d)</sup>	2.0E-03 ± 2.0E-03 <sup>(c)</sup>	5	1	7.3E-03 ± 2.1E-02	2.8E-02 ± 1.6E-02
	600	6	4	1.4E-02 ± 2.9E-02	4.2E-02 ± 9.3E-03	64	31	1.2E-01 ± 1.2E+00	4.9E+00 ± 1.3E+00
<b>Strontium 90</b>	100	0	0	N/A	N/A	41	1	-4.1E-01 ± 1.0E+00	7.3E-01 ± 5.5E-01
	200-East	8	6	2.9E-01 ± 6.3E-01	1.0E+00 ± 2.0E-01	59	16	1.9E-01 ± 4.6E+00	1.7E+01 ± 2.2E+00
	200-West	10	7	1.4E-01 ± 2.9E-01	5.2E-01 ± 1.1E-01	102	26	1.9E-02 ± 2.7E+00	1.1E+01 ± 1.4E+00
	300	8	0	9.7E-03 ± 4.5E-02	4.5E-02 ± 3.1E-02 <sup>(c)</sup>	64	4	6.7E-01 ± 1.4E+01	5.5E+01 ± 7.1E+00
	400	1	0	-2.1E-02 <sup>(d)</sup>	-2.1E-02 ± 2.4E-02 <sup>(c)</sup>	5	0	-2.5E-01 ± 1.3E+00	6.5E-01 ± 4.6E-01 <sup>(c)</sup>
	600	6	3	5.9E-02 ± 9.0E-02	1.4E-01 ± 4.0E-02	64	12	-1.5E-01 ± 1.1E+00	1.2E+00 ± 4.6E-01



**Table 9.3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples**  
(pCi/g dry weight)  
(2014 compared to previous years)

Isotope	Hanford Area	2014				2009 to 2013			
		Number of Samples	Detects	Average <sup>a</sup> ) (pCi/gm)	Maximum <sup>b</sup> (pCi/gm)	Number of Samples	Detects	Average <sup>a</sup> (pCi/gm)	Maximum <sup>b</sup> (pCi/gm)
Uranium 234	100	0	0	N/A	N/A	41	41	1.5E-01 ± 1.2E-01	3.4E-01 ± 1.1E-01
	200-East	8	8	5.9E-01 ± 3.8E-01	1.1E+00 ± 1.9E-01	59	58	1.4E-01 ± 8.5E-02	2.5E-01 ± 8.0E-02
	200-West	11	11	5.3E-01 ± 1.7E-01	7.5E-01 ± 1.2E-01	102	97	1.6E-01 ± 1.2E-01	4.3E-01 ± 1.2E-01
	300	8	8	5.1E-02 ± 7.5E-02	1.4E-01 ± 4.6E-02	64	49	4.6E-02 ± 1.0E-01	2.7E-01 ± 8.6E-02
	400	1	1	4.1E-01 <sup>(d)</sup>	4.1E-01 ± 8.3E-02	5	5	2.7E-01 ± 4.8E-01	7.4E-01 ± 2.1E-01
	600	6	6	5.2E-01 ± 1.4E-01	6.0E-01 ± 9.6E-02	64	63	1.6E-01 ± 1.5E-01	6.4E-01 ± 1.8E-01
Uranium 235	100	0	0	N/A	N/A	41	20	1.2E-02 ± 1.5E-02	3.4E-02 ± 1.9E-02
	200-East	8	7	3.7E-02 ± 1.9E-02	4.8E-02 ± 3.6E-02	59	30	1.1E-02 ± 1.4E-02	3.0E-02 ± 1.8E-02
	200-West	11	8	3.5E-02 ± 3.3E-02	7.3E-02 ± 4.2E-02	95	55	1.5E-02 ± 2.1E-02	5.1E-02 ± 2.7E-02
	300	8	8	5.1E-02 ± 7.5E-02	1.4E-01 ± 4.6E-02	64	49	4.6E-02 ± 1.0E-01	2.7E-01 ± 8.6E-02
	400	1	1	2.7E-02 <sup>(d)</sup>	2.7E-02 ± 2.1E-02	5	4	2.2E-02 ± 3.6E-02	5.8E-02 ± 2.7E-02
	600	6	2	3.1E-02 ± 2.3E-02	4.6E-02 ± 2.9E-02	54	26	1.3E-02 ± 1.7E-02	6.1E-02 ± 2.7E-02
Uranium 238	100	0	0	N/A	N/A	41	41	1.5E-01 ± 1.2E-01	4.2E-01 ± 1.2E-01
	200-East	8	8	5.8E-01 ± 4.2E-01	1.1E+00 ± 1.9E-01	59	58	1.5E-01 ± 7.9E-02	2.4E-01 ± 7.7E-02
	200-West	11	11	5.3E-01 ± 1.2E-01	6.6E-01 ± 1.0E-01	102	97	1.6E-01 ± 1.3E-01	4.5E-01 ± 1.3E-01
	300	8	3	9.5E-03 ± 3.5E-02	5.4E-02 ± 7.9E-03	64	16	1.1E-02 ± 3.4E-02	9.9E-02 ± 3.1E-02
	400	1	0	2.0E-03 <sup>(d)</sup>	2.0E-03 ± 2.0E-03 <sup>(c)</sup>	5	1	7.3E-03 ± 2.1E-02	2.8E-02 ± 1.6E-02
	600	6	4	1.4E-02 ± 2.9E-02	4.2E-02 ± 9.3E-03	64	31	1.2E-01 ± 1.2E+00	4.9E+00 ± 1.3E+00

<sup>a</sup> Average ± two standard deviations

<sup>b</sup> Maximum ± analytical uncertainty

<sup>c</sup> Maximum value reported is a non-detect.

<sup>d</sup> Standard deviation cannot be calculated for one sample.

**Table 9.4. Radionuclide Concentrations in Other Contractor Project Soil Samples**  
*pCi/g<sup>(a)</sup> dry weight<sup>(b)</sup>*

Project/Facility	Location <sup>(c)</sup>	Date	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-238	Plutonium-239/240
Trench 94	D457	11/19/2014	2.90E-03±1.30E-02	1.40E-00±2.60E-01	7.80E-00±6.30E-01	5.50E-01±9.20E-02	5.30E-01±9.00E-02	3.60E-03±3.20E-03
	D458	11/19/2014	1.30E-03±1.20E-02	1.40E-01±4.10E-02	7.80E-00±6.30E-01	5.30E-01±9.00E-02	4.90E-01±8.50E-02	3.90E-03±7.00E-03
	D459	11/19/2014	-5.10E-03±1.10E-02	1.90E-02±2.90E-02	1.90E-01±2.60E-02	6.10E-01±9.60E-02	6.10E-01±9.50E-02	3.00E-03±3.10E-03
Effluent Treatment Facility	D458	11/19/2014	1.30E-03±1.20E-02	1.40E-01±4.10E-02	7.80E-00±6.30E-01	5.30E-01±9.00E-02	4.90E-01±8.50E-02	3.90E-03±7.00E-03
	D460	11/19/2014	-3.60E-03±1.20E-02	3.40E-02±2.90E-02	8.80E-02±1.70E-02	4.50E-01±9.20E-02	4.40E-01±8.40E-02	1.70E-05±1.70E-04
	D461	11/19/2014	3.80E-03±1.40E-02	5.00E-01±1.10E-01	3.70E-00±3.00E-01	6.00E-01±9.60E-02	5.70E-01±9.20E-02	5.60E-03±3.20E-03
ERDF	D146	4/2/2014	3.90E-03±1.50E-02	N/A	1.2E-02±1.40E-02	5.00E-01±1.60E-01	5.1E-01±1.70E-01	-2.3E-03±1.40E-02
<b>Accessible soil concentration<sup>(d)</sup></b>			<b>7.1</b>	<b>2,800</b>	<b>30</b>	<b>630</b>	<b>370</b>	<b>190</b>

<sup>a</sup> 1 pCi = 0.037 Bq.

<sup>b</sup> ± total analytical uncertainty.

<sup>c</sup> Sampling location code.

<sup>d</sup> Hanford soils that are not behind security fences.

### 9.3 Radiological Contamination Investigations

Investigations for radioactive contamination in soil were conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. All samples collected during investigations were field surveyed for alpha- and beta-gamma radiation. Generally, the predominant radionuclides in samples from the 100 Area and 200 Areas were strontium-90, cesium-137, and plutonium-239/240. Uranium-234, uranium-235, and uranium-238 were routinely found in 300 Area samples.

There were 22 instances of radiological contamination in soil discovered during 2014 site investigations. Of the 22, 9 were cleaned up and disposed of on site in licensed burial grounds, and the other 13 were posted as contamination areas. None of the soil samples were submitted for radioisotopic analysis. The number of soil investigation contamination incidents in 2014 were generally within historical values. Table 9.5 summarizes the number and general locations of soil contamination incidents investigated during 2014, and provides the number of contamination incidents investigated from 2000 through 2014.

*Table 9.5. Soil Contamination Incidents Investigated*

Location	2014 Incidents	Year	Incidents
100 Area	0	2000	25
200-East Area		2001	20
Tank farms	3	2002	22
Burial grounds	1	2003	30
Cribs, ponds, and ditches	0	2004	19
Fence lines	1	2005	20
Roads and railroads	0	2006	25
Unplanned release sites	7	2007	17
Underground pipelines	0	2008	16
LERF/ETF	1	2009	28
Miscellaneous	1	2010	22
200-West Area		2011	10
Tank farms	4	2012	10
Burial grounds	0	2013	21
Cribs, ponds, and ditches	1	2014	22
Fence lines	0		
Roads and railroads	0		
Unplanned release sites	1		
Underground pipelines	0		
Miscellaneous	1		
Cross-site transfer line	0		
200-BC cribs and trenches	0		
200-North Area	0		
300 Area	0		
400 Area	0		
600 Area	1		
<b>Total</b>	<b>22</b>		

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## 10.0 Biota Monitoring

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### 10.1 Agricultural Monitoring

*ME Hoefer*

Food and farm products (cherries, leafy vegetables, milk, potatoes, and tomatoes) were collected in 2014 at locations near the Hanford Site (Figure 10.1). These products are used to determine pathway-specific exposure assumptions by way of annual dose calculations based on a 1 millirem/year (10 microsieverts/year) threshold and ingestion pathways for annual intake, assuming 100 percent of each food originated in the affected area. Samples analyzed to determine radiological contaminant concentrations were obtained from the following locations:

- ⊗ Generally downwind (east and southeast) of the Hanford Site where airborne emissions or contaminated dust from the site potentially would be deposited
- ⊗ Generally upwind of and distant from the Hanford Site to provide information about reference (background) contaminant levels
- ⊗ Farms irrigated with water taken from the Columbia River downstream of the Hanford Site.

Results of sample analyses are used to assess the amounts of Hanford Site-origin contaminants in food and farm products by comparing:

- ⊗ Analytical results obtained from similar samples collected from the same regions over long periods of time
- ⊗ Analytical results from samples collected at downwind locations to results from samples obtained from generally upwind or distant locations
- ⊗ Analytical results from samples collected in areas irrigated with water withdrawn from the Columbia River downstream of the Hanford Site to analytical results from samples obtained from locations irrigated with water from other regional sources.

Radionuclide concentrations in most food and farm product samples in 2014 were below the analytical laboratory detection levels; however, some potential Hanford Site-produced contaminants (e.g., tritium) were found at low levels in some samples. These findings are presented in the following sections.

Data for potassium-40 and beryllium-7 is included to show the natural radioactive elements that exist in food products relative to concentrations of potential Hanford Site-produced contaminants. Radiological doses associated with potential Hanford Site-produced contaminants are discussed in Section 4.0.

Where possible, the measured concentrations are compared to the applicable unusual concentration reporting levels. Unusual concentration reporting levels have been established based on environmental concentrations that would result in a 1-millirem (10-microsievert) dose per year ([DOE/RL-91-50, Rev. 6A](#)).

Agricultural products sampled in 2014 are listed in Table 10.1 and described in the following sections.

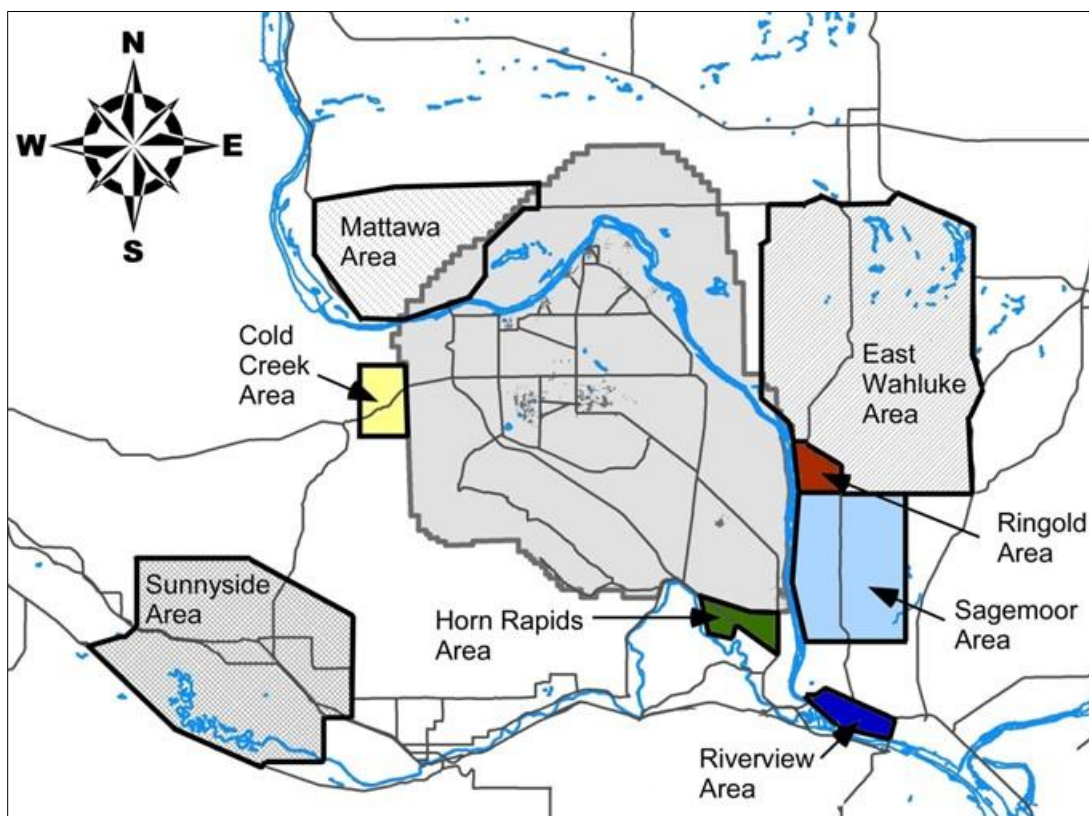
Figure 10.1. Agricultural Monitoring Locations<sup>a</sup><sup>a</sup>Not all agricultural monitoring locations are sampled each year.

Table 10.1. Agricultural Monitoring Locations (2014)

Product	Sampling Locations	Analytes
Cherries	East Wahluke, Riverview, and Sunnyside	Gamma, Strontium-90
Leafy Vegetables	Riverview, Sagemoor, and Sunnyside	Gamma, Strontium-90
Milk	East Wahluke, Sagemoor, and Sunnyside	Gamma, Strontium-90, Tritium
Potatoes	East Wahluke, Riverview, and Sunnyside	Gamma, Strontium-90
Tomatoes	Riverview and Sunnyside	Gamma, Strontium-90, Tritium

### 10.1.1 Milk

Milk samples were obtained quarterly in 2014 from several dairies in the East Wahluke area, Sagemoor area, and one dairy in the Sunnyside sampling area. The Sagemoor and East Wahluke sampling areas are located near the Hanford Site perimeter and could potentially be affected by airborne contaminants from the site. The Sunnyside area is a reference location generally upwind of the Hanford Site. If milk was obtained from more than one dairy within a sampling area, the milk samples were combined, and the composite sample was analyzed. All samples were analyzed for gamma-emitting radionuclides, tritium, and strontium-90. Milk sampling was conducted because Hanford Site-produced radionuclides have the potential to move through the air-pasture-cow-milk or water-pasture-cow-milk food chains to humans. In recent years, levels of Hanford Site-produced radiological contaminants in milk samples have



diminished in conjunction with facility shutdowns and remedial efforts. Concentrations in samples obtained from dairies downwind of the Hanford Site are now similar to levels measured in samples obtained from the dairies generally upwind of the Hanford Site.

**Tritium.** Tritium was detected in all but one milk sample collected in 2014, which was collected in the Sunnyside area. Overall concentrations ranged from a maximum of 34 pCi/L (1.3 Bq/L) in a Sagemoor-area sample to 6 pCi/L (0.74 Bq/L) in a Sunnyside-area sample. Annual average concentrations for the three sampling areas were 23 pCi/L (0.85 Bq/L). Specific location average was 29 pCi/L (1.1 Bq/L) for Sagemoor (n = 5); 20 pCi/L (0.72 Bq/L) for East Wahluke (n = 4); and 20 pCi/L (0.74 Bq/L) for Sunnyside (n = 4). Maximum and average concentrations were less than those historically measured over the last 5 years at these locations.

**Strontium-90.** No detectable concentrations were found in 2014 milk samples.

**Cesium-137.** No synthetic gamma emitters were detected in milk samples collected and analyzed in 2014.

**Potassium-40.** Naturally occurring potassium-40 was detected in all milk samples collected in 2014. Concentrations ranged from a maximum of 1,550 pCi/L (57 Bq/L) in an East Wahluke-area sample to a minimum of 1,310 pCi/L (48 Bq/L) in a Sunnyside sample. The Sagemoor area had a maximum of 1,490 pCi/L (55 Bq/L), and the overall average was 1,426 pCi/L (53 Bq/L) for all results.

### 10.1.2 Fruit and Vegetables

Leafy vegetable (e.g., lettuce), potato, tomato, and cherry samples were collected from upwind and downwind sampling areas during the 2014 growing season (Figure 10.1). All samples were analyzed for gamma-emitting radionuclides and strontium-90. Tomato samples also were monitored for tritium (Table 10.1). All fruit and vegetable concentrations of cesium-137, cobalt-60, strontium-90, and tritium were reported as non-detects and were well within historical five-year range.

All leafy vegetable, potato, tomato, and cherry samples had detectable concentration levels of naturally occurring potassium-40 and beryllium-7.

## 10.2 Animal Monitoring

*JW Wilde*

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants included smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), mule deer (*Odocoileus hemionus*), Rock Mountain elk (*Cervus elaphus*) and California quail (*Callipepla californica*). Monitoring fish and wildlife for uptake and exposure to Hanford Site operations-produced contaminants ensures that consumption of fish and wildlife obtained from Hanford Site environs does not pose a threat to human health and provides long-term contamination trends. These species were selected and monitored because they provide a potential pathway for offsite human consumption. Figure 10.2 shows the locations on and around the Hanford Site where fish and wildlife were collected in 2014. Samples of fish and wildlife were analyzed for selected (suspected or known to be present at the Hanford Site) radionuclides and metals (Table 10.2). In addition, samples were collected from locations distant from the Hanford Site to obtain reference (background) contaminant measurements. All fish and wildlife samples were monitored for strontium-90 contamination and analyzed by gamma spectrometry to detect a number of gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples.

Most fish and wildlife samples are collected on and around the Hanford Site and analyzed for human-pathway exposure every 2 to 3 years, with samples obtained at locations determined not to be affected by Hanford Site effluents and emissions approximately at least every 5 years.

Strontium-90 is present in Hanford Site environments because of past Hanford Site operations and waste disposal practices. Contaminated groundwater entering the Columbia River through shoreline springs in the 100-N and 100-H Areas, is the primary source of measurable Hanford Site-produced strontium-90 in the Columbia River. Strontium-90 is chemically similar to calcium; consequently, it accumulates in hard tissues rich in calcium such as bones, antlers, and eggshells. Strontium-90 has a biological half-life in hard tissue from 14 to 600 days

([PNL-9394](#), *Ecotoxicity Literature Review of Selected Hanford Site Contaminants*). Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90; however, since strontium-90 does not accumulate in the edible portions of fish and wildlife, it generally does not contribute much to the human dose ([NCRP 1991](#)).

Figure 10.2. Animal Monitoring Locations

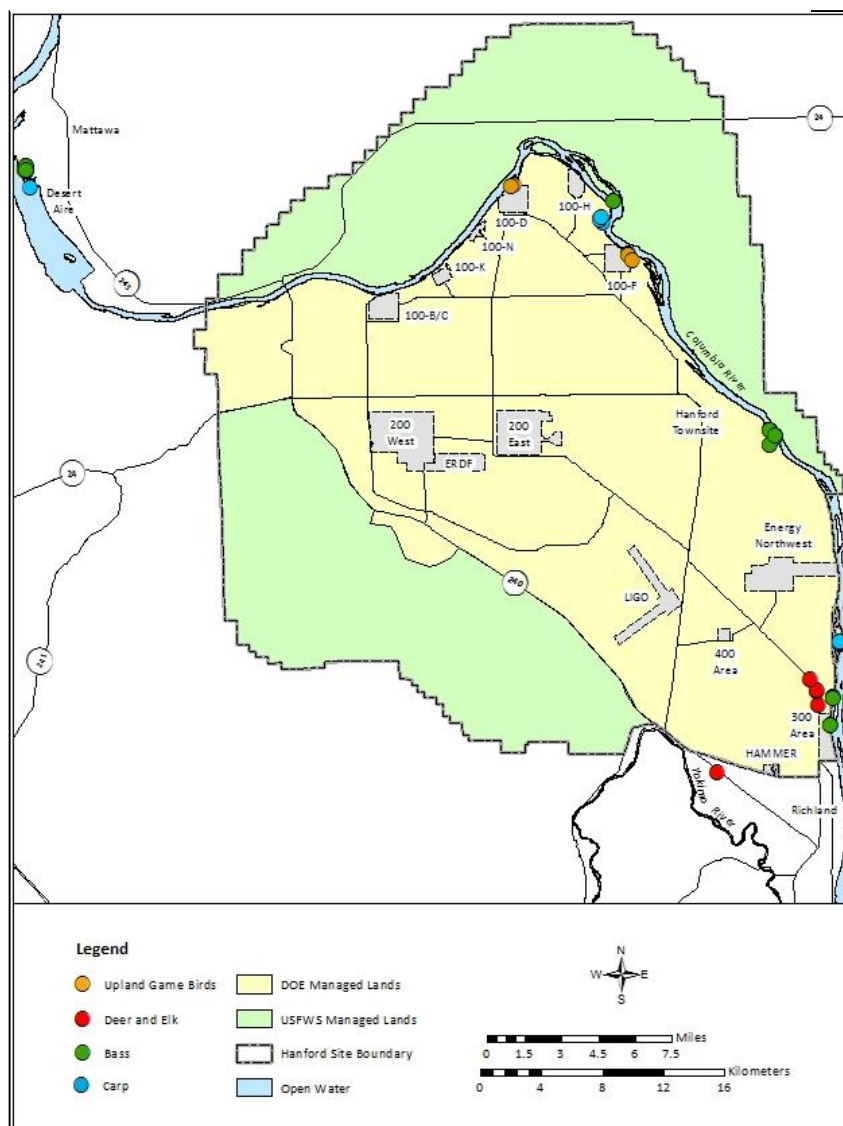


Table 10.2. Animal Monitoring Analysis

Biota	Offsite		Gamma	Strontium-90	Trace Metals
	Locations	Onsite Locations			
Fish (smallmouth bass)	1	3	18	18	4
Fish (common carp)	1	2	10	20	9
Mammals (deer/elk)	1	1	14	7	6
Game birds (California quail)	1	2	9	9	0

Cesium-137 is present in Hanford Site environments because of past Hanford Site operations, waste disposal practices, and from historical worldwide fallout resulting from nuclear weapons testing. Cesium-137 is particularly important to the human food chain because cesium-137 is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Cesium-137 is an indicator of recent exposure to radioactive materials because cesium-137 has a relatively short biological half-life (less than 200 days in muscle and less than 20 days in the gastrointestinal tract [[PNL-9394](#)]).

Gamma spectrometry results for most radionuclides generally are too low to measure, or the concentrations measured are considered artifacts of low background counts. Low background counts occur at random intervals during sample counting and can produce occasional spurious false-positive results. For many radionuclides, concentrations were below analytical laboratory detection levels.

A number of trace metals associated with Hanford Site operations have a potential to accumulate in certain fish and wildlife tissues. These metals are contaminants of potential concern (e.g., copper, lead, and mercury), particularly along the Hanford Site Columbia River shoreline where contaminated groundwater flows into the river. Hanford Site historical operations have resulted in the production of both radiological and non-radiological wastes, including trace-metal emissions in a variety of forms. Liquid and solid wastes that were placed in disposal sites (trenches, cribs, ditches, ponds, and underground storage tanks), and fly ash (produced from burning coal in coal-fired steam/power plants associated with some Hanford Site reactors) released to the atmosphere. The fly ash contains trace metals and natural radionuclides that may have deposited on soil surfaces around the 100 Area reactors.

### **10.2.1 Smallmouth Bass**

Fishing is a popular activity along the Hanford Reach of the Columbia River. Fish, such as the smallmouth bass, are sometimes harvested for food and could potentially contribute to human exposure. Smallmouth bass are a predatory fish that feed on invertebrates and smaller fish along the Hanford Reach and, therefore, may be exposed to trace metals and persistent radionuclides in the Columbia River environment through food sources.

Twenty-seven smallmouth bass were collected in 2014 from three locations in the Hanford Reach and a reference location: Ten fish were collected from the Hanford Townsite to Hanford Slough area (three fish were sent to WDOH for their oversight analysis), four from the areas around the 300 Area, and five from the 100 Areas. Eight reference samples were obtained in 2014 in the pool between Wanapum and Priest Rapids dams. Fillets and the eviscerated remains (carcasses) of the smallmouth bass were analyzed for a variety of radiological contaminants, and five samples (including a duplicate) were analyzed for metals, isotopic uranium, and isotopic plutonium.

**Cesium-137.** Manmade gamma-emitting radionuclides, including cesium-137, were not detected in 2014 in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

**Strontium-90.** Strontium-90 was not detected in smallmouth bass samples collected in 2014 from the reference area or Hanford Reach locations. These results are consistent with those reported throughout the past 10 years for smallmouth bass collected from the reference area and Hanford Site sampling locations.

**Trace Metals.** Five bass samples were analyzed for 17 different trace metal concentrations.

Aluminum, antimony, chromium, copper, manganese, mercury, nickel, selenium, and zinc were detected above the analytical detection limit (Table 10.3).

Surveillance data sets for trace-metal concentrations in fish, both on and near the Hanford Site, are relatively small, and the results are variable. At this time, no established state or federal adverse-effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue.

Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about the effects of this contribution are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment.

*Table 10.3. Smallmouth Bass Metals Analyses*

Isotope	Samples	Detects	Isotope	Samples	Detects
Aluminum	5	3	Manganese	5	1
Antimony	5	1	Mercury	5	3
Arsenic	5	0	Nickel	5	1
Beryllium	5	0	Selenium	5	4
Cadmium	5	0	Silver	5	0
Chromium	5	1	Thallium	5	0
Copper	5	2	Thorium	5	0
Lead	5	0	Uranium	5	0
			Zinc	5	5

### 10.2.2 Common Carp

Fishing is a popular activity along the Hanford Reach of the Columbia River. Fish, such as the common carp, are sometimes harvested for food and could potentially contribute to human exposure.

Common carp are an omnivorous fish that feeds on diet of plants, insects, crustaceans, crawfish and benthic worms on the bottom of the Columbia River along the Hanford Reach and, therefore, may be exposed to trace metals and persistent radionuclides in the Columbia River environment through food sources. Carp is a common food stuff of many cultures, therefore included in the sampling rotation.

Fifteen common carp were collected in 2014 from two locations in the Hanford Reach and a reference location (six fish were sent to WDOH for oversight analysis): There were five fish collected from the region known as the Hanford Slough and five fish from the waters around the 300 Area. Five reference samples were obtained in 2014 in the pool between Wanapum and Priest Rapids dams. Fillets and the eviscerated remains (carcasses) of the common carp were analyzed for a variety of radiological contaminants, metals, isotopic uranium and isotopic plutonium.

**Cesium-137.** Manmade gamma-emitting radionuclides, including cesium-137, were not found in 2014 in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

**Strontium-90.** Strontium-90 was detected in 1 of 10 common carp samples in 2014. The single sample was from the 300 Area at a value of 0.0085 pCi/g (0.00031 Bq/g).

**Uranium.** Uranium isotopic analysis was performed on 10 carp samples in 2014. Uranium-234 was detected in all 10 samples. Uranium-235 was detected in 4 of the 10 samples. Uranium-238 was detected in all 10 samples for 2014.

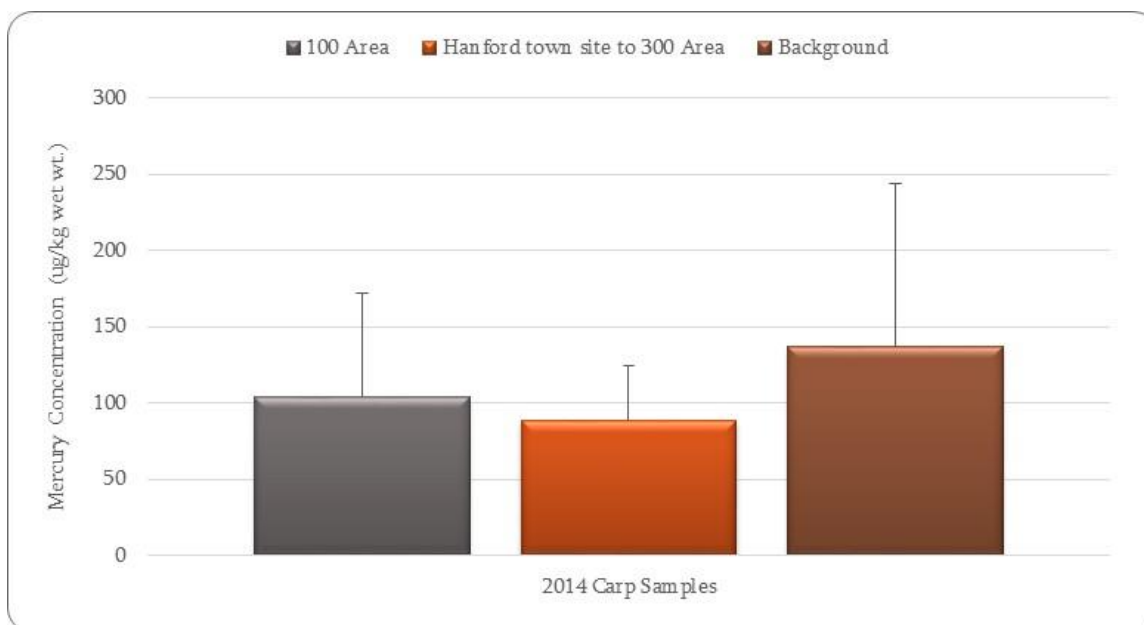
**Trace Metals.** Ten (including a duplicate) carp samples were analyzed for 17 different trace metal concentrations. Antimony, chromium, copper, manganese, mercury, nickel, selenium, uranium, and zinc were detected above the analytical detection limit (Table 10.4). Foraging methods of the common carp on invertebrates, insects and plants in the sediment of the river where these metals can concentrate increase the potential for bioaccumulation in sampled tissues. Figure 10.3 shows that in 2014 the mercury levels in carp were higher in the reference areas than within the 100 and 300 Areas.

*Table 10.4. Common Carp Metals Analyses*

Isotope	Samples	Detects	Isotope	Samples	Detects
Aluminum	10	0	Manganese	10	2
Antimony	10	1	Mercury	10	10
Arsenic	10	0	Nickel	10	2
Beryllium	10	0	Selenium	10	8
Cadmium	10	0	Silver	10	0
Chromium	10	1	Thallium	10	0
Copper	10	9	Thorium	10	0
Lead	10	0	Uranium	10	1
			Zinc	10	10

Surveillance data sets for trace-metal concentrations in fish, both on and near the Hanford Site, are relatively small and the results are variable. At this time, no established state or federal adverse-effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue.

Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about the effects of this contribution are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment.

*Figure 10.3. Carp Mercury Concentrations Compared in the 100, 300, and Reference Areas*

### 10.2.3 Deer and Elk

Deer and elk can be exposed to metals and persistent radionuclides when they forage on plants whose roots have access to contaminated groundwater or soil, drink contaminated water, or incidentally ingest contaminated soil. Deer and elk hunting is not allowed above the high-water mark on the Benton County side of the Columbia River (at the Hanford Site), but the river is not a barrier to large mammal movements. In 2014, the Hanford Site Environmental Surveillance Program collected deer and elk by road strikes, rather than hunting site animals. Deer and elk have been captured and tagged at the Hanford Site that were legally killed by hunters on the Hanford Reach shoreline below the high-water mark and across the Columbia River in Franklin County. Harvesting deer for food could potentially contribute to human exposure to contaminants.

A total of four deer and one elk were collected from vehicle collisions with animals. All samples were collected when the location led investigators to believe the herd could contact Hanford Environs. Radionuclide levels in the five animals collected on the Hanford Site in 2014 were compared to levels found in one elk collected by the WDFW in western Washington. The results from deer collected in 2014 were compared to samples collected in previous years from background locations distant from the Hanford Site and to results reported for deer and elk collected from the Hanford Site over the last 15 years.

**Cesium-137.** Cesium-137 was not detected in any of the seven muscle tissue samples collected as a Hanford sample or a reference sample. Cesium-137 was not detected in any of the seven liver samples collected as a Hanford sample or a reference sample. These results are consistent with a decline in cesium-137 levels in wildlife examined from the preceding 10 years.

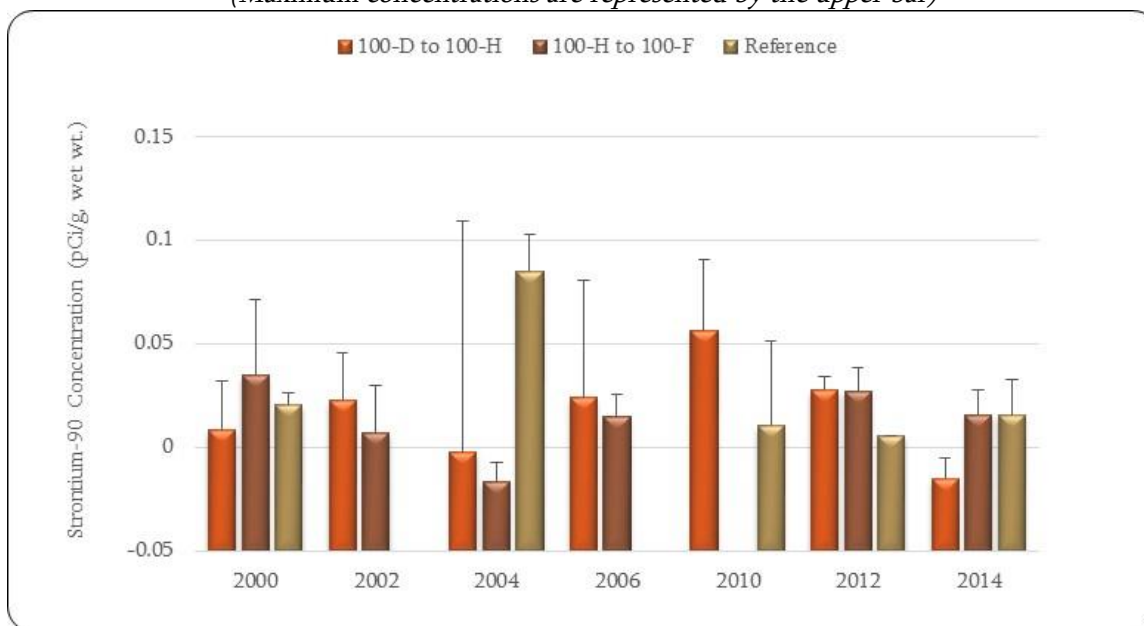
**Strontium-90.** Strontium-90 was detected in all seven bone samples analyzed including the reference sample from western Washington. Concentrations of strontium-90 detected in deer bone samples collected ranged from 0.0758 pCi/g (0.0028 Bq/g) wet weight to 0.19 pCi/g (0.007 Bq/g) wet weight. Strontium-90 concentrations measured in bone samples from the reference location were 229 pCi/g



(0.0085 Bq/g) wet weight, the highest strontium value of samples measured in 2014 (both on and offsite) (Figure 10.4).

**Trace Metals.** Trace metals were analyzed in mule deer and elk liver samples collected from Hanford Site samples and the reference location. Thirteen metals (aluminum, antimony, arsenic, cadmium, copper, chromium, copper, lead, manganese, selenium, thallium, thorium, and zinc) were found above analytical detection limits in 2014.

**Figure 10.4. Mule Deer and Elk Bone Strontium-90 Concentrations**  
(Maximum concentrations are represented by the upper bar)



#### 10.2.4 Upland Game Birds

California quail are one of the most prevalent upland game birds found at the Hanford Site. Most quail that reside on site are found along the Columbia River where trees and shrubs provide shelter. Quail forage for seeds, other plant parts, and grit in grassy and weedy places not far from cover. Ordinarily, quail do not travel far from where they hatch; as such, individual birds on the Hanford Site may spend their entire lives in the 100 Area near one of the retired reactors. Quail can be exposed to persistent radionuclides when they forage on materials from plants that have roots in contact with contaminated groundwater or soil, drink contaminated water, or ingest contaminated grit. Two California quail were collected from the Hanford Site from the region between the 100-D and 100-H Areas and four in the region between 100-H and 100-F Areas in 2014. Five additional quail were collected from a reference location near Prosser in Benton County. One quail from the 100-H to 100-F Areas and one from the reference location were sent to the WDOH oversight program for analysis. All quail were monitored for cesium-137 in muscle and strontium-90 in bone. Radionuclide levels found in muscle and bone samples analyzed during 2014 were compared to levels measured in upland game bird samples collected on the Hanford Site during the last 10 years and samples collected from reference locations.

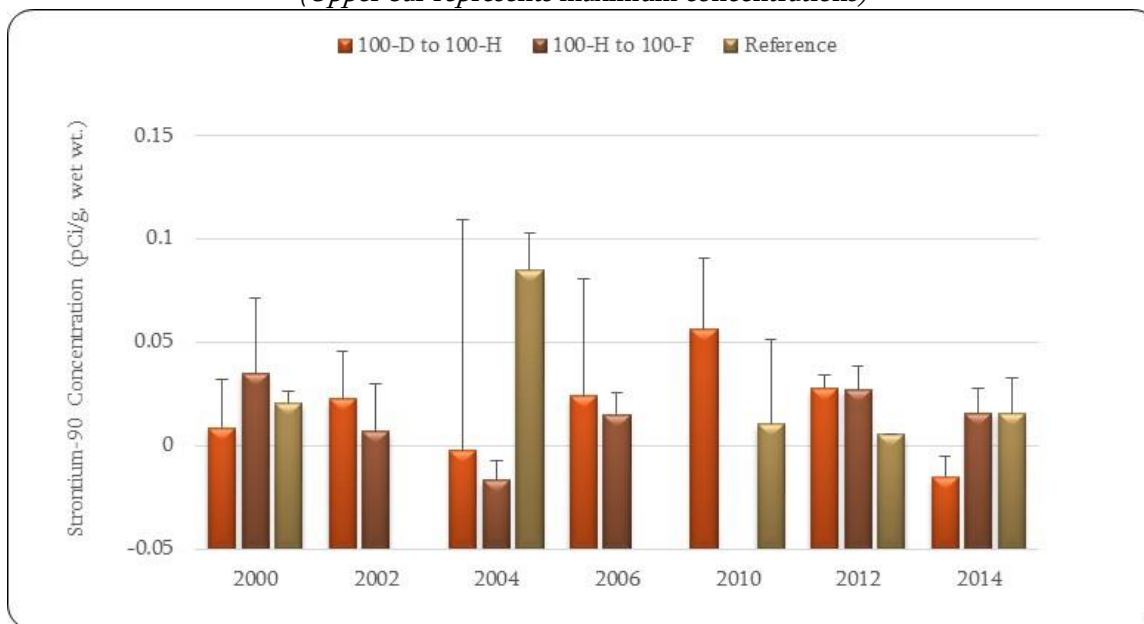
**Cesium-137.** Manmade gamma-emitting radionuclides, including cesium-137, were below the detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) for all upland game bird muscle samples analyzed in 2014. These results are consistent with those reported over the last 15 years, illustrating the continued

downward trend in worldwide levels of cesium-137 fallout resulting from materials released to the atmosphere during the nuclear weapons testing era (1950s through the 1970s).

**Strontium-90.** Strontium-90 concentrations were not detected in any quail bone samples collected in 2014. Comparisons of the maximum and median strontium-90 concentrations reported for game bird bone samples collected at the Hanford Site since 2000 and reference locations are consistent with these results, which do not indicate elevated levels of strontium-90 (Figure 10.5).

*Figure 10.5. California Quail Bone Strontium-90 Concentrations*

*(Upper bar represents maximum concentrations)*



### 10.3 Vegetation Monitoring

*JW Wilde*

Vegetation monitoring conducted on and around the Hanford Site is summarized in this section. Included are discussions of surveying and monitoring of Hanford Site plant populations, monitoring contaminants in perennial vegetation growing near facilities and operations, and controlling contaminated or unwanted vegetation.

Plant populations and habitats that occur on the Hanford Site are surveyed and monitored to assess the abundance, vigor or condition, and distribution of populations and species. These data can be integrated with contaminant monitoring results and used to help characterize potential risks or impacts to biota. Vegetation near onsite facilities and operations is monitored for radiation to determine the effectiveness of effluent monitoring and controls within facilities, assess the adequacy of containment at waste disposal sites, and detect and monitor unusual conditions. Hanford Site and historical offsite vegetation samples are analyzed for information about atmospheric deposition of contaminants in and around operational areas onsite and in uncultivated areas off site. These data provide a baseline against which unplanned releases can be compared. Vegetation management activities help prevent, limit, or remove contaminated plants or undesirable plant species. For further information about these monitoring and control efforts, the programs that support them, and their purposes, refer to Section 10.3.2 or [DOE/RL-91-50](#).

Monitoring rabbitbrush and sagebrush leaves and stems provides information about atmospheric deposition of radioactive materials in uncultivated areas and at Hanford Site locations that potentially could be affected by contaminants from Hanford Site operations. Vegetation samples have been collected on and around the Hanford Site for more than 50 years. Data from these samples are maintained in a database to document onsite and offsite levels of synthetic radionuclides in vegetation at specific locations. This database contains baseline data against which data from unplanned releases from the Hanford Site can be compared.

Vegetation samples were collected on or adjacent to waste disposal sites and from locations downwind and near or within the boundaries of operating facilities and remedial action sites. Samples were collected to evaluate long-term trends in environmental accumulation and potential migration of radioactive material. Contamination in vegetation can occur as the result of surface deposition of radioactive materials from other radiologically contaminated sources or by absorption of radionuclides through the roots of vegetation growing on or near former waste disposal sites.

The number and location of Hanford Site vegetation samples collected are summarized in Table 10.5. Only those radionuclides with concentrations consistently above analytical detection limits are discussed in this section. Data obtained from onsite vegetation samples is used as a qualitative indicator and verification of ambient air sampling results per [FF-01 \(WDOH 2014a\)](#). Vegetation samples from offsite locations were last collected in 2008 ([PNNL-18427](#)).

*Table 10.5. Vegetation Monitoring Locations*

Samples Analyzed	Operational Area (discrete samples analyzed)						Composites <sup>a, b</sup>
	100-N	200-East Area	200-West <sup>a</sup> Area	300 <sup>a</sup> Area	400 Area	600 <sup>a</sup> Area	
40	3	7	10	1	1	5	13

<sup>a</sup> Number of samples include one or more replicate samples.

<sup>b</sup> 35-individual vegetation samples from the 200 and 600 Areas were combined into 13 composite samples using a multi-incremental approach.

Individual vegetation samples (approximately 17.6 ounces [500 grams]) consisted of new-growth leaf cuttings taken from the available brushy, deep-rooted species (e.g., sagebrush and/or rabbitbrush). To avoid decimation of any individual plant through overharvesting, samples may consist of mixed biota representing several like members of the sampling-site plant community. Vegetation samples were dried prior to analyses, and analytical results were reported on a dry weight basis.

Some vegetation samples were analyzed as single parent samples (discrete data points) while others were composited with a multi-incremental sampling approach. A multi-incremental sampling technique is used when collecting samples from a large given area (i.e., a decision unit). Individual samples are processed using a gridded pattern approach, and combined with other samples from the decision unit to create a composite sample that represents the decision unit as a whole. This compositing limits the variability of selected environmental contaminant concentrations in a given area, and reduces the amount of sampling error due to heterogeneity, while allowing for a reproducible mean concentration for the decision unit.

Samples were analyzed for the radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides [cobalt-60 and cesium-137], strontium-90, uranium isotopes, and/or plutonium isotopes).

Selected analytical results were compared to concentrations in samples collected during 2008 at offsite sampling locations in Yakima, Benton, and Franklin counties ([PNNL-18427](#)). Comparisons can be used to determine the differences between contributions from site operations and remedial action sites and contributions from natural sources and worldwide fallout.

#### **10.3.1.1 Vegetation Monitoring Results**

Some degree of variability is always associated with collecting and analyzing environmental samples; therefore, variations in sample concentrations from year to year are expected. In general, radionuclide concentrations in vegetation samples collected from, or adjacent to, waste disposal facilities in 2014 were higher than concentrations in samples collected farther away, including concentrations measured offsite. Generally, the predominant radionuclides were activation and fission products in the 100 Areas, fission products in the 200 Areas and 600 Area, and uranium in the 300 Area and 400 Area.

Uranium-234, uranium-235 and/or uranium-238 were detected in ten of the 2014 samples. Thirteen samples showed detectable concentrations of cesium-137, and 13 samples showed detectable levels of strontium-90. Concentrations of detected radionuclides were elevated near and within facility boundaries compared to historic concentrations measured at distant communities; however, they remained within the historical range of those collected within facility boundaries. Figure 10.6 shows the Hanford Site average concentration of selected radionuclides for vegetation samples. (Note: Distant community vegetation samples were not collected in 2014.)

Table 10.6 provides a summary of selected radionuclides detected in vegetation samples collected and analyzed in 2014 and previous years. The average and maximum results are reported for the six primary waste facility/operational areas of interest, including comparative data for the preceding 5 years. Vegetation samples collected in 2014 at locations in the 100-N Area, 200-East Area, 200-West Area, 400 Area, and 600 Area were comparable to those collected in previous years. Vegetation samples collected in the 200 Areas and 600 Area showed concentrations of uranium-234, uranium-235, and uranium-238 that were comparable to historical data. A single detect of uranium-238 was found in the 300 Area that was higher than other sampled areas. The higher uranium levels in the 300 Area were normal in comparison to historical data. The uranium levels are a result of uranium releases to the environment during past fuel-fabrication operations in that area. Plutonium-239/240 was found at higher levels in vegetation samples in the 200-West Area. The range of strontium-90 concentrations was comparable to historical levels.

Figure 10.6. Hanford Site Vegetation Average Concentration of Selected Radionuclides

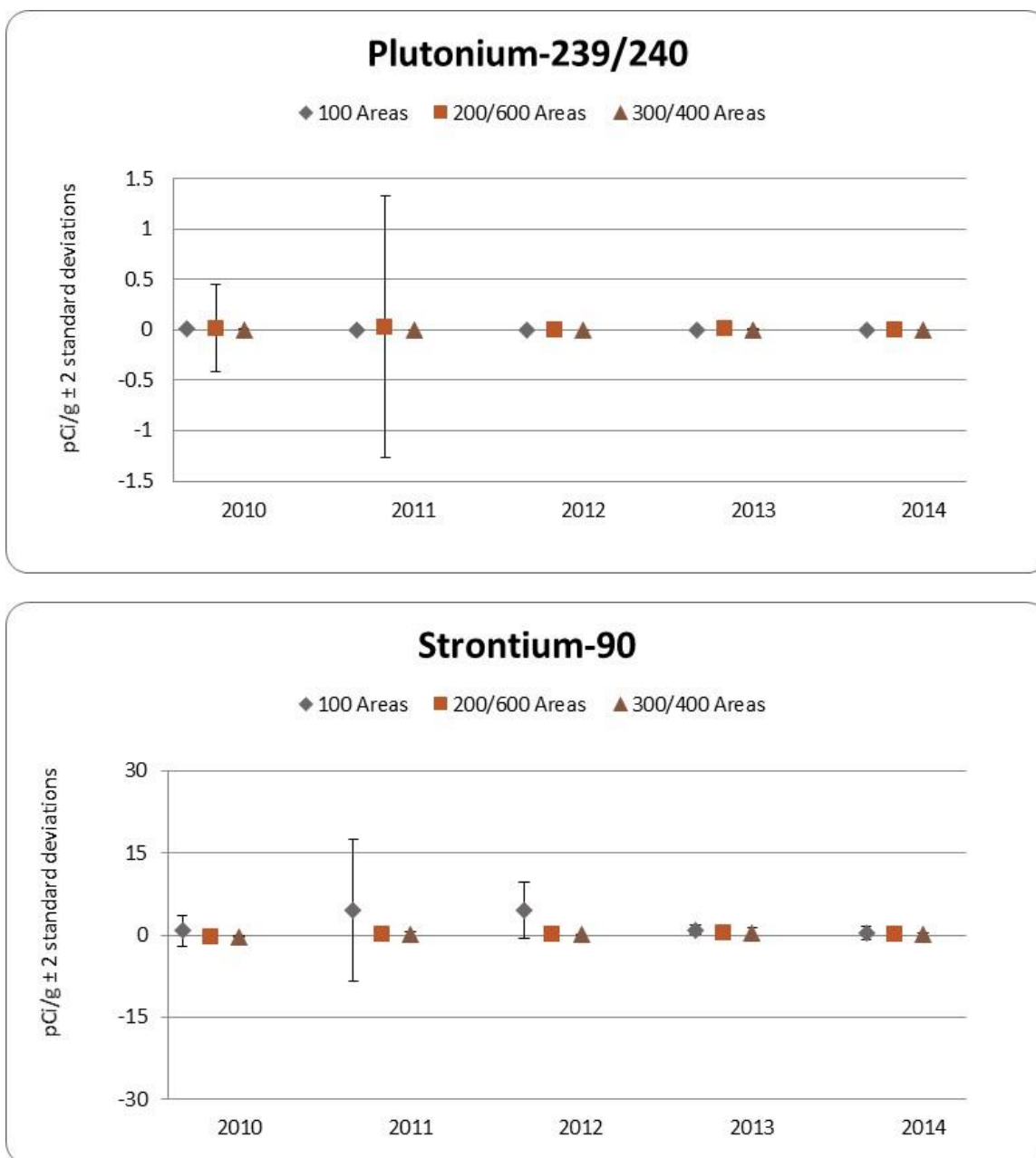


Figure 10.6. Average Concentration of Selected Radionuclides in Vegetation Samples from the Hanford Site (cont.)

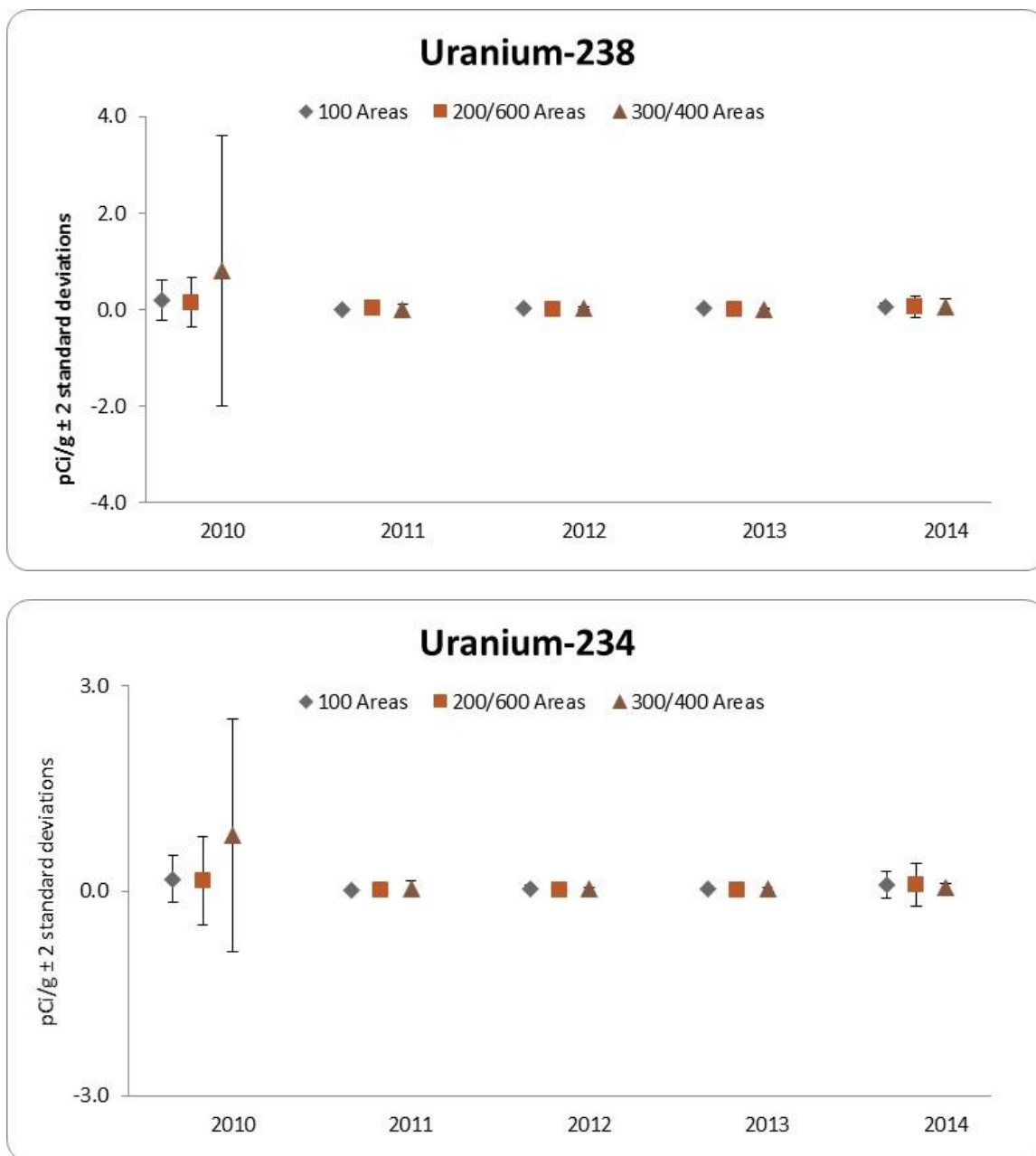




Table 10.6. Hanford Site Vegetation Concentrations of Selected Radionuclides

Isotope	Hanford Area	2014				2009-2013			
		Number of		Average <sup>a</sup>	Maximum <sup>b</sup>	Number of		Average <sup>a</sup>	Maximum <sup>b</sup>
		Samples	Detects	(pCi/gm)	(pCi/gm)	Samples	Detects	(pCi/gm)	(pCi/gm)
Cobalt-60	100	3	0	-7.8E-03 ± 1.7E-02	2.8E-03 ± 1.6E-02 <sup>c</sup>	13	0	1.1E-02 ± 3.7E-02	3.6E-02 ± 8.8E-02 <sup>c</sup>
	200-East	7	0	5.3E-03 ± 2.3E-02	2.3E-02 ± 1.5E-02 <sup>c</sup>	40	0	-4.1E-03 ± 5.5E-02	5.4E-02 ± 1.1E-01 <sup>c</sup>
	200-West	10	0	1.4E-03 ± 2.2E-02	2.4E-02 ± 2.7E-02 <sup>c</sup>	80	0	-6.4E-03 ± 5.8E-02	6.9E-02 ± 5.7E-02 <sup>c</sup>
	300	1	0	-0.0066 <sup>d</sup>	-6.6E-03 ± 2.2E-02 <sup>c</sup>	51	0	-2.7E-03 ± 6.9E-02	7.4E-02 ± 1.0E-01 <sup>c</sup>
	400	1	0	-0.016 <sup>d</sup>	-1.6E-02 ± 2.1E-02 <sup>c</sup>	4	0	-1.1E-02 ± 4.9E-02	2.5E-02 ± 3.8E-02 <sup>c</sup>
	600	5	0	-4.6E-03 ± 2.1E-02	1.1E-02 ± 2.6E-02 <sup>c</sup>	59	1	6.2E-03 ± 9.0E-02	2.6E-01 ± 1.3E-01
Cesium-137	100	3	0	1.0E-02 ± 1.7E-02	2.0E-02 ± 2.3E-02 <sup>c</sup>	13	1	2.0E-02 ± 5.8E-02	8.7E-02 ± 8.5E-02 <sup>c</sup>
	200-East	7	5	7.7E-02 ± 1.4E-01	2.4E-01 ± 2.6E-02	40	11	6.3E-02 ± 1.4E-01	3.3E-01 ± 1.4E-01
	200-West	10	4	2.5E-02 ± 4.4E-02	6.9E-02 ± 3.3E-02	80	17	6.6E-02 ± 1.2E-01	3.2E-01 ± 1.2E-01
	300	1	1	4.1E-02 <sup>d</sup>	4.1E-02 ± 2.9E-02	51	8	3.7E-02 ± 1.7E-01	3.6E-01 ± 9.7E-02
	400	1	0	-6.3E-03 <sup>d</sup>	-6.3E-03 ± 2.0E-02 <sup>c</sup>	4	0	1.7E-03 ± 5.9E-02	2.8E-02 ± 3.8E-02 <sup>c</sup>
	600	5	3	3.7E-02 ± 4.3E-02	6.7E-02 ± 3.5E-02	59	10	3.5E-02 ± 1.3E-01	2.0E-01 ± 8.6E-02
Plutonium-238	100	3	0	-1.8E-04 ± 3.3E-04	-6.0E-05 ± 4.9E-04 <sup>c</sup>	13	0	-3.2E-03 ± 2.1E-02	6.4E-03 ± 1.4E-02 <sup>c</sup>
	200-East	7	0	3.4E-05 ± 3.1E-04	2.2E-04 ± 7.0E-04 <sup>c</sup>	40	1	1.2E-03 ± 1.3E-02	1.6E-02 ± 1.9E-02 <sup>c</sup>
	200-West	10	0	1.2E-04 ± 4.0E-04	4.3E-04 ± 4.6E-04 <sup>c</sup>	80	2	5.2E-04 ± 1.3E-02	2.7E-02 ± 1.2E-02
	300	1	0	2.5E-06 <sup>d</sup>	2.5E-06 ± 2.5E-05 <sup>c</sup>	51	2	7.5E-04 ± 2.3E-02	4.6E-02 ± 2.2E-02
	400	1	0	2.8E-04 <sup>d</sup>	2.8E-04 ± 3.5E-04 <sup>c</sup>	4	0	1.8E-03 ± 1.4E-02	1.3E-02 ± 1.8E-02 <sup>c</sup>
	600	5	0	-8.7E-05 ± 5.1E-04	2.2E-04 ± 3.2E-04 <sup>c</sup>	58	1	3.0E-03 ± 1.6E-02	3.2E-02 ± 2.3E-02 <sup>c</sup>
Plutonium-239/240	100	3	0	2.3E-04 ± 6.5E-04	6.4E-04 ± 7.8E-04 <sup>c</sup>	13	2	1.5E-03 ± 8.9E-03	9.2E-03 ± 7.3E-03
	200-East	7	1	5.6E-04 ± 5.2E-04	9.2E-04 ± 5.3E-04	40	0	1.4E-03 ± 3.7E-03	5.7E-03 ± 5.6E-03 <sup>c</sup>
	200-West	10	9	3.8E-03 ± 8.1E-03	1.4E-02 ± 1.9E-03	80	30	2.9E-02 ± 3.0E-01	1.3E+00 ± 2.8E-01
	300	1	0	2.9E-04 <sup>d</sup>	2.9E-04 ± 4.4E-04 <sup>c</sup>	51	1	-1.9E-04 ± 1.7E-02	1.0E-02 ± 6.5E-03
	400	1	0	2.8E-04 <sup>d</sup>	2.8E-04 ± 4.4E-04 <sup>c</sup>	4	0	1.2E-03 ± 4.2E-03	3.7E-03 ± 4.3E-03 <sup>c</sup>
	600	5	2	4.6E-04 ± 9.8E-04	1.0E-03 ± 5.5E-04	59	7	2.5E-03 ± 1.1E-02	2.9E-02 ± 1.2E-02
Strontium-90	100	3	2	4.1E-01 ± 9.4E-01	1.1E+00 ± 2.1E-01	13	9	2.1E+00 ± 7.5E+00	1.3E+01 ± 1.7E+00
	200-East	7	4	1.4E-01 ± 2.2E-01	3.2E-01 ± 7.1E-02	40	16	6.3E-02 ± 1.3E+00	1.0E+00 ± 2.8E-01

Table 10.6. Hanford Site Vegetation Concentrations of Selected Radionuclides

Isotope	Hanford Area	2014				2009-2013			
		Number of		Average <sup>a</sup>	Maximum <sup>b</sup>	Number of		Average <sup>a</sup>	Maximum <sup>b</sup>
		Samples	Detects	(pCi/gm)	(pCi/gm)	Samples	Detects	(pCi/gm)	(pCi/gm)
	200-West	10	3	3.8E-02 ± 1.1E-01	1.3E-01 ± 3.9E-02	80	11	-3.3E-02 ± 5.9E-01	7.4E-01 ± 2.0E-01
	300	1	1	2.6E-01 <sup>d</sup>	2.6E-01 ± 6.0E-02	51	9	-8.4E-02 ± 6.4E-01	8.4E-01 ± 1.9E-01
	400	1	0	1.8E-02 <sup>d</sup>	1.8E-02 ± 2.6E-02 <sup>c</sup>	4	0	-1.1E-01 ± 3.8E-01	1.5E-01 ± 1.7E-01 <sup>c</sup>
	600	5	3	3.5E-02 ± 4.4E-02	7.2E-02 ± 3.1E-02	59	7	-4.6E-02 ± 8.3E-01	1.3E+00 ± 3.4E-01
Uranium-234	100	3	1	8.4E-02 ± 1.6E-01	1.8E-01 ± 1.4E-01	13	12	1.8E-02 ± 2.7E-02	6.2E-02 ± 2.2E-02
	200-East	7	2	1.8E-01 ± 2.9E-01	3.6E-01 ± 1.8E-01	40	31	1.2E-02 ± 1.1E-02	2.6E-02 ± 1.2E-02
	200-West	10	2	1.0E-01 ± 2.9E-01	3.4E-01 ± 1.7E-01	80	74	1.7E-02 ± 2.5E-02	1.1E-01 ± 3.5E-02
	300	1	0	7.9E-02 <sup>d</sup>	7.9E-02 ± 9.5E-02 <sup>c</sup>	51	44	3.8E-02 ± 1.3E-01	4.4E-01 ± 1.8E-01
	400	1	0	3.6E-02 <sup>d</sup>	3.6E-02 ± 1.2E-01 <sup>c</sup>	4	3	1.4E-02 ± 8.3E-03	1.9E-02 ± 1.1E-02
	600	5	0	1.7E-02 ± 2.3E-01	1.3E-01 ± 1.3E-01 <sup>c</sup>	59	41	1.3E-02 ± 2.2E-02	8.4E-02 ± 2.8E-02
Uranium-235	100	3	0	2.8E-02 ± 2.3E-02	4.4E-02 ± 1.1E-01 <sup>c</sup>	13	2	3.7E-03 ± 5.2E-03	9.2E-03 ± 6.2E-03
	200-East	7	1	7.5E-02 ± 1.5E-01	1.6E-01 ± 1.3E-01	40	4	2.8E-02 ± 3.1E-01	1.0E+00 ± 0.0E+00 <sup>c</sup>
	200-West	10	1	3.0E-02 ± 2.4E-01	1.6E-01 ± 1.2E-01	80	20	3.5E-03 ± 4.8E-03	1.3E-02 ± 7.9E-03
	300	1	0	-2.4E-02 <sup>d</sup>	-2.4E-02 ± 1.1E-01 <sup>c</sup>	51	13	6.2E-03 ± 2.1E-02	7.9E-02 ± 7.1E-02 <sup>c</sup>
	400	1	0	8.9E-02 <sup>d</sup>	8.9E-02 ± 1.1E-01 <sup>c</sup>	4	1	4.0E-03 ± 2.8E-03	6.1E-03 ± 5.2E-03
	600	5	0	-2.9E-02 ± 1.6E-01	5.8E-02 ± 1.0E-01 <sup>c</sup>	58	7	2.9E-03 ± 4.3E-03	1.1E-02 ± 7.7E-03
Uranium-238	100	3	0	7.1E-02 ± 5.5E-02	1.0E-01 ± 1.2E-01 <sup>c</sup>	13	10	1.2E-02 ± 2.4E-02	4.9E-02 ± 1.8E-02
	200-East	7	0	1.0E-01 ± 5.4E-02	1.4E-01 ± 1.3E-01 <sup>c</sup>	40	28	8.9E-03 ± 8.5E-03	1.7E-02 ± 9.3E-03
	200-West	10	1	3.3E-02 ± 1.6E-01	1.4E-01 ± 1.1E-01	80	67	1.4E-02 ± 3.2E-02	1.4E-01 ± 4.3E-02
	300	1	1	1.2E-01 <sup>d</sup>	1.2E-01 ± 1.1E-01	51	48	3.6E-02 ± 1.5E-01	5.2E-01 ± 1.9E-01
	400	1	0	1.8E-02 <sup>d</sup>	1.8E-02 ± 7.9E-02 <sup>c</sup>	4	4	9.9E-03 ± 6.7E-03	1.4E-02 ± 9.2E-03
	600	5	1	2.6E-02 ± 2.9E-01	1.6E-01 ± 2.5E-01 <sup>c</sup>	59	47	1.1E-02 ± 1.6E-02	6.1E-02 ± 2.1E-02

<sup>a</sup> Average ± two standard deviations<sup>b</sup> Maximum ± analytical uncertainty<sup>c</sup> Maximum value reported is a non-detect.<sup>d</sup> Standard deviation cannot be calculated for one sample.

### 10.3.2 Radiological Contamination

*JW Wilde and RC Roos*

Investigations of radioactive contamination in vegetation were conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. All samples collected during investigations were field-surveyed for alpha- and beta-gamma radiation.

Radiological contamination was found in 50 vegetation samples surveyed during the 2014 investigations. Forty-nine of the samples were Russian thistle (*Salsola tragus*) or fragments, and one sample was bunchgrass. No samples were analyzed for specific radionuclides. Tumbleweed surveys resulted in 10 locations posted as contamination areas; 40 samples were disposed at a licensed facility.

Section 10.3.1 provided a discussion of the vegetation control on the Hanford Site. Table 10.7 summarizes the number and general locations of vegetation contamination incidents investigated from 2000 through 2014.

**Table 10.7. Hanford Site Vegetation Contamination Incidents Investigated**

Location	2014 Incidents	Year	Incidents
100 Area	1	2000	66
<b>200-East Area</b>		2001	20
Tank farms	3	2002	16
Burial grounds	12	2003	32
Cribs, ponds, and ditches	7	2004	60
Fence lines	3	2005	66
Roads and railroads	0	2006	75
Unplanned release sites	1	2007	62
Underground pipelines	0	2008	127
LERF/ETF	2	2009	109
Miscellaneous	1	2010	36
<b>200-West Area</b>		2011	10
Tank farms	5	2012	18
Burial grounds	3	2013	35
Cribs, ponds, and ditches	2	<b>2014</b>	<b>50</b>
Fence lines	5		
Roads and railroads	0		
Unplanned release sites	0		
Underground pipelines	0		
Miscellaneous	2		
Cross-site transfer line	0		
600 Area burial grounds	3		
200-North Area	0		
300 Area	0		
400 Area	0		
600 Area	0		
<b>Total</b>	<b>50</b>		

### 10.3.3 Vegetation Control

*JM Rodriguez and RC Roos*

The purpose of vegetation control at the Hanford Site is effective control and minimization of noxious weeds, industrial weeds, and other vegetation to ensure protection of Hanford Site workers, the public, facilities, property, and the site's cultural and environmental (including biological) resources. Risks that are mitigated through effective vegetation control are the spread of contamination, wildfire fuel loading, harborage of vermin and insect pests around facilities, damage and destruction of native plant communities, damage to facilities and interference with work and transportation.

Approximately 7,425 acres (3,005 hectares) were treated with herbicides in 2014 on radiological waste sites, around operations areas, and along roadways to keep areas free of deep-rooted vegetation (e.g., Russian thistle, also known as tumbleweed). Follow-up treatments are included in the total treated acres; several areas received more than one herbicide application.

#### 10.3.3.1 Noxious Weeds

Noxious weeds are controlled at the Hanford Site to prevent their spread and eliminate populations. A noxious weed is a legal and administrative category designated by federal or state regulatory agencies (e.g., the U.S. Department of Agriculture or Washington State Department of Agriculture). Noxious weeds are non-native, aggressively invasive, and hard to control. Noxious weed plant communities degrade ecosystems unless control measures are taken. Control measures can be mechanical, chemical, cultural, or biological. Only 64 acres (26 hectares) of noxious weeds on the Hanford Site were treated with herbicides in 2014 along roadways. An unresolved procedure for NEPA compliance prevented treatment off roads and limited treatment on roads to the most critical areas. The *Environmental Assessment, Integrated Vegetation Management on the Hanford Site, Richland, Washington* ([DOE/EA-1728-F](#)) was completed in 2012. The FONSI clears the way to develop an appropriate process for NEPA clearance of noxious weed control. As the process is clarified, control of noxious weeds will resume.

Ten plant species are on a high-priority list for control at the Hanford Site. These species are described in the following paragraphs, along with a summary of 2014 control activities.

**Yellow Starthistle (*Centaurea solstitialis*).** Yellow starthistle represents the most rapidly expanding weed infestation in the western United States. Since 1995, yellow starthistle has been the highest priority weed for the Hanford Site noxious-weed control program because it has the potential to invade the entire site and have a dramatic impact on the ecology of the site and neighboring lands.

Control measures for yellow starthistle have included spot treatments and broadcast applications by ground equipment and aerial sprayers, biological control, and hand weeding in critical locations. Major populations near the Hanford Townsite have been reduced to scattered individual plants, mostly near live trees where aerial herbicide applications were not made. Control of the yellow starthistle in 2014 consisted of hand pulling individual plants as they were identified. Weather conditions unfavorable for yellow starthistle in fall 2013 and spring 2014 resulted in very poor germination and establishment of yellow starthistle in 2014. Less than 20 plants were found flowering, all in cracks of old pavement where the asphalt surface acted to capture rainfall into cracks, and prevented subsequent evaporation. The few plants that were found germinated in native soil withered before successful flowering.

Adequate precipitation and mild temperatures during fall 2014 are expected to result in more yellow starthistle germination and establishment in 2015.

Yellow starthistle seeds are known to remain viable for 10 years in the soil. The small number of seedlings found over much of the area of infestation indicates the seed bank is being exhausted. Careful control efforts over the next few years should result in the yellow starthistle changing from a major infestation to a monitoring and eradication effort.

Biological control agents for yellow starthistle are widely distributed across the infested area and have been highly effective during the early part of the flowering season. However, the adult phase of the control agent's annual lifecycle is completed before the end of the flowering season.

Consequently, flowers opening late in the season are largely spared the effects of insect predation.

Successful control of yellow starthistle in the past has substantially reduced the population in both area and density. The biological control organisms require yellow starthistle in order to complete their lifecycle. The reduced plant population can no longer sustain a robust population of biological control organisms. As the population of bio controls fails, greater emphasis needs to be placed on effective monitoring and control of the plants to continue toward eradication of yellow starthistle at Hanford.

**Rush Skeletonweed (*Chondrilla juncea*).** Rush skeletonweed is a challenging species to control because their seeds are spread by the wind, allowing seedlings to germinate and begin new populations miles away from other plants. The deep and extensive root system of rush skeletonweed makes it extremely difficult to control using herbicides. Herbicide application may kill the main plant, but roots deep in the soil or far from the green portion of the plant often avoid the effects of herbicide. Those roots can remain living in the soil for several years, eventually sending sprouts to the surface to begin new plants long after the effects of herbicide application have ended.

Rush skeletonweed is scattered over large areas of the Hanford Site. Areas of dense rush skeletonweed infestation north of the Wye Barricade largely have been eliminated. Nevertheless, considerable rush skeletonweed remains as scattered individual plants. Populations of rush skeletonweed have increased in some areas burned by past wildfires. Reduction in active control efforts over the past few years, while NEPA requirements have been evaluated, has allowed populations of skeletonweed to increase in both aerial extent and density.

The area north of the HAMMER facility has been treated with herbicides in the past and will continue to be monitored for sprouts emerging from roots remaining in the ground. Additional aerial applications may be needed to reduce the population of rush skeletonweed to a level that ground applications will be able to control the infestation.

Biological control agents are commonly found in rush skeletonweed at the Hanford Site; however, the agents have not significantly reduced plant populations or seed production.

**Babysbreath (*Gypsophila paniculata*).** Babysbreath is generally resistant to control by herbicides; however, the aboveground portion of the plant can be destroyed by some herbicides. Using these herbicides, flowering and seed production can be prevented. Eventually, the plants should be eradicated by continually removing the top portions through herbicide use. By removing the green portions of the plant, energy reserves in the roots will eventually be depleted and the plant killed. Herbicides were not used to control babysbreath in 2014 while NEPA authorization was being finalized. Active control of

babysbreath in 2014 at the Hanford Townsite consisted of hand pulling individual plants to prevent seed production.

**Dalmatian Toadflax (*Linaria genistifolia* ssp. *Dalmatica*).** A small population of dalmatian toadflax is found near Energy Northwest on the Hanford Site. Sprouts and seedlings of the long-lived perennial plant will be eliminated as they are identified. The current population consists of plants widely scattered across the area of infestation. The low-density population is not conducive to successful establishment of predatory species. Consequently, no biological controls have been released at the Hanford Site for dalmatian toadflax. Toadflax growing along road shoulders were controlled using herbicides.

**Diffuse Knapweed (*Centaurea diffusa*).** Aerial applications for control of diffuse knapweed have been effective in the past. In 2014, NEPA compliance limited control of diffuse knapweed to hand pulling in a few critical areas. The population of diffuse knapweed near the high-water mark of the Columbia River has not been actively controlled by herbicides because of the biological sensitivity of the area. Biological controls are established and monitored to observe their effectiveness in controlling the weed.

**Medusahead (*Taeniatherum asperum*).** No medusahead plants were discovered in 2014. The Hanford Site will continue to be monitored to verify the seed bank has been eradicated.

**Purple Loosestrife (*Lythrum salicaria*).** The bank of the Columbia River and islands along the Hanford Site are monitored for purple loosestrife. Populations are found on many islands and along the banks of the river. Individual plants and small populations are found along the south and west bank of the river.

Under good ecological conditions, biological controls are effective for controlling purple loosestrife. However, widely fluctuating water levels along the Columbia River destroy the biological control organisms as they attempt to over-winter in the soil at the base of the plants. Winter mortality prevents an effective population of control agents from developing. No control measures were applied in 2014 for purple loosestrife.

**Russian Knapweed (*Acroptilon repens*).** Biological controls for Russian knapweed are limited, and their success has been poor in the semi-arid climate of the Hanford Site. Chemicals and other control techniques are being developed that promise to be effective with this difficult-to-control species.

**Saltcedar (*Tamarix* spp.).** Several individual plants of saltcedar were found at the Hanford Site. Most are the remainders from ornamental plantings near homes in the early part of the previous century. A few populations are the result of natural seed dispersal. Most individual plants south and west of the Columbia River have been eliminated. Those remaining continue to be treated with herbicide and will be monitored until they are eradicated.

Saltcedar roots are very deep and store a great deal of energy, making control of the species difficult. A few trees that were treated with herbicide in the past began to show new green growth after years of appearing dead. These trees were again treated with herbicide in 2014.



**Spotted Knapweed (*Centaurea maculosa*).** Spotted knapweed at the Hanford Site has been controlled so that sprouts or seedlings are rare. In 2014, no sprouts or seedlings were found. The Hanford Site will continue to be monitored for several years to ensure viable seeds and roots have been eliminated from the soil. Cooperative efforts with neighboring landowners continue to eliminate spotted knapweed near the Hanford Site. *Cyphocleonus achates*, a root-feeding weevil has been released specifically for spotted knapweed. It is expected that the population of spotted knapweed at the Hanford Site is too small and scattered to sustain a biological control population. However, *Cyphocleonus* is known to use diffuse knapweed. It is hoped that a population of *Cyphocleonus* will establish in diffuse knapweed and cross over to control spotted knapweed when it appears. Most biological controls for diffuse knapweed also are effective for spotted knapweed.

## 10.4 Waste Site Remediation and Revegetation

*RC Roos and JM Rodriguez*

In 2014, 2 acres (0.81 hectares) were planted with native grass seed to stabilize areas where repair and maintenance activities disturbed existing vegetation. Waste sites in the 200 East and 200 West Areas were designed and constructed with a cap of perennial grass. The cap is essential to performance of engineered waste sites. However, soil used as backfill and cover on waste sites was often sandy, which provides a poor medium for growth of the grass. Over the years, poor soil combined with lack of maintenance has resulted in degradation and decreased function of the vegetative caps on many waste sites. Integrated Biological Control has been actively restoring vegetative caps on waste sites.

Vegetative caps on waste sites perform three primary functions:

1. **Prevent Erosion.** A well-designed and maintained grass cap stabilizes soil on waste sites by physically covering the soil surface and serves as a windbreak, reducing wind velocity at the soil surface.
2. **Exclude Tumbleweed Growth.** Tumbleweeds are the main biological vector of contamination spread on the Hanford Site. They are deep-rooted annual plants that quickly invade and establish on disturbed soil. The deep roots readily absorb radionuclides buried in the soil and transport them to the aboveground portions of the plant. At the end of the 1-year lifecycle, dead tumbleweeds detach from the roots and blow away with the wind. In this way, radioactive contamination can be transported from posted and monitored disposal areas.

A well-designed and maintained grass cap excludes tumbleweeds by direct competition for space and nutrients (primarily water). Stabilized soil forms a crypto-biotic crust composed of moss, lichen, algae, and other organisms that provide a poor surface for germination of tumbleweed seeds. The combination of competition for resources and prevention of germination effectively excludes tumbleweeds from establishing on waste sites.

3. **Prevent Water Percolation through the Soil Column.** Waste sites were designed with vegetative caps to prevent natural precipitation moving through the soil column and washing radioactive or hazardous materials downward toward groundwater.

The 6- to 7-inch (15- to 18-centimeter) average precipitation received at the Hanford Site typically percolates 2 to 4 feet (0.6 to 1.2 meters) into the soil during the winter. Evaporation during summer months removes some moisture from the soil. However, as surface soil dries, it acts as a mulch,

inhibiting further evaporation. Evaporation alone does not remove all the natural precipitation from the soil. Water remaining in the soil from the previous year has an additive effect during the subsequent wet season, allowing water to percolate to increasing depth.

Vegetative caps on waste sites were designed so that in addition to evaporation from the soil surface, plant roots would mine water from deeper in the soil profile, transporting it to leaves where it is lost through evaporation. The process of water moving from soil into plant roots, through the plant and out the leaves to the atmosphere is transpiration. The combination of evaporation and transpiration removes sufficient moisture from the soil so that precipitation during subsequent wet seasons falls on dry soil, yielding no net increase in depth of percolation. Effective containment of waste in burial grounds depends on the combination of evaporation and transpiration drying the soil, preventing additive percolation and transport of contaminants to groundwater.

## 11.0 Resource Protection

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### 11.1 Ecological Protection

*JW Wilde, JJ Nugent, JA Pottmeyer, and KJ Cranna*

Ecological monitoring is performed on the Hanford Site to collect and track data needed to ensure compliance with an array of environmental laws, regulations, and policies governing DOE activities. Ecological monitoring data provide baseline information about the plants, animals, and habitat under RL stewardship at Hanford that is required for decision-making under NEPA and CERCLA.

The Comprehensive Land Use Plan-Environmental Impact Statement ([CLUP] [DOE/EIS-0222-F](#)) evaluated the impacts associated with future land-use planning at the Hanford Site. The purpose of this land-use plan and its implementing procedures is to facilitate decision-making about the site's uses and facilities over at least the next 50 years. The DOE decision to adopt the CLUP seeks to balance continuing land-use needs at Hanford with the preservation of important ecological and cultural values of the site and future economic development in the area.

The *Hanford Site Biological Resource Management Plan* ([BRMP] [DOE/RL-96-32, Rev. 1](#)) is identified by the CLUP as the primary implementation control for managing and protecting natural resources on the Hanford Site. According to the CLUP, the BRMP:

*Provides a mechanism for ensuring compliance with laws protecting biological resources; provides a framework for ensuring that appropriate biological resource goals, objectives, and tools are in place to make DOE an effective steward of the Hanford biological resources; and implements an ecosystem management approach for biological resources on the Site. The BRMP provides a comprehensive direction that specifies DOE biological resource policies, goals, and objectives.*

RL places priority on monitoring those plant and animal species or habitats with specific regulatory protections or requirements; that are rare and/or declining (federal or state listed endangered, threatened, or sensitive species); or are of significant interest to federal, state, or tribal governments or the public. The BRMP ranks wildlife species and habitats (Levels 0-5), providing a graded approach to monitoring biological resources based on the level of concern for each resource.

Ecological monitoring and ecological compliance support the Hanford Site's waste management and environmental restoration mission through the following activities:

- ⊗ Ensuring the Hanford Site's operational compliance with laws and regulations including the Endangered Species Act of 1973 ([16 USC 1531](#)), Bald and Golden Eagle Protection Act ([16 USC 668-668c](#)), and Migratory Bird Treaty Act of 1918 ([16 USC 703](#)), as well as compliance with executive orders, DOE orders, and RL resource management guidance
- ⊗ Providing data for environmental impact and ecological risk assessments
- ⊗ Providing information and maps of the distribution and condition of biological resources at the Hanford Site
- ⊗ Supporting Hanford Site land-use planning and stewardship.

Hanford Site ecological monitoring activities provide information useful to the Hanford Site natural resource stakeholders and the public on the status of some of the site's most highly valued biological

resources. Population level surveys are conducted to monitor fish, wildlife, and plants and are used to develop baseline information and monitor any changes resulting from Hanford Site operations. Population data collection and analysis are integrated with data from environmental surveillance monitoring of biotic and abiotic media, and analytical results are used to characterize any potential risk or impact to the biota.

### 11.1.1 Fish and Wildlife Monitoring

This section provides inventory, monitoring, and survey information for species evaluated at the Hanford Site during 2014. This information is provided in context with historical data and trend information. Historically, four fish and wildlife species on the Hanford Site have been monitored annually: fall Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), bald eagles (*Haliaeetus leucocephalus*), and mule deer (*Odocoileus hemionus*). These species are either regulatory protected or of special interest to the public and stakeholders, with the exception of mule deer. Monitoring consisted of estimating numbers of fall Chinook salmon redds, surveying for steelhead redds, and assessing bald eagle nesting and night roosting activity because the species have the potential to be impacted by Hanford Site operations. Yearly monitoring provides occurrence and distribution data to ensure their protection from Hanford Site operations. Additional monitoring efforts included nesting raptors and migratory birds. The sections below provide summaries of the monitoring results; the detailed monitoring reports are available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

#### 11.1.1.1 Fall Chinook Salmon

Chinook salmon, commonly referred to as king salmon, are the largest of the Pacific salmon (Myers et al. 1998, Netboy 1958). Adult fall Chinook salmon destined for the Hanford Reach enter the Columbia River in late summer and spawn from mid-October through November. Females fan out nests or redds in suitable gravel substrate and deposit eggs in an egg pocket while males simultaneously extrude milt to fertilize the eggs. Redds are readily identifiable at this time and appear as clean swept gravel patches amidst darker undisturbed substrate that is covered by algae (periphyton).

The population of fall Chinook salmon that spawns in the Hanford Reach of the Columbia River is the largest run remaining in the Pacific Northwest and has regional ecological and cultural significance as well as economic importance that extends down the Columbia River and into the Pacific Ocean as far as southeast Alaska (Dauble and Watson 1997). These fall Chinook salmon have been vital in efforts to preserve and restore other depleted Chinook salmon stocks in the Columbia Basin (Anglin et al. 2006). Aerial counts of fall Chinook salmon redds have been conducted since 1948 at Hanford to provide an index of relative abundance among spawning areas and years (Wagner et al. 2012, Wagner et al. 2013, Lindsey and Nugent 2014, MSA 2015). The counts are also used to document the onset of spawning, locate spawning areas, and determine intervals of peak spawning activity. These data also allow for planning to avoid impacts, such as disturbance or siltation, to redds from Hanford Site activities. Understanding the location and abundance of spawning is a critical part of the management of this important population. The information collected during the surveys that are the focus of this report is vitally important for the implementation of the Hanford Reach Fall Chinook Protection Program (USACE 2006). Prior to 2011, the Hanford Reach was divided into 11 sections, which have been maintained in the current monitoring campaign. In 2011, eight additional sections (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, the dunes, and 300 Area) were defined to better monitor the abundance and distribution of fall Chinook redds in areas of potential upwelling of contaminated groundwater. The original 11 sections and

the newer 8 sections are not mutually exclusive areas; they simply represent different divisions of the Hanford Reach.

In 2014, four aerial surveys were completed along the length of the Hanford Reach (October 20, November 10, November 24, and December 1). Table 11.1 summarizes the results of visual aerial surveys for fall Chinook salmon redds in the originally defined 11 sections. The results for the same surveys, organized into the eight operational areas are shown in Table 11.2. The peak annual visual redd count for 2014 (15,951) was less than last year's (2013) all time highest count of 17,398 but was well in excess of the previous 10 year average (8,065) (see Figure 11.1). Additional information detailing the 2014 monitoring effort is available in [HNF-58823](#), *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2014*.

*Table 11.1. Summary of the Aerial Surveys for Fall Chinook Salmon Redd Counts in the Hanford Reach, Columbia River*

Area	Description	2014				Maximum Count
		10/20	11/10	11/24	12/1	
0	Islands 17-21 (Richland)	0	0	0	0	0
1	Islands 11-16	0	76	767	906	906
1a	Savage Island/Hanford Slough	0	0	0	0	0
2	Islands 8-10	0	427	1,470	1,565	1,565
3	Near Island 7	0	400	1,100	1,100	1,100
4	Island 6 (lower half)	10	1,020	2,230	2,530	2,530
5	Island 4, 5 and upper 6	25	730	2,030	2,080	2,080
6	Near Island 3	0	100	900	1,000	1,000
7	Near Island 2	23	1,010	2,030	2,050	2,050
8	Near Island 1	0	200	400	500	500
8a	Upstream of Island 1 to Coyote Rapids	0	0	0	0	0
9	Near Coyote Rapids	25	255	400	500	500
9a	Upstream of Coyote Rapids to China Bar	0	0	0	0	0
China Bar	China Bar/Midway	0	20	50	60	60
10	Near Vernita Bar	55	1,830	3,600	3,650	3,650
11	Upstream of Vernita Bar to Priest Rapids Dam	0	5	10	10	10
<b>Total</b>		<b>138</b>	<b>6,073</b>	<b>14,987</b>	<b>15,951</b>	<b>15,951</b>

**Table 11.2.** Summary of the Aerial Surveys for Fall Chinook Salmon Redd Counts by Potential Contaminated Groundwater Upwelling Subsections in the Hanford Reach, Columbia River (2014)

Sub-Area	10/20	11/10	11/24	12/1	Count
300	0	0	0	0	0
Dunes	0	0	0	0	0
100-F	0	400	1,100	1,100	1,100
100-H	25	730	2,030	2,080	2,080
100-D	0	200	400	500	500
100-N	0	0	0	0	0
100-K	0	0	0	0	0
100-BC	25	255	400	500	500
<b>Totals</b>	<b>50</b>	<b>1,585</b>	<b>3,930</b>	<b>4,180</b>	<b>4,180</b>

**Figure 11.1.** Fall Chinook Salmon Redd Counts (1948-2014)



### 11.1.1.2 Steelhead

Steelhead use the Hanford Reach for rearing as juveniles, as a migratory corridor for juveniles and adults, and for spawning as adults. Upper Columbia Summer-run Steelhead are currently listed as federally threatened under the Endangered Species Act of 1973 in [16 USC 1531](#) and as a state candidate in Washington ([WDFW 2015](#)). Because of their listing status and importance to recreational and tribal fisheries, steelhead were selected for monitoring under this program.

Steelhead build nests termed “redds,” in gravel or cobble substrate and spawn in the spring; the steelhead fry emerge from the gravel later that same spring. Adult steelhead generally use smaller tributary habitat and substrate; however, adult steelhead will spawn in larger mainstream rivers with suitable habitat, such as the Columbia River. Suitable spawning conditions within the Hanford Reach, occur between February and early June, with peak spawning in mid-May (Eldred 1970, *Steelhead Spawning in the Columbia River, Ringold to Priest Rapids Dam, September 1970 Progress Report*; (Watson 1973), *Estimate of Steelhead Trout Spawning in the Hanford Reach of the Columbia River*; [PNL-5371](#) and [DOE/RL-2000-27](#), *Anadromous Salmonids of the Hanford Reach, Columbia River: 1984 Status*

Aerial surveys for steelhead redds are conducted on the Hanford Reach in the spring of each year to identify potential spawning areas and timing as well as to provide an annual index of relative abundance among spawning areas. Although few redds have been counted in recent years, the surveys document any change in the status of steelhead spawning in the Hanford Reach and could help plan project activities to avoid redds, if any are identified. Similar to the methods used to document fall Chinook salmon spawning, the survey area is divided into 11 sections, with the number of redds being totaled by section. Eight additional sub-sections (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, the dunes, and 300 Area) were added in 2012 to monitor the abundance and distribution of steelhead redds in areas of potential upwelling of contaminated groundwater. The original 11 sections and the newer 8 sections are not mutually exclusive areas; they simply represent different divisions of the Hanford Reach area.

One aerial survey was completed along the length of the Hanford Reach for the 2014 survey season. The survey was performed on April 8, 2014. Viewing conditions were good. Weather was clear and warm with light and variable winds. River discharge from Priest Rapids Dam for the eight hours prior to the survey ranged from 121 to 131 thousand cubic feet per second (ft<sup>3</sup>/s) (3426 to 3710 thousand cubic meters/second [m<sup>3</sup>/s]). No steelhead redds were observed during the April 8 flight. River flows on the Hanford Reach increased above 160 thousand cubic feet per second (ft<sup>3</sup>/s) (4,531 thousand cubic meters/second [m<sup>3</sup>/s]) by mid-April and remained high for the remainder of the steelhead spawning season. No other steelhead redd survey flight was made in 2014.

### 11.1.1.3 Bald Eagle

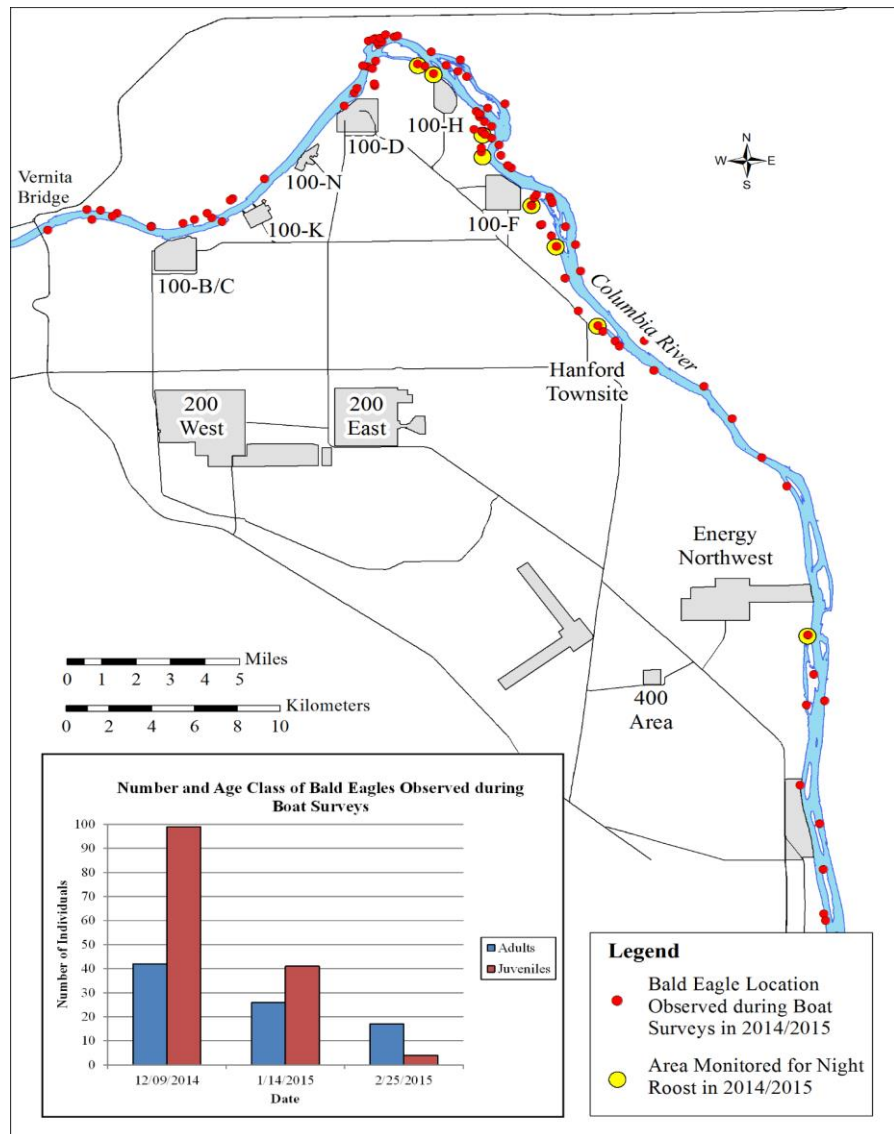
Bald eagles were removed from the federal endangered and threatened species list in July 2007, and were down-listed from threatened to sensitive by the WDFW in January 2008. Federal laws including the *Bald and Golden Eagle Protection Act of 1940* and the *Migratory Bird Treaty Act of 1918* still provide protection for eagles, their nest trees, and communal night roosts.

[DOE/RL-94-150](#) sets temporal and spatial restrictions on Hanford Site work activities to protect eagles and their habitats in accordance with current federal and state guidelines. Under the plan, communal night roosts and nest sites are protected with a 0.25 mile (400 meter) buffer zone. Night roost buffers are enforced from November 15 until March 15, and nest exclusion buffers are maintained until nest

abandonment or fledging of young, whichever is later. Work-related access into roost areas is allowed between 10 a.m. and 2 p.m. after notification of Hanford Site Ecological Compliance staff.

Monitoring bald eagles is essential to maintaining current biological information about their abundance and distribution on the Hanford Site, ensuring compliance with protection regulations, and informing future protection and management efforts and decisions. During the 2014-2015 season (as of March 24, 2015), 24 night roost surveys, 3 boat surveys, and 5 nest surveys were conducted. WDFW defines a communal or night roost as “a tree or a group of trees in which at least 3 eagles roost for at least two nights and during more than one year.” Night roost surveys were conducted at dusk, from ten minutes prior to sunset until dark. On three separate days between mid-December 2014 and late February 2015, night roost surveys were conducted at 8 locations.

Figure 11.2 Bald Eagle Boat Survey Results for the 2014-2015 Season



The entire Hanford Reach was surveyed by boat three times during the 2014-2015 season (mid-December, mid-January, and late February). Boat surveys are used to determine the number, age class, and distribution of eagles present on the Hanford Reach. Boat surveys also are used to identify additional potential night roosts and nest sites and to identify the primary foraging areas along the Hanford Reach. The maximum count of 141 bald eagles on the Hanford Reach for the 2014-2015 season (on December 9, 2014) was nearly double the previous record of 75 in 1996. This was most likely a result of the record number of adult fall Chinook salmon spawning in the Hanford Reach in 2013 and 2014. Spawning-out salmon carcasses that accumulate along the Hanford Reach provide bald eagles their primary food source. During 2014-2015 boat surveys, adult eagles were observed sitting on nests at both the upstream of Wooded Island location (on December 9, 2014) and the White Bluffs Peninsula (on February 25, 2015).

Nest site surveys were conducted in two locations (White Bluffs Peninsula and upstream of Wooded Island). Nest sites were monitored for nesting activities (e.g., a pair defending the nest from other eagles, nest tending, pair bonding behaviors). As of March 24, 2015, eagles appeared to be using both the White Bluffs Peninsula and the upstream of Wooded Island nests. The area is posted with a nest protection sign to ensure that no vehicular traffic approaches the nest within 436 yards (400 meters), as required by [DOE/RL-94-150](#). MSA staff will continue to monitor the nest to determine the outcome of the nesting attempt. Later in 2015, a complete bald eagle monitoring report will be available online at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

#### 11.1.1.4 Raptor Nest Monitoring

The Hanford Site supports a large and diverse community of raptorial birds ([Fitzner and Gray 1991](#)), with 26 species of raptors observed on the Hanford Site. Thirteen raptor species have been recorded nesting on the Hanford Site, including eight species of diurnal raptors and five species of owls. Several of these species are on state and federal threatened and endangered species lists ([WDFW 2015](#)). The ferruginous hawk (*Buteo regalis*) is a Washington State threatened species. The bald eagle is a Washington State sensitive species and a federal species of concern. The burrowing owl (*Athene cunicularia*) is a Washington State candidate species. And Swainson's hawks (*Buteo swainsoni*), prairie falcons (*Falco mexicanus*), and ospreys (*Pandion haliaetus*) are Washington State monitored species. Because of the status of these species, DOE-RL documents and protects nest locations to avoid disturbance during the nesting season and tracks populations over time to determine potential impacts of Hanford operations on these species and provide a level of protection afforded to them under the *Migratory Bird Treaty Act* (MBTA). Common ravens also nest on the Hanford Site, and although they are not considered raptors, they perform a similar ecological role.

Nest surveys for raptors and common ravens were conducted on DOE-managed lands, including central Hanford, McGee Ranch/Riverlands, the dunes, and southern shoreline of the Columbia River. Nests were located using vehicular and foot surveys. Nest searches occurred in late May and early June when all species occupy nesting territories. Survey methods used in 2014 were consistent with the methods used in 2012 and 2013 (Nugent et al. 2013, Nugent et al. 2014).

A total of 122 raptor nest sites were recorded in 2014 including 3 ferruginous hawks, 18 Swainson's hawks, 9-red-tailed hawks, 2 prairie falcons, 1 American kestrel, 1 bald eagle, 1 osprey, 1 great horned owl, 5 long-eared owls, 11 burrowing owls, and 70 common ravens. Nest substrates used by raptors and ravens on DOE-RL managed lands are shown in Table 11.3. All raptor and raven nest sites located in 2014 are displayed in Figure 11.3. A comparison of the number of raptor nest sites located from 2012 through 2014 is presented in Figure 11.4.

Figure 11.3. Raptor and Common Raven Nests (2014-2015 Season)

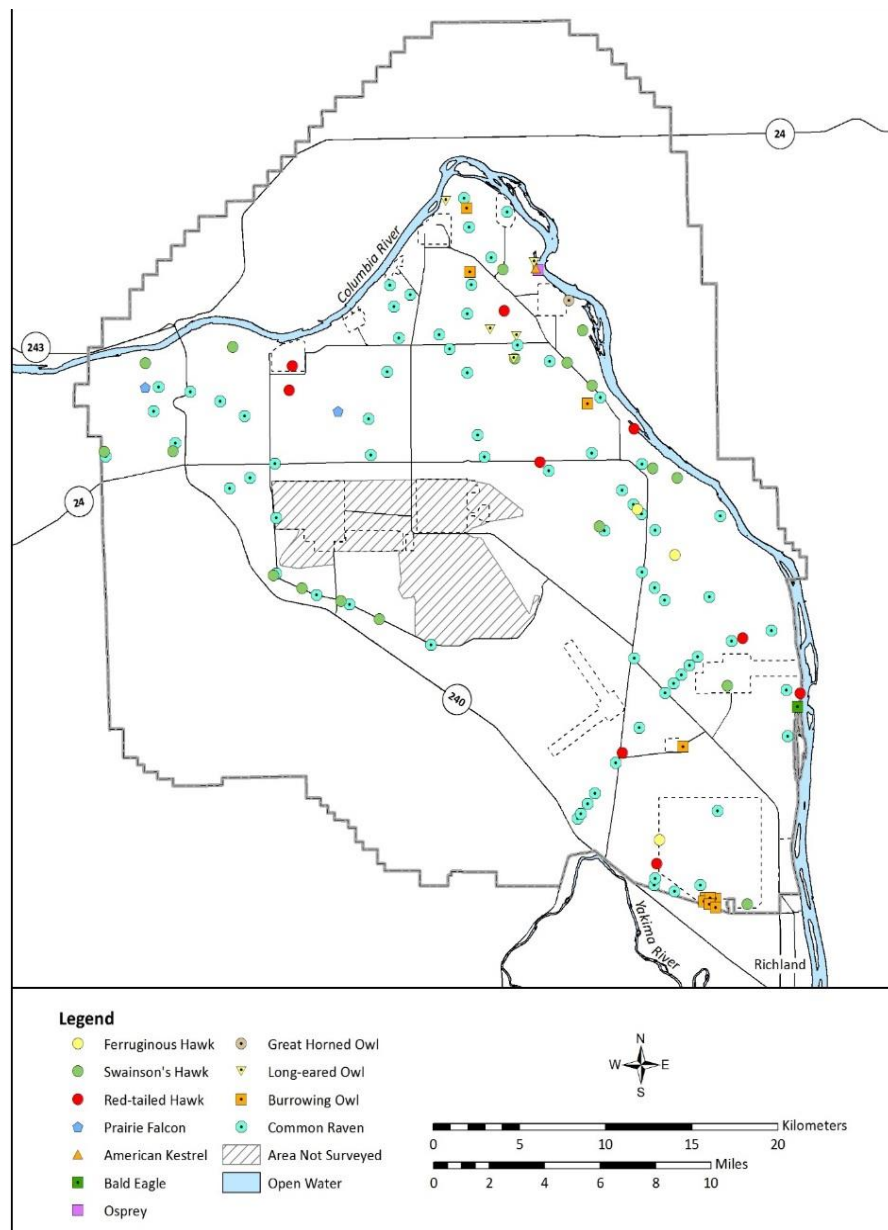
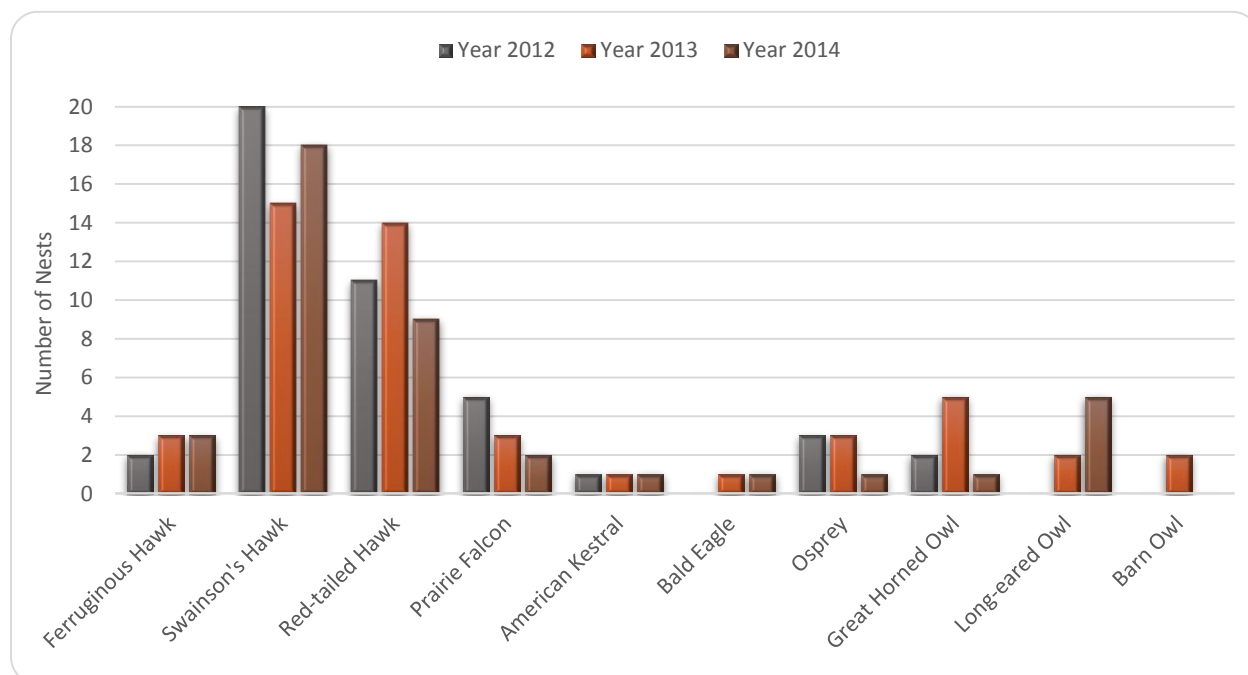


Table 11.2. Nest Substrates Used by Raptors and Ravens

Species	Tree	Cliff	Transmission Tower	Utility Pole	Electrical Substation	Nest Platform	Instrument Tower	Communications Tower	Building	Irrigation Pipe	Mammal Burrow	Artificial Burrow	Total
Ferruginous hawk			3										3
Swainson's hawk	15		1	2									18
Red-tailed hawk	3	1	4										9
Prairie falcon		2											2
American kestrel	1												1
Bald eagle	1												1
Osprey						1							1
Great horned owl	1												1
Long-eared owl	5												5
Burrowing owl <sup>1</sup>										2	3	6	11
Common raven <sup>2</sup>	12	1	45	7	2		1	1	1				70
<b>Total</b>	<b>38</b>	<b>4</b>	<b>53</b>	<b>9</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>6</b>	<b>122</b>

<sup>1</sup> Burrowing owls were recorded in separate monitoring reports in 2012 and 2013.<sup>2</sup> Common ravens are not technically raptors but occupy a similar ecological niche.

Figure 11.4. Number of Raptor Species Nest Sites



The first known successful bald eagle nest was documented on the Hanford Site upstream of Wooded Island in 2013. This bald eagle nest was successful again in 2014. In 2014, ferruginous hawks were observed at the same three nest sites that were occupied in 2013. In addition, 18 Swainson's hawk nests

were located, similar to observations the previous two years (20 in 2012 and 15 in 2013). These numbers were within the range (9 to 23 nests) found in the last 41 years. The number of red-tailed hawk nests located in 2014 (9) was fewer than observed the previous two years (11 in 2012 and 14 in 2013), but within the range (7 to 19 nests) located in the last 41 years. The 2 prairie falcon nests located were also fewer than observed the previous two years (5 in 2012 and 3 in 2013). American kestrel nest site numbers were expected to be much greater than the 1 nest detected during the survey; however, as secondary cavity nesters, American kestrels have many opportunities for nesting (holes and crevices on trees, cliffs, buildings, and other structures) on the Hanford Site that make locating their nests a considerable effort. In 2014, one osprey nest was observed on the nest platform near White Bluffs boat launch. Three nests were found in 2012 and 2013; it is unclear why the nest platforms in the 300 Area and the Hanford Townsite were not occupied in 2014 as they were in 2012 and 2013. Ospreys were first observed nesting on the Hanford Site in 2000 (Poston et al. 2001).

One great horned owl nest was located in 2014, which was a decrease from the 5 located in 2013 and the 2 found in 2012. Five long-eared owl nests were located, an increase from the 2 located in 2013, and 0 located in 2012. Barn owl nesting on the Hanford Site has been infrequent. No barn owl nests were located in 2014, although 2 nests were located in 2013. No nests were located in 2012. Short-eared owls rarely nest on the Hanford Site, and no nests were located from 2012 through 2014.

All burrowing owl nests located in 2014 were incidental observations; therefore, the number of burrowing owl nests recorded in 2014 should be considered incomplete. The incidental observations located 11 burrowing owl nest sites; 2 nest sites were located during one survey and an additional 9 were located during other ecological surveys. In 2012, 39 active burrows were located ([Wilde et al. 2012](#)), and in 2013, 50 active burrows were located ([Wilde et al. 2014](#)).

The number of common raven nest sites found on the Hanford Site has steadily increased in the last three years: 70 raven nests were located in 2014, 66 in 2013, and 63 in 2012. Additional details from this research are available in the *Hanford Site Raptor Nest Monitoring Report for Calendar Year 2014* ([HNF-58717](#)).

#### **11.1.1.5 Hanford Bird Surveys**

The Hanford Site contains a wide expanse of bird habitat, including basalt outcrops, riparian streams and springs, shrub-steppe on slopes and plains, sand dunes and blowouts, and abandoned fields or disturbed areas. Because of its large size, the site provides habitat for shrub-steppe birds that are entirely dependent on large expanses of sagebrush or areas with native grasses in the understory ([TNC 1999](#), *Biodiversity Inventory and Analysis of the Hanford Site*). In the majority of the Columbia Basin, human activities such as farming, urbanization, and industrial development have greatly decreased the amount of natural sagebrush-grass habitat and disturbance-free riparian zones that many endemic birds require for survival. Ultimately, human activities have caused the populations of a number of shrub-steppe birds to decrease, and some, such as the greater sage grouse (*Centrocercus urophasianus*), have been locally extirpated. Several sagebrush-steppe dependent species, such as the sagebrush sparrow (*Artemisiospiza nevadensis*), sage thrasher (*Oreoscoptes montanus*), and loggerhead shrike (*Lanius ludovicianus*) are currently listed by WDFW as candidate species and have the potential to be listed as threatened or endangered in the future ([WDFW 2015](#)).



In addition, the Hanford Site and surrounding area provide refuge to potentially 17 state-listed species including numerous birds: ferruginous hawks, state threatened; American white pelican (*Pelecanus erythrorhynchos*), state endangered; and bald eagle, state sensitive and federal species of concern ([WDFW 2015](#)).

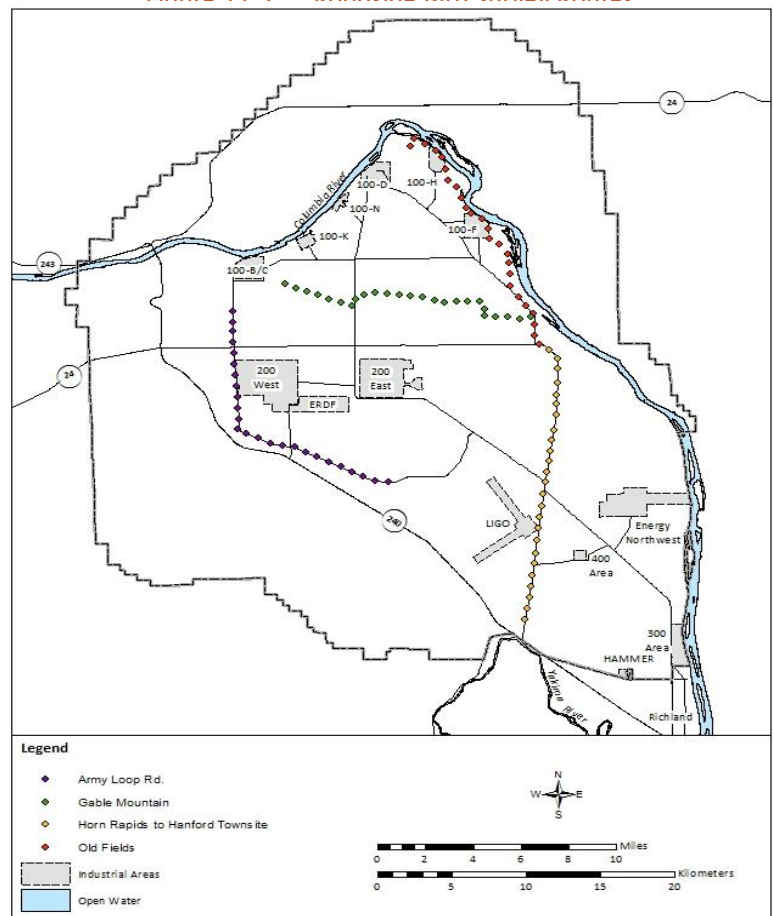
Ecological monitoring staff conduct road surveys to monitor changes in species richness and relative abundance of shrub-steppe birds over time and in response to various types of land-use changes. In 2014, roadside surveys were performed on June 9, 10, and 12. Three complete routes and a partial route from the four Hanford annual routes were surveyed in 2014 (Figure 11.5). The survey documented 1,332 individual birds, similar to the 1,264 individuals counted during the similar period on June 2013. A total of 51 bird species were documented, which was higher than the 47 species recorded in similar June 2013 surveys.

The Old Fields survey route had the highest species diversity, and the Army Loop Road survey route—where only one-half the points were surveyed—had the lowest species diversity (Table 11.3). The horned lark (*Eremophila alpestris*) was the most abundant species documented along all routes. Surveys documented 334 horned larks, 25.08 percent of all individuals counted.

The second most abundant species counted, the western meadowlark (*Sturnella neglecta*) documented 249 individuals (18.69 percent of birds surveyed). Horned larks were counted on 75 survey points (86.21 percent), and the western meadowlark was documented on 74 survey points (85.06 percent). These two species were counted at nearly three times as many survey points as any other species documented in 2014.

The Hanford bird monitoring program documents the presence, abundance, and distribution of species of concern on the Hanford Site. Both the USFWS and the WDFW maintain lists of species that are of management concern because populations or habitat availability are limited. In Washington, those listings include (in order of least to greatest concern) state candidate, state sensitive, state threatened, and state endangered. The WDFW also maintains a list of state monitor species, a group of birds that are not considered species of concern, but for which status and distribution data are document. There are currently no avian species listed as federally threatened or endangered on the Hanford Site, although several are considered federal species of concern in eastern Washington. Six state-listed species were recorded on the Hanford Site in the 2014 surveys: American white pelican, state endangered; bald eagle

Figure 11.5 Roadside Bird Survey Routes



state sensitive; ferruginous hawk, state threatened; loggerhead shrike, state candidate; sagebrush sparrow, state candidate; and sage thrasher, state candidate. Additional information detailing migratory bird monitoring efforts is available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

**Table 11.3. Species Richness and Abundance During 2014 Roadside Bird Surveys**

Route Name	Number of Surveys Performed	Number of Species	Abundance
Army Loop Road	0.5	8	116
Gable Mountain	1	13	214
Horn Rapids to Townsite	1	17	283
Old Fields	1	41	719
Total	3.5	51 <sup>a</sup>	1332

<sup>a</sup> Unique species identified.

## 11.2 Endangered and Threatened Species

*JA Pottmeyer*

This section describes federal and state endangered and threatened species, candidate or sensitive plant and animal species, and other species of concern potentially found at the Hanford Site. Endangered species are those in danger of extinction within all or a significant portion of their range. Threatened species are those likely to become endangered in the near future. Sensitive species are species that are vulnerable or declining and could become endangered or threatened without active management or removal of threats. The federal list of endangered and threatened species is maintained by the USFWS in [50 CFR 17.11](#), “Endangered and Threatened Wildlife” and [50 CFR 17.12](#), “Endangered and Threatened Plants.” The Washington Natural Heritage Program ([WNHP 2014](#)) and WDFW ([WDFW 2015](#)) maintain state lists.

The purposes of the *Endangered Species Act of 1973* ([16 USC 1531](#)), as amended, are to: 1) provide a means to conserve critical ecosystems; 2) provide a program for the conservation of endangered and threatened species; and 3) ensure appropriate steps are taken to achieve the purposes of the treaties and conventions established under the Act. Washington State regulations also list species as endangered and threatened, but such a listing does not carry the protection of the federal Endangered Species Act. The National Oceanic and Atmospheric Administration’s (NOAA) National Marine Fisheries Service ([NOAA 2015](#), *Endangered and Threatened Marine Species*) has the responsibility for federal listing of anadromous fish (i.e., fish that require both saltwater and freshwater to complete a lifecycle). The USFWS is responsible for all other federally listed species at the Hanford Site. Table 11.4 lists the federal species of plants and animals that occur or potentially occur on the Hanford Site and are listed as endangered, threatened, sensitive, or candidate by either the federal or state government.

Two federally listed fish species (spring-run Chinook salmon [*Oncorhynchus tshawytscha*] and steelhead [*Oncorhynchus mykiss*]) are known to occur regularly on the Hanford Site (Table 11.4). One additional fish species (bull trout [*Salvelinus confluentus*]) was recorded at the Hanford Site, but scientists believe this species is transient. Two plant species, Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Physaria douglasii* ssp. *tuplashensis*) were listed as threatened species under the federal *Endangered Species Act* in April 2013 ([78 FR 23984](#), “Endangered and Threatened Wildlife and Plants”); the rule was reaffirmed late in 2013 and was effective as of December 20, 2013 ([78 FR 23984](#), *Endangered*

and Threatened Wildlife and Plants). No other plants or animals known to occur on the Hanford Site are currently on the federal list of endangered and threatened species (<http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=50:2.0.1.1.1>), but one mammal species (Washington ground squirrel) and one bird species (greater sage grouse) are currently candidates for federal listing (Table 11.4). In addition, 12 plant species and 4 bird species have been listed as either endangered or threatened by Washington State. Numerous additional species of animals and plants are listed as candidate or sensitive species by Washington State. There are 33 state-level sensitive and candidate species of animals and 18 sensitive plant species occurring or potentially occurring on the Hanford Site (Table 11.4).

**Table 11.4 Federal and State Endangered, Threatened, Sensitive, and Candidate Species**

Common Name	Scientific Name	Federal Status <sup>a</sup>	State Status <sup>a</sup>
<b>Plants</b>			
Annual sandwort	<i>Minuartia pusilla</i> var. <i>pusilla</i>		Sensitive
Awned halfchaff sedge	<i>Lipocarpha</i> ( <i>Hemicarpha</i> ) <i>aristulata</i>		Threatened
Beaked spike-rush	<i>Eleocharis rostellata</i>		Sensitive
Canadian St. John's wort	<i>Hypericum majus</i>		Sensitive
Columbia milkvetch	<i>Astragalus columbianus</i>	Species of concern	Sensitive
Columbia yellowcress	<i>Rorippa columbiae</i>	Species of concern	Threatened
Coyote tobacco	<i>Nicotiana attenuata</i>		Sensitive
Desert cryptantha	<i>Cryptantha scoparia</i>		Sensitive
Desert dodder	<i>Cuscuta denticulata</i>		Threatened
Desert evening-primrose	<i>Oenothera cespitosa</i> ssp. <i>cespitosa</i>		Sensitive
Dwarf evening primrose	<i>Eremothera</i> ( <i>Camissonia</i> ) <i>pygmaea</i>		Sensitive
Fuzzytongue penstemon	<i>Penstemon eriantherus</i> var. <i>whitedii</i>		Sensitive
Geyer's milkvetch	<i>Astragalus geyeri</i> var. <i>geyeri</i>		Threatened
Grand redstem	<i>Ammannia robusta</i>		Threatened
Gray cryptantha	<i>Cryptantha leucophaea</i>	Species of concern	Sensitive
Great Basin gilia	<i>Aliciella</i> ( <i>Gilia</i> ) <i>leptomeria</i>		Threatened
Hairy bugseed	<i>Corispermum villosum</i>		Sensitive
Hedgehog cactus	<i>Pediocactus nigrispinus</i> ( <i>P. simpsonii</i> var. <i>robustior</i> )		Sensitive
Hoover's desert parsley	<i>Lomatium tuberosum</i>	Species of concern	Sensitive
Loeflingia	<i>Loeflingia squarrosa</i>		Threatened
Lowland toothcup	<i>Rotala ramosior</i>		Threatened
Piper's daisy	<i>Erigeron piperianus</i>		Sensitive
Rosy pussypaws	<i>Cistanthe</i> ( <i>Calyptridium</i> ) <i>rosea</i>		Threatened
Small-flowered evening-primrose	<i>Eremothera</i> ( <i>Camissonia</i> ) <i>minor</i>		Sensitive
Snake River cryptantha	<i>Cryptantha spiculifera</i> ( <i>C. interrupta</i> )		Sensitive
Suksdorf's monkey flower	<i>Erythranthe</i> ( <i>Mimulus</i> ) <i>suksdorfii</i>		Sensitive
Thompson's sandwort	<i>Eremogone</i> ( <i>Arenaria</i> ) <i>franklinii</i> var. <i>thompsonii</i>		Sensitive
Umtanum desert buckwheat	<i>Eriogonum codium</i>	Threatened	Endangered
White Bluffs bladderpod	<i>Physaria</i> ( <i>Lesquerella</i> ) <i>douglasii</i> ssp. <i>tuplashensis</i>	Threatened	Threatened
White eatonella	<i>Eatonella nivea</i>		Threatened
<b>Mollusks</b>			
California floater	<i>Anodonta californiensis</i>		Candidate
Columbia pebblesnail	<i>Fluminicola columbiana</i>		Candidate
Giant Columbia River limpet	<i>Fisherola nuttalli</i>		Candidate
<b>Insects</b>			
Columbia clubtail (Dragonfly)	<i>Gomphus lynnae</i>		Candidate
Columbia River tiger beetle <sup>b</sup>	<i>Cicindela columbica</i>		Candidate

Table 11.4 Federal and State Endangered, Threatened, Sensitive, and Candidate Species

Common Name	Scientific Name	Federal Status <sup>a</sup>	State Status <sup>a</sup>
Silver-bordered fritillary	<i>Boloria selene atrocostalis</i>		Candidate
<b>Fish</b>			
Bull trout <sup>c</sup>	<i>Salvelinus confluentus</i>	Threatened	Candidate
Leopard dace <sup>c</sup>	<i>Rhinichthys flacatus</i>		Candidate
Mountain sucker <sup>c</sup>	<i>Catostomus platyrhynchus</i>		Candidate
River lamprey <sup>c</sup>	<i>Lampetra ayresi</i>	Species of concern	Candidate
Chinook salmon (Upper Columbia Spring-Run)	<i>Oncorhynchus tshawytscha</i>	Endangered	Candidate
Steelhead (Upper Columbia)	<i>Oncorhynchus mykiss</i>	Threatened	Candidate
<b>Birds</b>			
American white pelican	<i>Pelecanus erythrorhynchos</i>		Endangered
Bald eagle	<i>Haliaeetus leucocephalus</i>	Species of concern	Sensitive
Burrowingowl	<i>Athene cunicularia</i>		Candidate
Clark's grebe	<i>Aechmophorus clarkii</i>		Candidate
Common loon	<i>Gavia immer</i>		Sensitive
Ferruginous hawk	<i>Buteo regalis</i>		Threatened
Flamulated owl <sup>c</sup>	<i>Otus flammeolus</i>		Candidate
Golden eagle	<i>Aquila chrysaetos</i>		Candidate
Greater sage grouse	<i>Centrocercus urophasianus</i>	Candidate	Threatened
Lewis's woodpecker <sup>c</sup>	<i>Melanerpes lewis</i>		Candidate
Loggerhead shrike	<i>Lanius ludovicianus</i>		Candidate
Northern goshawk <sup>c</sup>	<i>Accipiter gentilis</i>	Species of concern	Candidate
Peregrine falcon	<i>Falco peregrinus</i>	Species of concern	Sensitive
Sagebrush sparrow	<i>Artemisiospiza nevadensis (Amphispiza belli)</i>		Candidate
Sage thrasher	<i>Oreoscoptes montanus</i>		Candidate
Sandhill crane	<i>Grus canadensis</i>		Endangered
Western grebe	<i>Aechmophorus occidentalis</i>		Candidate
<b>Amphibians and Reptiles</b>			
Sagebrush lizard	<i>Sceloporus graciosus</i>		Candidate
Striped whipsnake	<i>Masticophis taeniatus</i>		Candidate
Western toad	<i>Bufo boreas</i>		Candidate
<b>Mammals</b>			
Black-tailed jackrabbit	<i>Lepus californicus</i>		Candidate
Merriam's shrew	<i>Sorex merriami</i>		Candidate
Townsend's ground squirrel	<i>Urocitellus townsendii</i>		Candidate
Washington ground squirrel <sup>c</sup>	<i>Urocitellus washingtoni</i>	Candidate	Candidate
White-tailed jackrabbit	<i>Lepus townsendii</i>		Candidate

<sup>a</sup> Endangered - Species in danger of extinction within all or a significant portion of its range.

Threatened - Species likely to become endangered in the near future.

Candidate - Species that are believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared.

Sensitive - Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats.

Species of concern - Species that are not currently listed or candidates under the Endangered Species Act of 1973, but are of conservation concern within specific USFWS regions.

<sup>b</sup> Probable, but not observed on the Hanford Site.<sup>c</sup> Reported, but seldom observed on the Hanford Site.

Washington State officials maintain additional lower level lists of species, including a monitor list for animals ([WDFW 2015](#)) and review and watch lists for plants ([WNHP 2014](#)). Species on the state monitor, watch, and review lists are not considered species of concern, but are monitored for status and distribution

(Table 11.5). These species are managed as needed by the state to prevent them from becoming endangered, threatened, or sensitive; however, an abundance of these species may be indicative of an ecosystem with relatively high native diversity. Approximately 50 state monitor list animal species occur or potentially occur on the Hanford Site (Table 11.5), as well as 24 watch or review list plant species (Table 11.6).

**Table 11.5 Washington State Monitored Animal Species**

Common Name	Scientific Name	Common Name	Scientific Name
<b>Birds</b>		<b>Fish</b>	
Arctic tern <sup>a</sup>	<i>Sterna paradisaea</i>	Pacific lamprey <sup>b</sup>	<i>Lampetra tridentata</i>
Ash-throated flycatcher <sup>a</sup>	<i>Myiarchus cinerascens</i>	Paiute sculpin	<i>Cottus beldingi</i>
Black tern <sup>a</sup>	<i>Chlidonias niger</i>	Reticulate sculpin	<i>Cottus perplexus</i>
Black-crowned night-heron	<i>Nycticorax nycticorax</i>	Sand roller	<i>Percopsis transmontana</i>
Black-necked stilt	<i>Himantopus mexicanus</i>	<b>Amphibians and Reptiles</b>	
Bobolink <sup>a</sup>	<i>Dolichonyx oryzivorus</i>	Night snake	<i>Hypsiglena torquata</i>
Caspian tern	<i>Sterna caspia</i>	Racer	<i>Coluber constrictor</i>
Forster's tern	<i>Sterna forsteri</i>	Short-horned lizard	<i>Phrynosoma douglasii</i>
Grasshopper sparrow	<i>Ammodramus savannarum</i>	Tiger salamander	<i>Ambystoma tigrinum</i>
Gray flycatcher	<i>Empidonax wrightii</i>	Woodhouse's toad	<i>Anaxyrus woodhousii</i>
Great blue heron	<i>Ardea herodias</i>	<b>Mollusks</b>	
Great egret	<i>Ardea alba</i>	Oregon floater	<i>Anodonta oregonensis</i>
Gyr Falcon <sup>a</sup>	<i>Falco rusticolus</i>	Western floater	<i>Anodonta kennerlyi</i>
Horned grebe	<i>Podiceps auritus</i>	Western pearlshell	<i>Margaritifera falcata</i>
Lesser goldfinch	<i>Spinus psaltria</i>	Winged floater	<i>Anodonta nuttalliana</i>
Long-billed curlew	<i>Numenius americanus</i>		
Osprey	<i>Pandion haliaetus</i>		
Prairie falcon	<i>Falco mexicanus</i>		
Red-necked grebe <sup>a</sup>	<i>Podiceps grisegena</i>		
Snowy owl	<i>Nyctea scandiaca</i>		
Swainson's hawk	<i>Buteo swainsoni</i>		
Turkey vulture <sup>a</sup>	<i>Cathartes aura</i>		
Western bluebird	<i>Sialia mexicana</i>		
<b>Insects</b>			
Juba skipper	<i>Hesperia juba</i>		
Nevada skipper	<i>Hesperia nevada</i>		
Pasco pearl crescent	<i>Phyciodes tharos pascoensis</i>		
Persius' duskywing	<i>Erynnis persius</i>		
Purplish copper	<i>Lycaena helloides</i>		
Ruddy copper	<i>Lycaena rubida perkinsorum</i>		
Viceroy	<i>Limenitis archippus lahontani</i>		
<b>Mammals</b>			
American badger	<i>Taxidea taxus</i>		
Canyon bat	<i>Parastrellus hesperus</i>		
Long-legged myotis <sup>b</sup>	<i>Myotis volans</i>		
Northern grasshopper mouse	<i>Onychomys leucogaster</i>		
Pallid bat	<i>Antrozous pallidus</i>		
Sagebrush vole	<i>Lemmys curtatus</i>		
Western small-footed myotis <sup>b</sup>	<i>Myotis ciliolabrum</i>		

<sup>a</sup> Reported, but seldom observed on the Hanford Site.

<sup>b</sup> Federal species of concern.

Table 11.6. Hanford Site Washington State Review and Watch List Plant Species

Common Name	Scientific Name	State Listing <sup>a</sup>
Annual paintbrush	<i>Castilleja exilis</i>	Watch List
Basalt milkvetch	<i>Astragalus conjunctus</i> var. <i>rickardii</i>	Watch List
Bristly combseed	<i>Pectocarya setosa</i>	Watch List
Chaffweed	<i>Anagallis (Centunculus) minima</i>	Watch List
Columbia River mugwort	<i>Artemisia lindleyana</i>	Watch List
Crouching milkvetch	<i>Astragalus succumbens</i>	Watch List
False pimpernel	<i>Lindernia dubia</i> var. <i>anagallidea</i>	Watch List
Giant helleborine	<i>Epipactis gigantea</i>	Watch List
Kittitas larkspur	<i>Delphinium multiplex</i>	Watch List
Medic milkvetch	<i>Astragalus speirocarpus</i>	Watch List
Pigmy-weed	<i>Crassula aquatica</i>	Watch List
Porcupine sedge	<i>Carex hystericina</i>	Watch List
Robinson's onion	<i>Allium robinsonii</i>	Watch List
Rosy balsamroot	<i>Balsamorhiza rosea</i>	Watch List
Scilla onion	<i>Allium scilloides</i>	Watch List
Shining flatsedge	<i>Cyperus bipartitus (C. rivularis)</i>	Watch List
Shy gilly-flower	<i>Gilia inconspicua</i>	Review Group 1
Small-flowered nama	<i>Nama densum</i> var. <i>parviflorum</i>	Watch List
Smooth cliffbrake	<i>Pellaea glabella</i> var. <i>simplex</i>	Watch List
Smooth willowherb	<i>Epilobium pygmaeum</i>	Review Group
Southern mudwort	<i>Limosella acaulis</i>	Watch List
Stalked-pod milkvetch	<i>Astragalus sclerocarpus</i>	Watch List
Vanilla grass	<i>Anthoxanthum hirtum (Hierchloe odorata)</i>	Review Group 1
Winged combseed	<i>Pectocarya penicillata</i>	Watch List

<sup>a</sup> Watch List: Taxa that are of conservation concern, but are more abundant and/or less threatened than previously assumed. Review Group 1: Taxa for which currently there are insufficient data available to support listing as threatened, endangered, or sensitive.

### 11.3 Cultural and Historic Resource Protection

MC Petrich-Guy, CD Currie, AP Fergusson, and KM Mendez

Cultural and historic resources protection on the portions of the Hanford Site is conducted under the auspices of the RL Cultural Resources Program to ensure site compliance with federal cultural resources laws and regulations (Section 2.5). Program activities in 2014 included the following:

- ⊗ Performed Cultural Resource Reviews (CRR) for federal undertakings conducted at the Hanford Site in accordance with Section 106 of the NHPA ([16 USC 470](#)) and NEPA
- ⊗ Monitored site conditions to ensure important cultural resources are protected
- ⊗ Maintained a database of cultural resources site records, project records, and regional ethno-history
- ⊗ Maintained archaeological and historical collections
- ⊗ Identified and evaluated new cultural resources to ensure they are appropriately managed
- ⊗ Consulted with Native American Tribes and other stakeholders to gather input on the identification, documentation, and management of cultural resources important to them.



RL's Cultural Resources Program personnel oversee all cultural resource activities at the Hanford Site. NHPA Section 106 compliance work scope in 2014 was performed by staff archaeologists from MSA and WCH.

The RL Cultural Resources Program also schedules monthly meetings with all archaeological staff from the Hanford Site contractors to discuss and resolve issues relating to Cultural Resources Management (including survey procedures, site testing, site evaluation, consultations with external parties, etc.), with the objective of establishing and maintaining consistency among contractors.

### 11.3.1 Cultural Resources Reviews

Pursuant to the NEPA, and Section 106 of the *National Historic Preservation Act of 1966*, RL conducts cultural resources reviews of federal undertakings at the Hanford Site. The Section 106 regulations are also addressed as ARAR ([Section 121\(d\)](#)) under the [CERCLA](#), requiring remedial actions to identify and take into account the effects of activities on historic properties included on or eligible for inclusion on the National Register of Historic Places (NRHP). Section 106 cultural resource reviews ensure that important cultural resources are identified and effects to those resources are evaluated prior to project initiation so that mitigation measures can be conducted, if necessary.

Hanford Site archaeologists completed 122 Section 106 cultural resource reviews, including 73 proposed projects that did not involve ground disturbance. These projects were determined exempt by Hanford Site archaeologists after meeting the RL-approved [Historic Buildings Programmatic Agreement](#) (DOE/RL-96-77) exemption criteria following an initial review, or had satisfied the requirements of *National Historic Preservation Act* Section 106 under a prior review (Previously Reviewed Project Analyses Reviewed Project Analysis). Hanford Site archaeologists reviewed and completed five projects under an emergency declaration (Post Reviews) in accordance with Section 5.1.1 of the *Hanford Cultural Resources Management Plan* ([DOE/RL-98-10](#)). Most projects cleared under these expedited reviews occurred in the 200 Areas of the Hanford Site (Figure 11.6).

Hanford Site archaeologists also reviewed 17 undertakings in 2014 that had the potential to affect cultural resources, which included efforts to identify cultural resources that might be affected by project activity, an assessment of potential impacts, and the development of mitigation measures, if necessary<sup>3</sup>. Of the 17 undertakings, 13 were identified as *No Historic Properties Affected*, while four were determined to have *No Adverse Effects* to historic properties. One project identified as having *Adverse Effects* required mitigation measures as documented in a resulting project-specific Memorandum of Agreement. Adverse effects were avoided by taking specific actions to minimize impacts, including avoidance, following treatment plan guidelines, and archaeological monitoring. Approximately 1,566 acres (634 hectares) of new ground was surveyed for cultural resources, because of the 17 undertakings that had the potential to physically affect cultural resources. In addition, some undertakings required NRHP ([36 CFR 60](#)) eligibility evaluations, including sub-surface archaeological testing.

During CY 2014, DOE-RL completed the Section 106 work for proposed radiological characterization sampling of sediments within the area being evaluated for a proposed land conveyance on the Hanford

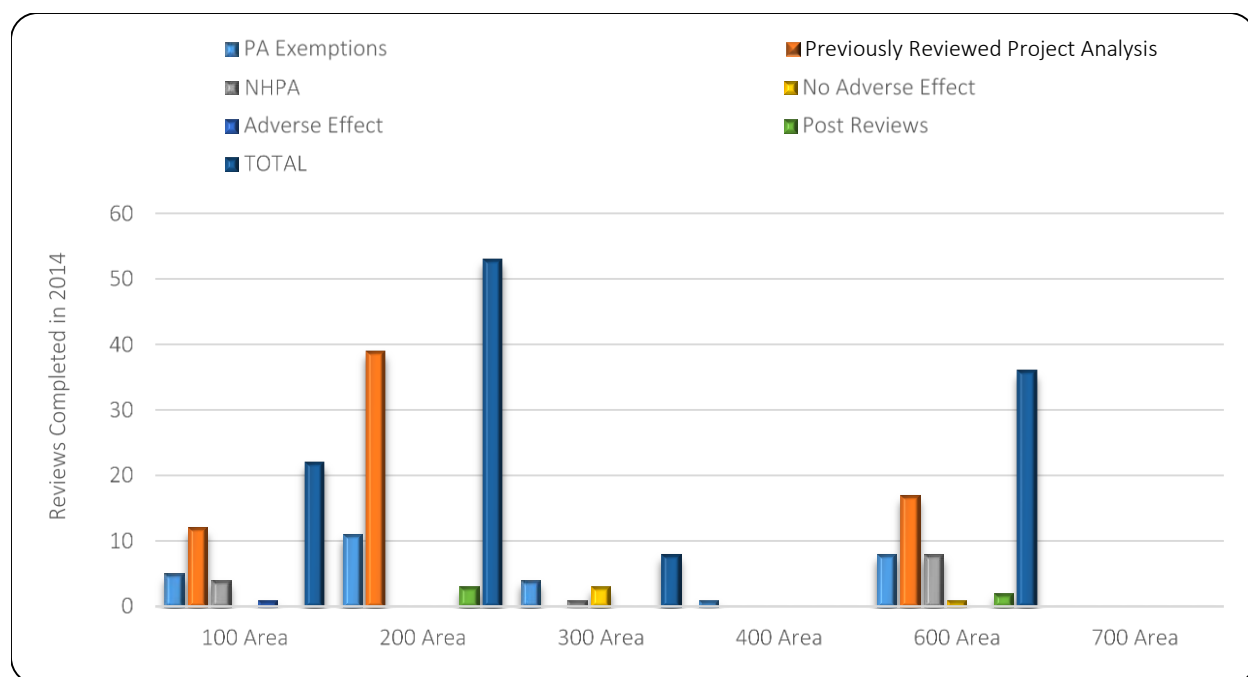
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<sup>3</sup> This number does not reflect all full cultural resources reviews initiated in 2013. Additional reviews were initiated in 2014, but completed in 2015, and are not included in this report.

Site. The radiological characterization sampling activities included collecting surface soil samples at 165 locations and 8 landscape features and ground scanning with an all-terrain vehicle-mounted gamma spectrometer. The area being evaluated contains a number of archaeological sites and isolates, including three properties that are eligible for listing in the NRHP.

An archaeological survey was conducted as part of the Section 106 review of this activity. During that survey, five previously unrecorded archaeological sites were identified. Subsurface testing was conducted at each of the newly identified sites to aid in the completion of NRHP evaluations. All subsurface testing results were negative, and the five newly discovered sites were found to be not eligible for listing in the NRHP. The radiological sampling plan was revised to relocate samples outside of archaeological sites, and monitoring of sample locations was conducted to avoid affecting historic properties. Through archaeological survey, testing, and monitoring and project design DOE was able to make a finding of No Historic Properties Affected, and the Washington State Department of Archaeology and Historic Preservation (DAHP) concurred with this finding.

*Figure 11.6. Hanford Site National Historic Preservation Act Section 106 Reviews by Area*



Cultural Resources staff completed Section 106 work for proposed radiological and chemical characterization sampling of sediments at two large waste sites on the Columbia River floodplain of the Hanford Site. These waste sites were associated with discharged water from the cooling of the 100-K Area reactor cores during Hanford Site operations and overlapped with areas of both significance and importance to area tribes and NRHP- ([36 CFR 60](#)) eligible properties. DOE, along with several other state and federal agencies (including Ecology and EPA) and tribal leaders, worked together to incorporate tribal preference in soil sampling techniques into protocols to be implemented in these culturally sensitive areas. Soil characterization sampling activities would generally include invasive and extensive excavations using heavy machinery; however, in consultation with area tribes, the working group was able to design minimally invasive sampling techniques to recover characterization samples from these waste sites.

Specifically, characterization samples were collected from shovel test units excavated using archaeological excavation techniques with the assistance of tribal monitors and elders. Artifacts encountered in the test units were documented and analyzed in the field and reburied. Archaeological information collected during these field efforts is being compiled into a technical report, which will be shared with consulting parties and maintained in the records of both DOE and the DAHP. Performing the work in this way, with the archaeological testing and characterization sampling completed in tandem, ensured that data on the sites of cultural and religious significance were appropriately documented for future use, while also ensuring that soil for characterization was collected with minimum impacts to this culturally sensitive area.

### 11.3.2 Cultural Resources Protections and Section 110 Activities

To ensure protection of the cultural and historic resources located on the Hanford Site, monitoring activities are conducted to comply with Section 110 of the NHPA ([36 CFR 60](#)), and the *Archaeological Resources Protection Act* (ARPA) ([54 USC 312501](#)). ARPA was enacted “...to secure, for the present and future benefit of the American people, the protection of archaeological resources and sites which are on public lands and Indian lands, and to foster increased cooperation and exchange of information between governmental authorities, the professional archaeological community, and private individuals” (Sec. 2(4)(b)). A monitoring program has been in place since 1989 to assess the effects of weathering and erosion and/or unauthorized excavation and collection of significant cultural resources on the Hanford Site. Activities include onsite inspections to monitor site conditions, assess impacts, and identify protective measures, if necessary.

In 2014, nine pre-contact archaeological sites were monitored under the Section 110 Site Conditions Monitoring program. Site visits are conducted with the participation of tribal cultural resources personnel. In addition, the Section 110 program was adjusted to ensure compliance with applicable regulations. A work plan was established that will ensure all components of Section 110 are addressed, including identification, nomination, and protection of historic properties. A five-year plan was established that, if implemented, will allow all sites included in the monitoring program to be evaluated for National Register eligibility by 2020. The changes made to the monitoring program will ensure that site condition monitoring is completed in a comprehensive and efficient manner that can be helpful in making resource management decisions.

#### 11.3.2.1 Identification and Evaluation Activities

Identification and evaluation activities are performed to comply with Sections 106 and 110 of the NHPA. In 2014, eight new archaeological sites were recorded, and no new isolated finds were located (Table 11.7). National Register evaluations were completed on three newly discovered sites; two were determined eligible for listing in the National Register. Five new sites were not evaluated. Archaeological site forms for three previously recorded archaeological sites were updated, of which two were evaluated for National Register eligibility; one was determined eligible for listing. No Historic Property Inventory Forms (HPIF) were completed during the reporting period for components of Hanford’s built environment.

*Table 11.7. Sites and Isolates Recorded or Updated*

<b>2014</b>	<b>Eligible</b>	<b>Not Eligible</b>	<b>Unevaluated</b>	<b>Total</b>
Site updates	1	1	1	<b>3</b>
New sites	2	1	5	<b>8</b>
New isolates	0	0	0	<b>0</b>
Historic Property Inventory Form	0	0	0	<b>0</b>
<b>Total</b>	<b>3</b>	<b>2</b>	<b>6</b>	<b>11</b>

### 11.3.2.2 Data and Artifact Collections Management.

In 2014, the Cultural Resources Program transitioned to a paperless record keeping system. The Hanford Site Section 106 database tracks all cultural resource reviews conducted on the Hanford Site. The Section 106 database tracks dates, actions, letters, and results of the cultural resource reviews. Once a project is complete, it is closed out in the database and accessioned into the MSA digital archives for use by all Hanford Site Cultural Resource contractors and other interested researchers. Maintenance of these files is essential to the completion of all cultural resource compliance activities conducted on the Hanford Site.

In 2014, 174 new projects were opened, with pertinent information entered as acquired into the Section 106 database, and 143 projects were closed out after data entry was complete, with a digital copy of the project documentation added to the digital archive.

The cultural resources Geographic Information System (GIS) database contains cultural resource data collected from Hanford Site contractors, including new archaeological surveys completed as part of Section 106 work, newly recorded, and updated archaeological site locations, and contextual information describing the survey or site. All Hanford Site contractors use the GIS database for literature reviews, cultural resource compliance reporting, and documentation, and research by RL approved users. In 2014, as part of ongoing database management, a total of 20 polygons delineating completed archaeological surveys were added to the Hanford Site Survey Master shapefiles (map file), and five new archaeological sites/isolates, together with associated spatial and contextual information, were added to the GIS Archaeological Site and Isolate database. Spatial and contextual information for four archaeological sites/isolates were updated in this database based on information gathered during recent re-visits to these locations.

Largely due to excavations conducted as mitigation for adverse effects on archaeological sites, the Cultural and Historic Resources Program manages a collection of artifacts relating to the Native American settlement of the area within the mid-Columbia Basin that would become the Hanford Site. Similarly, a small collection of artifacts that mark the pre-1943 Euro-American settlement of the Priest Rapids Valley, later designated as the Hanford Site, is also maintained. These artifacts are stored at the Washington State University Tri-Cities Campus, Central Information Center, which maintains a climate controlled, restricted access facility. The forms and reports that document the excavations and interpret these sites also are held by the Cultural and Historic Resources Program. No new artifacts were added to either the prehistoric or the pre-Hanford collections in 2014.

### 11.3.3 Cultural Resources Consultations and Public Involvement

DOE conducts formal consultations with the Washington State Historic Preservation Officer (SHPO) within the DAHP, Native American tribes, and other interested parties for cultural resource reviews to

comply with Section 106 of the NHPA and NEPA (Section 2.1.4). RL consulted with the Washington SHPO and Native American tribes on all 17 projects that required a full review because of their potential to affect cultural resources within the project area.

DOE Cultural Resources Program staff held 10 meetings in 2014 with Tribal Cultural Resources staff from the [CTUIR](#), the Confederated Tribes and Bands of the Yakama Nation, the Nez Perce Tribe, and the Wanapum. Discussions focused on the cultural resource reviews both completed and initiated in 2014; proposed undertakings within traditional cultural property (TCP) boundaries and view sheds; and approaches to protecting threatened archaeological sites and places containing Native American human remains.

### **11.4 Hanford Site Manhattan Project and Cold War Era Collection Management**

*TE Marceau*

The Hanford Collection comprises artifacts from the Manhattan Project and Cold War era. These artifacts were obtained in compliance with the *Programmatic Agreement among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington* ([DOE/RL-96-77](#)). This programmatic agreement directs RL to identify and preserve any artifacts that may have value as interpretive or educational exhibits within national, state, or local museums. During 2014, 47 artifacts were picked up from Hanford Site facilities and delivered to the 4732-A Artifact Staging Facility, leaving 42 (5.7 percent) of the 743 tagged artifacts to be collected. Of the final 42 artifacts remaining to be collected, 3 were determined to be unfeasible to collect, 12 have radiological concerns that must be resolved before release, and 27 are scheduled for collection between 2015 and 2048.

To address the risks of releasing radiologically controlled artifacts (artifacts within or known to have been within radiologically controlled areas), a museum scenario was developed to evaluate these artifacts and the technical and administrative feasibility of releasing them. The museum scenario uses a graded approach to determine the level of radiological survey required. It also uses the existing Hanford Site pre-approved authorized limits and dose constraints identified in [DOE O 458.1](#) to determine whether the radiologically controlled artifacts can be released for public clearance/viewing without additional conditions or restrictions on the storage, handling, or display.

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## 12.0 Quality Assurance

RA Westberg

Quality assurance (QA) and quality control (QC) practices encompass all aspects of Hanford Site environmental monitoring and surveillance activities. Hanford Site contractors, subcontractors, and multiple DOE organizations are involved in and conduct environmental monitoring and surveillance activities independently—each driven by different missions and regulatory requirements, but with the same goal in mind. This section describes the Environmental Surveillance program, part of the Public Safety and Resource Protection Program managed by MSA. The Environmental Surveillance program includes environmental surveillance and monitoring across multiple media types both on and off the Hanford Site. The program conducts multi-media environmental monitoring to assess Hanford Site and offsite human health exposures to radionuclides and chemicals and evaluate the potential impact of site operations on the environment. This section provides information on specific measures taken in 2014 to ensure quality and defensibility in project management, sample collection, and analytical results.

Note: Because of the complexity of the groundwater program, QA/QC specifications for groundwater sampling and program management are reported independently in the <http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports> and in Appendix D of this report and are not discussed in this section.

Quality assurances and controls of the Hanford Site and offsite surveillance programs are documented through QA program plans and describe applicable QA elements (e.g., MSC-23333, *Environmental Quality Assurance Program Plan*). Sample analyses across all media types are performed by onsite and offsite contracted laboratories, which are also required to meet these plan specifications. To ensure the highest quality data are obtained, accredited offsite laboratories used were audited for equipment and services before the contract awards were made.

### 12.1 Program Management

Per federal requirements, environmental surveillance activities are subject to an overall QA program. This program satisfies the requirements for collecting and assessing environmental data in compliance with the following:

- ⊗ [10 CFR 830](#), “Nuclear Safety Management,” Subpart A, Quality Assurance Requirements
- ⊗ [DOE O 414.1D](#), *Quality Assurance*
- ⊗ [Analytical Services - Hanford Site](#), *Hanford Analytical Services Quality Assurance Requirements Documents* (HASQARD)
- ⊗ [EPA/240/B-01/003](#), *EPA Requirements for Quality Assurance Project Plans*
- ⊗ Richland Requirements Document 008, Quality Assurance Program Requirements
- ⊗ Project-specific QA plans and documentation are found in MSC-23333 and describe the QA/QC elements associated with the Environmental Surveillance program.

#### DOE O 414.1D QA Program Requirements

- ⊗ Management/QA Program
- ⊗ Personnel Training/Qualification
- ⊗ Quality Improvement
- ⊗ Documents and Records
- ⊗ Work Processes
- ⊗ Design
- ⊗ Procurement
- ⊗ Inspection and Acceptance Testing
- ⊗ Management Assessment
- ⊗ Independent Assessment

### 12.1.1 Personnel Training and Qualifications

Hanford Site personnel are provided with the knowledge and skills necessary to perform specific jobs safely, effectively, and efficiently with minimal supervision. This capacity is accomplished by establishing and enforcing site-wide policies, procedures, and guidance through training programs that provide general and specialized training classes and housing hands-on training facilities dedicated to ensuring personnel are qualified and confident to perform the task safely. The following principles and practices are included in the training program and are documented in MSC-23333:

- ⊗ Develop training standards and procedures that meet valid requirements and regulations and are consistent with industry-proven best management practices
- ⊗ Recognize management's responsibility to lead and coach their employees to ensure employees are trained and remain proficient to perform assigned tasks
- ⊗ Conduct evaluations of employee training to ensure regulatory compliance, compliance with standards and instructions, and improve the training process
- ⊗ Employ instructional staff and subject matter experts who are qualified and maintain their instructional and subject area skills and knowledge
- ⊗ Use a graded approach to develop training programs to ensure value and effectiveness.

## 12.2 Quality Control Samples

Several types of QC samples are collected during monitoring and sampling events. The QC samples are in place to help reduce data uncertainty and collect the highest quality data possible. The tasks vary by monitoring and sampling event, and QC procedures are followed in the field and laboratory to ensure reliable data are obtained.

Field environmental QC samples are collected to evaluate the potential for cross-contamination and provide information pertinent to field variability. Field QC samples require the collection of field duplicates, trip or field blanks, and equipment blanks.

Laboratory QC samples estimate the precision and accuracy of the analytical data and include method blanks, laboratory replicates, matrix spikes, and matrix spike duplicates. Table 12.1 summarizes the different types, characteristics, and frequency of QC samples.

A QC sample frequency goal of 5 percent, or 1 in 20 samples, where feasible, is set for environmental surveillance activities on the Hanford Site for the number of QC samples needed for environmental data collection and surveillance activities.

**Blanks:** A sample of the carrying agent (gas, liquid, or solid) normally used to measure selectively a material of interest that is subjected to the usual analytical process and associated procedures to establish a baseline or background value. This value is then used to adjust or correct the routine analytical results.

**Field Duplicate Samples:** Two samples produced from material collected in the same location at roughly the same time. The parent sample and its duplicate are each uniquely labeled and used to provide information on the homogeneity of the matrix and ensure consistency in sample collection procedures.

**Laboratory Replicate Sample:** A single sample aliquoted alternately into two sets of sample containers for duplicate analysis by the primary laboratory. Lab replicates are a measure of variation of aliquots analyzed from the same sample.

**Spiked Sample:** A normal sample of material (gas, liquid, or solid) to which a known amount of some substance of interest is added. Spiked samples check the accuracy of a routine analysis or the recovery efficiency of an analytical method. Spiked samples are exclusively used by the laboratory.

**Table 12.1** Field and Laboratory Quality Control Sample Types, Characteristics, and Frequency

Sample Type	Primary Characteristics Evaluated	Frequency
<b>Field QC Samples</b>		
Field trip blank (FTB)	Volatile organic compound cross-contamination from other sources during transportation	1 per field trip
Equipment blank (EB)	Cross-contamination from non-dedicated equipment	1 per sampling method type per year for selected analytes
Duplicate	Reproducibility	1 per 20 samples, where feasible
<b>Laboratory QC Samples</b>		
Method blank	Laboratory contamination	<sup>a</sup>
Laboratory replicate	Laboratory reproducibility	<sup>a</sup>
Matrix spike	Matrix effect and laboratory accuracy	<sup>a</sup>
Matrix spike duplicate	Laboratory reproducibility/accuracy	<sup>a</sup>

<sup>a</sup> As defined in the laboratory contract or QA plan, and/or analysis procedures.

### 12.3 Sample Collection Quality Assurance and Quality Control

Environmental samples were collected for air, surface water, biota (wildlife and food and farm products), soil and vegetation, and sediment by trained personnel in accordance with approved desk instructions and/or procedures. Established sampling locations were accurately identified with visible postings or plotted GPS readings and documented to ensure continuity of data. In 2014, environmental samples collected were either submitted to General Engineering Laboratories, LLC (GEL) or the WSCF laboratory, located in the 200 Area of the Hanford Site for radiochemical analyses, from January 1, 2014, until the lab closed on May 31, 2014 (Table 12.2).

**Table 12.2.** Laboratories and Types of Environmental Surveillance Samples Analyzed

Analytical Laboratory	Environmental Monitoring and Surveillance Samples			
	Air	Water	Biota	Other
WSCF	X			X
GEL	X	X	X	X
GEL = General Engineering Laboratories, LLC		WSCF = Waste Sampling and Characterization Facility		

Personnel are trained to conduct sampling in accordance with approved schedules, instructions, and procedures. Field assessments are routinely performed by media task leads and documented. Field duplicate samples are used to assess sampling and measurement precision. In 2014, duplicate samples were collected and analyzed for offsite media in air, Columbia River water, milk, potatoes, sediment, and seep samples (Table 12.3).

**Table 12.3.** Hanford Site Offsite Media Field Duplicate Samples and Locations

Media	Location	Number of Samples
-------	----------	-------------------

Air	300 South Gate	26
Columbia River Water	Hanford Townsite - HRM 28.7	5
Columbia River Water	Priest Rapids Dam	5
Milk	Sagemoor Area	1
Potato	East Wahluke Area	1
Sediment	Hanford Slough	1
Seep	Hanford Townsite	6

HRM: Hanford River Mile.

Field duplicates for Hanford Site samples and locations collected included air, soil, and natural vegetation (Table 12.4). Hanford Site air samples were collected and analyzed bi-weekly from two locations, then composited semiannually, by location, for isotopic analysis.

*Table 12.4. Hanford Site Media Field Duplicate Samples, Locations, and Constituents Analyzed*

Media	Location	Number of Samples
Air	200-West Area	26
Soil	Various	6
Water	Fast Flux Test Facility Pond	2
Wildlife	Various	6
Natural Vegetation	U-Plant	2

Analytical results for onsite and offsite parent and duplicate samples were reviewed against the criterion that the result must be greater than the minimum detectable activity value or the method detection limit to be evaluated (commonly known as a detect). To be considered an acceptable result (a result within the control limits); the relative percent difference (RPD) of the detected routine sample and its duplicate must also be less than 30 percent. Duplicate results for 2014 are shown in Tables 12.5 and 12.6.

#### ***Relative Percent Difference (RPD)***

A measure of the precision of the measurement of a sample (S) and its duplicate (D). The formula is as follows:

$$RPD = \left( \frac{|S - D|}{\frac{(S + D)}{2}} \right) \times 100$$

*Table 12.5. Offsite Media<sup>a</sup> Field Duplicate Sample Results*

Media	Detected Analytes	Number of Results Within Control Limits <sup>b</sup>	Percent of Results within Control Limits
Air	Alpha (gross)	15 of 26	58
	Beta (gross)	22 of 26	85
	Americium-241	1 of 1	100
	Antimony-125	1 of 1	100
	Colbalt-60	1 of 1	100
	Cesium-134	1 of 1	100
	Cesium-137	1 of 1	100
	Europium-152	1 of 1	100
	Europium-154	1 of 1	100
	Europium-155	1 of 1	100
	Hydrogen-3 (tritium)	12 of 12	100
	Plutonium-238	1 of 1	100
	Plutonium-239/240	1 of 1	100
	Potassium-40	1 of 1	100
	Ruthenium-106	1 of 1	100
	Strontium-90	1 of 1	100
	Uranium-234	1 of 1	100
	Uranium-235	1 of 1	100
	Uranium-238	1 of 1	100
Farm Products			
Milk	Hydrogen-3 (tritium)	1 of 1	100
	Potassium-40	1 of 1	100
Potato	Potassium-40	1 of 1	100
Surface Water			
Pond	Beta (gross)	0 of 1	0
	Hydrogen-3 (tritium)	1 of 1	100
	Cesium-137	0 of 1	0
Columbia River	Potassium-40	0 of 1	0
	Hydrogen-3 (tritium)	1 of 2	50
	Uranium-234	2 of 3	67
	Uranium-235	0 of 1	0
	Uranium-238	3 of 3	100
Seep	Beta (gross)	1 of 1	100
Offsite Irrigation	Hydrogen-3 (tritium)	0 of 1	0
Sediment	Potassium-40	1 of 1	100
	Cesium-137	1 of 1	100
	Uranium-234	1 of 1	100
	Uranium-235	0 of 1	0
	Uranium-238	1 of 1	100
	Plutonium-239/240	1 of 1	100
Wildlife	Potassium-40	4 of 4	100
	Strontium-90	1 of 1	100

Table 12.5. Offsite Media<sup>a</sup> Field Duplicate Sample Results

Media	Detected Analytes	Number of Results Within Control Limits <sup>b</sup>	Percent of Results within Control Limits
<b>Anions</b>			
Surface Water	Chloride	1 of 1	100
	Fluoride	1 of 1	100
	NO <sub>3</sub> -N	1 of 1	50
	Sulfate	1 of 1	100
Seep	Chloride	1 of 1	100
	Fluoride	1 of 1	100
	NO <sub>3</sub> -N	1 of 1	100
	Sulfate	1 of 1	100
Sediment	Chloride	0 of 1	0
	Sulfate	1 of 1	100
<b>Metals</b>			
Surface Water	Copper	1 of 2	50
	Uranium	2 of 2	100
	Zinc	2 of 2	100
Seep	Copper	2 of 2	100
	Uranium	2 of 2	100
	Zinc	1 of 2	50
	Arsenic	1 of 1	100
Wildlife	Copper	1 of 1	100
	Manganese	1 of 1	100
	Zinc	2 of 2	100
	Selenium	1 of 1	100
Sediment	Arsenic	1 of 1	100
	Beryllium	1 of 1	100
	Cadmium	1 of 1	100
	Chromium	1 of 1	100
	Copper	1 of 1	100
	Lead	1 of 1	100
	Mercury	1 of 1	100
	Nickel	1 of 1	100
	Zinc	1 of 1	100



Table 12.6. Hanford Site Media Field Duplicate Sample Results

Detected Analytes	Number of Results in Control Limits <sup>a</sup>	Percentage of Results in Control Limits
<b>Air Filters</b>		
Alpha (gross)	24 of 27	89
Beta (gross)	22 of 27	81
Antimony-125	2 of 2	100
Cesium-134	2 of 2	100
Cesium-137	2 of 2	100
Cobalt-60	2 of 2	100
Europium-152	2 of 2	100
Europium-154	2 of 2	100
Europium-155	2 of 2	100
Plutonium-238	2 of 2	100
Plutonium-239/240	2 of 2	100
Ruthenium-106	2 of 2	100
Strontium-90	2 of 2	100
Uranium-234	2 of 2	100
Uranium-235	2 of 2	100
Uranium-238	2 of 2	100
<b>Soil</b>		
Antimony-125	3 of 3	100
Cesium-134	1 of 3	33
Cesium-137	3 of 3	100
Cobalt-60	3 of 3	100
Europium-152	3 of 3	100
Europium-154	3 of 3	100
Europium-155	2 of 3	66
Plutonium-238	3 of 3	100
Plutonium-239/240	3 of 3	100
Ruthenium-106	3 of 3	100
Strontium-90	2 of 3	67
Uranium-234	3 of 3	100
Uranium-235	3 of 3	100
Uranium-238	3 of 3	100
<b>Natural Vegetation</b>		
Antimony-125	1 of 1	100
Cesium-134	1 of 1	100
Cesium-137	0 of 1	0
Cobalt-60	1 of 1	100
Europium-152	1 of 1	100
Europium-154	1 of 1	100
Europium-155	1 of 1	100
Plutonium-238	1 of 1	100
Plutonium-239/240	1 of 1	100
Ruthenium-106	1 of 1	100
Strontium-90	1 of 1	100
Uranium-234	1 of 1	100
Uranium-235	1 of 1	100
Uranium-238	1 of 1	100

<sup>a</sup> Number of reported results within control limits for radiological analysis is those with the relative percent difference value less than 30 percent, and the result is greater than the minimum detectable activity.

## 12.4 Media Audits and Comparisons

Selected sediment, surface water, food and farm products, wildlife, soil, and vegetation samples are provided to the WDOH for comparative analysis as part of the Public Safety and Resource Protection QA program ([DOE/RL-91-50](#)). The Hanford Environmental Radiation Oversight Program of the WDOH independently verifies the quality of DOE monitoring programs at the Hanford Site. Since 1985, WDOH and DOE have collaboratively participated in the collection of environmental samples located on or in the surrounding areas of the Hanford Site ([WDOH 320-097](#), *Hanford Environmental Radiation Oversight Program 2011 Data Summary Report*). This includes, but is not limited to, conducting split, collocated, and independent sampling at locations that have the potential to release radionuclides to the environment, or that could be impacted by such releases. This program is not intended to characterize completely the environmental radiation on the Hanford Site; but provide oversight to Hanford Site contractors in determining the impact of Hanford releases on the environment and the public. More information can be found on the WDOH website at [WDOH's Environmental Sciences](#). Media types analyzed by the WDOH included the following:

- |                                     |  |
|-------------------------------------|--|
| ✧ Air Filters from 11 locations     | ✧ Quail from 1 location                                      |
| ✧ Apricots from 1 location          | ✧ Bass from 1 location                                       |
| ✧ Leafy vegetables from 2 locations | ✧ Carp from 2 locations                                      |
| ✧ Potatoes from 2 locations         | ✧ Columbia River surface water from 2 locations              |
| ✧ Sediment from 5 locations         | ✧ Offsite irrigation water from 2 locations                  |
| ✧ Cherries from 2 locations         | ✧ Columbia River shoreline springs (seeps) from 6 locations. |

No comparison data were available at the time this report was written; however, links to past data summary reports and other environmental science publications for the Hanford Environmental Radiation Oversight program are available online at

<http://www.doh.wa.gov/communityandenvironment/radiation/publications/environmentalsciences.aspx>.

## 12.5 Laboratory Quality Assurance Programs

Contracted analytical laboratories are required to maintain internal QC programs and participate in independent QC programs used to determine analytical precision and accuracy. These laboratories house chemical technologists who are qualified to perform these analyses through formal classroom education and on-the-job training. Internal QC programs for contracted laboratories involve routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation-check sources and background counts, replicate and spiked sample analyses, use of matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Examples of independent QC programs are the Mixed Analyte Performance Evaluation Program (MAPEP) ([DOE 2004](#)) and the DOE Consolidated Audit Program (DOECAP). They are described in the following sections.

### 12.5.1 Analytical Quality Assurance and Quality Control

Hanford Site environmental samples were sent to one laboratory in 2014 (Table 12.7) and included routine chemical and radiological analyses of air, water, soil and vegetation, sediment and biota. In 2014, General Engineering Laboratories, LLC (GEL) participated in independent QA and QC programs including MAPEP and DOECAP. These managed programs use standardized audit methods, processes, and procedures to ensure, annually, the validity, reliability, and defensibility of data from the contract laboratories.

**Table 12.7** DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC

Environmental Sample Media and Analytes		MAPEP 30 Series March 2014 <sup>a</sup>	MAPEP 31 Series August 2014 <sup>a</sup>
<b>Radionuclides</b>			
Air Filters	Alpha (gross), beta (gross), americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/240, strontium-90, uranium-234/233, uranium-238	100% Acceptable	100% Acceptable
Water	Alpha (gross), beta (gross), americium-241, cesium-134, cesium-137, cobalt-60, iodine-129, plutonium-238, plutonium-239/240, potassium-40, strontium-90, technetium-99, tritium, uranium-234/233, uranium-238	Uranium-234/233 <sup>b</sup> Uranium-238 <sup>b</sup>	100% Acceptable
Vegetation	Cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/240, strontium-90, uranium-234/233, uranium-238	Uranium-235 <sup>b</sup>	100% Acceptable
Soil	Cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/240, strontium-90	Technetium-99 <sup>b</sup> Uranium-235 <sup>b</sup> Uranium-238 <sup>b</sup> Uranium-total <sup>b</sup>	100% Acceptable
<b>Inorganic Compounds</b>			
Water	Antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, thallium, zinc	100% Acceptable	Lead <sup>b</sup>
<b>Organic Compounds</b>			
Water	1,4-Dichlorobenzene	100% Acceptable	100% Acceptable

<sup>a</sup> Performance results 100 percent acceptable for all analytes unless otherwise noted.<sup>b</sup> Result not acceptable, Bias > 30 percent due to the sensitivity evaluation of the analyte in the sample. No adverse effect on Hanford sample.

GEL was audited by DOECAP in March 2014. The objective of [DOECAP](#) is to ensure the application of consistent standards between the analytical laboratories supporting the DOE complex and its compliance programs. Audit objectives included assessing the ability of the laboratory to produce data of acceptable and documented quality through analytical operations that follow approved and technically sound methods, and the handling of DOE samples and associated waste in a manner that protected human health and the environment. GEL also participated in MAPEP Studies 30 and 31 and a number of Environmental Resource Associates's proficiency studies for water, soil, air filter, and vegetation matrices.

Prior to shutdown, WSCF maintained Ecology and American Industrial Hygiene Association accreditation and had an internal QA program plan. In 2014, WSCF did not participate in laboratory performance evaluation programs.

### 12.5.2 Laboratory Performance Evaluation and Proficiency Testing

Participation of Hanford Site analytical laboratories in DOE and EPA laboratory performance evaluation programs serves to ensure data quality. Hanford Site environmental monitoring contract laboratories

participate in MAPEP-sanctioned proficiency testing provided by an independent laboratory (e.g., Environmental Resource Associates).

DOE's MAPEP provides critical QA testing for environmental analytical services. Radiological and non-radiological (organic and inorganic) constituents are evaluated by performing semiannual proficiency testing of the Hanford Site DOE laboratories, and other federal, state, commercial, and international laboratories. MAPEP proficiency tests help to ensure the accuracy of analytical results reported to DOE and other stakeholders, while also providing an efficient means for laboratories to demonstrate analytical proficiency. Results to past MAPEP studies can be found on the DOE's Mixed Analyte Performance Evaluation Program webpage at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

GEL's MAPEP program results were 100 percent acceptable for Studies 30 and 31 in 2014 for air and water; however, radiological results for vegetation in Study 30 failed for uranium-234 and uranium-238 due to sensitivity evaluations. Radiological vegetation results for Study 31 were 100 percent acceptable. Results of MAPEP Studies 30 and 31 for GEL are provided in Table 12.7 or at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

In 2014, due to DOE direction to close the WSCF, this laboratory did not participate in MAPEP Studies 30 and 31. WSCF did not provide any other proficiency studies prior to shut down; therefore, it is uncertain whether the laboratory participated in 2014.

## **12.6 Data Recording and Data Management**

Record keeping is a vital part of all environmental programs on the Hanford Site. Maintenance of environmental data is essential for QA, regulatory compliance, trend analysis, and optimization purposes. The Environmental Surveillance program is responsible for ensuring that analytical data are appropriately reviewed, managed, and stored in accordance with applicable programmatic requirements governing data management procedures. Project documentation includes environmental sample logbooks and processing forms, and as applicable, monthly, quarterly, and annual occurrence reports. Several electronic data repositories are used to house the environmental data, all of which have their own internal QA and QC policies and procedures.

## 13.0 References

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- 08-5085-RMP. Letter, E. Moniz (Secretary of Energy) to Washington State Department of Ecology, dated December 5, 2014, United States' Response to the State of Washington's Petition to Modify Consent Decree, U.S. Department of Energy, Washington D.C.
- 10 CFR 820. "Procedural Rules for DOE Nuclear Activities," Code of Federal Regulations, U.S. Department of Energy. Online at <http://energy.gov/ea/downloads/10-cfr-part-820-procedural-rules-doe-nuclear-activities>.
- 10 CFR 830. "Nuclear Safety Management," Code of Federal Regulations, U.S. Department of Energy. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title10/10cfr830\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title10/10cfr830_main_02.tpl).
- 10 CFR 835. 2009. "Occupational Radiation Protection," Code of Federal Regulations, U.S. Department of Energy. Online at [http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=962360c4cb61939863791b9ed7238e91&ty=HTML&h=L&mc=true&n=pt1\\_0.4.835&r=PART](http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=962360c4cb61939863791b9ed7238e91&ty=HTML&h=L&mc=true&n=pt1_0.4.835&r=PART).
- 10 CFR 1021. 1996. "National Environmental Policy Act Implementing Procedures," Code of Federal Regulations, U.S. Department of Energy. Online at <http://energy.gov/nepa/downloads/10-cfr-1021-department-energy-national-environmental-policy-act-implementing>.
- 10 CFR 1021.410. "Application of Categorical Exclusions (Classes of Actions that normally do not require EAs or EISs)," Code of Federal Regulations, U.S. Department of Energy. Online at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=4f8afd3d76d9373f8526b023c6525508&rgn=div8&view=text&node=10:4.0.3.5.14.4.9.1.2&idno=10>.
- 10 CFR 1022. "Compliance with Floodplain and Wetland Environmental Review Requirements," Code of Federal Regulations, Advisory Council on Historic Preservation. Online at [http://energy.gov/sites/prod/files/nepapub/nepa\\_documents/RedDont/Req-DOE-10CFR1022.pdf](http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/Req-DOE-10CFR1022.pdf).
- 29 CFR 1910. Subpart Z, "Occupational Safety and Health Standards," Code of Federal Regulations, Occupational Safety and Health Administration, Department of Labor. Online at [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10106](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106).
- 32 CFR 644.319, "Protection of Wetlands." Code of Federal Regulations. By executive order. Online at [http://www.ecfr.gov/cgi-bin/text-idx?SID=be716e613041a930cfe2c677100c7686&mc=true&node=se32.4.644\\_1319&rgn=div8](http://www.ecfr.gov/cgi-bin/text-idx?SID=be716e613041a930cfe2c677100c7686&mc=true&node=se32.4.644_1319&rgn=div8).
- 32 CFR 644.320, "Floodplain management." Code of Federal Regulations. By executive order. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=32:4.1.1.2.11.6.33.10>.
- 36 CFR 60. "National Register of Historic Places," Code of Federal Regulations, National Park Service, U.S. Department of the Interior. Online at <http://www.gpo.gov/fdsys/granule/CFR-2012-title36-vol1/CFR-2012-title36-vol1-part60/content-detail.html>.
- 36 CFR 63. "Determinations of Eligibility for Inclusion in the National Register of Historic Places," Code of Federal Regulations, National Park Service, U.S. Department of the Interior. Online at

<http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5;node=36%3A1.0.1.1.29>.

36 CFR 65. "National Historic Landmarks Program," Code of Federal Regulations, National Park Service,

U.S. Department of the Interior. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=36:1.0.1.1.31>.

36 CFR 79. "Curation of Federally-Owned and Administered Archaeological Collections," Code of Federal Regulations, National Park Service, U.S. Department of the Interior. Online at <http://www.nps.gov/archeology/tools/36cfr79.htm>.

36 CFR 800. "Protection of Historic Properties," Code of Federal Regulations, National Park Service, U.S. Department of the Interior. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title36/36cfr800\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title36/36cfr800_main_02.tpl).

40 CFR. "Protection of Environment," Code of Federal Regulations, Environmental Protection Agency. Online at <http://www.ecfr.gov/cgi-bin/searchECFR?ob=r&idno=40&q1=&r=&SID=6a07d62abde1e4c4178aeadb675bf3e&mc=true>.

40 CFR 52. "Approval and Promulgation of Implementation Plans," Code of Federal Regulations, Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr52\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr52_main_02.tpl).

40 CFR 60. "Standards of Performance for New Stationary Sources," Code of Federal Regulations, Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr60\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr60_main_02.tpl).

40 CFR 61. "National Emission Standards for Hazardous Air Pollutants," Code of Federal Regulations, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr61\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr61_main_02.tpl).

40 CFR 61, Appendix E, Table 2. 2009. "National Emission Standards for Hazardous Air Pollutants," Appendix E, Compliance Procedures Methods for Determining Compliance with Subpart I; Concentration Levels for Environmental Compliance. Code of Federal Regulations, U.S. Environmental Protection Agency. Online at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=b595e31b52329086f062b5bc2eeae23d&rgn=div5&view=text&node=40:9.0.1.1.1&idno=40#top>.

40 CFR 61.92. "Standard," Code of Federal Regulations, U.S. Environmental Protection Agency. Online at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=645372711a6ce05bdd5e7b9670a7a7a&rgn=div8&view=text&node=40:9.0.1.1.1.8.1.3&iidno=40>.

40 CFR 63. "National Emission Standards for Hazardous Air Pollutants for Source Categories," Code of Federal Regulations, Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr63\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr63_main_02.tpl).



- 40 CFR 68. "Chemical Accident Prevention Provisions," Code of Federal Regulations, U.S. Environmental Protection Agency. Online at <http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=326bfe5c01fa3ef1d00698fed04857b6&ty=HTML&h=L&mc=true&r=PART&n=pt40.16.68>
- 40 CFR 70. "State Permit Operating Permit Programs," Code of Federal Regulations, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr70\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr70_main_02.tpl)
- 40 CFR 82. "Protection of Stratospheric Ozone," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr82\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr82_main_02.tpl).
- 40 CFR 122. "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr122\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr122_main_02.tpl).
- 40 CFR 131.36 – "Toxics Criteria for Those States not Complying with Clean Water Act Section 303(C)(2)(B)," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?sid=bb6c7680a61f01d620c88827efb8d0d1&mc=true&node=pt40.22.131&rgn=div5#se40.22.131\\_136](http://www.ecfr.gov/cgi-bin/text-idx?sid=bb6c7680a61f01d620c88827efb8d0d1&mc=true&node=pt40.22.131&rgn=div5#se40.22.131_136)
- 40 CFR 141. "National Primary Drinking Water Regulations," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr141\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr141_main_02.tpl).
- 40 CFR 143. "National Secondary Drinking Water Regulations," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr143\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr143_main_02.tpl).
- 40 CFR 264. "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at <http://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol27/xml/CFR-2012-title40-vol27-part264.xml>.
- 40 CFR 265. "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr265\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr265_main_02.tpl).
- 40 CFR 300. "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr300\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr300_main_02.tpl).
- 40 CFR 355. "Emergency Planning Notifications," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at <http://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol29/xml/CFR-2012-title40-vol29-part355.xml>.
- 40 CFR 372. "Toxic Chemical Release Reporting," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at <http://www.gpo.gov/fdsys/granule/CFR-2011-title40-vol28/CFR-2011-title40-vol28-part372/content-detail.html>.

- 40 CFR 761. "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions," *Code of Federal Regulations*, U.S. Environmental Protection Agency. Online at [http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/title40/40cfr761\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/title40/40cfr761_main_02.tpl).
- 40 CFR 1500-1508. "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act," *Code of Federal Regulations*, Council on Environmental Quality Executive Office of the President. Online at [http://energy.gov/sites/prod/files/NEPA-40CFR1500\\_1508.pdf](http://energy.gov/sites/prod/files/NEPA-40CFR1500_1508.pdf).
- 43 CFR 7. "Protection of Archeological Resources," *Code of Federal Regulations*, Public Lands: Office of the Secretary of the Interior. Online at <http://www.nps.gov/history/local-law/43cfr7.htm>.
- 43 CFR 10. "Native American Graves Protection and Repatriation and Regulations," *Code of Federal Regulations*, National Park Service, U.S. Department of the Interior. Online at [http://www.nps.gov/nagpra/MANDATES/43CFR10\\_10-1-03.htm](http://www.nps.gov/nagpra/MANDATES/43CFR10_10-1-03.htm).
- 50 CFR 17. "Endangered and Threatened Wildlife and Plants," *Code of Federal Regulations*, U.S. Department of Interior. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=50:2.0.1.1.1>.
- 50 CFR 17.11. "Endangered and Threatened Wildlife," *Code of Federal Regulations*, U.S. Department of Interior. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=50:2.0.1.1.1.2.1.1>.
- 50 CFR 17.12. "Endangered and Threatened Plants," *Code of Federal Regulations*, U.S. Department of Interior. Online at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=50cb02f1dfa9fad8fe59caa49b67f509&rgn=div8&view=text&node=50:2.0.1.1.1.2.1.2&idno=50>.
- 64 FR 61615. November 12, 1999. "Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement" (DOE/EIS-0222; September 1999). *Federal Register*, U.S. Department of Energy. Online at <http://www.gpo.gov/fdsys/pkg/FR-1999-11-12/pdf/99-29325.pdf>.
- 65 FR 37253. June 13, 2000. "Establishment of the Hanford Reach National Monument." Presidential Proclamation 7319 of June 9, 2000, by the President of the United States of America. *Federal Register*, Office of the President. Online at [http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2000\\_register&docid=00-15111-filed.pdf](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2000_register&docid=00-15111-filed.pdf).
- 65 FR 76708. December 7, 2000. *National Primary Drinking Water Regulations; Radionuclides; Final Rule*. Federal Register, U.S. Environmental Protection Agency. Online at <https://www.federalregister.gov/articles/2000/12/07/00-30421/national-primary-drinking-water-regulations-radionuclides-final-rule>.
- 76 FR 63764. October 13, 2011. "National Environmental Policy Act Implementing Procedures." *Federal Register*. U.S. Department of Energy. Online at <http://www.gpo.gov/fdsys/pkg/fr-2011-10-13/pdf/2011-25413.pdf>.
- 77 FR 58112. September 19, 2012. "Notice of Intent to Prepare an Environmental Assessment and Notice of Potential Floodplain and Wetland Involvement for the Proposed Conveyance of Land at the Hanford Site, Richland, Washington (DOE/EA-1915)." *Federal Register*, U.S. Department of Energy. Online at <http://energy.gov/sites/prod/files/ea-1915-noi-2012.pdf>.

- 78 FR 75913. December 13, 2013. "Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington." *Federal Register*, U.S. Department of Energy. Online at <http://www.gpo.gov/fdsys/pkg/FR-2013-12-13/pdf/2013-29734.pdf>.
- 14-ECD-0047, K. W. Smith to J. M. Martell, Washington State Department of Health, dated October 3, 2014, *U.S. Department of Energy, Office of River Protection Transmittal of Response to the Washington State Department of Health Letter, AIR 14-603*, U.S. Department of Energy, Office of River Protection, Richland, Washington.
- 14-NWP-023. 2014. *Agreed Order and Stipulated Penalty Docket No. DE 10156, Hanford Solid Waste Operations Complex*. Washington State Department of Ecology, U.S. Department of Energy, Richland Operations Office, and CH2M HILL Plateau Remediation Company, Olympia, Washington. Online at <http://www.ecy.wa.gov/programs/nwp/pi/pdf/settlements/de10156/de10156.pdf>.
- 14-NWP-135, Letter from N. Ware to K. Smith, U.S. Department of Energy, Office of River Protection, and P. McCullough, Bechtel National, Inc., dated July 10, 2014, *Department of Ecology's (Ecology) Dangerous Waste Compliance Inspection of Generator Activities at the Material Handling Facility (MHF), RCRA Site ID WA78900008967 on May 19, 2014*. Washington State Department of Ecology, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1407170445>.
- 14-NWP-152, Letter from N. Ware to K. Smith, U.S. Department of Energy, Office of River Protection; and P. McCullough, Bechtel National, Inc, dated July 22, 2014, *Department of Ecology's (Ecology) Dangerous Waste Compliance Inspection of Generator Activities at the Waste Treatment and Immobilization Plant, RCRA Site ID WA78900008967 on April 30, 2014*. Washington State Department of Ecology, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1408040274>.
- 14-NWP-183, Letter from E. Holbrook to D. Shoop, U.S. Department of Energy, Richland Operations Office,, and K. McNeel, Washington Closure Hanford, dated August 25, 2014, *Department of Ecology's (Ecology) Dangerous Waste Compliance Inspection of Generator Activities at the Sampling and Characterization Warehouse, 1060 Building, RCRA Site ID WA78900008967 on July 2, 2014*. Washington State Department of Ecology, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1409030329>.
- 15-AMRP-0014, Letter from R. Corey to D. Faulk, U.S. Environmental Protection Agency, dated October 21, 2014, Initiation of Dispute Resolution Regarding Disapproval of Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Change Control Form M-16-14-02, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0083430h>.
- 15-AMRP-0031, Letter from R. Corey to D. Faulk U.S. Environmental Protection Agency, dated December 3, 2014, Statement of Dispute Regarding Disapproval of Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Change Control Form M-16-14-02, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0082937h>.

- 15-ESQ-0042, Letter from S. Charboneau to I.K. Aguilera, Washington State Department of Ecology, dated March 4, 2015, *New Dangerous Waste Site Identification Number for the Waste Treatment and Immobilization Plant Material Handling Facility*, U.S. Department of Energy Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0081935h>.
- 14-AMRP-0214, Letter from R. Corey to D. Faulk U.S. Environmental Protection Agency, dated June 12, 2014, *Notification of TPA Milestone M-016-175, Begin Sludge Removal from 105-KW Fuel Storage Basin, September 30, 2014, Will be Missed*, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0085326>.
- 14-AMRP-0311, Letter from R. Coreyto D. Faulk U.S. Environmental Protection Agency, dated September 30, 2014, *Notification of TPA Milestone M-016-175, Begin Sludge Removal from 105-KW Fuel Storage Basin, September 30, 2014, Will be Missed*, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0085326>.
- 1959-Present. Annual Hanford Site Environmental Reports. U.S. Department of Energy, Richland, Washington. Online at <http://msa.hanford.gov/page.cfm/enviroreports>.
- AIR 14-603, Letter from J. Martell to K. Smith, U.S. Department of Energy, Office of River Protection, dated June 5, 2014, *Standards and Maintenance Requirements for the Ventilation Systems in the Tank Farm Facilities*, State of Washington Department of Health, Richland, Washington.
- American Indian Religious Freedom Act of 1978*. 42 USC 1996 and 1996a. Online at [http://www.nps.gov/history/local-law/fhpl\\_indianrelfreact.pdf](http://www.nps.gov/history/local-law/fhpl_indianrelfreact.pdf).
- Anglin, D. R., S. L. Haeseker, J. J. Skalicky, H. Schaller, K. F. Tiffan, J. R. Hatten, P. Hoffarth, J. Nugent, D. Benner, M. Yoshinaka. 2006. *Effects of Hydropower Operations on Spawning Habitat, Rearing Habitat, and Stranding/Entrapment Mortality of Fall Chinook Salmon in the Hanford Reach of the Columbia River*. Final Report, Columbia River Fisheries Program Office, U.S. Fish and Wildlife Service, Vancouver, Washington. Online at: [http://www.fws.gov/columbiariver/publications/final\\_hanford\\_report\\_8-10-2006.pdf](http://www.fws.gov/columbiariver/publications/final_hanford_report_8-10-2006.pdf)
- Antiquities Act of 1906*. 16 USC 431-433, as amended. Online at [http://www.cr.nps.gov/local-law/fhpl\\_antiact.pdf](http://www.cr.nps.gov/local-law/fhpl_antiact.pdf).
- AP-42. 1995. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*, Fifth Edition. Office of Air Quality Planning and Standards, Office of Air and Radiation, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Online at <http://www.epa.gov/otaq/ap42.htm>.
- Archaeological and Historic Preservation Act of 1974*. 16 USC 469-469c-2, as amended. Online at [http://www.cr.nps.gov/local-law/fhpl\\_archhistpres.pdf](http://www.cr.nps.gov/local-law/fhpl_archhistpres.pdf).
- Archaeological Resources Protection Act of 1979*. Public Law 96-95, as amended, 16 USC 469 et seq. Online at [http://www.cr.nps.gov/local-law/fhpl\\_archsrcsprot.pdf](http://www.cr.nps.gov/local-law/fhpl_archsrcsprot.pdf).

- ARH-CD-775. 1976. *Geohydrologic Study of the West Lake Basin*. R.E. Gephart, P.A. Eddy, R.C. Arnett, and G.A. Robinson. Atlantic Richfield Hanford Company, Richland, Washington. Online at [http://www.osti.gov/energycitations/product.biblio.jsp?osti\\_id=6463383](http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6463383).
- Atomic Energy Act of 1954*. Chapter 724, 60 Stat. 755, 42 USC 2011 et seq. Online at <http://epw.senate.gov/atomic54.pdf>.
- Bald and Golden Eagle Protection Act*. (16 USC 688 et seq). Online at <http://www.gpo.gov/fdsys/granule/USCODE-2010-title16/USCODE-2010-title16-chap5A-subchapII-sec668>
- Barfuss, Brad Craig. 2007. *Development of a Tritium Dilution Factor from Measured Laboratory Emissions and Localized Ambient Air Sampling Measurements* (Master's thesis), Washington State University, May 2007. Online at <http://www.worldcat.org/title/development-of-a-tritium-dilution-factor-from-measured-laboratory-emissions-and-localized-ambient-air-sampling-measurements/oclc/155845006>.
- BHI-01153, Rev. 0. 1998. *Aquifer Sampling Tube Completion Report: 100 Area and Hanford Townsite Shorelines*. R.E. Peterson, J.V. Borghese, and D.B. Erb, Bechtel Hanford, Inc., Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D198103289>.
- BHI-01747, Rev. 0. 2004. *Results of Hexavalent Chromium Sampling Near 100-D Area Sodium Dichromate Transfer Station Railroad Tracks*. R.A. Carlson, K.A. Anselm, P.E. Kruger, W.S. and Thompson, Bechtel Hanford, Inc., Richland, Washington. Online at <http://pdw.hanford.gov/arpir/pdf.cfm?accession=DA01162955>.
- BNWL-1979. 1976. *Environmental Surveillance at Hanford for CY 1975*. D.R. Speer, J.J. Fix, and P.J. Blumer, Pacific Northwest Laboratory, Richland, Washington. Online at <http://www.osti.gov/energycitations/servlets/purl/7152131-sadf9a/>.
- CAA-10-2014-0073. Docket No. CAA 10 2014-0073, Consent Agreement and Final Order, filed April 2, 2014, issued In the Matter of the United States Department of Energy and Washington Closure Hanford LLC and the United States Department of Energy Hanford (WA) Facility, Consent Agreement and Final Order, U.S. Environmental Protection Agency, Seattle, Washington.
- Calabrese, E. J. 2009. "The road to linearity: why linearity at low doses became the basis for carcinogen risk assessment." *Archives of Toxicology*. March, 2009, Volume 83, Issue 3, pp 203-225.
- CERCLA. 1980. *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq., Public Law 107-377, December 31, 2002. Online at <http://www.epw.senate.gov/cercla.pdf>.
- City of Richland Code, *Richland Pretreatment Act* – Chapter 17.30. Online at <http://www.codepublishing.com/wa/richland/html/richland17/richland1730.html>.
- Clean Air Act of 1986*. Public Law 88-206, as amended, 42 USC 7401 et seq. Online at <http://www.epa.gov/air/caa/>.
- Clean Air Act Amendments of 1990*. As amended through Public Law 108-201. Online at <http://www.epw.senate.gov/envlaws/cleanair.pdf>.

- Clean Water Act of 1977*. Public Law 95-217, as amended, 33 USC 1251 et seq. Online at [http://uscode.house.gov/view.xhtml?req=\(title:33%20section:1251%20edition:prelim\)](http://uscode.house.gov/view.xhtml?req=(title:33%20section:1251%20edition:prelim)).
- CR-IU-010. Industrial Wastewater Permit, 300 Area Combined Sewer. City of Richland, Richland, Washington.
- Dauble, D. D. and D. G. Watson. 1997. *Status of Fall Chinook Salmon Populations in the Mid-Columbia River, 1948–1992*. North American Journal of Fisheries Management 17:2, 283-300. Online at: [http://dx.doi.org/10.1577/1548-8675\(1997\)017<0283:sofscsp>2.3.co;2](http://dx.doi.org/10.1577/1548-8675(1997)017<0283:sofscsp>2.3.co;2).
- DNFSB. 2010-2. *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*. Recommendation 2011-1, Defense Nuclear Facilities Safety Board, Washington, D.C. Online at <http://www.dnfsb.gov/board-activities/letters/board-closes-recommendation-2010-2-pulse-jet-mixing-waste-treatment-and-imm>.
- DNFSB. 2011-1. *Safety Culture at the Waste Treatment and Immobilization Plant*. Recommendation 2011-1, Defense Nuclear Facilities Safety Board, Washington, D.C. Online at [http://www.dnfsb.gov/sites/default/files/board%20activities/recommendations/rec\\_2011-1\\_11826.pdf](http://www.dnfsb.gov/sites/default/files/board%20activities/recommendations/rec_2011-1_11826.pdf).
- DNFSB. 2012. *Hanford Tank Farms Flammable Gas Safety Strategy*, dated September 28, 2012. Defense Nuclear Facilities Safety Board, Washington, D.C. Online at <http://www.dnfsb.gov/board-activities/recommendations/hanford-tank-farms-flammable-gas-safety-strategy>.
- DNFSB. 2013. *Report to Congress on the Status of Significant Unresolved Technical Differences between the Board and the Department of Energy on Issues Concerning the Design and Construction of DOE's Defense Nuclear Facilities*, dated December 26, 2013. Defense Nuclear Facilities Safety Board, Washington, D.C. Online at [http://www.dnfsb.gov/sites/default/files/board%20activities/reports/reports%20to%20congress/2013/qtr\\_20131226\\_23521.pdf](http://www.dnfsb.gov/sites/default/files/board%20activities/reports/reports%20to%20congress/2013/qtr_20131226_23521.pdf).
- DNFSB. 2014a. *Board Closes the Remaining Issue Concerning the Preliminary Design and Safety Basis for Phase I of the Sludge Treatment Project (STP) Richland Operations Office (RL)*, dated April 23, 2014. Defense Nuclear Facilities Safety Board, Washington, D.C. Online at <http://www.dnfsb.gov/board-activities/letters/board-closes-remaining-issue-concerning-preliminary-design-and-safety-basis>. Online at [http://www.dnfsb.gov/sites/default/files/Board%20Activities/Letters/2014/ltr\\_2014423\\_24201.pdf](http://www.dnfsb.gov/sites/default/files/Board%20Activities/Letters/2014/ltr_2014423_24201.pdf).
- DNFSB. 2014b. *Board Summary of Sludge Treatment Project Final Design and Safety Basis*, dated May 2, 2014. Defense Nuclear Facilities Safety Board, Washington, D.C. Online at [http://www.dnfsb.gov/sites/default/files/Board%20Activities/Letters/2014/ltr\\_201452\\_24336.pdf](http://www.dnfsb.gov/sites/default/files/Board%20Activities/Letters/2014/ltr_201452_24336.pdf).
- DNFSB. 2014c. *Report to Congress on the Status of Significant Safety Issues Concerning the Design and Construction of DOE's Defense Nuclear Facilities* dated May 16, 2014. Defense Nuclear Facilities Safety Board, Washington, D.C. Online at <http://www.dnfsb.gov/board-activities/reports/reports-to-congress/report-congress-status-significant-safety-issues-concer>.



- DNFSB. 2014d. *Report to Congress on the Status of Significant Unresolved Issues with the DOE's Design and Construction Projects*, dated September 19, 2014. Defense Nuclear Facilities Safety Board, Washington, D.C. Online at [http://www.dnfsb.gov/sites/default/files/Board%20Activities/Reports/Reports%20to%20Congress/2014/pr\\_2014919\\_25181.pdf](http://www.dnfsb.gov/sites/default/files/Board%20Activities/Reports/Reports%20to%20Congress/2014/pr_2014919_25181.pdf).
- DOE. 2004. *Handbook for the Department of Energy's Mixed Analyte Performance Evaluation Program (MAPEP)*. MAPEP Handbook, Rev. 4, U.S. Department of Energy, Idaho Falls, Idaho. Online at <http://www.inl.gov/resl/mapep/handbookv10.pdf>.
- DOE. 2007. Letter, M. McCormick (RL) to N. Ceto (EPA, and J. Hedges (Ecology). *Amended Record of Decision for the Environmental Restoration Disposal Facility*. U.S. Department of Energy Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=da04316406>.
- DOE. 2012. *Independent Oversight Assessment of Nuclear Safety Culture and Management of Nuclear Safety Concerns at the Hanford Site Waste Treatment and Immobilization Plant*. Office of Enforcement and Oversight Office of Health, Safety and Security U.S. Department of Energy. Online at [http://energy.gov/sites/prod/files/hss/Enforcement%20and%20Oversight/Oversight/docs/reports/semevals/Final\\_Hanford\\_WTP-Report\\_Jan%202012.pdf](http://energy.gov/sites/prod/files/hss/Enforcement%20and%20Oversight/Oversight/docs/reports/semevals/Final_Hanford_WTP-Report_Jan%202012.pdf).
- DOE. 2013a. Letter, E. Moniz (Secretary of Energy) to P.S. Winokur (DNFSB), dated June 6, 2013, *Implementation Plan for Recommendation 2012-2*, U.S. Department of Energy, Washington, DC. Online at <http://www.dnfsb.gov/board-activities/recommendations/implementation-plans/doe-implementation-plan-board-recommendation-2>.
- DOE. 2013b. Letter, M. Moury (Deputy Assistant Secretary for Safety, Security, and Quality Assurance Environmental Management) to P.S. Winokur (DNFSB), dated December 27, 2011, *Implementation Plan for Recommendation 2011-1, Safety Culture at the Waste Treatment and Immobilization Plant*, U.S. Department of Energy, Washington, D.C. Online at [http://www.dnfsb.gov/sites/default/files/Board%20Activities/Recommendations/Implementation%20Plans/ip\\_rec-id\\_11826\\_0.pdf](http://www.dnfsb.gov/sites/default/files/Board%20Activities/Recommendations/Implementation%20Plans/ip_rec-id_11826_0.pdf).
- DOE. 2014a. *Scientific Opportunities for Defining and Achieving Risk-Informed Remediation Endpoints*. U.S. Department of Energy, Office of Environmental Management, *Washington, DC*.
- DOE, U.S. Department of the Interior, Nez Perce Tribe, State of Oregon, CTUIR, State of Washington, Confederated Tribes and Bands of the Yakama Indian Nation. 1996. *Memorandum of Agreement U.S. Department of Energy – Hanford Site*, U.S. Department of Energy, U.S. Department of the Interior, Nez Perce Tribe, State of Oregon, Confederated Tribes of the Umatilla Indian Reservation, State of Washington, and the confederated Tribes and Bands of the Yakama Indian Nation, Richland Washington. Online at <http://www.hanford.gov/?page=651>.
- DOE M 231.1-2. 2003. *Occurrence Reporting and Processing of Operations Information*. U.S. Department of Energy, Washington, D.C. Online at <https://www.directives.doe.gov/directives/0231.1-dmanual-2/view>.

- DOE M 450.4-1. *Integrated Safety Management System Manual*. U.S. Department of Energy, Washington, D.C. Online at <https://www.directives.doe.gov/directives-documents/400-series/0450.4-DManual-1/view>.
- DOE O 144.1, Adm. Chg.1. 2009. *Department of Energy American Indian Tribal Government Interactions and Policy*. U.S. Department of Energy, Washington, D.C. Online at <http://energy.gov/em/downloads/doe-order-1441-department-energy-american-indian-tribal-government>.
- DOE O 144.1, Attachment 3. 2006. *Department of Energy American Indian & Alaska Native Tribal Government Interactions and Policy*. Online at <http://energy.gov/em/downloads/doe-order-1441-department-energy-american-indian-tribal-government>.
- DOE O 231.1B. 2011. *Environmental, Safety and Health Reporting*. U.S. Department of Energy, Washington, D.C. Online at [http://energy.gov/sites/prod/files/Attch\\_o231%201b-AdminChg1\\_11-28-12%20pdf1.pdf](http://energy.gov/sites/prod/files/Attch_o231%201b-AdminChg1_11-28-12%20pdf1.pdf).
- DOE O 414.1D, Chg. 1. 2011. *Quality Assurance*. Office of Health, Safety and Security, U.S. Department of Energy, Washington D.C. Online at <https://www.directives.doe.gov/directives-documents/0414.1-border-dadmchg1>.
- DOE O 430.2B. *Departmental Energy, Renewable Energy and Transportation Management*. U.S. Department of Energy, Washington, D.C. Online at <https://www.directives.doe.gov/directives-documents/400-series/0430.2-BOrder-b/view>.
- DOE O 435.1, Chg. 1. 2001. *Radioactive Waste Management*. U.S. Department of Energy, Washington, D.C. Online at [https://www.directives.doe.gov/directives/0435.1-border-c1/at\\_download/file](https://www.directives.doe.gov/directives/0435.1-border-c1/at_download/file).
- DOE O 436.1. 2011. *Departmental Sustainability*. U.S. Department of Energy, Washington, D.C. Online at <https://www.directives.doe.gov/directives-documents/400-series/0436.1-border>.
- DOE O 440.1A. 1998. *Worker Protection Management for DOE Federal and Contractor Employees*. U.S. Department of Energy, Washington, D.C. Online at [https://www.directives.doe.gov/directives/0440.1-border-a/at\\_download/file](https://www.directives.doe.gov/directives/0440.1-border-a/at_download/file).
- DOE O 451.1B. 2000. *National Environmental Policy Act Compliance Program*. U.S. Department of Energy, Washington, D.C. Online at <https://www.directives.doe.gov/>.
- DOE O 458.1, Chg. 2. 2011. *Radiation Protection of the Public and the Environment*. U.S. Department of Energy, The Office of Environment, Safety and Health, Washington, D.C. Online at <https://www.directives.doe.gov/directives-documents/400-series/0458.1-BOrder-admc2/view>.
- DOE P 141.1. 2001. *Department of Energy Management of Cultural Resources*. U.S. Department of Energy, The Office of Environment, Safety and Health, Washington, D.C. Online at [https://www.directives.doe.gov/directives/0141.1-apolicy/at\\_download/file](https://www.directives.doe.gov/directives/0141.1-apolicy/at_download/file).
- DOE-STD-1153-2002. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. U.S. Department of Energy, Washington, D.C. Online at [http://energy.gov/sites/prod/files/2013/09/f3/1153\\_Frontmatter.pdf](http://energy.gov/sites/prod/files/2013/09/f3/1153_Frontmatter.pdf).

- DOE-STD 1195-2011. 2011. *Design of Safety Significant Safety Instrumented Systems Used at DOE Non-Reactor Nuclear Facilities*. U.S. Department of Energy, Office of Nuclear Safety Policy and Assistance Online at <http://energy.gov/ehss/downloads/doe-std-1195-2011>.
- DOE-STD-3009-94. 2006. *Preparation Guidance for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses* (superseded by DOE-STD-3009-2014). U.S. Department of Energy, Office of Environment, Health, Safety & Security, Washington, D.C. Online at <http://energy.gov/ehss/downloads/doe-std-3009-94>.
- DOE/EA-1707. 2011. *Draft Environmental Assessment for Closure of the Solid Waste Landfill and the Nonradioactive Dangerous Waste Landfill*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://energy.gov/nepa/ea-1707-closure-nonradioactive-dangerous-waste-landfill-and-solid-waste-landfill-hanford-site>.
- DOE/EA-1728-F. 2012. *Environmental Assessment. Integrated Vegetation Management on the Hanford Site, Richland, Washington*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://energy.gov/nepa/ea-1728-integrated-vegetation-management-hanford-site-richland-washington>.
- DOE/EA-1915. 2012. *Draft Environmental Assessment for Hanford Land Conveyance and Notice of Potential Floodplain and Wetland Involvement at the Hanford Site, Richland, Washington*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://energy.gov/nepa/downloads/ea-1915-notice-intent-prepare-environmental-assessment-and-notice-potential>.
- DOE/EA-1919. 2012. *Draft Programmatic Environmental Assessment for the Recycle of Scrap Metals Originating from Radiological Areas*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at [http://energy.gov/sites/prod/files/DOE-EA-1919\\_Draft\\_EA\\_December\\_2012.pdf](http://energy.gov/sites/prod/files/DOE-EA-1919_Draft_EA_December_2012.pdf).
- DOE/EA-1934. 2013. *Environmental Assessment for Expansion of Borrow Areas on the Hanford Site*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at [http://www.hanford.gov/files.cfm/doe-ea-1934\\_rev0\\_final.pdf](http://www.hanford.gov/files.cfm/doe-ea-1934_rev0_final.pdf).
- DOE/EA-1934. 2015. *Mitigation Action Plan Annual Report Calendar Year 2014, Environmental Assessment for Expansion of Borrow Areas on the Hanford Site*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://energy.gov/sites/prod/files/2015/03/f20/EA-1934-FEA-MAP-2014.pdf>.
- DOE/EH-0173T. 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. U.S. Department of Energy, Washington, D.C. Online at <https://www.ornl.gov/ptp/pdf/eh0173t.pdf>.
- DOE/EH-0676. 2004. "User's Guide, Version 1. RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation." *Interagency Steering Committee on Radiation Standards Technical Report 2004-02*. U.S. Department of Energy, Washington, D.C. Online at [http://homer.ornl.gov/sesa/environment/guidance/risk/resrad-biota\\_user\\_guide\\_version1.pdf](http://homer.ornl.gov/sesa/environment/guidance/risk/resrad-biota_user_guide_version1.pdf).

- DOE/EIS-0222-F. 1999. *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*. U.S. Department of Energy, Washington, D.C. Online at [http://www.hanford.gov/files.cfm/final\\_hanford\\_comprehensive\\_land-use\\_plan\\_eis\\_september\\_1999\\_.pdf](http://www.hanford.gov/files.cfm/final_hanford_comprehensive_land-use_plan_eis_september_1999_.pdf).
- DOE/EIS-0391. 2012. *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (78 FR 75913-75919). U.S. Department of Energy, Washington, D.C. Online at <http://energy.gov/nepa/eis-0391-hanford-tank-closure-and-waste-management-richland-washington>.
- DOE/EIS-0391D-SA-01. 2012. *Supplemental Analysis of the Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland Washington*. U.S. Department of Energy, Washington, D.C. Online at <http://energy.gov/nepa/downloads/eis-0391-supplement-analysis-environmental-impact-statement>
- DOE/EIS-0423. 2011. *Final Long-Term Management and Storage of Elemental Mercury Environmental Impact Statement (Mercury Storage EIS)*. U.S. Department of Energy, Washington, D.C. Online at <http://energy.gov/nepa/downloads/eis-0423-final-environmental-impact-statement>.
- DOE/EIS-0423-S1. 2011. *Final Supplemental Environmental Impact Statement Long-Term Management and Storage of Elemental Mercury*. U.S. Department of Energy. Online at <http://www.energy.gov/nepa/downloads/eis-0423-s1-final-supplemental-environmental-impact-statement>.
- DOE/EIS-0467. 2012. *Notice of Intent to Prepare an Environmental Impact Statement for the Acquisition of a Natural Gas Pipeline and Natural Gas Utility Service at the Hanford Site, Richland, WA, and Notice of Floodplains and Wetlands Involvement* (77 FR 3255). U.S. Department of Energy, Washington, D.C. Online at <http://energy.gov/nepa/downloads/eis-0467-notice-intent-prepare-environmental-impact-statement-and-notice-floodplains>.
- DOE/EPA. 2005. *Action Memorandum #1 for the 300 Area Facilities*. U.S. Department of Energy, Richland Operations Office, Richland, Washington; and U.S. Environmental Protection Agency, Region 10, Seattle, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=d7135498>.
- DOE/EPA. 2006a. *Action Memorandum #2 for the 300 Area Facilities*. U.S. Department of Energy, Richland Operations Office, Richland, Washington; and U.S. Environmental Protection Agency, Region 10, Seattle, Washington. Online at <http://pdw.hanford.gov/arpir/pdf.cfm?accession=da02553852>.
- DOE/EPA. 2006b. *Action Memorandum #E for the 300 Area Facilities*. U.S. Department of Energy, Richland Operations Office Richland, Washington; and U.S. Environmental Protection Agency, Region 10, Seattle, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04027779>.
- DOE/EPA. 2014. *Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*. U.S. Department of Energy and the U.S. Environmental Protection Agency. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0083577>.

- DOE/EPA/Ecology. 2005. *Record of Decision 221-U Facility (Canyon Disposition Initiative) Hanford Site Washington*. U.S. Department of Energy, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology. Online at [http://yosemite.epa.gov/r10/cleanup.nsf/sites/hanford2/\\$file/cdirod.pdf](http://yosemite.epa.gov/r10/cleanup.nsf/sites/hanford2/$file/cdirod.pdf).
- DOE/EPA/Ecology. 2011. *Record of Decision Hanford 200 Area Superfund Site 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*. U.S. Department of Energy, Richland Operations Office, Richland, Washington; U.S. Environmental Protection Agency, Region 10, Seattle, Washington; and Washington State Department of Ecology, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093644>.
- DOE/EPA/Ecology. 2013. *Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1 and Record of Decision Amendment for 300-FF-1*. U.S. Department of Energy, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology. Online at <http://pdw.hanford.gov/arpir/pdf.cfm?accession=0087180>.
- DOE/ORP-2008-01, Rev. 1. 2009. *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas*. U.S. Department of Energy, Office of River Protection, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1001051140>.
- DOE/RL-91-50, Rev. 6A. 2013. *Environmental Monitoring Plan, United States Department of Energy, Richland Operations Office*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1503160460>.
- DOE/RL-92-12, Rev. 1. 1992. *Sampling and Analysis of 100 Area Springs*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=d196102723>.
- DOE/RL-92-67, Draft B. 1992. *Final Remedial Investigation/Feasibility Study - Environmental Assessment Report for the 1100-EM-1 Operable Unit, Hanford*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at  
Section 1 <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=d199042470>.  
Section 2 <http://pdw.hanford.gov/arpir/index.cfm/docdetail?accession=d199042475>.  
Section 3 <http://pdw.hanford.gov/arpir/index.cfm/docdetail?accession=d199042545>.
- DOE/RL-94-150, Rev. 2. 2013. *Bald Eagle Management Plan for the Hanford Site, South-Central Washington*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.hanford.gov/files.cfm/hanford%20bald%20eagle%20management%20plan%20rev.%202%20-%20final.pdf>.
- DOE/RL-96-32, Rev. 0. 2001. *Hanford Site Biological Resources Management Plan*, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.
- DOE/RL-96-68, Rev. 3. 2007. *Hanford Analytical Services Quality Assurance Requirements Documents*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/analyticalservices>.

- DOE/RL-96-77, Rev 0. 1996. *Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=da06717578>.
- DOE/RL-98-10, Rev. 0. 2003. *Hanford Cultural Resources Management Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at [http://www.hanford.gov/files.cfm/han\\_cult\\_res\\_mngmt\\_plan\\_full\\_doc.pdf](http://www.hanford.gov/files.cfm/han_cult_res_mngmt_plan_full_doc.pdf).
- DOE/RL-2000-27, Rev. 0. 2000. *Threatened and Endangered Species Management Plan: Salmon and Steelhead*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.
- DOE/RL-2001-41, Rev. 6. 2013. *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0089720>.
- DOE/RL-2004-60, Rev. 1, Draft A. 2011. *200-SW-2 Radioactive Landfills Group Operable Unit RCRA Facility Investigation/Corrective Measures Study Remedial Investigation/Feasibility Study Work Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1112150343>.
- DOE/RL-2006-20. 2006. *The Second CERCLA Five-Year Review Report for the Hanford Site*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.hanford.gov/files.cfm/cercla-5yr-final-nov.pdf>.
- DOE/RL-2006-21, Rev. 0. 2008. *Remedial Design/Remedial Action Work Plan for the 221-U Facility*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0902180737>.
- DOE/RL-2007-50, Rev. 1. 2011. *Central Plateau Ecological Risk Assessment Data Package Report*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1108100554>.
- DOE/RL-2009-10, Rev. 1. 2010. *Hanford Site Cleanup Completion Framework*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at [http://www.hanford.gov/files.cfm/comp\\_framework\\_jan\\_201-23-13-lfm.pdf](http://www.hanford.gov/files.cfm/comp_framework_jan_201-23-13-lfm.pdf).
- DOE/RL-2009-121, Rev. 0. 2010. *Sampling and Analysis Plan for the West Lake Site*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0084064>.
- DOE/RL-2009-94. 2010. *216-U-8 Crib and 216-U-12 Vadose Zone Characterization Sampling and Analysis Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0084142>.



- DOE/RL-2010-22. 2010. *Action Memorandum for General Hanford Site Decommissioning Activities*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0084142>.
- DOE/RL-2010-49. 2011. *Remedial Investigation/Feasibility Study Work Plan 200-WA-1 and 200-BC-1 Operable Units*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0093514>.
- DOE/RL-2010-89, Rev. 0. 2010. *Long-Range Deep Vadose Zone Program Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0084131>.
- DOE/RL-2010-114, Draft A. 2011. *200-IS-1 Operable Unit Pipeline System Waste Sites RFI/CMS and RI/FS Work Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093547>.
- DOE/RL-2011-56, Rev. 1. 2012. *Hanford Site Third CERCLA Five-Year Review Report*. U.S. Department of Energy, Richland, Washington. Online at <http://www.hanford.gov/?page=641>.
- DOE/RL-2011-58, Rev. 0. 2011. *200-CW-3 Operable Unit Interim Remedial Action Report*. U.S. Department of Energy, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0093638>.
- DOE/RL-2011-102, Draft A. 2015. *Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-DV-1 Operable Unit*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081657H>.
- DOE/RL-2011-119. 2012. *Hanford Site Environmental Report for Calendar Year 2011*. Rev. 0. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0091455>.
- DOE/RL-2011-104, Rev. 0. 2012. *Characterization Sampling and Analysis Plan for the 200-DV-1 Operable Unit*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1202020261>.
- DOE/RL-2013-12, Rev. 0. 2013. *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2012*. U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE/RL-2013-18, Rev. 0. 2013. *Hanford Site Environmental Report for Calendar Year 2012*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://msa.hanford.gov/page.cfm/enviroreports>.
- DOE/RL-2013-47, Rev. 0. 2014. *Hanford Site Environmental Report for Calendar Year 2013*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at [http://msa.hanford.gov/files.cfm/2013\\_DOE-RL-2013-47\\_R0.pdf](http://msa.hanford.gov/files.cfm/2013_DOE-RL-2013-47_R0.pdf).
- DOE/RL-2013-53, Rev. 0. *Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2014*, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at [http://www.hanford.gov/files.cfm/mss\\_2014.pdf](http://www.hanford.gov/files.cfm/mss_2014.pdf).

- DOE/RL-2014-17, Rev. 0. 2014. *Calendar Year 2013 Hanford Site Mixed Waste Land Disposal Restrictions Summary Report*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/pdf.cfm?accession=0082925h>.
- DOE/RL-2014-38, Rev. 0. 2014. *100-OL-1 Operable Unit Field Portable X-Ray Fluorescence (XRF) Analyzer Pilot Study Plans*. Bunn AL, BG Fritz, and DM Wellman. PNNL-23471, Pacific Northwest National Laboratory, Richland, WA. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-23471.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23471.pdf).
- DOE/RL-2015-07, Rev. 0. 2015. *Hanford Site Groundwater Monitoring Report for 2014*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports>
- DOE/RL-2015-09, Rev. 0. 2015. *2014 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory, Emergency Planning and Community Right-To-Know Act Section 312*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE/RL-2015-12, Rev. 0. 2015. *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2014*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080156H>.
- DOE/RL-2015-13, Rev. 0. 2015. *Hanford Site Annual Dangerous Waste Report Calendar Year 2014*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0081883h>.
- DOE/RL-2015-24, Rev. 0. 2015. *2014 Hanford Site Polychlorinated Biphenyl Annual Report*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080921H>.
- DOE/RL-2015-25, Rev. 0. 2015. *2014 Hanford Site Polychlorinated Biphenyl Annual Document Log*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080922H>.
- DOE/RL-2015-43, Rev. 0. 2015, *2014 Hanford Site Toxic Chemical Release Inventory, Emergency Planning and Community Right-To-Know Act Section 313*. U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE/STD-1153-2002. 2002. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. Final Technical Standard, U.S. Department of Energy and the Office of Environmental Policy and Guidance, Washington, D.C. Online at [http://energy.gov/sites/prod/files/2013/09/f3/1153\\_Frontmatter.pdf](http://energy.gov/sites/prod/files/2013/09/f3/1153_Frontmatter.pdf).
- Ecology. 2014a. *08-5085-FVS*. Letter, B. Ferguson (Attorney General); to D. Kaplan (U.S. Department of Justice), and S. Silverman (U.S. Department of Justice), dated March 31, 2014, *Washington v. Chu, U.S.D.C. Eastern No. 08-5085-FVS, State of Washington's Proposal to Amend Consent Decree*, Attorney General of Washington Ecology Office, Olympia, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0086019>.

- Ecology. 2014b. *08-5085-FVS*. Letter, B. Ferguson (Attorney General); to D. Kaplan (U.S. Department of Justice), and S. Silverman (U.S. Department of Justice), dated April 18, 2014, *Washington v. Chu, U.S.D.C. Eastern No. 08-5085-FVS, Response to Department of Energy's March 31, 2014, Proposal to Amend Consent Decree*, Attorney General of Washington Ecology Office, Olympia, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1404220427>.
- Ecology. 2014c. *08-5085-FVS*. Letter, B. Ferguson (Attorney General); to D. Kaplan (U.S. Department of Justice), and S. Silverman (U.S. Department of Justice), dated April 23, 2014, *Washington's Notice Invoking Dispute Resolution Based on Department of Energy's Refusal to Accept Washington's March 31, 2014, Proposal to Amend Consent Decree*, Attorney General of Washington Ecology Office, Olympia, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1404240532>.
- Ecology. 2014d. *08-5085-FVS*. Letter, B. Ferguson (Attorney General) to E. Moniz (DOE Secretary of Energy); and D. Olson (WRPS); and G. McCarthy (EPA), dated November 19, 2014, *Notice of Endangerment and Intent to File Suit Pursuant to 42 U.S.C. 6972(a)(1)(B), Resource Conservation and Recovery Act 7002(a)(1)(B)*. Attorney General of Washington Ecology Office, Olympia, Washington.
- Ecology/EPA/DOE. 1989a. *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) as amended. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. Richland, Washington. Online at <http://www.hanford.gov/?page=81>.
- Ecology/EPA/DOE. 1989b. *Hanford Federal Facility Agreement and Consent Order Action Plan*, as amended. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. Richland, Washington. Online at <http://www.hanford.gov/?page=82>.
- Eisenbud M. 1987. *Environmental Radioactivity: From Natural, Industrial, and Military Sources* (Third Edition, Chapter 5), Academic Press, Inc., New York.
- Eldred, D. 1970. Steelhead Spawning in the Columbia River, Ringold to Priest Rapids Dam, September 1970 Progress Report. Washington Department of Game, Ephrata, Washington. 4 pp.
- Emergency Planning and Community Right to Know Act of 1986*. U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/oecaagct/lcra.html>.
- Endangered Species Act of 1973*. Public Law 93-205, as amended, 16 USC 1531 et seq. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C. Online at <http://www.epw.senate.gov/esa73.pdf>.
- Endangered and Threatened Wildlife and Plants*. April 23, 2013. Federal Register, 78 FR 23984 Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C. Online at <http://www.gpo.gov/fdsys/pkg/fr-2013-04-23/html/2013-09409.htm>.
- EPA 402-R-93-081. 1993. *External Exposure to Radionuclides in Air, Water, and Soil*. Federal Guidance Report No. 12, U.S. Environmental Protection Agency, Washington, D.C. Online at <https://crpk.ornl.gov/documents/fgr12.pdf>.

- EPA 402-R-99-001. 1999. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*. Federal Guidance Report No. 13, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/rpdweb00/docs/federal/402-r-99-001.pdf>.
- EPA. 2001. *USDOE Hanford Site First Five-Year Review Report*. U.S. Environmental Protection Agency, Region 10, Richland, Washington. Online at <http://www.epa.gov/superfund/sites/fiveyear/f01-10001.pdf>.
- EPA et al. 2000. *Framework Agreement for Management of Polychlorinated Biphenyls (PCBs) in Hanford Tank Waste*, Approved by Department of Ecology State of Washington, U.S. Environmental Protection Agency Region 10, U. S. Department of Energy Office of River Protection, and U. S. Department of Energy-Richland Operations Office on August 31, 2000. Online at <http://yosemite.epa.gov/R10/OWCM.NSF/72b5220edcd9cf5b88256500005decf3/ce50d3fe12e371f488256a00006ffa0f1OpenDocument>
- EPA-402-R-93-081. 1993. *External Exposure to Radionuclides in Air, Water, and Soil*. Federal Guidance Report No. 12, U.S. Environmental Protection Agency, Washington, D.C. Online at <https://crpk.ornl.gov/documents/fgr12.pdf>.
- EPA-402-R-00-004. 2000. *Updated User's Guide for CAP88-PC, Version 2.0*. Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/rpdweb00/docs/cap88/402-r-00-004.pdf>.
- EPA-520/1-88-020. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. Federal Guidance Report No. 11, U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/radiation/docs/federal/520-1-88-020.pdf>.
- [EPA-570/9-76-0003](#). 1975. *National Interim Primary Drinking Water Regulations*. U.S. Environmental Protection Agency, Washington, D.C.
- EPA/240/B-01/003. 2001. *EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5*. U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/quality/qs-docs/r5-final.pdf>.
- EPA/520/1-89-005. 1989. *Risk Assessment Methodology Environmental Impact Statement NESHAPS for Radionuclides Background Information Document – Volume 1*. U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/radiation/docs/neshaps/subpart-w/historical-rulemakings/risk-assessments-methodology-eis-neshaps-for-radionuclides.pdf>.
- EPA/600/R-09/052F. 2011. *Exposure Factors Handbook: 2011 Edition*. U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/ncea/efh/pdfs/efh-frontmatter.pdf>.
- EPA/ROD/R10-01-119. 2001. *EPA Superfund Record of Decision: Hanford 300-Area (USDOE), EPA ID: WA2890090077, OU 03, Benton County, WA*, dated April 20, 2001, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.epa.gov/superfund/sites/rods/fulltext/r1001119.pdf>.

- EPA/ROD/R10-95/100. 1995. *EPA Superfund Record of Decision: Hanford 200 Area (USDOE)*, EPA ID: WA1890090078, OU 14, Benton County, WA, dated January 20, 1995, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.epa.gov/superfund/sites/rods/fulltext/r1095100.pdf>.
- Executive Order 11593. May 13, 1971. *Protection and Enhancement of the Cultural Environment*. Office of the President 36 FR 8921. Online at <http://www.gsa.gov/portal/content/101025>.
- Executive Order 11988. May 24, 1977. *Floodplain Management*. Federal Register, Office of the President 32 CFR 644.320. Online at [http://www.fws.gov/r9esnepa/nepa\\_handbook/eo\\_11988.pdf](http://www.fws.gov/r9esnepa/nepa_handbook/eo_11988.pdf).
- Executive Order 11990. May 24, 1977. *Protection of Wetlands*. Federal Register, Office of the President 32 CFR 644.319. Online at <http://denix.osd.mil/nr/upload/executive-order-11990.pdf>.
- Executive Order 12580. January 23, 1987. *Superfund Implementation*. Federal Register, Office of the President 52 FR 2923. Online at <http://www.archives.gov/federal-register/codification/executive-order/12580.html>.
- Executive Order 13007, *Indian Sacred Sites*. May 24, 1996. Federal Register, Office of the President 61 FR 26771. Online at <http://energy.gov/em/downloads/executive-order-13007-indian-sacred-sites-1996>.
- Executive Order 13175. November 6, 2000. *Consultation and Coordination with Indian Tribal Governments*, Office of the President 65 FR 67249. Online at <http://www.gpo.gov/fdsys/pkg/fr-2000-11-09/pdf/00-29003.pdf>.
- Executive Order 13287. February 15, 2006. *Preserve America*. Office of the President 68 FR 10635. Online at <http://www.achp.gov/docs/EO.FINAL.highres.pdf>.
- Executive Order 13423. January 26, 2007. *Strengthening Federal Environmental, Energy and Transportation Management*. Office of the President 72 FR 3919. Online at <http://edocket.access.gpo.gov/2007/pdf/07-374.pdf>.
- Executive Order 13514. October 5, 2009. *Federal Leadership in Environmental, Energy, and Economic Performance*. Federal Register, Office of the President. 74 FR 52117. Online at <https://www.federalregister.gov/articles/2009/10/08/E9-24518/federal-leadership-in-environmental-energy-and-economic-performance>.
- Federal Facility Compliance Act of 1992*. Public Law 102-386. Office of Health, Safety and Security. U.S. Department of Energy, Washington, D.C. Online at [http://www.labtrain.noaa.gov/ppguide/ffpp\\_55.htm](http://www.labtrain.noaa.gov/ppguide/ffpp_55.htm).
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)*. U.S. Environmental Protection Agency, Washington, D.C. Online at <http://www.epa.gov/oecaagct/lfra.html>.
- Fitzner, R.E. and R.H. Gray. 1991. *Status, Distribution, and Ecology of Wildlife on the U.S. DOE Hanford Site: A historical overview of Research Activities*, Environmental Monitoring and Assessment. V 18, pp 173-202. Online at <http://www.ncbi.nlm.nih.gov/pubmed/24233850>.

- Gibbons, G.J. 2000. *An Investigation of the Origin of <sup>152</sup>Eu in Columbia River Sediments*. Master's Thesis, Idaho State University, Department of Physics, Pocatello, Idaho.
- Hanford Natural Resource Trustee Council. 1966. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/hnrtc>.
- Hanford Site Real-Time and Historical Data from the Hanford Meteorology Station. U.S. Department of Energy, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/hms>.
- Hazardous and Solid Waste Amendments of 1984*. Public Law 98-616, as amended. Online at <http://thomas.loc.gov/cgi-bin/bdquery/z?d098:HR02867:@@D&summ2=5&TOM:/bss/d098query.html>
- Hazardous Waste Management Act of 1976*. RCW 70.105, as amended. Revised Code of Washington, Olympia, Washington. Online at <http://apps.leg.wa.gov/rcw/default.aspx?cite=70.105>.
- Historic Sites Act of 1935*. 1935. 16 USC 461-467, as amended. Online at [http://www.cr.nps.gov/local-law/fhpl\\_histsites.pdf](http://www.cr.nps.gov/local-law/fhpl_histsites.pdf).
- HNF-58717. 2015. *Hanford Site Raptor Nest Monitoring Report for Calendar Year 2014*. Mission Support Alliance, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.
- HNF-58823. 2015. *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2014*. Mission Support Alliance, Richland, Washington. Online at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>
- Howard P. "Buck" McKeon National Defense Authorization Act for Fiscal Year 2015*, Public Law 113-291.
- ICRP. 1959. ICRP Publication 2. *Permissible Dose for Internal Radiation*, International Commission on Radiological Protection. Pergamon Press, Elmsford, New York. Online at <http://www.icrp.org/publication.asp?id=icrp%20publication%202>.
- ICRP. 1977. ICRP Publication 26. *Recommendations of the ICRP*, Annals ICRP 1 (3) International Commission on Radiological Protection. Pergamon Press, Elmsford, New York. Online at <http://www.icrp.org/publication.asp?id=icrp%20publication%2026>.
- ICRP. 1979a. ICRP Publication 30, Part 1. *Limits for Intakes of Radionuclides by Workers*. *Annals of the ICRP*, 2(3/4). International Commission on Radiological Protection. Pergamon Press, Elmsford, New York. Online at [http://www.icrp.org/publication.asp?id=icrp%20publication%2030%20\(index\)](http://www.icrp.org/publication.asp?id=icrp%20publication%2030%20(index)).
- ICRP. 1979b. ICRP Publication 30, Supplement to Part 1. *Limits for Intakes of Radionuclides by Workers*. *Annals ICRP* 3 (1-4). International Commission on Radiological Protection. Pergamon Press, Elmsford, New York. Online at [http://www.icrp.org/publication.asp?id=icrp%20publication%2030%20\(index\)](http://www.icrp.org/publication.asp?id=icrp%20publication%2030%20(index)).
- ICRP. 1991. ICRP Publication 60, *Recommendations of the International Commission on Radiological Protection*. *Annals of the ICRP* 21(1-3). International Commission on Radiological Protection, Pergamon Press, Elmsford, New York. Online at [http://www.icrp.org/publication.asp?id=ICRP%20Publication%2060%20\(Users%20Edition\)](http://www.icrp.org/publication.asp?id=ICRP%20Publication%2060%20(Users%20Edition)).



- ICRP. 1996. ICRP Publication 72, Age-dependent Doses to the Members of the Public from Intake of Radionuclides – Part 5 Compilation of Ingestion and Inhalation Coefficients. International Commission on Radiological Protection, Pergamon Press, Elmsford, New York. Online at <http://www.icrp.org/publication.asp?id=icrp%20publication%2072>.
- ISCORS. 2002. *A Method for Estimating Radiation Risk from TEDE*. ISCORS Technical Report No. 1, Interagency Steering Committee on Radiation Standards, Washington, D.C. Online at <http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/doe%202003c.pdf>.
- ISO 14001:2004(E). 2004. *Environmental Management Systems – Requirements with Guidance for Use*. International Organization for Standardization, Geneva, Switzerland.
- Jenkins, O.P. 1922. *Underground Water Supply of the Region About White Bluffs and Hanford*. State of Washington Department of Conservation and Development, Olympia, Washington. Online at <http://biodiversitylibrary.org/page/34454948>.
- Lindsey, C. and J. Nugent. 2014. *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2013*. HNF-56707. Prepared by Mission Support Alliance for the U.S. Department of Energy, Richland, Washington. Online at: [http://www.hanford.gov/files.cfm/HNF-56707\\_-\\_Rev\\_00.pdf](http://www.hanford.gov/files.cfm/HNF-56707_-_Rev_00.pdf).
- Mercury Export Ban Act of 2008*, Public Law 110-414. Online at <http://www.gpo.gov/fdsys/pkg/PLAW-110publ414/pdf/PLAW-110publ414.pdf>.
- Microbial and Disinfection Byproduct Rules*, adapted from U.S. Environmental Protection Agency website. Online at: <http://web.cecs.pdx.edu/~fishw/UO-DisinfectionRules.pdf>
- MSA. 2015. *Hanford Site Annual Environmental Report*. Prepared by Mission Support Alliance for the U.S. Department of Energy, Richland, Washington. Online at: <http://msa.hanford.gov/page.cfm/enviroreports>.
- Myers, J.M, R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California*. U.S. Department of Commerce, NOAA Tech. Memo NMFS-NWFSC-35, 443 p. Online at [http://www.nwfsc.noaa.gov/assets/25/7190\\_07042012\\_124647\\_Myers.et.al.1998-rev.pdf](http://www.nwfsc.noaa.gov/assets/25/7190_07042012_124647_Myers.et.al.1998-rev.pdf).
- Migratory Bird Treaty Act of 1918. 40 Stat. 755, as amended, 16 USC 710, U.S. Fish and Wildlife Service. Online at <http://www.fws.gov/laws/lawsdigest/migtrea.html>.
- National Environmental Policy Act of 1969*. Public Law 91-190, as amended, 42 USC 4321 et seq. Online at [http://www.nps.gov/history/local-law/fhpl\\_ntlenvirnpolicy.pdf](http://www.nps.gov/history/local-law/fhpl_ntlenvirnpolicy.pdf).
- National Historic Preservation Act of 1966*. Public Law 89-665, as amended, 16 USC 470 et seq. Online at [http://www.cr.nps.gov/local-law/fhpl\\_histprsvt.pdf](http://www.cr.nps.gov/local-law/fhpl_histprsvt.pdf).
- National Register of Historic Places. *Code of Federal Regulations*, National Park Service, U.S. Department of the Interior. Online at <http://www.nps.gov/nr/regulations.htm>.
- National Research Council. 2006. *Health Risks from Exposure to Low Levels of Ionizing Radiation Phase 2*. National Academy Press, Washington, D.C. Online at [http://www.nap.edu/catalog.php?record\\_id=11340](http://www.nap.edu/catalog.php?record_id=11340).

- Native American Graves Protection and Repatriation Act of 1990*. Public Law 101-601, as amended, 25 USC 3001 et seq. Online at [http://www.nps.gov/history/local-law/fhpl\\_nagpra.pdf](http://www.nps.gov/history/local-law/fhpl_nagpra.pdf).
- NCRP. 2009. Report 160. *Ionizing Radiation Exposure of the Population of the United States*. National Council on Radiation Protection and Measurements, Washington, D.C. Purchase online at <http://www.ncrppublications.org/reports/160>.
- Netboy, A. 1958. *Salmon of the Pacific Northwest: Fish vs. Dams*. Birnfields & Mort, Publishers, Portland, Oregon.
- NOAA. 2013. *Endangered and Threatened Marine Species*. National Oceanic and Atmospheric Administration Fisheries. Office of Protected Resources, Seattle, Washington. Online at <http://www.nmfs.noaa.gov/pr/species/esa>.
- Nugent, J., C. Lindsey, and G. Malin. 2013. *Raptor Nest Monitoring Report for Calendar Year 2012*. HNF-53073, Rev. 0. Mission Support Alliance, Richland, Washington. Online at: <http://www.hanford.gov/files.cfm/HNF-53073 - rev 00 No Coversheets.pdf>.
- Nugent, J., C. Lindsey, and J. Wilde. 2014. *Hanford Site Raptor Nest Monitoring Report for Calendar Year 2013*. HNF-56769, Rev. 0. Mission Support Alliance, Richland, Washington. Online at: <http://www.hanford.gov/files.cfm/HNF-56769 - Rev 00.pdf>.
- Patton G.W., A.T. Cooper, and M.R. Tinker. 1997. *Ambient Air Sampling for Tritium - Determination of Breakthrough Volumes and Collection Efficiencies for Silica-Gel Absorbent*. Health Physics 72(3):397-407, March 1997. Online at [http://journals.lww.com/health-physics/Abstract/1997/03000/Ambient\\_Air\\_Sampling\\_for\\_Tritium\\_Determination\\_of.7.aspx](http://journals.lww.com/health-physics/Abstract/1997/03000/Ambient_Air_Sampling_for_Tritium_Determination_of.7.aspx).
- PCHB. 2014. PCHB-14-041C, Settlement Agreement, Washington River Protection Solutions; and U.S. Department of Energy Office of River Protection (Appellants) v. State of Washington Department of Ecology (Respondent), dated September 29, 2014, *PCHB No. 14-041c, Settlement Agreement*, Pollution Control Hearings Board, Olympia, Washington.
- PNL-5289. 1984. *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River*. W.D. McCormack and J.M.V. Carlile, Pacific Northwest Laboratory, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196018566>.
- PNL-5371. 1985. *Anadromous Salmonids of the Hanford Reach, Columbia River: 1984 Status*. Becker, C.D, Pacific Northwest Laboratory, Richland, Washington. Online at [http://www.osti.gov/energycitations/product.biblio.jsp?query\\_id=5&page=0&osti\\_id=5222130](http://www.osti.gov/energycitations/product.biblio.jsp?query_id=5&page=0&osti_id=5222130).
- PNL-6584. 1988. *GENII: The Hanford Environmental Radiation Dosimetry Software System: Volume 1, Conceptual Representation*. B.A. Napier, R.A. Peloquin, D.L. Streng, and J.V. Ramsdell, Pacific Northwest National Laboratory, Richland, Washington. Online at <http://www.osti.gov/scitech/biblio/6865398>.
- PNL-7500. 1990. *1988 Hanford Riverbank Springs Characterization Report*. R.L. Dirks, Pacific Northwest Laboratory, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196110656>.

- PNL-9394. 1994. *Ecotoxicity Literature Review of Selected Hanford Site Contaminants*. C.J. Driver, Pacific Northwest Laboratory, Richland, Washington. Online at <http://www.osti.gov/bridge/servlets/purl/10136486-6slptz/native/10136486.pdf>.
- PNL-8531. 1993. *Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pumpouse*. R.L. Dirkes, Pacific Northwest Laboratory, Richland, Washington. Online at <http://www.osti.gov/scitech/servlets/purl/10140874>.
- PNNL-6415, Rev. 18. 2007. Hanford Site National Environmental Policy Act (NEPA) Characterization. J.P. Duncan, ed. Pacific Northwest National Laboratory, Richland, Washington. Online at: [http://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-6415Rev18.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-6415Rev18.pdf).
- PNNL-11933. 1998. *Survey of Radiological Contaminants in the Near-Shore Environment at the Hanford Site 100-N Reactor Area*. G.W. Patton, M.L. Blanton, T.M. Poston, A.T. Cooper, E.J. Antonio, Pacific Northwest National Laboratory, Richland, Washington. S.P. Van Verst, C.L. Albin, Washington State Department of Health. Online at <http://www.osti.gov/bridge/servlets/purl/676900-tnbq2q/webviewable/676900.pdf>.
- PNNL-13417. 2001. *Simultaneously-Extracted Metals/Acid-Volatile-Sulfide and Total Metals in Surface Sediment from the Hanford Reach of the Columbia River and the Lower Snake River*. G.W. Patton and E.A. Crecelius, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/pnnl-13417.pdf](http://www.pnl.gov/main/publications/external/technical_reports/pnnl-13417.pdf).
- PNNL-13487. 2001. *Hanford Site Environmental Report for Calendar Year 2000*. T.M. Poston, R.W. Hanf, J.R., R.L. Dirkes, and L. F. Morasch, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/pnnl-13487-sum/pnnl-13487-sum.pdf](http://www.pnl.gov/main/publications/external/technical_reports/pnnl-13487-sum/pnnl-13487-sum.pdf).
- PNNL-13692, Rev. 1. 2002. *Survey of Radiological and Chemical Contaminants in the Near-Shore Environment at the Hanford Site 300 Area*. G.W. Patton, S.P. Van Verst, B.L. Tiller, E.J. Antonio, and T.M. Poston, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/pnnl-13692rev1.pdf](http://www.pnl.gov/main/publications/external/technical_reports/pnnl-13692rev1.pdf).
- PNNL-14444. 2003. *Aquifer Sampling Tube Results for Fiscal Year 2003*. M.J. Hartman and R.E. Peterson, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/PNNL-14444.pdf](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14444.pdf).
- PNNL-14583, Rev 3a. 2010. *GENII Version 2 Users' Guide*. B.A. Napier, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-14583rev3.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-14583rev3.pdf).
- PNNL-14584. 2011. *GENII Version 2 Software Design Document*. B.A. Napier, D.L. Streng, J.V. Ramsdell, Jr., P.W. Eslinger, and C. Fosmire, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-14584Rev3.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-14584Rev3.pdf).

- PNNL-15160. 2005. *Hanford Site Climatological Data Summary 2004 with Historical Data*. D.J. Hoitink, J.V. Ramsdell Jr., K.W. Burk, and W.J. Shaw, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/PNNL-15160.pdf](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15160.pdf).
- PNNL-16538. 2007. *T Tank Farm Interim Surface Barrier Demonstration – Vadose Zone Monitoring Plan*. Z.F. Zhang, J.M. Keller, and C.E. Strickland, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/pnnl-16538.pdf](http://www.pnl.gov/main/publications/external/technical_reports/pnnl-16538.pdf).
- PNNL-16805. 2007. *Investigation of the Hyporheic Zone at the 300 Area, Hanford Site*. B.G. Fritz, N.P. Kohn, T.J. Gilmore, D. McFarland, E.V. Arntzen, R.D. Mackley, G.W. Patton, D.P. Mendoza, and A.L. Bunn, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/PNNL-16805.pdf](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16805.pdf).
- PNNL-16894. 2007. *Investigation of the Strontium-90 Contaminant Plume along the Shoreline of the Columbia River at the 100-N Area of the Hanford Site*. D.P. Mendoza, B.G. Fritz, G.W. Patton, T.J. Gilmore, M.J. Hartman, R. Mackley, F.A. Spane, B.N. Bjornstad, M.D. Sweeney, and R.E. Clayton, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/pnnl-16894.pdf](http://www.pnl.gov/main/publications/external/technical_reports/pnnl-16894.pdf).
- PNNL-16990. 2007. *Summary of Radiological Monitoring of Columbia and Snake River Sediment, 1988 Through 2004*. G.W. Patton and R.L. Dirkes, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/PNNL-16990.pdf](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16990.pdf).
- PNNL-17306. 2008. *T Tank Farm Interim Surface Barrier Demonstration – Vadose Zone Monitoring FY07 Report*. Z.F. Zhang, C.E. Strickland, J.M. Keller, C.D. Wittreich, and H.A. Sydnor, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/pnnl-17306.pdf](http://www.pnl.gov/main/publications/external/technical_reports/pnnl-17306.pdf).
- PNNL-18427, App. 1. 2008. *Hanford Site Environmental Surveillance Data Report for Calendar Year 2008*. Pacific Northwest National Laboratory, Richland, Washington. Online at [http://msa.hanford.gov/files.cfm/2008\\_pnnl-18427\\_app1\\_surv-data.pdf](http://msa.hanford.gov/files.cfm/2008_pnnl-18427_app1_surv-data.pdf).
- PNNL-19168. 2010. *Hanford Site Annual Report Radiological Dose Calculation Upgrade Evaluation*. S.F. Snyder, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnl.gov/main/publications/external/technical\\_reports/PNNL-19168.pdf](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19168.pdf).
- PNNL-19455. 2010. *Hanford Site Environmental Report*. Pacific Northwest National Laboratory, Richland, Washington. Online at [http://msa.hanford.gov/files.cfm/2009\\_pnnl-19455.pdf](http://msa.hanford.gov/files.cfm/2009_pnnl-19455.pdf).
- PNNL-20548. 2011. *Hanford Site Environmental Report for Calendar Year 2010*, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://msa.hanford.gov/files.cfm/2010\\_PNNL-20548\\_Env-Report.pdf](http://msa.hanford.gov/files.cfm/2010_PNNL-20548_Env-Report.pdf).
- PNNL-20631. 2011. *Hanford Site Regional Population—2010 Census*. E.L. Hamilton and S.F. Snyder, Pacific Northwest National Laboratory, Richland, Washington. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-20631.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20631.pdf).

- PNNL-23665. 2014. *Gas-Phase Treatment of Technetium in the Vadose Zone at the Hanford Site Central Plateau*. Truex MJ, JE Szecsody, L Zhong, and N Qafoku, Pacific Northwest National Laboratory, Richland, WA. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-23665.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23665.pdf).
- PNNL-23666. 2014. *Conceptual Model of Uranium in the Vadose Zone for Acidic and Alkaline Wastes Discharged at the Hanford Site Central Plateau*. Truex MJ, JE Szecsody, N Qafoku, and JR Serne, Pacific Northwest National Laboratory, Richland, WA. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-23666.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23666.pdf).
- PNNL-23669. 2014. *Inorganic Sorbents for Iodine Removal from Subsurface Plumes: FY 2014 Status Report*. Levitskaia TG, S Chatterjee, JM Peterson, NK Pence, and J Romero, Pacific Northwest National Laboratory, Richland, WA.
- PNNL-23699. 2014. *Scale-Up Information for Gas-Phase Ammonia Treatment of Uranium in the Vadose Zone at the Hanford Site Central Plateau*. Truex MJ, JE Szecsody, L Zhong, JN Thomle, and TC Johnson. Pacific Northwest National Laboratory, Richland, WA. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-23699.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23699.pdf).
- PNNL-23730; RPT-DVZ-AFRI-021, Rev. 0. 2014. *Iodine Adsorption on Ion-Exchange Resins and Activated Carbons– Batch Testing*. Parker KE, EC Golovich, and DM Wellman, Pacific Northwest National Laboratory, Richland, WA. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-23730.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23730.pdf).
- PNNL-23731. 2014. Deep Vadose Zone Treatability Test for the Hanford Central Plateau: Interim Post-Desiccation Monitoring Results, Fiscal Year 2014. Truex MJ, CE Strickland, TC Johnson, CD Johnson, RE Clayton, and GB Chronister, Pacific Northwest National Laboratory, Richland, WA. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-23731.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23731.pdf).
- PNNL-23783. 2014. *E4D: A Distributed Memory Parallel Electrical Geophysical Modeling and Inversion Code*. Johnson TC, Pacific Northwest National Laboratory, Richland, WA.
- PNNL-23868. 2014. *100-OL-1 Operable Unit Pilot Study: XRF Evaluation of Select Pre-Hanford Orchards*. Bunn AL, BG Fritz, BA Pulsipher, AM Gorton, LE Bisping, JM Brandenberger, C Pino, DM Martinez, K Rana, and DM Wellman. Pacific Northwest National Laboratory, Richland, WA. Online at [http://www.pnnl.gov/main/publications/external/technical\\_reports/pnnl-23868.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-23868.pdf).
- Pollution Prevention Act of 1990*. 1990. U.S. Environmental Protection Agency. Online at <http://www.epw.senate.gov/PPA90.pdf>.
- PNNL-13487. 2001. *Hanford Site Environmental Report for Calendar Year 2000*. Pacific Northwest National Laboratory, Richland, Washington. Online at [https://msa.hanford.gov/files.cfm/PNNL-13487\\_2000.pdf](https://msa.hanford.gov/files.cfm/PNNL-13487_2000.pdf).
- RCRA. 1976. *Resource Conservation and Recovery Act of 1976*, 42 USC. 6901, et seq. Online at <http://www.epw.senate.gov/rcra.pdf>.
- RCW 15.58. “Washington Pesticide Control Act.” *Revised Code of Washington*, as amended. Olympia, Washington. Online at <http://longbeach.wsu.edu/cranberries/documents/rcw15581997washingtonpesticidecontrolact.pdf>.

- RCW 17.21. "Washington Pesticide Application Act." *Revised Code of Washington*, as amended. Olympia, Washington. Online at <http://longbeach.wsu.edu/cranberries/documents/rcw17211997washingtonpesticideapplicationact.pdf>.
- RCW 70.94. "Washington Clean Air Act." *Revised Code of Washington*, as amended, Olympia, Washington. Online at <http://apps.leg.wa.gov/rcw/default.aspx?cite=70.94>.
- Richardson, B. 2000. "Release of Surplus and Scrap Materials." Memorandum for Heads of Departmental Elements, dated July 13, 2000, Secretary of Energy, Washington, D.C. Online at [http://homer.ornl.gov/sesa/environment/radprotection/richardson\\_memo\\_7-13-2000.pdf](http://homer.ornl.gov/sesa/environment/radprotection/richardson_memo_7-13-2000.pdf)
- RPP-PLAN-53808, Rev. 1. 2013. *200 West Area Tank Farms Interim Measures Investigation Work Plan*. Washington River Protection Solutions, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0089300>.
- RPP-PLAN-57332. 2014. *Field Sampling and Analysis Plan for Soil Samples at Waste Management Area A-AX*. Washington River Protection Solutions, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081545H>.
- RPP-PLAN-58339, Draft A. 2014. *Phase 2 RCRA Facility Investigation Report for Waste Management Area C*. Washington River Protection Solutions, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/docdetail?accession=0082798h>.
- RPP-RPT-56430. 2014. *Three-Dimensional Surface Geophysical Exploration of the U Tank Farm*. Washington River Protection Solutions, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0081544h>.
- RPP-RPT-56596. 2014. *Pore-Water Extraction Proof-of-Principle Field Test Report*. Washington River Protection Solutions, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0083586>.
- RPP-RPT-56760. 2014. *Three-Dimensional Surface Geophysical Exploration of the 200-Series Tanks at the 241-C Tank Farm*. Washington River Protection Solutions, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0081543h>.
- RPP-RPT-57964. 2014. *Vadose Zone Characterization Report for 241-TX Tank Farm*. Washington River Protection Solutions, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0083674>.
- Safe Drinking Water Act of 1974*. 42 USC 300f, Public Law 93.523, as amended. Online at <http://water.epa.gov/lawsregs/rulesregs/sdwa/index.cfm>.
- Safe Drinking Water Act Amendments of 1996*. U.S. Environmental Protection Agency, Washington D.C. Online at <http://water.epa.gov/lawsregs/guidance/sdwa/theme.cfm>.
- SGW-41497, Rev. 0. 2009. *Aquifer Tube Optimization Evaluation*, M.J. Hartman, CH2M HILL Plateau Remediation Company, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0908311237>.



- SRNL-RP-2014-00791. 2014. *Hanford Tank Vapor Assessment Report*. Savannah River National Laboratory, Aiken, SC. Online at [http://srnl.doe.gov/documents/hanford\\_tvat\\_report\\_2014-10-30-final.pdf](http://srnl.doe.gov/documents/hanford_tvat_report_2014-10-30-final.pdf).
- ST-4500. 2014. *State Waste Discharge Permit ST 4500, 200 Area Effluent Treatment Facility (ETF)*. Washington State Department of Ecology. Richland, Washington. Online at <http://www.ecy.wa.gov/programs/nwp/permitting/wwd/pdf/st4500/st0004500.pdf>.
- ST-4502. 2012. *State Waste Discharge Permit ST 4502, 200 Area Treated Effluent Disposal Facility (TEDF)*. Washington State Department of Ecology. Richland, Washington. Online at <http://www.ecy.wa.gov/programs/nwp/permitting/wwd/pdf/st4502/st4502.pdf>.
- ST0004511. 2014. *State Waste Discharge Permit Number, Miscellaneous Streams*. Washington State Department of Ecology. Richland, Washington. Online at <http://www.ecy.wa.gov/programs/nwp/permitting/wwd/pdf/st4511/st4511.pdf>.
- ST0045514. 2012. *State Waste Discharge Permit ST-0045514, 200 West Area Evaporative Sewage Lagoon*. Washington State Department of Ecology. Richland, Washington. Online at <http://www.ecy.wa.gov/programs/nwp/permitting/wwd/pdf/st45514/st-45514.pdf>.
- Superfund Amendments and Reauthorization Act of 1986*. 2002. Located at <http://epw.senate.gov/sara.pdf>.
- Toxic Substances Control Act*. 1976. Public Law 94-469, as amended, 15 USC 2601 et seq. Online at <http://www.gpo.gov/fdsys/pkg/STATUTE-90/pdf/STATUTE-90-Pg2003.pdf>.
- TNC. 1999. *Biodiversity Inventory and Analysis of the Hanford Site, Final Report 1994-1999*. The Nature Conservancy of Washington, Seattle, WA. Online at [http://nerp.pnnl.gov/docs/ecology/biodiversity/biodiversity\\_1999.pdf](http://nerp.pnnl.gov/docs/ecology/biodiversity/biodiversity_1999.pdf).
- TPA. 2012a. *Hanford Public Involvement Plan*, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. Richland, Washington. Online at [http://www.hanford.gov/files.cfm/FacAgreementand-Consent-Order\\_FINAL.pdf](http://www.hanford.gov/files.cfm/FacAgreementand-Consent-Order_FINAL.pdf).
- TPA. 2012. *Tri-Party Agreement Agencies - Public Involvement Calendar Fiscal Year 2012*. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. Richland, Washington. Online at <http://www.hanford.gov/?page=81>.
- TPA. 2014. TPA Change Control Form M-16-14-02, R. Quintero (RL), and R. Lobos (EPA), dated November 7, 2014, Hanford Federal Facility Agreement and Consent Order (HFFACO) Extension of Dispute at the Project Manager Level for Change Control Form M-16-14-02. U.S. Department of Energy and U.S. Environmental Protection Agency, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1411100538>.
- TPA. 2015. Administrative Record. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. Richland, Washington. Online at <http://pdw.hanford.gov/arpir/>.
- UNSCEAR. 2012. *Biological Mechanisms of Radiation Actions at Low Doses*. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York. Online at [http://www.unscear.org/docs/reports/biological\\_mechanisms\\_wp\\_12-57831.pdf](http://www.unscear.org/docs/reports/biological_mechanisms_wp_12-57831.pdf).

- U.S. Government. 1855. *Treaty with the Nez Perce, 1855*. Online at <http://www.firstpeople.us/fp-html-treaties/treatywiththenezperces1855.html>.
- U.S. Government. 1855. *Treaty with the Walla Walla, Cayuse, etc., 1855*. Online at <http://www.firstpeople.us/fp-html-treaties/treaty-of-walla-walla-1855.html>.
- U.S. Government. 1855. *Treaty with the Yakama, 1855*. Online at <http://www.firstpeople.us/fp-html-treaties/treatywiththeyakima1855.html>.
- USACE (U.S. Army Corps of Engineers). 2006. *Hanford Reach Fall Chinook Protection Program*. Online at: <http://www.nwd-wc.usace.army.mil/tmt/documents/wmp/2006/draft/app7.pdf>.
- USFWS. 2010a. *Final Bull Trout Critical Habitat. Pacific Region, Portland, Oregon*. U.S. Fish and Wildlife Service. Online at <http://www.fws.gov/pacific/bulltrout/pdf/Justification%20Docs/BTFinalJustifyfulldoc.pdf>.
- USFWS. 2010b. *Endangered Species Program*. U.S. Fish and Wildlife Service. Online at [http://ecos.fws.gov/tess\\_public/pub/statelistingandoccurrenceindividual.jsp?state=wa](http://ecos.fws.gov/tess_public/pub/statelistingandoccurrenceindividual.jsp?state=wa).
- USGS. 2013. *Water-Data Report for 2013, 12472800 Columbia River Below Priest Rapids Dam, WA*. United States Geological Survey. Online at <http://wdr.water.usgs.gov/wy2013/pdfs/12472800.2013.pdf>.
- USGS Circular 1144. 1998. *Water Quality in the Central Columbia Plateau, Washington and Idaho, 1992-95*. A.K. Williamson, M.D. Munn, S.J. Ryker, R.J. Wagner, J.C. Ebbert, and A.M. Vanderpool, U.S. Geological Survey, Tacoma, Washington. Online at <http://pubs.usgs.gov/circ/circ1144/>.
- USGS Open File Report 95-445. 1995. *Nitrate Concentrations in Ground Water of the Central Columbia Plateau*. S.J. Ryker and J.L. Jones, U.S. Geological Survey, Tacoma, Washington. Online at <http://wa.water.usgs.gov/pubs/ofr/ofr95-445/>.
- WA7890008967. 1994. *Hanford Facility Dangerous Waste Permit*. As amended. State of Washington Department of Ecology, Richland, Washington.
- WA7890008967, Draft Rev. 9. 2012. *Hanford Facility Dangerous Waste Permit*. State of Washington Department of Ecology, Kennewick, Washington. Online at <http://www.ecy.wa.gov/programs/nwp/permitting/hdwp/index.html>.
- WA7890008967, Rev. 8C. 2014. *Hanford Facility Dangerous Waste Permit*. State of Washington Department of Ecology, Richland, Washington.
- WAC 16-228. "General Pesticide Rules," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=16-228>.
- WAC 173-201A. 2006. "Water Quality Standards for Surface Waters of the State of Washington," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-201a>.
- WAC 173-201A-240. "Toxic Substances," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-201a-240>.
- WAC 173-216. "State Waste Discharge Permit Program," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-216>.

- WAC 173-240. "Submission of Plans and Reports for Construction of Wastewater Facilities," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-240>.
- WAC 173-303. "Dangerous Waste Regulations," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-303>.
- WAC 173-303-060. "Notification and Identification Numbers," *Washington Administrative Code*, Olympia, Washington. Online at <http://app.leg.wa.gov/WAC/default.aspx?cite=173-303-060>.
- WAC 173-303-070(3). "Designation of Dangerous Waste," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-303-070>.
- WAC 173-303-145. "Spills to the Environment," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-303-145>.
- WAC 173-303-830. "Permit Changes," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-303-830>.
- WAC 173-350. "Solid Waste Handling Standards," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-350>.
- WAC 173-400. "General Regulations for Air Pollution Sources," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-400>.
- WAC 173-400-110. "New Source Review (NSR) for Sources and Portable Sources," *Washington Administrative Code*, Olympia, Washington. Online at <http://app.leg.wa.gov/WAC/default.aspx?cite=173-400-110>.
- WAC 173-401. "Operating Permit Regulation," *Washington Administrative Code*, Olympia, Washington. Online at <http://app.leg.wa.gov/WAC/default.aspx?cite=173-401>.
- WAC 173-425. "Outdoor Burning," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-425>.
- WAC 173-460. "Controls for New Sources of Toxic Air Pollutants," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-460>.
- WAC 173-460-040. "New Source Review," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-460-040>.
- WAC 173-480. "Ambient Air Quality Standards and Emission Limits for Radionuclides," *Washington Administrative Code*, Olympia, Washington. Online at <http://app.leg.wa.gov/WAC/default.aspx?cite=173-480>.
- WAC 173-491. "Gasoline Vapor Control Requirements," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-491-040>.
- WAC 246-247. "Radiation Protection – Air Emissions," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=246-247>.
- WAC 246-290. "Group A Public Water Supplies," *Washington Administrative Code*, Olympia, Washington. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=246-290>.

- WAG-50-5180. October 1, 2010. *Approval of the Sand and Gravel General Permit; Concrete Batch Plant*. Washington State Department of Ecology. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1009201525>.
- WAG-50-5181. September 13, 2010. *Approval of the Sand and Gravel General Permit; Gravel Pit 30*. Washington State Department of Ecology. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1009201524>.
- Wagner, P., C. Lindsey, and J. Nugent. 2012. *Fall Chinook Redd Monitoring Report Calendar Year 2011*. HNF-52190. Prepared by Mission Support Alliance for the U.S. Department of Energy, Richland, Washington. Online at: [http://www.hanford.gov/files.cfm/hnf-52190\\_-\\_rev\\_00%20public%20released.pdf](http://www.hanford.gov/files.cfm/hnf-52190_-_rev_00%20public%20released.pdf).
- Wagner, P., J. Nugent, and C. Lindsey. 2013. *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2012*. HNF-54808. Prepared by Mission Support Alliance for the U.S. Department of Energy, Richland, Washington. Online at: [http://www.hanford.gov/files.cfm/hnf-54808\\_-\\_rev\\_00\\_nc.pdf](http://www.hanford.gov/files.cfm/hnf-54808_-_rev_00_nc.pdf).
- Watson, D.G. 1973. *Estimate of Steelhead Trout Spawning in the Hanford Reach of the Columbia River*. Pacific Northwest National Laboratory, Richland, Washington. Online at [https://books.google.com/books/about/Estimate\\_of\\_Steelhead\\_Trout\\_Spawning\\_in.html?id=OtWRtgAACAAJ&hl=en](https://books.google.com/books/about/Estimate_of_Steelhead_Trout_Spawning_in.html?id=OtWRtgAACAAJ&hl=en).
- WCH-380. 2010. *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*. Washington Closure Hanford, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093555>.
- WCH-561. 2013. *Expansion of Borrow Areas on the Hanford Site Mitigation Action Plan for DOE/EA-1934*. B.L. Vedder, J.E. Bernhard, L.C. Purtzer, Washington Closure Hanford, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=1311010264>.
- WDFW (Washington Department of Fish and Wildlife). 2015. *Species of Concern in Washington*. Washington Department of Fish and Wildlife. Online at: <http://wdfw.wa.gov/conservation/endangered/>.
- WDOH 320-097. 2013. *Hanford Environmental Radiation Oversight Program 2011 Data Summary Report*. Environmental Radiation Monitoring and Assessment Program, Washington State Department of Health, Olympia, Washington. Online at <http://www.doh.wa.gov/portals/1/documents/pubs/320-0972011are.pdf>.
- WDOH. 2012. FF-01. Radioactive Air Emissions License for the Department of Energy Richland Operations Office Hanford Site, License Number FF-01. Washington State Department of Health, Olympia, Washington. Online at <http://www.ecy.wa.gov/programs/nwp/permitting/AOP/renewal/two/Final/Att-2/Att-2.pdf>.
- WDOH. 2014a. Environmental Sciences. Online at <http://www.doh.wa.gov/communityandenvironment/radiation/environmentalsciences.aspx>.

- WHC-EP-0609. 1992. *Riverbank Seepage of Groundwater Along the 100 Areas Shoreline, Hanford Site*. R.E. Peterson and V.G. Johnson, Westinghouse Hanford Company, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=d196124079>.
- WHC-SD-EN-TI-006, Rev. 0. 1992. *Hydrologic and Geologic Data Available for the Region North of Gable Mountain, Hanford Site, Washington*. Westinghouse Hanford Company, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0088998>.
- WHC-SD-EN-TI-070. 1992. *Soil Concentration Limits for Accessible and Inaccessible Areas*, PD Rittman, Westinghouse Hanford Company, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0089106>.
- WHC-SD-EN-TI-125, Rev. 0. 1993. *Sampling and Analysis of 300-FF-5 Operable Unit Springs and Near-Shore Sediments and River Water*. Westinghouse Hanford Company, Richland, Washington. Online at <http://pdw.hanford.gov/arpir/index.cfm/viewdoc?accession=0088997>.
- WHC-SD-EN-TI-198. *100 Area Columbia River Sediment Sampling*. S.G. Weiss, Westinghouse Hanford Company, Richland, Washington. Online at [http://www.osti.gov/bridge/product.biblio.jsp?osti\\_id=10184754](http://www.osti.gov/bridge/product.biblio.jsp?osti_id=10184754).
- WNHP. March 2014. *Washington Natural Heritage Program, Benton County*. Washington State Department of Natural Resources, Olympia, Washington. Online at <http://www1.dnr.wa.gov/nhp/refdesk/lists/plantsxco/benton.html>.
- Wilde, J., C. Lindsey, J. Nugent and M. Sackschewsky. 2012. *Burrowing Owl Monitoring Report for Calendar Year 2012*. HNF-54294. Mission Support Alliance, Richland, Washington. Online at: <http://www.hanford.gov/files.cfm/hnf-54294 - rev 00 cleared public.pdf>.
- Wilde, J., C. Lindsey, J. Nugent and M. Filan. 2014. *Hanford Site Burrowing Owl Monitoring Report for Calendar Year 2013*. HNF-56531. Mission Support Alliance, Richland, Washington. Online at: <http://www.hanford.gov/files.cfm/HNF-56531 - Rev 00.pdf>

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## A. Glossary

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This glossary contains selected words and phrases used in this report that may not be familiar to the reader. Words appearing in *italic* type within a definition are also defined in this glossary.

### A

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**absorbed dose** – Energy absorbed per unit mass from any kind of ionizing *radiation* in any kind of matter.

Units: *rad*, which is equal to the absorption of 100 ergs per gram of material irradiated, or *gray*, which is the International System of Units (SI) equivalent (1 *gray* = 100 *rad*).

**activation product** – Material made radioactive by *exposure* to *radiation*, principally by neutron radiation as in metals in a nuclear reactor (e.g., cobalt-60 from cobalt-59 in stainless steel).

**adsorption** – The accumulation of gases, liquids, or solutes on the surface of a solid or liquid.

**alpha particle** – A positively charged particle composed of two protons and two neutrons ejected spontaneously from the nuclei of some *radionuclides*. It has low penetrating power and short range. The most energetic alpha will generally fail to penetrate the skin. Alpha particles are hazardous when an alpha-emitting *isotope* is introduced into the body.

**anion** – A negatively charged ion.

**apatite** – A mineral that has the capability to capture and retain radioactive metal contaminants.

**aquifer** – Underground sediment or rock that stores and/or transmits water.

**aquifer tube** – A small-diameter, flexible plastic tube used to sample shallow *aquifers*, natural seepage areas, or springs.

### B

---

**background radiation** – *Radiation* in the natural environment, including cosmic rays from space and *radiation* from naturally occurring radioactive elements in the air, in the earth, and in human bodies. It also includes *radiation* from worldwide *fallout* from historical atmospheric nuclear weapons testing. In the United States, the average person receives approximately 310 *millirem* of background radiation per year.

**bank storage** – Hydrologic term that describes river water that flows into and is retained in permeable stream banks during periods of high river stage. Flow is reversed during periods of low river stage.

**becquerel (Bq)** – Unit of activity or amount of a radioactive substance (also *radioactivity*) equal to one nuclear transformation per second (1 Bq = 1 disintegration per second). Another unit of *radioactivity*, the *curie*, is related to the becquerel: 1 Ci =  $3.7 \times 10^{10}$  Bq.

**beta particle** – A negatively charged particle (essentially an electron) emitted from a nucleus during radioactive *decay*. Large amounts of beta particles may cause skin burns and are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

**biological half-life** – The time required for one-half of the amount of a *radionuclide* to be expelled from the body by natural metabolic processes, excluding radioactive *decay*, following ingestion, inhalation, or absorption.

**black cell** – A section of the Hanford Tank Waste Treatment and Immobilization Plant where high-level nuclear waste will be routed that will never be accessible to humans because of its high *radiation* levels.

---

## C

**cation** – A positively charged ion.

**clean closed** – A facility is classified as “clean closed” under *Resource Conservation and Recovery Act of 1976* regulations when all hazardous waste has been removed and *any remaining hazardous waste constituents do not exceed applicable cleanup levels*.

**collective total effective dose (equivalent)** (also referred to as “collective dose”) – Sum of the *total effective dose* for individuals comprising a defined population. Collective dose is expressed in units of *person-rem* or *person-sievert*.

**committed dose equivalent** – The *dose equivalent* to organs or tissues that will be received from an intake of radioactive material by an individual during the 50-year period following intake.

**committed effective dose equivalent** – The sum of the *committed dose equivalent* to various tissues in the body, each multiplied by the appropriate weighting factor.

**composite sample** – Sample formed by mixing discrete samples taken at different times or from different locations.

**confined aquifer** – An *aquifer* bounded above and below by less-permeable layers. *Groundwater* in the confined aquifer is under a pressure greater than atmospheric pressure.

**continuous sample** – Sample formed by the continuous collection of the medium or contaminants within the medium during the entire sampling period.

**cosmic radiation** – High-energy subatomic particles and electromagnetic *radiation* from outer space that bombard the earth. Cosmic radiation is part of natural *background radiation*.

**crib** – An underground structure designed to receive liquid waste that percolates into the soil directly or percolates into the soil after having traveled through a connected tile field. These structures are no longer used at the Hanford Site.

**curie (Ci)** – A unit of *radioactivity* equal to 37 billion ( $3.7 \times 10^{10}$ ) nuclear transformations per second (*becquerels*).

---

## D

**decay** – The decrease in the amount of any radioactive material (disintegration) with the passage of time. See *radioactivity*.

**decay product** – The atomic nucleus or nuclei that are left after radioactive transformation of a radioactive material. Decay products may be radioactive or non-radioactive (stable). They are informally referred to as daughter products. See *radioactivity*.

**deep-dose equivalent** – The *dose equivalent* at a tissue depth of 1 centimeter from *radiation* originating outside of the body.

**derived concentration guide (DCG)** – Concentrations of *radionuclides* in air and water that an individual could continuously consume, inhale, or be immersed in at average annual rates and not receive a *total effective dose (equivalent)* of greater than 100 *millirem* per year.

**desiccation** – A process whereby water or moisture is removed, resulting in dryness.

**detection level (or limit)** – Minimum amount of a substance that can be measured with a specified or implied confidence that the analytical result is greater than a specific value (e.g., zero).

**direct-push technology** – A cost-effective means of collecting subsurface samples; this technology uses a hydraulic hammer to drive a hollow rod into the soil either vertically or at an angle. Sensors can be deployed within the rod to detect radioactive contaminants, soil moisture, and other sampling criteria.

**dispersion** – Process whereby *effluent* or *emissions* are spread or mixed when they are transported by *groundwater*, surface water, or air.

**dose equivalent** – Product of the *absorbed dose*, a quality factor, and any other modifying factors. The dose equivalent is a quantity for comparing the biological effectiveness of different kinds of *radiation* on a common scale. The unit of dose equivalent is the *rem*.

**dose limits (regulatory)** – Public and occupational regulatory dose limits are set by federal [i.e., Environmental Protection Agency, Nuclear Regulatory Commission, and Department of Energy] and state agencies to limit cancer risk. Other radiation dose limits are applied to limit other potential biological effects with workers' skin and lens of the eye.

**dose rate** – The rate at which a dose is delivered over time (e.g., *dose equivalent* rate in *millirem* per hour [mrem/hr]).

**dosimeter** – Portable device for measuring the accumulated *exposure* or *absorbed dose* from specific types or energies of ionizing *radiation* fields.

---

## E

**effective dose (equivalent)** – The sum of products of *dose equivalent* to selected tissues of the body and appropriate tissue weighting factors. The tissue weighting factors put doses to various tissues and organs on an equal basis in terms of health *risk*.

**effluent** – Liquid material released from a facility.

**effluent monitoring** – Sampling or measuring specific liquid *effluent* streams for the presence of pollutants.

**emission** – Gaseous stream released from a facility.

**exposure** – The interaction of an organism with a physical agent (e.g., *radiation*) or a chemical agent (e.g., arsenic) of interest. Also used as a term for quantifying x- and *gamma-radiation* fields. See *roentgen*.

**external radiation** – *Radiation* originating from a source outside the body.

---

**F**

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**fallout** – Typically refers to radioactive materials that are released into the earth’s atmosphere following a nuclear explosion or atmospheric release and that eventually fall to earth.

**field duplicate sample** – Replicate sample to determine the precision of the sampling and analytical measurement process by comparing results from identical samples collected at the same time and location. Matching field duplicates are stored in separate containers and are analyzed independently by the same laboratory.

**fission** – The splitting or breaking apart of a nucleus into at least two other nuclei, accompanied with a release of a relatively large amount of energy.

**fission products** – *Nuclides* formed from fissioning. Many fission products are radioactive.

**found fuel** – Incomplete pieces of spent nuclear fuel elements too small to have been located and removed during previous debris removal.

**fully institutionalized** – To incorporate into a formalized, structured system and be implemented and fully functional.

---

**G**

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**gamma radiation** – High-energy electromagnetic *radiation (photons)* originating in the nucleus of decaying *radionuclides*. Gamma radiation is substantially more penetrating than *alpha* or *beta particles*.

**grab sample** – A short-duration sample (e.g., air, water, and soil) that is grabbed from the collection site.

**ground truth** – Direct physical observations that are used to test indirect interpretations.

**groundwater** – Subsurface water that is in the pores of sand and gravel or in the cracks of fractured rock.

**gray (Gy)** – Unit of *absorbed dose* in the International System of Units (SI) equal to the absorption of 1 joule per kilogram. The common unit of *absorbed dose*, the *rad*, is equal to 0.01 Gy.

---

**H**

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**half-life** – Length of time in which a radioactive substance will lose one half of its *radioactivity* by *decay*. Half-lives range from a fraction of a second to billions of years, and each *radionuclide* has a unique half-life.

**high-activity waste** – See *high-level waste*.

**high-level waste** – Highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains *fission products* and other *radioisotopes* in sufficient concentrations to require permanent isolation.

---

**I**

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**institutional controls** – Long-term actions or restrictions including *monitoring*, periodic sampling, access controls, and land-use restrictions designed to mitigate any *risks* posed by contamination following *remediation*. Institutional controls alone may be sufficient to reduce *risks* posed by low levels of contamination.



**internal radiation** – *Radiation* from radioactive material inside the body.

**ion exchange** – The reversible exchange of one species of ion for a different species of ion within a medium.

**ion exchange resin** – High molecular weight insoluble polymers containing functional groups that are capable of undergoing exchange reactions with ions in a solution with which it is in contact.

**irradiation** – *Exposure to radiation.*

**isotopes** – *Nuclides* of the same chemical element with the same number of protons but a differing number of neutrons.

**isotopic plutonium** – Any of two or more atoms of the chemical element *plutonium* with the same atomic number and position in the periodic table and nearly identical chemical behavior but with differing atomic mass number and different physical properties. Plutonium-239 is produced by neutron *irradiation* of uranium-238.

**isotopic uranium** – Any of two or more atoms of the chemical element uranium with the same atomic number and position in the periodic table and nearly identical chemical behavior but with differing atomic mass number and different physical properties. Uranium exists naturally as a mixture of three *isotopes* of mass 234, 235, and 238 in the proportions of 0.006%, 0.71%, and 99.27%, respectively.

## L

**legacy waste** – Waste that was generated before the Hanford Site's nuclear materials production mission was terminated.

**low-activity waste** – See *low-level waste*.

**low-level waste** – Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, *transuranic waste*, byproduct material, or naturally occurring radioactive material.

## M

**material at risk** – The inventory of radioactive material that could potentially be released to the environment from an accident.

**maximally exposed individual** – A hypothetical member of the public residing near the Hanford Site who, by virtue of location and living habits, would reasonably receive the highest possible *radiation* dose from materials originating from the site.

**mean (or average)** – Average value of a series of measurements. The mean is computed using the following equation:

$$\text{mean} = \frac{\sum x}{n}$$

where *n* is the number of measurements, and  $\sum x$  is the sum of all measurements.

**median** – Middle value in an odd-numbered set of results when the data are ranked in increasing or decreasing order or the *average* of two central values in an even number set of results.

**millirem** – A unit of *radiation dose equivalent* that is equal to one one-thousandth (1/1000) of a *rem*.

**minimum detectable amount or concentration** – Smallest amount or concentration of a chemical or radioactive material that can be reliably detected in a sample.

**mitigation** – Prevention or reduction of expected *risks* to workers, the public, or the environment.

**mixed waste** – A U.S. Environmental Protection Agency or state-designated dangerous, extremely hazardous, or acutely hazardous waste that contains both a nonradioactive hazardous component and a radioactive component.

**monitoring** – As defined in DOE O 458.1, Chg 2, The measurement of radiation levels, discharges or environmental releases, residual radioactive levels, quantities of radioactive material, or exposure to members of the public and the use of the results of these measurements to evaluate radiological discharges or releases or potential and actual dose resulting from exposures to radioactive material or radiation.

---

## N

**noble gas** – Any of a group of chemically and biologically inert gases that includes argon, krypton, radon, and xenon. These gases are not retained in the body following inhalation. The principal *exposure* pathway for radioactive noble gases is direct external dose from the surrounding air.

**nuclide** – A particular combination of neutrons and protons. A *radionuclide* is a radioactive nuclide.

---

## O

**offsite locations** – Sampling and measurement locations outside the Hanford Site boundary.

**onsite locations** – Sampling and measurement locations within the Hanford Site boundary.

**operable unit** – A discrete area for which an incremental step can be taken toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated with the site.

**outfall** – End of a drain or pipe that carries wastewater or other *effluent* into a ditch, pond, or river.

---

## P

**person-rem or person-sievert (person-Sv)** – Unit of *collective total effective dose (equivalent)*. 1 person-Sv = 100 person-rem.

**photon** – A quantum of radiant energy. *Gamma radiation* and x-radiation (x-rays) are both composed of photons of varying energy.

**phytoremediation** – Use of plants to degrade or immobilize pollutants or toxins from the environment.

**plume** – The cloud of a pollutant in air, surface water, or *groundwater* formed after the pollutant is released from a source.

**plutonium** – A heavy, radioactive, metallic element consisting of several *isotopes*. One important *isotope* is plutonium-239, which is produced by the *irradiation* of uranium-238. Routine analysis cannot distinguish between the plutonium-239 and plutonium-240 *isotopes*; hence, the term plutonium-239/240 as used in this report is symbolic of the presence of one or both of these *isotopes* in the analytical results.

**primordial radionuclide** – A radioactive material in the earth's crust that has a very long *half-life* and has existed since the beginning of the planet.

---

**Q**

---

**quality assurance** – Actions that provide confidence that an item or process meets or exceeds a user's requirements and expectations.

**quality control** – Comprises all those actions necessary to control and verify the features and characteristics of a material, process, product, or service to specified requirements. Quality control is an element of *quality assurance*.

---

**R**

---

**rad** – The unit of *absorbed dose*. 1 rad = 0.01 *gray* (Gy).

**radiation** – The energy emitted in the form of *photons* or particles (e.g., *alpha* and *beta particles*) such as that from transforming *radionuclides*. For this report, radiation refers to ionizing types of radiation; not radiowaves, microwaves, radiant light, or other types of non-ionizing radiation.

**radioactivity** – Property possessed by *radioisotopes* emitting *radiation* (such as *alpha* or *beta particles*, or high-energy *photons*) spontaneously in their *decay* process; also, the *radiation* emitted.

**radioisotope** – An unstable *isotope* of an element that *decays* or disintegrates spontaneously, emitting *radiation*.

**radiologically controlled area** – An area to which access is controlled to protect individuals from exposure to *radiation* or radioactive materials.

**radionuclide** – A species of atoms having a particular number of protons (Z), a particular number of neutrons (A), and a particular atomic weight (N = Z + A) that happens to emit *radiation*. Carbon-14 is a radionuclide but carbon-12, which is not radioactive, is referred to simply as a *nuclide*.

**recruitment** – Survival from one life form or stage to the next or from one age class to the next.

**redox** – A chemical reaction involving oxidation and reduction.

**refractory** – A material that has a high melting point (i.e., heat resistant).

**refugium (refugia)** – An area that has not experienced ecological changes that have affected surrounding regions, providing a habitat for species that were once more widespread.

**relative percent difference (RPD)** – A measure of the precision of the measurement of a sample (S) and its duplicate (D). The formula is:

$$RPD = \left( \frac{|S - D|}{\left( \frac{S + D}{2} \right)} \right) \times 100$$

**rem** – A unit of dose equivalent and total effective dose (equivalent).

**remediation** – Reduction (or cleanup) of known *risks* to the public and environment to an agreed-upon level.

**risk** – The probability that a detrimental health effect will occur.

**risk-based disposal approval** – A written application intended to manage and dispose of *Toxic Substances Control Act*-regulated polychlorinated biphenyl waste not addressed suitably within the regulations. The risk-based disposal approval process applies to any person wishing to sample, clean up, or dispose of waste in a manner other than as prescribed in 40 CFR 761. For polychlorinated biphenyl *remediation* waste, the requirements for a risk-based disposal approval are specified in 40 CFR 761.61(c). A written approval from the U.S. Environmental Protection Agency is required before waste management activities are performed.

**roentgen (R)** – The unit of x-ray or gamma *photon exposure* as measured in air, historically used to describe *external radiation* levels. An *exposure* of 1 roentgen typically causes an *effective dose* of 1 *rem*.

---

## S

**shrub-steppe** – A drought-resistant shrub and grassland ecosystem.

**sievert (Sv)** – The unit of *dose equivalent* and its variants in the International System of Units (SI). The common unit for *dose equivalent* and its variants, the *rem*, is equal to 0.01 Sv.

**special case waste** – Waste for which there is an undetermined disposal path because of high levels of *radioactivity* and difficulties in characterization, classification, and packaging.

**specific retention facilities** – Historical structures consisting of *cribs*, ditches, trenches, or holes in the ground that received relatively small volumes of high concentration liquid radioactive waste. The small volume of liquid waste was designed to prevent flushing of the contaminants through the soil column to the *groundwater*.

**spent fuel** – Uranium metal or oxide and its metal container that have been used to power a nuclear reactor and for one reason or another has reached the end of its useful life. It is highly radioactive and typically contains *fission products*, *plutonium*, and residual uranium.

**standard error of the mean** – A measure of the precision of a *mean* of observed values; that is, an estimate of how close a *mean* of observed values is expected to be to the true *mean*.

**surveillance** – As defined in DOE Order 5400.5, Chg 2, the collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media, and the measurement of *external radiation* for purposes of demonstrating compliance with applicable standards, assessing *exposures* to the public, and assessing effects, if any, on the local environment.

---

## T

**tank farm** – A group of underground waste storage tanks.

**thermoluminescent dosimeter** – A device containing a material that, after being exposed to beta and/or *gamma radiation*, emits light when heated. The amount of light emitted is proportional to the *absorbed dose* to the thermoluminescent dosimeter.

**total effective dose (equivalent)** – The sum of *committed effective dose equivalent* from the intake of radioactive material and dose equivalent from *exposure* to *external radiation*. Unit: *rem* or *sievert*.

**total uranium** – The sum of concentrations of the *isotopes* uranium-234, uranium-235, and uranium-238.

**transuranic element** – An element with an atomic number greater than 92 (92 is the atomic number of uranium).

**transuranic waste** – Waste containing more than 100 nanocuries ( $10^{-9}$  *curies*) per gram of alpha-emitting transuranic *isotopes* (*half-lives* greater than 20 years).

**tritium** – The heaviest radioactive *isotope* of hydrogen (hydrogen-3) with a 12.3-year half life.

---

## U

**unconfined aquifer** – An *aquifer* containing groundwater that is not confined above by relatively impermeable rocks. The pressure at the top of the unconfined aquifer is equal to that of the atmosphere. At the Hanford Site, the unconfined *aquifer* is the uppermost aquifer and is most susceptible to contamination from site operations.

---

## V

**vadose zone** – Underground area from the ground surface to the top of the *water table* or *aquifer*.

**volatile organic compounds** – Lightweight organic compounds that vaporize easily; used in solvents and degreasing compounds as raw materials.

---

## W

**water table** – The top of the *unconfined aquifer*.

**wind rose** – A diagram showing how often winds of various speeds blow from different directions, usually based on yearly averages.

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**Appendix B****Useful Information****B. Useful Information ..... B.1**

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## B. Useful Information

The following information is provided to assist the reader in understanding this report. Included here is information on scientific notation, units of measure, radioactivity units, radiological dose units, chemical and elemental nomenclature, understanding data tables and data uncertainty, understanding graphs, and selected mathematical symbols. Definitions of technical terms can be found in Appendix A.

### B.1 Public Reading Rooms

University of Washington  
Government Publications Division,  
Suzzallo & Allen Libraries  
Box 352900  
Seattle, WA 98195-2900  
(206) 543-4164  
[www.catalog.kub.wa.edu](http://www.catalog.kub.wa.edu)

Portland State University  
Government Information  
Branford Price Millar Library  
1875 SW Park Avenue  
Portland, OR 97207-1151  
(503) 725-4542  
<http://library.pdx.edu/governmentinformationservice.html>  
and [http://library.pdx.edu/public\\_comment.html#hanf](http://library.pdx.edu/public_comment.html#hanf)

Washington State University, Tri-Cities  
US DOE Public Reading Room  
Consolidated Information Center, Room 101-L  
2770 University Drive  
Richland, WA 99352  
(509) 372-7443  
<http://reading-room.labworks.org>

Gonzaga University, Foley Center  
East 502 Boone  
Spokane, WA 99258-0001  
(509) 313-3847  
<http://www.gonzaga.edu/Academics/Libraries/Foley-Library/Departments/Special-Collections/default.asp>

Hanford Health Info Archive:  
<http://www.gonzaga.edu/Academics/Libraries/Foley-Library/Departments/Special-Collections/Collections/Hanford-Health-and-Information-Archives/default.asp>

### B.2 Scientific Notation

Scientific notation is used to express very large or very small numbers. For example, the number 1 billion could be written as 1,000,000,000 or, by using scientific or E notation, written as  $1 \times 10^9$  or 1.0E+09. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from its current location. If the value given is  $2.0 \times 10^3$  (or 2.0E+03), the decimal point should be moved three places to the **right** so that the number would then read 2,000. If the value given is  $2.0 \times 10^{-5}$  (or 2.0E-05), the decimal point should be moved five places to the **left** so that the result would be 0.00002.

### B.3 Units of Measure

The primary units of measure used in this report follow the International System of Units and are metric. Table B.1 summarizes and defines the terms and corresponding symbols (metric and non-metric). A conversion table is provided in Table B.2.

### B.4 Radioactivity Units

Much of this report provides data on levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of **curies (Ci)**, with conversions to **becquerels (Bq)**, the International System of Units measure (Table B.3). The curie is the basic unit used to describe the amount of activity present, and activities are generally expressed in terms of curies per mass or volume (e.g., picocuries per liter). One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. One becquerel is equivalent to one disintegration per second.

Nuclear disintegrations produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. Table B.4 includes selected conversions from curies to becquerels.

Table B.1. Units of Measure

Symbol	Name
<b>Temperature</b>	
°C	degree Celsius
°F	degree Fahrenheit
<b>Time</b>	
d	day
hr	hour
min	minute
sec	second
yr	year
<b>Rate</b>	
cfs (or ft <sup>3</sup> /sec)	cubic feet per second
cpm	counts per minute
gpm	gallon per minute
mph	mile per hour
mR/hr	milliroentgen per hour
mrem/yr	millirem per year
<b>Volume</b>	
cm <sup>3</sup>	cubic centimeter
ft <sup>3</sup>	cubic foot
gal	gallon
L	liter
m <sup>3</sup>	cubic meter
mL	milliliter ( $1 \times 10^{-3}$ L)
yd <sup>3</sup>	cubic yard

Symbol	Name
<b>Concentration</b>	
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
<b>Length</b>	
cm	centimeter ( $1 \times 10^{-2}$ m)
ft	foot
in.	inch
km	kilometer ( $1 \times 10^3$ m)
m	meter
mi	mile
mm	millimeter ( $1 \times 10^{-3}$ m)
μm	micrometer ( $1 \times 10^{-6}$ m)
<b>Area</b>	
ha	hectare ( $1 \times 10^4$ m <sup>2</sup> )
km <sup>2</sup>	square kilometer
mi <sup>2</sup>	square mile
ft <sup>2</sup>	square foot
<b>Mass</b>	
g	gram
kg	kilogram ( $1 \times 10^3$ g)
mg	milligram ( $1 \times 10^{-3}$ g)
μg	microgram ( $1 \times 10^{-6}$ g)
lb	pound

Table B.2. Conversion Table

Multiply	By	To Obtain
cm	0.394	in.
m	3.28	ft
km	0.621	mi
kg	2.205	lb
L	0.2642	gal
m <sup>2</sup>	10.76	ft <sup>2</sup>
ha	2.47	acre
km <sup>2</sup>	0.386	mi <sup>2</sup>
m <sup>3</sup>	35.31	ft <sup>3</sup>
m <sup>3</sup>	1.308	yd <sup>3</sup>
pCi	1,000	nCi
μCi/mL	109	pCi/L
Ci/m <sup>3</sup>	1012	pCi/m <sup>3</sup>
mCi/cm <sup>3</sup>	1015	pCi/m <sup>3</sup>
nCi/m <sup>2</sup>	1.0	mCi/km <sup>2</sup>
Ci	$3.7 \times 10^{10}$	Bq
pCi	0.037	Bq
rad	0.01	Gy
rem	0.01	Sv
ppm	1,000	ppb
°C	$(^{\circ}\text{C} \times 9/5) + 32$	°F
oz	28.349	g
ton	0.9078	tonne

Multiply	By	To Obtain
in.	2.54	cm
ft	0.305	m
mi	1.61	km
lb	0.454	kg
gal	3.785	L
ft <sup>2</sup>	0.093	m <sup>2</sup>
acre	0.405	ha
mi <sup>2</sup>	2.59	km <sup>2</sup>
ft <sup>3</sup>	0.0283	m <sup>3</sup>
yd <sup>3</sup>	0.7646	m <sup>3</sup>
nCi	0.001	pCi
pCi/L	10 <sup>-9</sup>	μCi/mL
pCi/m <sup>3</sup>	10 <sup>-12</sup>	Ci/m <sup>3</sup>
pCi/m <sup>3</sup>	10 <sup>-15</sup>	mCi/cm <sup>3</sup>
mCi/km <sup>2</sup>	1.0	nCi/m <sup>2</sup>
Bq	$2.7 \times 10^{-11}$	Ci
Bq	27	pCi
Gy	100	rad
Sv	100	rem
ppb	0.001	ppm
°F	$(^{\circ}\text{F} - 32) \div 9/5$	°C
g	0.035	oz
tonne	1.1	ton

Table B.3. Radioactivity Unit Conversions

aCi	fCi	fCi	pCi	pCi	nCi	nCi	μCi	μCi	mCi	mCi	Ci	Ci	kCi
27	1	27	1	27	1	27	1	27	1	27	1	27	1
1	37	1	37	1	37	1	37	1	37	1	37	1	37
μBq	μBq	mBq	mBq	Bq	Bq	kBq	kBq	MBq	MBq	GBq	GBq	TBq	TBq

New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) (1 Ci =  $3.7 \times 10^{10}$  dps).

1 Becquerel = 1 disintegrations/sec (dps).

Table B.4. Radioactivity Units

Symbol	Name
Ci	curie
mCi	millicurie ( $1 \times 10^{-3}$ Ci)
μCi	microcurie ( $1 \times 10^{-6}$ Ci)
nCi	nanocurie ( $1 \times 10^{-9}$ Ci)
pCi	picocurie ( $1 \times 10^{-12}$ Ci)
fCi	femtocurie ( $1 \times 10^{-15}$ Ci)
aCi	attocurie ( $1 \times 10^{-18}$ Ci)

Symbol	Name
Bq	becquerel ( $2.7 \times 10^{-11}$ Ci)
mBq	millibecquerel ( $1 \times 10^{-3}$ Bq)
kBq	kilobecquerel ( $1 \times 10^3$ Bq)
MBq	megabecquerel ( $1 \times 10^6$ Bq)
GBq	gigabecquerel ( $1 \times 10^9$ Bq)
TBq	terabecquerel ( $1 \times 10^{12}$ Bq)

**B.5 Radiological Dose Limits**

Regulatory dose limits, both public and occupational regulatory dose limits, are set by federal (i.e., U.S. Environmental Protection Agency [EPA], Nuclear Regulatory Commission [NRC], and U.S. Department of Energy [DOE]) and state agencies to limit cancer risk (Table B.5). Other radiation dose limits are applied to limit other potential biological effects with workers' skin and lens of the eye.

**Table B.5. Radioactivity Units**

<b>Annual Radiation Dose Limits</b>	<b>Agency</b>
Radiation Worker - 5,000 mrem	NRC, occupationally exposed
General Public - 100 mrem	NRC, member of the public
General Public - 25 mrem	NRC, D&D all pathways
General Public - 10 mrem	EPA, air pathway
General Public - 4 mrem	EPA, drinking water pathway

D&D = decontamination and decommissioning.

**B.6 Radiological Dose Units**

Radiological dose in this report is usually written in terms of total effective dose (equivalent) and reported numerically in units of millirem (mrem), with the metric units millisievert (mSv) or microsievert ( $\mu$ Sv) following in parenthesis or footnoted.

Millirem (millisievert) is a term that relates a given amount of absorbed radiation energy to its biological effectiveness or risk to humans. For perspective, a dose of 1.0 millirem (10 microsievert) would have a biological effect roughly the same as received from 1 day's exposure to natural background radiation. An acute (short-term) dose to the whole body of 100 rem (1 sievert) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 sievert) would soon result in death in approximately 50% of those exposed. Exposure to lower amounts of radiation (10 mrem [100  $\mu$ Sv] or less) produces no immediate observable effects, but long-term (delayed) effects are possible. The average person in the United States receives an annual dose from exposure to naturally produced radiation of approximately 310 mrem (3.1 mSv; National Council on Radiation Protection and Measurements 2009). Medical and dental x-rays and air travel add to this total. Table B.6 includes selected conversions from rem to sievert.

Also used in this report is the term **rad**, with the corresponding unit **gray (Gy)** in parenthesis or footnoted. The rad (gray) is a measure of the energy absorbed by any material, whereas a rem relates to both the amount of radiation energy absorbed by humans and its consequence. The gray can be converted to rad by multiplying by 100. The conversions in Table B.6 also can be used to convert grays to rads.

**Table B.6. Radiological Dose Units Conversions**

$\mu$ Sv 0.01	$\mu$ Sv 0.1	$\mu$ Sv 1	$\mu$ Sv 10	$\mu$ Sv 100	mSv 1	mSv 10	mSv 100	Sv 1
1	10	100	1	10	100	1	10	100
$\mu$ rem	$\mu$ rem	$\mu$ rem	mrem	mrem	mrem	rem	rem	Rem

Unit of absorbed dose – Gray (Gy) (formerly rad).

Unit of dose equivalent – Sievert (Sv) (formerly rem).

Table also converts Gy to rad.



The **Roentgen (R)** is a measure of exposure to electromagnetic radiation (i.e., gamma and x-radiation). One roentgen is equivalent to a charge release of 258 microcoulombs per kilogram of air. The names and symbols for units of radiation dose used in this report are listed in Table B.7.

Table B.7. Radiation Dose or Exposure Units

Symbol	Name
mrad	millirad ( $1 \times 10^{-3}$ rad)
mrem	millirem ( $1 \times 10^{-3}$ rem)
$\mu$ rem	microrem ( $1 \times 10^{-6}$ rem)
Sv	sievert (100 rem)
mSv	millisievert ( $1 \times 10^{-3}$ Sv)
$\mu$ Sv	microsievert ( $1 \times 10^{-6}$ Sv)
nSv	nanosievert ( $1 \times 10^{-9}$ Sv)
R	roentgen
mR	milliroentgen ( $1 \times 10^{-3}$ R)
$\mu$ R	microroentgen ( $1 \times 10^{-6}$ R)
Gy	gray (100 rad)
mGy	milligray ( $1 \times 10^{-3}$ rad)

Additional information on radiation and dose terminology can be found in Appendix A. A list of the radionuclides discussed in this report, their symbols, and their half-lives are included in Table B.8.

Table B.8. Radionuclides and Half-Lives

Symbol	Radionuclide	Half-Life
$^3\text{H}$	tritium	12.35 yr
$^7\text{Be}$	beryllium-7	53.3 d
$^{14}\text{C}$	carbon-14	5,730 yr
$^{40}\text{K}$	potassium-40	$1.28 \times 10^9$ yr
$^{51}\text{Cr}$	chromium-51	27.704 d
$^{54}\text{Mn}$	manganese-54	312.5 d
$^{55}\text{Fe}$	iron-55	2.7 yr
$^{59}\text{Fe}$	iron-59	44.529 d
$^{59}\text{Ni}$	nickel-59	$7.5 \times 10^4$ yr
$^{60}\text{Co}$	cobalt-60	5.271 yr
$^{63}\text{Ni}$	nickel-63	96 yr
$^{65}\text{Zn}$	zinc-65	243.9 d
$^{85}\text{Kr}$	krypton-85	10.72 yr
$^{90}\text{Sr}$	strontium-90	29.12 yr
$^{90}\text{Y}$	yttrium-90	64.0 hr
$^{95}\text{Zr}$	zirconium-95	63.98 d
$^{99}\text{Tc}$	technetium-99	$2.13 \times 10^5$ yr
$^{103}\text{Ru}$	ruthenium-103	39.28 d
$^{106}\text{Ru}$	ruthenium-106	368.2 d
$^{113}\text{Sn}$	tin-113	115.1 d
$^{125}\text{Sb}$	antimony-125	2.77 yr
$^{129}\text{I}$	iodine-129	$1.57 \times 10^7$ yr
$^{131}\text{I}$	iodine-131	8.04 d
$^{134}\text{Cs}$	cesium-134	2.062 yr
$^{137}\text{Cs}$	cesium-137	30.0 yr

Symbol	Radionuclide	Half-Life
$^{137}\text{mBa}$	barium-137m	2.552 min
$^{152}\text{Eu}$	europium-152	13.33 yr
$^{154}\text{Eu}$	europium-154	8.8 yr
$^{155}\text{Eu}$	europium-155	4.96 yr
$^{212}\text{Pb}$	lead-212	10.64 hr
$^{220}\text{Rn}$	radon-220	55.6 sec
$^{222}\text{Rn}$	radon-222	3.8235 d
$^{232}\text{Th}$	thorium-232	$1.405 \times 10^{10}$ yr
U or uranium	natural uranium	$\sim 4.5 \times 10^9$ <sup>(a)</sup> yr
$^{233}\text{U}$	uranium-233	$1.585 \times 10^5$ yr
$^{234}\text{U}$	uranium-234	$2.445 \times 10^5$ yr
$^{235}\text{U}$	uranium-235	$7.038 \times 10^8$ yr
$^{237}\text{Np}$	neptunium-237	$2.14 \times 10^6$ yr
$^{238}\text{U}$	uranium-238	$4.468 \times 10^9$ yr
$^{238}\text{Pu}$	plutonium-238	87.74 yr
$^{239}\text{Pu}$	plutonium-239	$2.4065 \times 10^4$ yr
$^{240}\text{Pu}$	plutonium-240	$6.537 \times 10^3$ yr
$^{241}\text{Pu}$	plutonium-241	14.4 yr
$^{242}\text{Pu}$	plutonium-242	$3.763 \times 10^5$ yr
$^{241}\text{Am}$	americium-241	432.2 yr
$^{243}\text{Am}$	americium-243	7,380 yr
$^{243}\text{Cm}$	curium-243	28.5 yr
$^{244}\text{Cm}$	curium-244	18.11 yr
$^{245}\text{Cm}$	curium-245	8,500 yr

<sup>a</sup> Natural uranium is a mixture dominated by uranium-238; thus, the half-life is approximately  $4.5 \times 10^9$  years.

**B.7 Chemical and Elemental Nomenclature**

Many of the chemical contaminants discussed in this report are listed in Table B.9 along with their chemical (or elemental) names and their corresponding symbols.

**Table B.9. Elemental and Chemical Constituent Nomenclature**

<b>Symbol</b>	<b>Constituent</b>	<b>Symbol</b>	<b>Constituent</b>
Ag	silver	K	potassium
Al	aluminum	LiF	lithium fluoride
As	arsenic	Mg	magnesium
B	boron	Mn	manganese
Ba	barium	Mo	molybdenum
Be	beryllium	NH <sub>3</sub>	ammonia
Br	bromine	NH <sub>4</sub> <sup>+</sup>	ammonium
C	carbon	N	nitrogen
Ca	calcium	Na	sodium
CaF <sub>2</sub>	calcium fluoride	Ni	nickel
CCl <sub>4</sub>	carbon tetrachloride	NO <sub>2</sub> <sup>-</sup>	nitrite
Cd	cadmium	NO <sub>3</sub> <sup>-</sup>	nitrate
CHCl <sub>3</sub>	trichloromethane	Pb	lead
Cl <sup>-</sup>	chloride	PO <sub>4</sub> <sup>-3</sup>	phosphate
CN <sup>-</sup>	cyanide	P	phosphorus
Cr <sup>+6</sup>	chromium (hexavalent)	Sb	antimony
Cr	chromium (total)	Se	selenium
CO <sub>3</sub> <sup>-2</sup>	carbonate	Si	silicon
Co	cobalt	Sr	strontium
Cu	copper	SO <sub>4</sub> <sup>-2</sup>	sulfate
F <sup>-</sup>	fluoride	Ti	titanium
Fe	iron	Tl	thallium
HCO <sub>3</sub> <sup>-</sup>	bicarbonate	V	vanadium
Hg	mercury		

**B.8 Understanding the Data Tables**

Some degree of variability, or uncertainty, is associated with all analytical measurements. This uncertainty is the consequence of random or systematic inaccuracies related to collecting, preparing, and analyzing the samples. These inaccuracies could include errors associated with reading or recording the result, handling or processing the sample, calibrating the counting instrument, and numerical rounding. With radionuclides, inaccuracies also can result from the randomness of radioactive decay. In this report, the uncertainties used include standard deviation, total propagated analytical uncertainty, and standard error of the mean.

**B.9 Standard Deviation**

The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual sample results. If differences in analytical results occur among samples, then two times the standard deviation (or  $\pm 2$  SD) implies that 95 percent of the time, a re-count or re-analysis of the same sample would give a value somewhere between the mean result minus two times the standard deviation and the mean result plus two times the standard deviation.

**B.10 Total Propagated Analytical Uncertainty**

For samples that are prepared or manipulated in the laboratory prior to counting (counting the rate of radioactive emissions from a sample), the total propagated analytical uncertainty includes both the counting uncertainty and the uncertainty associated with sample preparation and chemical separations. For samples that are not manipulated (e.g., ashed, dried, or chemically treated) in the laboratory before counting, the total propagated analytical uncertainty only accounts for the uncertainty associated with counting the sample. The uncertainty associated with samples that are analyzed but not counted (e.g., chemical or water quality measurements) includes only the analytical process uncertainty. In this situation, the total propagated analytical uncertainty is assumed the nominal detection limit.

**B.11 Standard Error of the Mean**

Just as individual values are accompanied by counting uncertainties, the mean of mean values (averages) is accompanied by  $\pm 2$  times the standard error of the calculated mean. Two times the standard error of the mean implies that approximately 95 percent of the time the next calculated mean will fall somewhere between the reported value minus two times the standard error and the reported value plus two times the standard error.

**B.12 Median, Maximum, and Minimum Values**

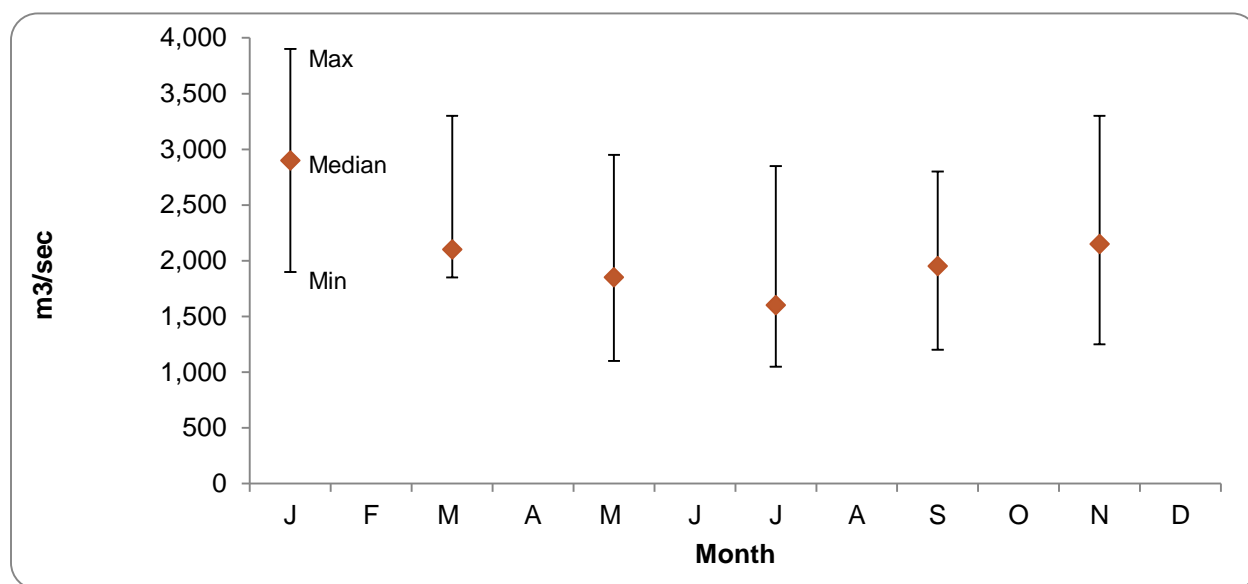
Median, maximum, and minimum values are reported in some sections of this report. A median value is the middle value of an odd numbered set and the average of the two central values in an even numbered set. For example, the median value in the odd numbered series of numbers — 1, 2, 3, 3, 4, 5, 5, 5, 6 is 4. The maximum value would be 6 and the minimum value would be 1. Median, maximum, and minimum values are reported when there are too few analytical results to accurately determine the average with a  $\pm$  statistical uncertainty or when the data do not follow a bell-shape (i.e., normal) distribution. Figure B.1 provides a graphical representation of median, maximum, and minimum values. The upper line is the maximum value, the center dot is the median value, and the lower line is the minimum value.

**B.13 Negative Concentrations**

Instruments used in the laboratory to measure radioactivity in Hanford Site environmental samples are sensitive enough to measure natural, or background, radiation along with any contaminant radiation in a sample. To obtain a true measure of the contaminant level in a sample, the background radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radioactive emissions, the very low activities of some contaminants, or the presence of undesirable materials, it is possible to obtain a background measurement that is larger than the actual contaminant measurement. When the larger background measurement is subtracted from the smaller contaminant measurement, a negative result is generated. The negative results are reported because they are essential when conducting statistical evaluations of the data.

**B.14 Greater Than (>) or Less Than (<) Symbols**

Greater than (>) or less than (<) symbols are used to indicate that the actual value may either be larger than the number given or smaller than the number given. For example,  $>0.09$  would indicate that the actual value is greater than 0.09. A symbol pointed in the opposite direction ( $<0.09$ ) would indicate that the number is less than the value presented. A symbol used with an underscore ( $\leq$  or  $\geq$ ) indicates that the actual value is less than or equal to or greater than or equal to the number given, respectively.

**Figure B.1** Maximum, Median, and Minimum Values Graphical Representation**B.15 Understanding Graphs**

Graphs are useful when comparing numbers collected at several locations or at one location over time. Graphs often make it easy to visualize differences in data where they exist. However, careful consideration should be given to the scale (linear or logarithmic) and units.

Some of the data graphed in this report may be plotted using logarithmic, or compressed, scales. Logarithmic scales are useful when plotting two or more numbers that differ greatly in size or are very close together. For example, a sample with a concentration of 5 grams per liter would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 grams per liter (Figure B.2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure B.3).

The mean (average) and median (defined earlier) values seen in graphics in this report have vertical lines extending above and below the data point. When used with a value, these lines (called error bars) indicate the amount of uncertainty (standard deviation, total propagated analytical uncertainty, or standard error of the mean) in the reported value. The error bars in this report represent a 95 percent chance that the value is between the upper and lower ends of the error bar and a 5 percent chance that the true value is either lower or higher than the error bar.<sup>(1)</sup> For example, in Figure B.4, the first plotted value is  $2.0 \pm 1.1$ , so there is a 95 percent chance that the true value is between 0.9 and 3.1, a 2.5 percent chance that it is less than 0.9, and a 2.5 percent chance that it is greater than 3.1. Error bars are computed statistically, employing all of the information used to generate the value. These bars provide a quick, visual indication that one value may be statistically similar to or different from another value. If the error bars of two or more values overlap, as is the case with values 1 and 3 and values 2 and 3, the values may be statistically similar. If the error bars do not overlap (values 1 and 2), the values may be statistically different. Values that appear to be very different visually (values 2 and 3) may actually be quite similar when compared statistically.

(1) Assuming the data are normally distributed.

Figure B.2 Data Plotted Using a Linear Scale

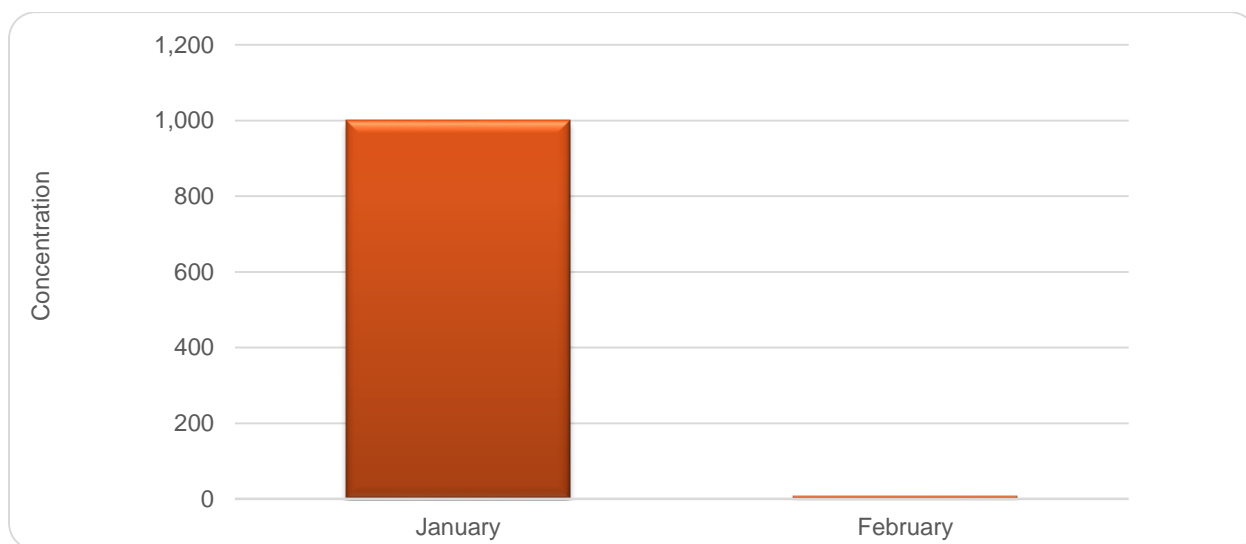


Figure B.3 Data Plotted Using a Logarithmic Scale

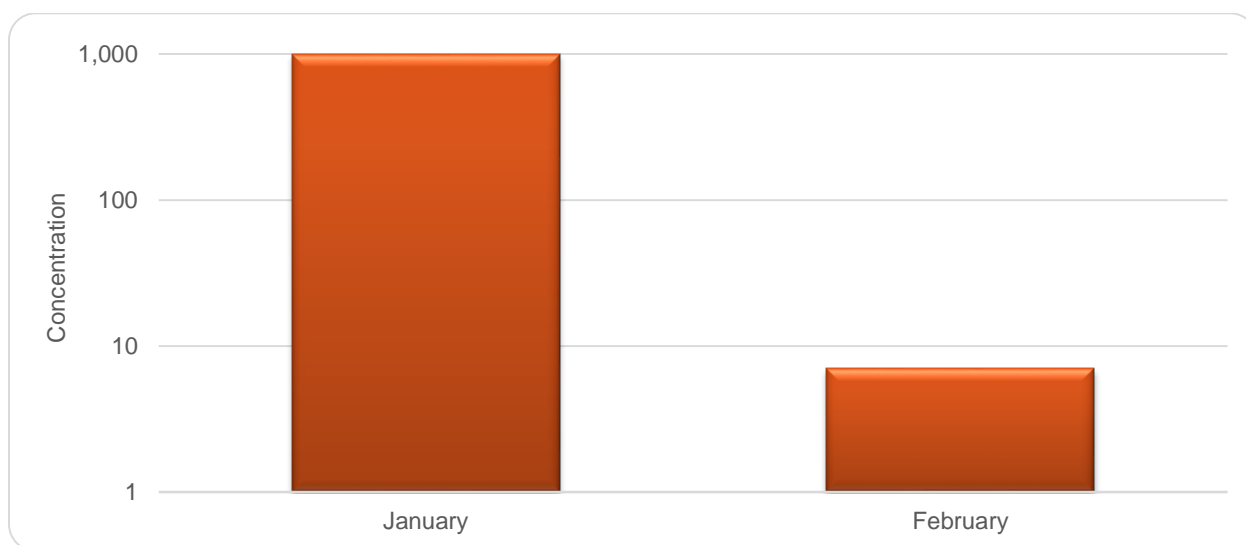
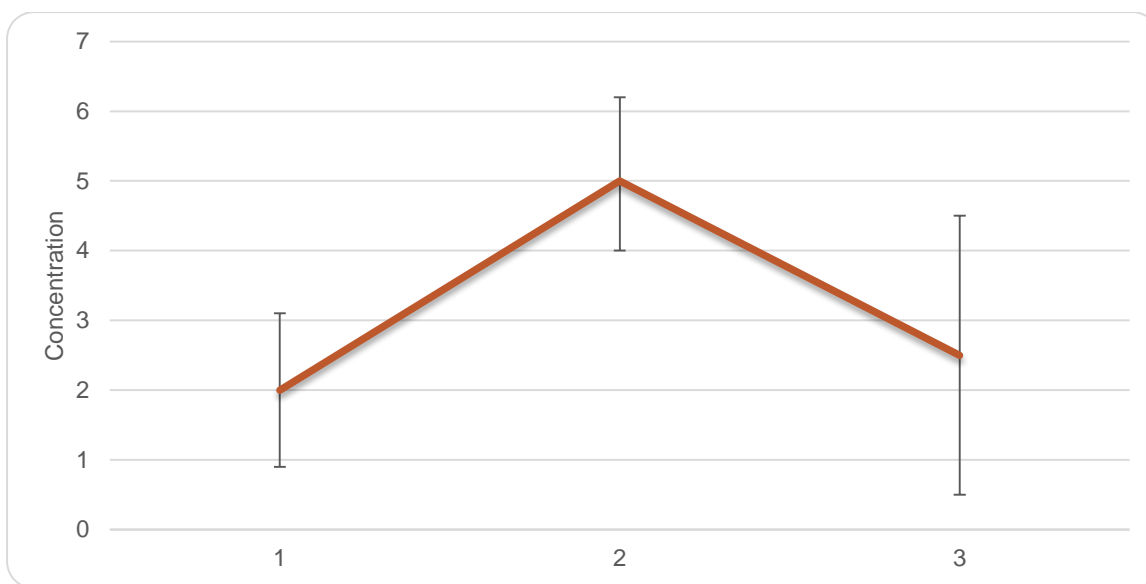


Figure B.4 Data with Error Bars Plotted Using a Linear Scale



**Appendix C****Additional Monitoring Results****C. Additional Monitoring Results ..... C.1****Tables**

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## **C. Additional Monitoring Results**

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This appendix contains additional information on monitoring results and supplements data summarized in the main body of the report.

Table C.1. Radionuclide Concentrations in FFTF Pond Water

Isotope	2014				2009 - 2013			
	No. of Samples	No. of Detects	Average <sup>a</sup> pCi/L <sup>c</sup>	Maximum <sup>b</sup> pCi/L <sup>c</sup>	No. of Samples	No. of Detects	Average <sup>a</sup> pCi/L <sup>c</sup>	Maximum <sup>b</sup> pCi/L <sup>c</sup>
Antimony-125 <sup>d</sup>	5	0	-2.5E-00	1.6E+00 ± 6.8E+00	24	0	-4.8E-01 ± 4.9E+00	4.4E+00 ± 5.4E+00
Cesium-134 <sup>d</sup>	5	0	9.3E-02	1.8E+00 ± 1.8E+00	24	0	0.80E+00 ± 2.2E+00	3.0E+00 ± 3.0E+00
Cesium-137 <sup>d</sup>	5	0	1.5E-01	0.53E+00 ± 1.9E+00	24	0	-1.8E-02 ± 2.2E+00	2.9E+00 ± 2.5E+00
Cobalt-60 <sup>c</sup>	5	0	4.4E-01	2.4E+00 ± 2.3E+00	24	0	2.4E-01 ± 1.6E+00	1.7E+00 ± 2.1E+00
Europium-152 <sup>d</sup>	5	0	1.9E+00	4.9E+00 ± 7.4E+00	24	0	1.45E+00 ± 5.7E+00	6.9E+00 ± 6.5E+00
Europium-154 <sup>d</sup>	5	0	0.89E+00	2.2E+00 ± 4.9E+00	24	0	-0.36E+00 ± 5.4E+00	6.7E+00 ± 7.0E+00
Europium-155 <sup>d</sup>	5	0	-2.4E+00	1.7E+00 ± 7.3E+00	24	0	-1.2E+00 ± 9.1E+00	8.5E+00 ± 1.0E+01
Gross Alpha <sup>d</sup>	5	0	0.10E+00	0.58E+00 ± 0.98E+00	24	2	8.2E-01 ± 1.8E+00	3.1E+00 ± 1.8E+00
Gross Beta	5	5	9.2E+00	11.7E+00 ± 2.6E+00	24	24	8.4E+00 ± 7.6E+00	1.9E+01 ± 3.3E+00
Tritium	5	5	11.9E+02	13.3E+02 ± 3.3E+02	24	24	2.9E+03 ± 6.3E+03	1.2E+04 ± 2.5E+03
Potassium-40 <sup>d</sup>	5	0	11.4E+00	24.4E+00 ± 35.8E+00	24	0	6.7E+00 ± 4.8E+01	7.6E+01 ± 3.5E+01
Ruthenium-106 <sup>d</sup>	5	0	3.5E+00	22.5E+00 ± 33.1E+00	24	0	2.2E+00 ± 1.4E+01	1.6E+01 ± 1.7E+01

<sup>a</sup> Average ± two standard deviations.  
<sup>b</sup> Maximum ± analytical uncertainty.  
<sup>c</sup> 1pCi = 0.037 Bq.  
<sup>d</sup> Maximum value reported is a non-detect.

Table C.2 Radionuclide Concentrations in West Lake Sediment

Radionuclide	2014		2009-2013		
	No. of Samples	Concentration $pCi/g^a$ Result <sup>b</sup>	No. of Samples	Concentration $pCi/g^a$	
				Average <sup>c</sup>	Maximum <sup>b</sup>
Antimony-125	1	-2.7E-02 ± 7.0E-02 <sup>d</sup>	6	1.0E-02 ± 3.0E-02 <sup>d</sup>	3.6E-02 ± 4.6E-02 <sup>d</sup>
Cesium-134	1	1.2E-02 ± 4.0E-02 <sup>d</sup>	6	4.8E-02 ± 5.6E-02 <sup>d</sup>	9.7E-02 ± 5.6E-02 <sup>d</sup>
Cesium-137	1	4.4E-01 ± 7.7E-02	6	1.2E+00 ± 4.5E-01	1.9E+00 ± 1.6E-01
Cobalt-60	1	-2.3E-03 ± 3.2E-02 <sup>d</sup>	6	-1.4E-03 ± 1.2E-02 <sup>d</sup>	8.6E-03 ± 1.7E-02 <sup>d</sup>
Europium-152	1	5.4E-02 ± 8.0E-02 <sup>d</sup>	6	-6.4E-03 ± 4.2E-02 <sup>d</sup>	2.5E-02 ± 5.8E-02 <sup>d</sup>
Europium-154	1	-3.8E-02 ± 9.7E-02 <sup>d</sup>	6	-1.2E-02 ± 9.2E-02 <sup>d</sup>	4.7E-02 ± 6.0E-02 <sup>d</sup>
Europium-155	1	-2.5E-02 ± 1.0E-01 <sup>d</sup>	6	5.3E-02 ± 4.6E-02 <sup>d</sup>	8.5E-02 ± 8.6E-02 <sup>d</sup>
Gross Alpha	1	9.9E+00 ± 2.1E+00 <sup>d</sup>	6	9.0E+00 ± 7.9E+00	12.2E+00 ± 3.1E+00
Gross Beta	1	20.9E+00 ± 2.6E+00	6	2.3E+01 ± 14E+00	3.1E+01 ± 5.4E+00
Potassium-40	1	6.3E+00 ± 1.0E+00	6	1.6E+01 ± 4.8E+00	1.9E+01 ± 2.0E+00
Ruthenium-106	1	-2.3E-01 ± 3.2E-01 <sup>d</sup>	6	7.2E-03 ± 1.6E-01 <sup>d</sup>	1.2E-01 ± 1.5E-01 <sup>d</sup>
Strontium-90	1	3.1E-02 ± 2.4E-02 <sup>d</sup>	6	3.3E-01 ± 2.4E-01	4.9E-01 ± 9.7E-02
Technetium-99	1	1.2E-02 ± 4.7E-01 <sup>d</sup>	6	-1.4E-01 ± 4.0E-01 <sup>d</sup>	1.4E-01 ± 4.7E-01 <sup>d</sup>
Uranium-234	1	7.6E+00 ± 1.1E+00	6	2.8E+00 ± 3.9E+00	6.4E+00 ± 8.7E-01
Uranium-235	1	3.2E-01 ± 8.9E-02	6	1.6E-01 ± 2.0E-01	3.6E-01 ± 6.8E-02
Uranium-238	1	6.8E+00 ± 1.0E+00	6	2.7E+00 ± 3.7E+00	6.1E+00 ± 8.3E-01

<sup>a</sup> 1 pCi = 0.037 Bq.<sup>b</sup> Result and maximum values are ± total propagated analytical uncertainty (2 Sigma).<sup>c</sup> Averages are ±2 standard deviations of the mean. Average values calculated using reporting limit values for all results at or below minimum detectable concentrations.<sup>d</sup> Result was below detection limit.<sup>e</sup> No result available.

**Table C.3. Radionuclide Concentrations in West Lake Seep Water  
(2014 and 2012, 2013)**

Radionuclide	No. of Samples	2014 Concentration <sup>a</sup>		No. of Samples	2012 and 2013 Concentration <sup>a</sup>		DOE-Derived Concentration Guides/Standards	Washington State Ambient Surface Water Quality Standard <sup>d</sup>
		Average <sup>b</sup> pCi/L	Maximum <sup>c</sup> pCi/L		Average <sup>b</sup> pCi/L	Maximum <sup>c</sup> pCi/L		
Tritium	1	f	17.7E+01 ± 14.5E+01	1	f	6.9E+02 ± 21.0+01	2,000,000	20,000 <sup>d,e</sup>
Uranium-234	1	f	6.2E+01 ± 11E+00	2	26.0E+01 ± 7.0E+01	26.3E+01 ± 38.1E+00	500	—
Uranium-235	1	f	3.1E+00 ± 0.68E+00	2	13.0E+00 ± 1.5E+00	13.8E+00 ± 4.3E+00	600	—
Uranium-238	1	f	5.8E+01 ± 10E+00	2	24.4E+01 ± 13E+00	23.7E+01 ± 34.4E+00	600	—

<sup>a</sup> 1 pCi = 0.037 Bq.

<sup>b</sup> Averages are ±2 standard deviations of the mean. Average values calculated using reporting limit values for all results at or below minimum detectable concentrations.

<sup>c</sup> Maximum values are ± total propagated analytical uncertainty.

<sup>d</sup> WAC 246-290, 40 CFR 141. Dashes indicate no concentration guides available.

<sup>e</sup> WAC 173-201A-250 and EPA-570/9-76-003.

<sup>f</sup> Average values are not calculated when only one sample was analyzed; 2012 West Lake Seep Water did not have tritium analyses performed.

**Table C.4. Radionuclide Concentrations in West Lake Surface Water  
(2014 and 2012, 2013)**

Radionuclide	No. of Samples	2014 Concentration <sup>a</sup>		No. of Samples	2012 and 2013 Concentration <sup>a</sup>		DOE-Derived Concentration Guides/Standards	Washington State Ambient Surface Water Quality Standard <sup>d</sup>
		Average <sup>b</sup> pCi/L	Maximum <sup>c</sup> pCi/L		Average <sup>b</sup> pCi/L	Maximum <sup>c</sup> pCi/L		
Tritium	1	--- <sup>f</sup>	9.6E+01 ± 15.0E+01	2	23.7E+00 ± 1.2E+00	24.3E+00 ± 13.5E+01	2,000,000	20,000 <sup>d,e</sup>
Uranium-234	1	--- <sup>f</sup>	65.8E+02 ± 10.7E+01	2	19.3E+02 ± 38.3E+02	38.5E+02 ± 52.5E+01	500	—
Uranium-235	1	--- <sup>f</sup>	24.8E+01 ± 93.7E+00	2	73.8E+00 ± 14.6E+01	14.7E+01 ± 4.7E+01	600	—
Uranium-238	1	--- <sup>f</sup>	63.8E+02 ± 10.4E+01	2	18.3E+02 ± 36.4E+02	36.5E+02 ± 5.0E+02	600	—

<sup>a</sup> 1 pCi = 0.037 Bq.

<sup>b</sup> Averages are ±2 standard deviations of the mean. Average values calculated using reporting limit values for all results at or below minimum detectable concentrations.

<sup>c</sup> Maximum values are ± total propagated analytical uncertainty.

<sup>d</sup> [WAC 246-290](#), [40 CFR 141](#). Dashes indicate no concentration guides available.

<sup>e</sup> [WAC 173-201A-250](#) and [EPA-570/9-76-003](#).

<sup>f</sup> Average values are not calculated when only one sample was analyzed.

Table C.5. Concentrations of Selected Radionuclides (pCi/m<sup>3</sup>)<sup>a</sup> in Onsite Air Samples, 2014 Compared to Previous Years

Radionuclide	Site	2014					2009 – 2013				EPA Table 2 <sup>e,f</sup>
		No. of Samples	Detections <sup>b</sup>	Average <sup>c</sup>	Maximum <sup>d</sup>	Sampler	No of Samples	Detections <sup>b</sup>	Average <sup>c</sup>	Maximum <sup>d</sup>	
Gross alpha	100-K Area	187	181	1.7E-03 ± 2.7E-03	7.8E-03 ± 1.3E-03	N534	E	1094	1.2E-03 ± 2.0E-03	2.0E-02 ± 2.5E-03	2.0E-02
	100-N D4	14	14	3.1E-03 ± 5.8E-03	9.3E-03 ± 6.6E-03	N106	381	360	1.2E-03 ± 1.5E-03	5.5E-03 ± 1.4E-03	
	200-East	555	550	1.8E-03 ± 2.5E-03	6.8E-03 ± 1.1E-03	N480	2734	2607	1.2E-03 ± 1.3E-03	6.6E-03 ± 1.1E-03	
	200-West	597	595	1.8E-03 ± 2.5E-03	9.2E-03 ± 1.6E-03	N304	3126	2947	1.2E-03 ± 1.5E-03	1.4E-02 ± 2.0E-03	
	300 D4	162	149	1.1E-03 ± 1.5E-03	4.1E-03 ± 8.0E-04	N903	771	706	8.3E-04 ± 1.1E-03	3.9E-03 ± 1.5E-03	
	618-10 BG	103	103	1.5E-03 ± 1.5E-03	6.0E-03 ± 1.3E-03	N548	331	304	1.1E-03 ± 2.5E-03	1.6E-02 ± 2.3E-03	
	ERDF	133	133	1.4E-03 ± 2.0E-03	5.6E-03 ± 9.7E-04	N168	652	601	1.0E-03 ± 1.2E-03	5.1E-03 ± 1.1E-03	
Gross beta	100-K Area	189	189	1.9E-02 ± 2.2E-02	6.1E-02 ± 4.8E-03	N900	1168	1167	2.4E-02 ± 1.1E-01	1.2E+00 ± 8.4E-02	9.0E+00
	100-N D4	14	14	2.8E-02 ± 5.7E-02	1.2E-01 ± 1.7E-02	N106	381	381	1.7E-02 ± 2.0E-02	6.9E-02 ± 6.4E-03	
	200-East	555	554	1.8E-02 ± 2.1E-02	6.0E-02 ± 4.9E-03	N499	2734	2734	1.7E-02 ± 2.2E-02	1.2E-01 ± 9.0E-03	
	200-West	597	597	1.8E-02 ± 2.1E-02	7.5E-02 ± 6.2E-03	N304	3126	3124	1.7E-02 ± 2.1E-02	1.0E-01 ± 2.3E-02	
	300 D4	162	162	2.2E-02 ± 2.6E-02	7.3E-02 ± 6.3E-03	N903	776	776	2.0E-02 ± 2.6E-02	1.1E-01 ± 1.2E-02	
	618-10 BG	103	103	1.9E-02 ± 2.0E-02	5.1E-02 ± 8.6E-03	N580	331	330	1.6E-02 ± 2.6E-02	1.1E-01 ± 9.0E-03	
	ERDF	133	133	1.6E-02 ± 2.0E-02	5.6E-02 ± 4.7E-03	N963	652	651	1.5E-02 ± 2.0E-02	7.6E-02 ± 5.8E-03	
Strontium-90	100-K Area	14	0	1.9E-05 ± 3.8E-04	3.6E-04 ± 2.9E-04	N476	102	20	6.3E-04 ± 4.9E-03	1.5E+00 ± 4.4E-03	1.9E-02
	100-N D4	3	0	2.4E-03 ± 3.5E-03	4.3E-03 ± 5.8E-03	N106	30	4	7.4E-06 ± 4.3E-04	5.7E-04 ± 2.3E-04	
	200-East	42	0	5.2E-05 ± 3.2E-04	3.9E-04 ± 4.5E-04	N984	210	37	-7.4E-06 ± 4.3E-04	1.7E-03 ± 5.7E-04	
	200-West	46	0	2.7E-05 ± 3.5E-04	5.5E-04 ± 4.7E-04	N964	243	25	-6.2E-05 ± 3.5E-04	5.0E-04 ± 3.9E-04	
	300 D4	10	0	1.2E-05 ± 3.3E-04	4.1E-04 ± 3.0E-04	N557	43	2	-8.8E-05 ± 4.8E-04	3.4E-04 ± 2.7E-04	
	618-10 BG	8	0	8.9E-05 ± 1.0E-04	1.9E-04 ± 1.6E-04	N579	32	4	-2.9E-05 ± 5.5E-04	3.7E-04 ± 3.2E-04	
	ERDF	10	0	1.1E-04 ± 2.7E-04	3.3E-04 ± 3.6E-04	N517	50	5	-5.1E-05 ± 3.1E-04	3.1E-04 ± 1.1E-04	
Cesium-134	100-K Area	14	0	4.7E-05 ± 4.0E-04	5.0E-04 ± 4.1E-04	N900	102	7	9.6E-06 ± 3.4E-04	3.3E-04 ± 1.7E-04	2.7E-02
	100-N D4	3	0	-2.1E-03 ± 1.3E-02	5.0E-03 ± 9.2E-03	N106	30	3	-2.6E-05 ± 2.9E-04	3.3E-04 ± 1.5E-04	
	200-East	42	0	-2.0E-05 ± 4.3E-04	6.8E-04 ± 6.4E-04	N978	210	19	3.3E-06 ± 2.8E-04	5.2E-04 ± 2.1E-04	
	200-West	46	0	3.9E-05 ± 5.0E-04	6.2E-04 ± 5.5E-04	N155	244	23	-9.0E-06 ± 3.1E-04	5.2E-04 ± 4.0E-04	
	300 D4	10	0	4.6E-05 ± 1.8E-04	2.1E-04 ± 3.2E-04	N904	44	0	4.6E-05 ± 3.8E-04	4.8E-04 ± 1.5E-03	
	618-10 BG	8	0	1.2E-05 ± 2.0E-04	2.3E-04 ± 2.1E-04	N548	32	3	-5.6E-05 ± 4.5E-04	6.8E-04 ± 2.3E-04	
	ERDF	10	0	2.5E-05 ± 1.8E-04	1.6E-04 ± 3.2E-04	N963	50	2	1.9E-05 ± 2.9E-04	5.8E-04 ± 4.5E-04	
Cesium-137	100-K Area	14	0	9.4E-05 ± 3.5E-04	4.1E-04 ± 3.7E-04	N534	102	44	5.1E-03 ± 3.7E-02	1.2E-01 ± 3.9E-02	1.9E-02
	100-N D4	3	0	-3.0E-04 ± 7.1E-03	3.8E-03 ± 8.2E-03	N102	30	12	3.1E-04 ± 9.5E-04	1.9E-03 ± 6.5E-04	
	200-East	42	1	9.7E-05 ± 4.1E-04	6.9E-04 ± 3.8E-04	N999	210	49	2.6E-04 ± 2.7E-03	1.9E-02 ± 6.2E-03	
	200-West	45	0	5.7E-05 ± 3.3E-04	4.0E-04 ± 4.5E-04	N168	244	32	5.5E-05 ± 2.8E-04	7.6E-04 ± 3.8E-04	
	300 D4	10	1	1.0E-04 ± 4.8E-04	6.5E-04 ± 5.1E-04	N904	44	2	1.0E-04 ± 3.1E-04	5.3E-04 ± 2.7E-04	
	618-10 BG	8	0	1.6E-05 ± 2.1E-04	1.8E-04 ± 1.9E-04	N548	32	4	8.1E-05 ± 5.1E-04	1.2E-03 ± 4.0E-04	
	ERDF	10	0	9.1E-05 ± 2.6E-04	4.0E-04 ± 4.5E-04	N168	50	7	6.6E-05 ± 2.1E-04	3.8E-04 ± 1.5E-04	
Plutonium-238	100-K Area	13	0	4.0E-07 ± 3.0E-06	5.0E-06 ± 4.6E-06	N534	99	5	7.0E-06 ± 4.5E-05	1.5E-04 ± 7.1E-05	2.1E-03
	100-N D4	2	0	-3.4E-05 ± 2.2E-05	-2.3E-05 ± 2.3E-04	N106	30	0	2.1E-06 ± 1.1E-05	1.9E-05 ± 1.8E-05	
	200-East	36	0	-2.1E-08 ± 1.9E-06	1.6E-06 ± 3.0E-06	N968	210	3	1.4E-06 ± 9.5E-06	3.6E-05 ± 3.0E-05	
	200-West	35	0	-1.1E-07 ± 2.0E-06	2.4E-06 ± 2.9E-06	N165	244	9	1.5E-06 ± 1.1E-05	3.7E-05 ± 1.9E-05	

Table C.5. Concentrations of Selected Radionuclides (pCi/m<sup>3</sup>)<sup>a</sup> in Onsite Air Samples, 2014 Compared to Previous Years

Radionuclide	Site	2014					2009 – 2013				EPA Table 2 <sup>e,f</sup>
		No. of Samples	Detections <sup>b</sup>	Average <sup>c</sup>	Maximum <sup>d</sup>	Sampler	No of Samples	Detections <sup>b</sup>	Average <sup>c</sup>	Maximum <sup>d</sup>	
Plutonium-239/240u	300 D4	10	0	1.4E-06 ± 6.7E-06	1.0E-05 ± 1.5E-05	N557	40	3	1.8E-06 ± 1.3E-05	2.3E-05 ± 2.8E-05	2.0E-03
	618-10 BG	8	0	3.6E-06 ± 9.8E-06	1.2E-05 ± 1.7E-05	N548	32	2	3.1E-06 ± 1.8E-05	4.6E-05 ± 2.2E-05	
	ERDF	10	0	4.9E-07 ± 4.0E-06	4.4E-06 ± 1.8E-05	N517	50	1	1.3E-06 ± 8.5E-06	1.6E-05 ± 8.3E-06	
	100-K Area	12	0	1.3E-06 ± 2.4E-06	3.3E-06 ± 3.2E-06	N576	102	46	5.0E-05 ± 3.3E-04	1.2E-03 ± 4.7E-04	
	100-N D4	2	0	2.4E-04 ± 5.0E-06	2.4E-04 ± 5.8E-04	N106	30	13	7.6E-06 ± 1.8E-05	3.9E-05 ± 1.8E-05	
	200-East	36	0	1.9E-07 ± 2.2E-06	2.6E-06 ± 3.7E-06	N532	210	20	1.9E-06 ± 6.3E-06	3.1E-05 ± 1.5E-05	
	200-West	43	4	3.5E-06 ± 2.2E-05	6.3E-05 ± 2.1E-05	N165	244	85	1.8E-05 ± 1.1E-04	4.5E-04 ± 1.6E-04	
	300 D4	10	0	7.9E-07 ± 3.0E-06	4.4E-06 ± 4.1E-06	N902	41	3	2.2E-06 ± 1.1E-05	2.9E-05 ± 1.7E-05	
	618-10 BG	8	6	9.9E-05 ± 2.9E-04	4.6E-04 ± 1.7E-04	N548	32	16	6.2E-05 ± 2.6E-04	6.8E-04 ± 2.6E-04	
Uranium-234	ERDF	10	0	2.0E-06 ± 6.8E-06	1.0E-05 ± 1.8E-05	N517	50	22	6.8E-06 ± 2.1E-05	6.1E-05 ± 2.4E-05	7.7E-03
	100-K Area	12	2	3.2E-06 ± 7.4E-06	1.1E-05 ± 7.7E-06	N576	84	61	1.1E-05 ± 1.3E-05	4.7E-05 ± 3.0E-05	
	100-N D4	3	0	-1.2E-04 ± 5.6E-04	1.5E-04 ± 5.0E-04	N102	30	25	9.0E-06 ± 1.1E-05	1.9E-05 ± 1.2E-05	
	200-East	42	11	4.0E-06 ± 4.7E-06	9.7E-06 ± 6.1E-06	N999	210	156	9.6E-06 ± 9.6E-06	4.4E-05 ± 2.0E-05	
	200-West	45	9	3.6E-06 ± 3.5E-06	8.6E-06 ± 7.5E-06	N994	244	186	2.4E-05 ± 2.8E-04	2.2E-03 ± 7.4E-04	
	300 D4	10	8	4.1E-05 ± 3.9E-05	6.1E-05 ± 2.2E-05	N905	43	34	3.6E-05 ± 4.4E-05	8.8E-05 ± 2.1E-05	
	618-10 BG	8	1	9.5E-06 ± 1.7E-05	2.9E-05 ± 2.4E-05	N548	32	21	1.3E-05 ± 1.5E-05	3.0E-05 ± 1.5E-05	
	ERDF	10	2	1.0E-05 ± 1.2E-05	1.9E-05 ± 2.7E-05	N517	50	42	2.6E-05 ± 1.2E-04	4.3E-04 ± 1.7E-04	
	100-K Area	8	0	3.8E-07 ± 2.3E-06	2.4E-06 ± 3.8E-06	N476	83	8	2.1E-06 ± 7.6E-06	2.6E-05 ± 2.1E-05	7.1E-03
Uranium-235	100-N D4	3	0	1.1E-04 ± 2.0E-04	2.5E-04 ± 5.0E-04	N102	30	2	1.6E-06 ± 4.6E-06	7.2E-06 ± 5.5E-06	
	200-East	33	0	3.8E-07 ± 2.1E-06	2.3E-06 ± 2.9E-06	N984	210	16	1.7E-06 ± 3.7E-06	7.3E-06 ± 7.4E-06	
	200-West	37	0	4.3E-07 ± 2.1E-06	3.0E-06 ± 4.2E-06	N956	243	31	3.7E-06 ± 3.0E-05	2.1E-04 ± 7.8E-05	
	300 D4	9	1	1.7E-06 ± 5.5E-06	5.8E-06 ± 5.9E-06	N918	39	5	4.0E-06 ± 4.8E-06	1.2E-05 ± 4.9E-06	
	618-10 BG	3	0	2.7E-07 ± 1.8E-06	1.5E-06 ± 8.9E-06	N549	32	2	1.9E-06 ± 7.7E-06	1.0E-05 ± 1.1E-05	
	ERDF	6	0	1.3E-06 ± 3.6E-06	4.9E-06 ± 1.1E-05	N517	50	7	3.0E-06 ± 1.5E-05	5.3E-05 ± 2.3E-05	
	100-K Area	12	2	2.3E-06 ± 2.4E-06	5.4E-06 ± 5.1E-06	N535	84	55	8.3E-06 ± 9.7E-06	2.5E-05 ± 2.1E-05	
	100-N D4	3	0	2.8E-04 ± 5.4E-04	6.5E-04 ± 1.2E-03	N106	30	25	7.5E-06 ± 7.4E-06	1.6E-05 ± 9.2E-06	
	200-East	42	14	3.5E-06 ± 4.4E-06	1.2E-05 ± 1.0E-05	N976	210	154	7.6E-06 ± 7.2E-06	2.3E-05 ± 1.1E-05	8.3E-03
Uranium-238	200-West	45	14	3.3E-06 ± 3.4E-06	8.0E-06 ± 6.1E-06	N554	244	182	2.1E-05 ± 2.5E-04	1.9E-03 ± 6.6E-04	
	300 D4	10	9	3.8E-05 ± 2.8E-05	5.3E-05 ± 2.2E-05	N905	43	37	3.2E-05 ± 4.2E-05	8.1E-05 ± 1.9E-05	
	618-10 BG	8	5	5.3E-05 ± 9.6E-05	1.6E-04 ± 7.1E-05	N548	32	22	1.3E-05 ± 1.7E-05	4.3E-05 ± 1.9E-05	
	ERDF	9	0	6.7E-06 ± 1.6E-05	2.1E-05 ± 2.2E-05	N517	50	44	2.4E-05 ± 1.0E-04	3.7E-04 ± 1.4E-04	
	100-K Area	13	0	4.3E-05 ± 4.1E-04	7.3E-04 ± 7.3E-04	N900	95	39	2.9E-05 ± 4.8E-04	1.1E-03 ± 3.9E-04	1.9E-03
	100-N D4	3	0	-5.7E-05 ± 7.7E-05	-5.7E-06 ± 1.7E-05	N103	30	18	1.1E-05 ± 2.0E-05	3.9E-05 ± 1.7E-05	
	200-East	42	0	-4.2E-05 ± 1.3E-03	1.0E-03 ± 2.8E-03	N967	20	2	3.1E-06 ± 5.9E-06	9.5E-06 ± 6.0E-06	
	200-West	46	0	-2.2E-04 ± 1.9E-03	2.4E-03 ± 2.3E-03	N965	10	10	4.0E-05 ± 2.9E-05	6.4E-05 ± 2.8E-05	
	300 D4	8	0	1.5E-06 ± 2.4E-06	3.1E-06 ± 3.9E-06	N918	23	3	-2.1E-06 ± 1.7E-03	1.9E-03 ± 2.7E-03	
	618-10 BG	8	3	4.1E-05 ± 9.5E-05	1.6E-04 ± 7.5E-05	N548	24	16	3.7E-05 ± 1.1E-04	2.4E-04 ± 9.4E-05	
Plutonium-241	100-K Area	12	0	-8.7E-05 ± 4.7E-04	2.9E-04 ± 6.9E-04	N534	78	11	6.6E-04 ± 3.0E-03	9.2E-03 ± 2.9E-03	1.9E-03
	200-East	4	0	2.2E-04 ± 4.0E-04	5.4E-04 ± 7.4E-04	N481	20	0	3.9E-05 ± 6.1E-04	7.7E-04 ± 1.1E-03	



Table C.5. Concentrations of Selected Radionuclides (pCi/m<sup>3</sup>)<sup>a</sup> in Onsite Air Samples, 2014 Compared to Previous Years

Radionuclide	Site	2014					2009 – 2013				EPA Table 2 <sup>e,f</sup>
		No. of Samples	Detections <sup>b</sup>	Average <sup>c</sup>	Maximum <sup>d</sup>	Sampler	No of Samples	Detections <sup>b</sup>	Average <sup>c</sup>	Maximum <sup>d</sup>	
<sup>a</sup> 1 pCi = 0.037 Bq.											
<sup>b</sup> Number of samples with measurable concentrations of contaminant.											
<sup>c</sup> Average ± two standard deviations of all samples analyzed.											
<sup>d</sup> Maximum ± analytical uncertainty											
<sup>e</sup> DOE derived concentration guides are shown for gross alpha and gross beta											
<sup>f</sup> EPA values are based on an effective dose equivalent of 10 millirem/year (100 micro Sievert) (40 CFR 61, Appendix E, Table 2).											
BG = Burial Ground project.											
D4 = Deactivation, decontamination, decommissioning, and demolition.											
DOE = U.S. Department of Energy.											
EPA = Environmental Protection Agency.											
ERDF = Environmental Restoration Disposal Facility.											

Table C.6. Concentrations of Selected Radionuclides (pCi/m<sup>3</sup>)<sup>a</sup> in Offsite Air Samples, 2014 Compared to Previous Years

Radionuclide	Location	2014				2009- 2013				EPA Table 2 <sup>e,f</sup>
		No. of Samples	No. of Detects <sup>b</sup>	Average <sup>c</sup> pCi/m <sup>3</sup>	Maximum <sup>d</sup> pCi/m <sup>3</sup>	No. of Samples	No. of Detects <sup>b</sup>	Average <sup>c</sup> pCi/m <sup>3</sup>	Maximum <sup>d</sup> pCi/m <sup>3</sup>	
Gross alpha	Onsite	552	491	1.1E-03 ± 1.8E-03	7.9E-03 ± 1.1E-03	2586	2322	7.6E-04 ± 1.0E-03	4.7E-03 ± 5.0E-04	2.0E-02
	Perimeter	296	263	1.1E-03 ± 2.3E-03	7.7E-03 ± 1.2E-03	1399	1248	7.5E-04 ± 1.1E-03	8.2E-03 ± 1.6E-03	
	Nearby communities	86	81	1.3E-03 ± 2.1E-03	6.0E-03 ± 9.2E-04	386	351	7.4E-04 ± 1.1E-03	4.2E-03 ± 8.3E-04	
	Distant community	27	21	9.2E-04 ± 1.7E-03	4.2E-03 ± 8.5E-04	128	108	6.7E-04 ± 1.0E-03	3.6E-03 ± 7.9E-04	
Gross beta	Onsite	554	554	2.3E-02 ± 2.8E-02	8.4E-02 ± 7.7E-03	2591	2591	2.0E-02 ± 2.6E-02	1.3E-01 ± 1.0E-02	9.0E+00
	Perimeter	296	296	2.3E-02 ± 2.8E-02	8.0E-02 ± 6.4E-03	1400	1400	1.9E-02 ± 2.5E-02	9.5E-02 ± 8.8E-03	
	Nearby communities	188	188	2.3E-02 ± 3.3E-02	1.6E-01 ± 1.6E-02	879	879	1.9E-02 ± 2.5E-02	9.9E-02 ± 9.2E-03	
	Distant community	27	27	2.0E-02 ± 2.2E-02	5.6E-02 ± 4.6E-03	128	128	1.7E-02 ± 2.3E-02	9.5E-02 ± 7.4E-03	
Cesium-137	Onsite	40	1	5.9E-05 ± 3.2E-04	6.5E-04 ± 5.1E-04	203	2	8.9E-05 ± 6.0E-04	1.2E-03 ± 1.0E-03	1.9E-02
	Perimeter	22	0	-7.7E-05 ± 3.5E-04	2.4E-04 ± 5.3E-04	153	3	1.1E-04 ± 1.4E-03	6.9E-03 ± 2.0E-03	
	Nearby communities	14	0	5.2E-05 ± 4.2E-04	3.4E-04 ± 2.6E-04	114	1	7.5E-05 ± 8.2E-04	1.2E-03 ± 7.0E-04	
	Distant community	2	0	9.2E-05 ± 1.8E-04	1.8E-04 ± 3.1E-04	18	0	8.6E-05 ± 7.5E-04	7.7E-04 ± 9.1E-04	
Plutonium- 239/240	Onsite	34	0	2.4E-07 ± 2.8E-06	4.4E-06 ± 4.2E-06	184	21	1.6E-06 ± 2.4E-05	1.6E-04 ± 5.2E-05	2.0E-03
	Perimeter	17	1	3.2E-07 ± 3.9E-06	5.3E-06 ± 3.8E-06	109	6	8.4E-07 ± 1.1E-05	5.5E-05 ± 1.3E-05	
	Nearby communities	9	1	1.2E-06 ± 4.3E-06	5.9E-06 ± 4.0E-06	54	6	6.9E-07 ± 5.4E-06	1.6E-05 ± 4.6E-06	
	Distant community	2	0	-1.3E-06 ± 7.1E-07	-9.9E-07 ± 1.5E-06	16	0	1.7E-07 ± 2.3E-06	2.7E-06 ± 2.6E-06	
Strontium-90	Onsite	32	0	-3.9E-06 ± 2.8E-04	3.1E-04 ± 2.7E-04	127	2	1.9E-05 ± 1.4E-04	3.8E-04 ± 2.8E-04	1.9E-02
	Perimeter	18	0	-1.5E-05 ± 2.9E-04	3.7E-04 ± 3.0E-04	116	2	1.6E-05 ± 1.7E-04	4.2E-04 ± 3.3E-04	
	Nearby communities	7	0	-9.0E-06 ± 1.8E-04	8.7E-05 ± 1.7E-04	41	1	3.8E-05 ± 3.1E-04	7.2E-04 ± 1.9E-04	
	Distant community	2	0	1.6E-04 ± 9.9E-05	2.1E-04 ± 2.9E-04	17	0	5.6E-05 ± 3.5E-04	6.7E-04 ± 8.0E-04	
Hydrogen-3	Onsite	126	82	9.9E+00 ± 2.7E+01	8.8E+01 ± 1.8E+01	503	347	8.4E+00 ± 2.5E+01	1.1E+02 ± 1.1E+01	1.5E+03

Table C.6. Concentrations of Selected Radionuclides (pCi/m<sup>3</sup>)<sup>a</sup> in Offsite Air Samples, 2014 Compared to Previous Years

Radionuclide	Location	2014				2009- 2013				EPA Table 2 <sup>e,f</sup>
		No. of Samples	No. of Detects <sup>b</sup>	Average <sup>c</sup> pCi/m <sup>3</sup>	Maximum <sup>d</sup> pCi/m <sup>3</sup>	No. of Samples	No. of Detects <sup>b</sup>	Average <sup>c</sup> pCi/m <sup>3</sup>	Maximum <sup>d</sup> pCi/m <sup>3</sup>	
	Perimeter	97	50	5.4E+00 ± 9.8E+00	2.2E+01 ± 5.2E+00	441	248	6.4E+00 ± 2.1E+01	9.4E+01 ± 8.9E+00	
	Nearby communities	28	13	6.0E+00 ± 1.3E+01	2.2E+01 ± 4.9E+00	128	77	6.3E+00 ± 1.5E+01	4.8E+01 ± 1.1E+01	
	Distant community	14	4	4.8E+00 ± 1.8E+01	2.9E+01 ± 6.5E+00	65	28	2.3E+00 ± 4.9E+01	7.1E+01 ± 1.2E+01	
	Onsite	26	26	4.0E-05 ± 1.8E-05	6.1E-05 ± 2.2E-05	153	137	4.0E-05 ± 3.2E-05	8.8E-05 ± 2.1E-05	
Uranium-234	Perimeter	8	8	4.8E-05 ± 1.4E-05	5.8E-05 ± 2.0E-05	74	67	4.8E-05 ± 4.0E-05	8.9E-05 ± 2.1E-05	7.7E-03
	Nearby communities	11	11	4.7E-05 ± 1.7E-05	5.9E-05 ± 2.7E-05	77	68	4.6E-05 ± 3.0E-05	8.7E-05 ± 1.9E-05	
	Distant community	2	2	3.3E-05 ± 6.7E-06	3.7E-05 ± 1.4E-05	17	15	3.8E-05 ± 2.9E-05	7.2E-05 ± 3.5E-05	
	Onsite	26	26	3.7E-05 ± 1.6E-05	5.3E-05 ± 2.2E-05	153	146	4.3E-05 ± 2.6E-05	8.7E-05 ± 5.8E-05	
Uranium-238	Perimeter	8	8	5.2E-05 ± 9.6E-06	5.9E-05 ± 2.1E-05	74	70	5.1E-05 ± 3.7E-05	1.2E-04 ± 6.4E-05	8.3E-03
	Nearby communities	11	11	4.8E-05 ± 1.4E-05	6.1E-05 ± 2.7E-05	77	75	5.1E-05 ± 2.8E-05	9.5E-05 ± 3.2E-05	
	Distant community	2	2	3.0E-05 ± 1.5E-05	3.8E-05 ± 1.4E-05	17	16	3.9E-05 ± 1.8E-05	6.0E-05 ± 2.5E-05	
	Onsite	26	26	3.7E-05 ± 1.6E-05	5.3E-05 ± 2.2E-05	153	146	4.3E-05 ± 2.6E-05	8.7E-05 ± 5.8E-05	
Americium-241	Perimeter	22	0	4.8E-05 ± 1.6E-03	2.1E-03 ± 2.1E-03	140	0	-2.6E-04 ± 2.4E-03	3.3E-03 ± 4.1E-03	1.9E-03
	Nearby communities	14	0	1.3E-04 ± 7.7E-04	9.4E-04 ± 2.2E-03	104	0	-4.2E-04 ± 3.2E-03	5.1E-03 ± 5.3E-03	
	Distant community	2	0	-2.0E-06 ± 1.9E-04	9.3E-05 ± 3.1E-04	17	0	-8.9E-04 ± 3.0E-03	1.8E-03 ± 2.1E-03	
	Onsite	40	0	1.6E-04 ± 1.9E-03	4.0E-03 ± 3.2E-03	188	3	-1.0E-04 ± 2.1E-03	3.0E-03 ± 6.0E-03	

<sup>a</sup> 1 pCi = 0.037 Bq.<sup>b</sup> Number of samples with measurable concentrations of contaminant. Detection is defined as a value. reported above the minimum detectable activity and above the total propagated analytical uncertainty.<sup>c</sup> Average ± two standard deviations of all samples analyzed.<sup>d</sup> Maximum ± analytical uncertainty.<sup>e</sup> DOE derived concentration guides are shown for gross alpha and gross beta.<sup>f</sup> EPA values are based on an effective dose equivalent of 10 millirem/year (100 micro Sievert) (40 CFR 61, Appendix E, Table 2).

Table C.7. Radionuclide Concentrations in Columbia River Water (Richland, Washington)

Radionuclide <sup>b</sup>		2014				2009-2013				WA Ambient Surface Water Quality Standard
		Number of		Concentration <sup>a</sup>		Number of		Concentration <sup>a</sup>		
		Samples	Detects	Maximum (pCi/L) <sup>c</sup>	Average (pCi/L) <sup>c</sup>	Samples	Detects	Maximum (pCi/L) <sup>c</sup>	Average (pCi/L) <sup>c</sup>	
Strontium-90		13	0	5.6E-02 ± 3.7E-02	2.3E-03 ± 4.6E-02	60	0	5.6E-02 ± 3.8E-02	1.8E-02 ± 4.4E-02	8
Technetium-99		13	0	4.0E-01 ± 3.7E-01	1.3E-01 ± 2.8E-01	60	0	6.2E-01 ± 4.5E-01	1.0E-02 ± 5.0E-01	900
Tritium		13	13	6.3E+01 ± 9.7E+01	2.7E+01 ± 2.5E+01	61	59	1.4E+02 ± 3.2E+01	4.3E+01 ± 4.8E+01	20,000 <sup>d</sup>
Uranium-234		13	13	3.4E-01 ± 7.5E-02	2.7E-01 ± 9.0E-02	60	60	3.5E-01 ± 7.3E-02	2.6E-01 ± 6.7E-02	--8
Uranium-235		13	4	2.8E-02 ± 2.2E-02	2.5E-02 ± 3.5E-03	60	16	3.7E-02 ± 2.4E-02	1.3E-02 ± 1.9E-02	--8
Uranium-238		13	13	2.8E-01 ± 6.3E-02	2.2E-01 ± 6.1E-02	60	60	3.0E-01 ± 1.2E-01	2.1E-01 ± 6.9E-02	--8
Cesium-137	P <sup>b</sup>	12	0	6.0E-03 ± 4.7E-03	1.9E-03 ± 4.4E-03	20	0	2.0E-03 ± 1.6E-03	-2.9E-05 ± 2.3E-03	200 <sup>c</sup>
	D <sup>b</sup>	12	0	1.6E-03 ± 1.6E-03	1.3-04 ± 1.4E-03	20	0	4.1E-03 ± 4.4E-03	5.1E-04 ± 3.5E-03	
Plutonium-238	P <sup>b</sup>	4	0	8.7E-05 ± 7.4E-05	2.9E-05 ± 6.7E-05	7	0	6.3E-05 ± 1.2E-04	1.1E-05 ± 4.4E-05	600 <sup>c</sup>
	D <sup>b</sup>	4	0	1.5E-04 ± 1.4E-04	4.5E-05 ± 1.3E-04	7	1	3.6E-04 ± 1.6E-04	7.7E-05 ± 2.4E-04	
Plutonium-239/240	P <sup>b</sup>	4	0	1.8E-05 ± 4.3E-05	4.7E-06 ± 2.1E-05	7	0	3.1E-05 ± 1.1E-04	6.8E-06 ± 3.3E-05	
	D <sup>b</sup>	4	0	6.1E-05 ± 1.2E-04	-4.7E-06 ± 8.5E-05	7	0	1.4E-04 ± 1.3E-04	5.6E-05 ± 9.6E-05	

<sup>a</sup> Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard deviations of the mean.

<sup>b</sup> Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered water samples collected by the composite system (see Section 7.2); Cesium-137, plutonium-238, and plutonium-239/240 data is only available from 2012 through 2014 as historical sampling took place by analyses of water and not the dissolved or fraction concentrations.

<sup>c</sup> 1 pCi = 0.037 Bq.

<sup>d</sup> WAC 173-201A-250 and EPA-570/9-76-003.

<sup>e</sup> WAC 246-290.

<sup>f</sup> 40 CFR 141.

<sup>g</sup> Dashes indicate no concentration guides available.

<sup>h</sup> Average values are not calculated when only one sample was analyzed.

WA = Washington State.

Table C.8. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, Washington)

Radionuclide <sup>b</sup>	2014				2009-2013				WA Ambient Surface Water Quality Standard	
	Number of		Concentration <sup>a</sup>		Number of		Concentration <sup>a</sup>			
	Samples	Detects	Maximum ( <i>pCi/L</i> ) <sup>c</sup>	Average ( <i>pCi/L</i> ) <sup>c</sup>	Samples	Detects	Maximum ( <i>pCi/L</i> ) <sup>c</sup>	Average ( <i>pCi/L</i> ) <sup>c</sup>		
Composite System										
Strontium-90	13	0	4.0E-02 ± 3.6E-02	1.5E-02 ± 4.2E-02	63	3	1.3E-01 ± 5.0E-02	2.1E-02 ± 5.1E-02	8 <sup>e, f</sup>	
Technetium-99	13	0	2.9E-01 ± 4.8E-01	7.3E-03 ± 4.0E-01	59	0	4.8E-01 ± 4.6E-01	-2.2E-02 ± 4.7E-01	900 <sup>d</sup>	
Tritium	13	13	2.5E+01 ± 6.4E+00	1.7E+01 ± 8.0E+00	61	58	3.0E+01 ± 8.8E+00	1.9E+01 ± 9.5E+00	20,000 <sup>d</sup>	
Uranium-234	13	13	3.2E-01 ± 7.2E-02	2.3E-01 ± 9.3E-02	58	58	2.8E-01 ± 6.5E-02	2.2E-01 ± 6.1E-02	-- <sup>g</sup>	
Uranium-235	13	3	2.2E-02 ± 5.9E-02	9.3E-03 ± 1.5E-02	60	12	3.0E-02 ± 3.2E-02	9.9E-03 ± 1.7E-02	-- <sup>g</sup>	
Uranium-238	13	13	2.4E-01 ± 5.3E-02	1.9E-01 ± 7.2E-02	60	60	2.3E-01 ± 8.3E-02	1.8E-01 ± 5.2E-02	-- <sup>g</sup>	
Continuous System										
Cesium-137	P <sup>b</sup>	13	0	3.7E-03± 5.0E-03	8.5E-04 ± 3.5E-03	21	0	4.0E-03 ± 2.7E-03	5.7E-04 ± 2.0E-03	200 <sup>c</sup>
	D <sup>b</sup>	12	0	2.2E-03 ± 3.0E-03	3.6E-04 ± 1.6E-03	21	0	3.8E-03 ± 4.0E-03	5.4E-04 ± 4.3E-03	
Plutonium-238	P <sup>b</sup>	4	0	7.1E-06 ± 4.2E-05	-8.23.0E-07 ± 2.0E-05	7	0	4.5E-05 ± 7.4E-05	1.2E-05 ± 3.2E-05	-- <sup>g</sup>
	D <sup>b</sup>	4	0	1.9E-04 ± 1.5E-04	5.2E-05 ± 1.6E-04	7	0	5.3E-05 ± 9.8E-05	1.7E-05 ± 6.4E-04	
Plutonium-239/240	P <sup>b</sup>	4	0	1.9E-05 ± 7.0E-05	-5.6E-06 ± 4.1E-05	7	4	6.8E-05 ± 1.2E-04	1.1E-05 ± 6.8E-05	-- <sup>g</sup>
	D <sup>b</sup>	4	0	5.6E-05 ± 9.7E-05	6.9E-06 ± 9.3E-05	7	1	2.5E-05 ± 3.6E-05	7.1E-06 ± 2.9E-05	

<sup>a</sup> Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard deviations of the mean.<sup>b</sup> Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered water samples collected by the composite system (see Section 7.2); Cesium-137, plutonium-238, and plutonium-239/240 data is only available from 2012 through 2014 as historical sampling took place by analyses of water and not the dissolved or fraction concentrations.<sup>c</sup> 1 pCi = 0.037 Bq.<sup>d</sup> WAC 173-201A-250 and EPA-570/9-76-003.<sup>e</sup> WAC 246-290.<sup>f</sup> 40 CFR 141.<sup>g</sup> Dashes indicate no concentration guides available.<sup>h</sup> Average values are not calculated when only one sample was analyzed.

WA = Washington State.

**Table C.9. Radionuclide Concentrations in Columbia River Water (Hanford Reach)**

Transect/Radionuclide	No. of Detections	No. of Samples	Concentration <sup>b</sup>					
			Maximum (pCi/L <sup>a</sup> )			Minimum (pCi/L <sup>a</sup> )		
Vernita Bridge (HRM 0.3)								
Strontium-90	0	4	0.031	±	0.035	-0.019	±	0.031
Tritium	4	4	26	±	7.2	15	±	6.0
Uranium-234	4	4	0.24	±	0.07	0.15	±	0.06
Uranium-235	0	4	0.018	±	0.022	0.006	±	0.012
Uranium-238	4	4	0.18	±	0.06	0.11	±	0.04
100-N Area (HRM 9.5)								
Strontium-90	0	5	0.037	±	0.036	-0.001	±	0.032
Tritium	5	5	33	±	13	14	±	6.6
Uranium-234	5	5	0.27	±	0.06	0.19	±	0.044
Uranium-235	2	5	0.023	±	0.017	0.006	±	0.018
Uranium-238	5	5	0.19	±	0.044	0.15	±	0.038
Hanford Townsite (HRM 28.7)								
Strontium-90	0	5	0.054	±	0.038	0.001	±	0.03
Tritium	5	5	196	±	67	14	±	8.2
Uranium-234	5	5	0.26	±	0.06	0.16	±	0.05
Uranium-235	0	5	0.010	±	0.019	0	±	0.012
Uranium-238	5	5	0.17	±	0.05	0.13	±	0.04
300 Area (HRM 43.1)								
Strontium-90	0	5	0.029	±	0.03	-0.02	±	0.023
Tritium	5	5	65	±	11	18	±	5.2
Uranium-234	5	5	0.55	±	0.11	0.21	±	0.06
Uranium-235	0	5	0.019	±	0.022	0.007	±	0.013
Uranium-238	5	5	0.44	±	0.09	0.17	±	0.05
Richland (HRM 46.4)								
Strontium-90	0	5	0.039	±	0.036	-0.0005	±	0.031
Tritium	5	5	29	±	7.2	16	±	6.3
Uranium-234	5	5	0.29	±	0.074	0.18	±	0.05
Uranium-235	0	5	0.016	±	0.019	0.018	±	0.02
Uranium-238	5	5	0.23	±	0.06	0.16	±	0.05

<sup>a</sup> 1 pCi = 0.037 Bq.<sup>b</sup> Maximum and minimum values are ± total propagated analytical uncertainty (2 sigma).<sup>c</sup> Less than the laboratory—reported detection limit.<sup>d</sup> Result listed as the maximum value when only one sample is analyzed.

HRM = Hanford river marker.

**Table C.10. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site**

Discharge Water Concentrations in Columbia River Hanford Water Treatment Plant Effluent								
Metal	No. of Samples	No. of Detections	Maximum (µg/L) <sup>a</sup>	Minimum (µg/L) <sup>a</sup>	Average (±2 SD) (µg/L) <sup>a</sup>		Minimum Detectable Concentrations	Washington State Ambient Surface Water Quality Chronic Toxicity Level <sup>b</sup>
Vernita Bridge								
Antimony	8	0	—	—	—	—	1.0	—
Arsenic	8	0	—	—	—	—	1.7	190
Beryllium	8	0	—	—	—	—	0.2	—
Cadmium	8	0	—	—	—	—	0.11	—
Chromium	8	0	—	—	—	—	2	10
Copper	8	8	0.79	0.53	0.63	0.16	0.35	6
Lead	8	0	—	—	—	—	0.5	1.1
Nickel	8	8	0.74	0.50	0.59	0.13	0.5	83
Selenium	8	0	—	—	—	—	1.5	5
Silver	8	0	—	—	—	—	0.2	—
Thallium	8	0	—	—	—	—	0.45	—
Uranium	8	8	0.45	0.42	0.43	0.02	0.67	—
Zinc	8	2	5.8	3.5	3.8	1.5	3.5	55
100-N Area								
Antimony	10	0	—	—	—	—	1	—
Arsenic	10	0	—	—	—	—	1.7	190
Beryllium	10	0	—	—	—	—	0.2	—
Cadmium	10	0	—	—	—	—	0.11	—
Chromium	10	0	—	—	—	—	2	10
Copper	10	10	0.94	0.63	0.73	0.18	0.35	6
Lead	10	0	—	—	—	—	0.5	1.1
Nickel	10	10	1.11	0.52	0.63	0.33	0.5	83
Selenium	10	0	—	—	—	—	1.5	5
Silver	10	0	—	—	—	—	0.2	—
Thallium	10	0	—	—	—	—	0.45	—
Uranium	10	10	0.61	0.52	0.56	0.05	0.67	—
Zinc <sup>c</sup>	10	1	3.53	3.53	—	—	3.5	55
Hanford Townsite								
Antimony	12	0	—	—	—	—	1.0	—
Arsenic	12	0	—	—	—	—	1.7	190
Beryllium	12	0	—	—	—	—	0.2	—
Cadmium	12	0	—	—	—	—	0.11	—
Chromium	12	0	—	—	—	—	2	10
Copper	12	12	1.7	0.66	0.79	0.53	0.35	6
Lead	12	0	—	—	—	—	0.5	1.1
Nickel	12	12	0.63	0.51	0.58	0.08	0.5	83
Selenium	12	0	—	—	—	—	1.5	5
Silver	12	0	—	—	—	—	0.2	—
Thallium	12	0	—	—	—	—	0.45	—
Uranium	12	12	0.58	0.47	0.52	0.06	0.67	—
Zinc	12	1	4.52	3.5	---	---	3.5	55



**Table C.10. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site**

Table 6.16: Dissolved Metal Concentrations in Columbia River Herring Water Near Hanford Site								
Metal	No. of Samples	No. of Detections	Maximum (µg/L) <sup>a</sup>	Minimum (µg/L) <sup>a</sup>	Average (±2 SD) (µg/L) <sup>a</sup>		Minimum Detectable Concentrations	Washington State Ambient Surface Water Quality Chronic Toxicity Level <sup>b</sup>
300 Area								
Antimony	10	0	—	—	—	—	1	—
Arsenic	10	0	—	—	—	—	1.7	190
Beryllium	10	0	—	—	—	—	0.2	—
Cadmium	10	0	—	—	—	—	0.11	—
Chromium	10	0	—	—	—	—	2	10
Copper	10	10	0.84	0.65	0.74	0.13	0.35	6
Lead	10	0	—	—	—	—	0.5	1.1
Nickel	10	10	0.73	0.51	0.66	0.12	0.5	83
Selenium	10	0	—	—	—	—	1.5	5
Silver	10	0	—	—	—	—	0.2	—
Thallium	10	0	—	—	—	—	0.45	—
Uranium	10	10	1.6	0.56	0.82	0.77	0.67	—
Zinc	10	0	—	—	—	—	3.5	55
Richland								
Antimony	10	0	—	—	—	—	1.0	—
Arsenic	10	0	—	—	—	—	1.7	190
Beryllium	10	0	—	—	—	—	0.2	—
Cadmium	10	0	—	—	—	—	0.11	—
Chromium	10	0	—	—	—	—	2	10
Copper	10	10	0.89	0.68	0.76	0.14	0.35	6
Lead	10	0	—	—	—	—	0.5	1.1
Nickel	10	10	0.67	0.55	0.62	0.07	0.5	83
Selenium	10	0	—	—	—	—	1.5	5
Silver	10	0	—	—	—	—	0.2	—
Thallium	10	0	—	—	—	—	0.45	—
Uranium	10	10	0.76	0.54	0.60	0.16	0.67	—
Zinc	10	4	7.8	3.5	4.0	2.5	3.5	55

<sup>a</sup> Dashes indicate results at or below minimum detectable concentrations.<sup>b</sup> WAC 173-201A-240, and WAC 173-201A-250. Table 240(3) Toxic Substances Criteria for the protection of aquatic life. For hardness—dependent criteria, the minimum value of 47 mg CaCO<sub>3</sub>/L, for 1992 through 2000 water samples collected near Vernita Bridge by the U.S. Geological Survey was used. Parts per million (ppm) values are equivalent to the reported micrograms per liter (µg/L) concentrations shown.<sup>c</sup> Single detected value.<sup>d</sup> Average calculated using reporting limit values for all results at or below minimum detectable concentrations.  
SD = Standard deviation.

Table C.11. Radionuclide and Total Organic Carbon Concentrations in Columbia River Sediment (Near Hanford Site)

Location / 2014 Total Organic Carbon Concentration Value	Radionuclide	2014			2009-2013		
		No. of Samples	Concentration, Ci/g <sup>a</sup>		No. of Samples	Concentration, Ci/g <sup>a</sup>	
			Average <sup>b</sup>	Maximum <sup>d</sup>		Average <sup>bc</sup>	Maximum <sup>d</sup>
Priest Rapids Dam (21,500 – 39,500 mg/kg)	Cobalt-60	2	-0.00343 ± 0.0057	-0.00057 ± 0.0141	10	-0.0057 ± 0.017	0.009 ± 0.017
	Strontium-90	2	-0.00584 ± 0.008	0.00184 ± 0.0245	10	0.0094 ± 0.035	0.043 ± 0.021
	Cesium-137	2	0.23 ± 0.01	0.23 ± 0.032	10	0.284 ± 0.075	0.35 ± 0.05
	Europium-152	2	-0.0193 ± 0.0792	0.0203 ± 0.0528	10	-0.011 ± 0.11	0.089 ± 0.038
	Europium-155	2	0.0566 ± 0.0304	0.0718 ± 0.0524	10	0.071 ± 0.053	0.114 ± 0.057
	Uranium-234	2	1.27 ± 0.08	1.35 ± 0.227	10	1.2 ± 0.28	1.4 ± 0.20
	Uranium-235	2	0.1025 ± 0.003	0.104 ± 0.0496	10	0.059 ± 0.028	0.09 ± 0.032
	Uranium-238	2	1.15 ± 0.14	1.22 ± 0.209	10	1.1 ± 0.25	1.2 ± 0.17
	Plutonium-239/240	2	0.0095 ± 0.0027	0.0109 ± 0.0044	10	0.010 ± 0.003	0.013 ± 0.002
100-F Slough (2,520 mg/kg)	Cobalt-60	1		-0.00234 ± 0.0262	4	0.013 ± 0.012	0.019 ± 0.019
	Strontium-90	1		0.0104 ± 0.0274	4	0.019 ± 0.010	0.027 ± 0.025
	Cesium-137	1		0.226 ± 0.0519	4	0.211 ± 0.053	0.24 ± 0.025
	Europium-152	1		-0.0357 ± 0.0647	4	0.030 ± 0.049	0.064 ± 0.033
	Europium-155	1		0.0346 ± 0.0537	4	0.044 ± 0.063	0.079 ± 0.056
	Uranium-234	1		0.457 ± 0.0956	4	0.46 ± 0.17	0.59 ± 0.15
	Uranium-235	1		0.0646 ± 0.0345	4	0.041 ± 0.025	0.054 ± 0.035
	Uranium-238	1		0.431 ± 0.0925	4	0.417 ± 0.025	0.437 ± 0.129
	Plutonium-239/240	1		0.00428 ± 0.00328	4	0.002 ± 0.001	0.002 ± 0.002
White Bluffs Slough (9,870 mg/kg)	Cobalt-60	1		0.0093 ± 0.0282	6	0.007 ± 0.028	0.024 ± 0.026
	Strontium-90	1		0.000268 ± 0.0206	6	0.0044 ± 0.04	0.04 ± 0.031
	Cesium-137	1		0.415 ± 0.0595	6	0.38 ± 0.17	0.47 ± 0.11
	Europium-152	1		0.232 ± 0.144	6	0.065 ± 0.086	0.145 ± 0.0766
	Europium-155	1		0.101 ± 0.0639	6	0.071 ± 0.49	0.1 ± 0.068
	Uranium-234	1		1.11 0.0459 ± 0.183	6	0.79 ± 0.30	1.01 ± 0.184
	Uranium-235	1		0.0459 ± 0.0342	6	0.043 ± 0.010	0.053 ± 0.035
	Uranium-238	1		1.05 ± 0.175	6	0.78 ± 0.35	1.03 ± 0.179
	Plutonium-239/240	1		0.00508 ± 0.00366	6	0.003 ± 0.001	0.004 ± 0.003
100-D Spring 102-1 (4,030 mg/kg)	Cobalt-60	1		0.00675 ± 0.0173	2	-0.002 ± 0.012	0.0022 ± 0.019
	Strontium-90	1		0.00157 ± 0.0272	2	0.017 ± 0.004	0.019 ± 0.026
	Cesium-137	1		0.117 ± 0.0371	2	0.16 ± 0.11	0.209 ± 0.0238
	Europium-152	1		0.0465 ± 0.0537	2	-0.0052 ± 0.042	0.016 ± 0.054
	Europium-155	1		0.0395 ± 0.0687	2	0.044 ± 0.010	0.0487 ± 0.0351
	Uranium-234	1		0.363 ± 0.0815	2	0.502 ± 0.028	0.516 ± 0.11

Table C.11. Radionuclide and Total Organic Carbon Concentrations in Columbia River Sediment (Near Hanford Site)

Location / 2014 Total Organic Carbon Concentration Value	Radionuclide	2014			2009-2013		
		No. of Samples	Concentration, Ci/g <sup>a</sup>		No. of Samples	Concentration, Ci/g <sup>a</sup>	
			Average <sup>b</sup>	Maximum <sup>d</sup>		Average <sup>bc</sup>	Maximum <sup>d</sup>
Hanford Slough (8,580 – 10,200 mg/kg)	Uranium-235	1		0.0377 ± 0.026	2	0.048 ± 0.017	0.057 ± 0.037
	Uranium-238	1		0.491 ± 0.0988	2	0.468 ± 0.044	0.49 ± 0.104
	Plutonium-239/240	1		0.000688 ± 0.00194	2	0.0010 ± 0.0037	0.0028 ± 0.0019
	Cobalt-60	1		0.0000275 ± 0.0318	5	0.007 ± 0.061	0.038 ± 0.018
	Strontium-90	1		0.00567 ± 0.0192	5	0.002 ± 0.025	0.015 ± 0.014
	Cesium-137	1		0.26 ± 0.0629	5	0.21 ± 0.17	0.288 ± 0.036
	Europium-152	1		-0.00786 ± 0.0947	5	0.04 ± 0.05	0.074 ± 0.058
	Europium-155	1		-0.0498 ± 0.0894	5	0.069 ± 0.048	0.094 ± 0.045
	Uranium-234	1		0.83 ± 0.161	5	1.4 ± 2.7	4.1 ± 0.58
	Uranium-235	1		0.0496 ± 0.0364	5	0.087 ± 0.185	0.267 ± 0.083
	Uranium-238	1		0.74 ± 0.149	5	0.787 ± 0.42	1.09 ± 0.192
	Plutonium-239/240	1		0.0031 ± 0.00183	5	0.002 ± 0.002	0.004 ± 0.0015
McNary Dam (16,100 – 24,200 mg/kg)	Cobalt-60	2	0.0278 ± 0.0092	0.0324 ± 0.0262	10	0.0001 ± 0.038	0.017 ± 0.027
	Strontium-90	2	0.04165 ± 0.0091	0.0462 ± 0.0313	10	0.0035 ± 0.029	0.031 ± 0.028
	Cesium-137	2	0.2565 ± 0.005	0.259 ± 0.0458	10	0.23 ± 0.042	0.27 ± 0.038
	Europium-152	2	0.0708 ± 0.0046	0.0731 ± 0.0675	10	0.047 ± 0.076	0.097 ± 0.084
	Europium-155	2	0.0837 ± 0.0002	0.0838 ± 0.0598	10	0.077 ± 0.056	0.123 ± 0.062
	Uranium-234	2	1.47 ± 0.08	1.51 ± 0.223	10	1.5 ± 0.26	1.7 ± 0.31
	Uranium-235	2	0.08105 ± 0.0317	0.0969 ± 0.0332	10	0.073 ± 0.022	0.09 ± 0.05
	Uranium-238	2	1.22 ± 0.04	1.24 ± 0.189	10	1.23 ± 0.06	1.4 ± 0.23
	Plutonium-239/240	2	0.007975 ± 0.00465	0.0103 ± 0.00472	10	0.009 ± 0.004	0.021 ± 0.0061

<sup>a</sup> 1 pCi = 0.037 Bq.<sup>b</sup> Average values are not provided when only one sample was analyzed; Values are ± 2 standard deviations of the mean.<sup>c</sup> Average values calculated using reporting limit values for all results at or below minimum detectable concentrations.<sup>d</sup> Values are ± total propagated analytical uncertainty (2 sigma).<sup>e</sup> No sample data for this time period.

**Table C.12. Dissolved Metal Concentrations in Columbia River Sediment (Near Hanford Site)**

<b>Metal</b>	<b>Priest Rapids Dam (mg/kg dry weight)</b>	<b>Hanford Sloughs <sup>a</sup> (mg/kg dry weight)</b>	<b>McNary Dam (mg/kg dry weight)</b>	<b>Hanford Shoreline <sup>b</sup> (mg/kg dry weight)</b>
Antimony	0.8 – 1.2 <sup>c</sup>	0.51 <sup>c</sup> – 2.7	0.66 – 0.78	1.9
Arsenic	6.6 – 7.6	2.8 – 13	5.0 – 6.0	3.1
Beryllium	0.97 – 1.0	0.49 – 0.83	0.88 – 1.2	0.68
Cadmium	4.0 – 5.3	0.91 – 1.9	0.94 – 1.5	1.1
Chromium	32 - 33	11 - 26	17 - 20	70
Copper	42 - 46	14 - 38	18 - 28	13.8
Lead	35 - 37	0.55 - 71	14 - 18	6.6
Mercury	0.10 – 0.12	0.01 – 0.05	0.07 – 0.08	0.03
Nickel	36 - 36	10 - 20	17 - 20	11
Selenium	3.1 – 4.1	Not Detected	3.7 – 3.8	Not Detected
Silver	0.24 – 0.31 <sup>c</sup>	0.15 <sup>c</sup> – 0.38	0.20 – 0.24	0.30
Thallium	1.2 – 1.5 <sup>c</sup>	0.77 – 4.1	1.0 – 1.2 <sup>c</sup>	2.8
Zinc	386 - 428	121-549	155 - 176	161
<b>No. of Samples</b>	<b>2</b>	<b>4</b>	<b>2</b>	<b>1</b>

<sup>a</sup> 100-F Slough (n=1), Hanford Slough (n=1), White Bluffs Slough (n=1); where n = number of samples.<sup>b</sup> 100-D Area at 100-D Spring 102-1 (n=1).<sup>c</sup> Minimum detection limit met but fell below required detection limit.

Table C.13. Radionuclide Concentrations Measured in Water Samples Collected from Shoreline Seeps along the Hanford Site (2009-2014)

Location/Radionuclide	2014			2009-2013			Washington State Ambient Surface Water Quality Standard, <sup>(d)</sup> pCi/L
	No. of Samples	Concentration, <sup>(a)</sup> pCi/L		No. of Samples	Concentration, <sup>(a)</sup> pCi/L		
		Maximum <sup>(b)</sup>	Average <sup>(c)</sup>		Maximum <sup>(b)</sup>	Average <sup>(c)</sup>	
100-B Area (Spring 38-3)							
Strontium-90	1	7.8E-03 ± 0.034 <sup>(e)</sup>	NC	5	5.5E-02 ± 3.8E-02 <sup>(e)</sup>	2.2E-02 ±5.0E-02 <sup>(e)</sup>	8.0E+00
Tritium	1	1.0E+03 ± 2.8E+02	NC	5	1.5E+03 ± 3.7E+02	1.3E+03 ± 4.3E+02	2.0E+04
100-D Area (Spring 110-1)							
Alpha (gross)	1	2.9E+00 ± 2.6E+00 <sup>(e)</sup>	NC	5	2.6E+00 ± 1.6E+00 <sup>(e)</sup>	7.0E-01 ± 2.0E+00 <sup>(e)</sup>	1.5E+01
Beta (gross)	1	1.1E+01 ± 3.0E+00	NC	5	1.0E+01 ± 2.2E+00	4.3E+00 ± 5.9E+00	5.0E+01
Strontium-90	1	2.7E+00 ± 4.7E-01	NC	6	3.2E+00 ± 5.2E-01 <sup>(e)</sup>	7.9E-01 ± 2.2E+00 <sup>(e)</sup>	8.0E+00
Technetium-99	1	3.5E-01 ± 4.2E-01 <sup>(e)</sup>	NC	4	6.3E-01 ± 5.3E-01 <sup>(e)</sup>	2.5E-01 ± 5.2E-01 <sup>(e)</sup>	9.0E+02 <sup>(f)</sup>
Tritium	1	2.5E+03 ± 1.2E+03	NC	5	3.0E+03 ± 6.2E+02	9.6E+02 ± 2.1E+03	2.0E+04
Uranium-234	1	1.0E+00 ± 1.9E-01	NC	3	1.1E+00 ± 1.6E-01	5.4E-01 ± 8.5E-01	(g)
Uranium-235	1	5.9E-02 ± 4.2E-02	NC	3	4.9E-02 ± 2.1E-02 <sup>(e)</sup>	2.6E-02 ± 3.6E-02 <sup>(e)</sup>	(g)
Uranium-238	1	7.9E-01 ± 1.5E-01	NC	3	1.0E+00 ± 1.5E-01	4.7E-01 ± 7.5E-01	(g)
100-F Area (Spring 207-1)							
Strontium-90	1	-3.2E-02 ± 3.1E-02 <sup>(e)</sup>	NC	3	2.2E-02 ± 3.4E-02 <sup>(e)</sup>	-6.3E-03 ± 4.0E-02 <sup>(e)</sup>	8.0E+00
Tritium	1	4.5E+02 ± 1.9E+02	NC	3	8.8E+02 ± 2.4E+02	6.8E+02 ± 3.9E+02	2.0E+04
100-F Area (Spring 211-1)							
Strontium-90	1	-1.1E-02 ± 3.2E-02 <sup>(e)</sup>	NC	0	Data not available		8.0E+00
Tritium	1	3.2E+02 ± 1.6E+02	NC	0	Data not available		2.0E+04
100-H Area (Spring 145-1)							
Strontium-90	1	-2.2E-02 ± 3.1E-02 <sup>(e)</sup>	NC	4	3.2E-03 ± 3.2E-02 <sup>(e)</sup>	6.2E-04 ±4.0E-02 <sup>(e)</sup>	8.0E+00
Technetium-99	1	2.7E-01 ± 3.7E-01 <sup>(e)</sup>	NC	4	1.7E+00 ± 8.6E-01 <sup>(e)</sup>	6.7E-01 ± 1.3E+00 <sup>(e)</sup>	9.0E+02 <sup>(f)</sup>
Tritium	1	1.5E+02 ± 1.4+02 <sup>(e)</sup>	NC	4	1.6E+03 ± 3.8E+02	7.4E+02 ± 1.1E+03	2.0E+04
100-K Area (Spring 63-1)							
Alpha (gross)	1	4.3E-01 ± 1.9E+00 <sup>(e)</sup>	NC	4	3.7E+00 ± 2.4E+00	2.5E+00 ± 1.9E+00	1.5E+01
Beta (gross)	1	5.0E+00 ± 2.7E+00	NC	4	1.9E+01 ± 2.7E+00	1.3E+01 ± 9.6E+00	5.0E+01
Carbon-14	1	4.1E+02 ± 4.0E+02	NC	1	2.2E+03 ± 4.0E+02	NC	2.0E+03
Strontium-90	1	-7.1E-03 ± 3.2E-02 <sup>(e)</sup>	NC	4	3.2E-02 ± 3.3E-02 <sup>(e)</sup>	1.5E-02 ± 3.8E-02 <sup>(e)</sup>	8.0E+00
Tritium	1	2.0E+02 ± 1.4E+02 <sup>(e)</sup>	NC	4	1.4E+03 ± 3.4E+02	1.0E+03 ± 5.2E+02	2.0E+04
100-K Area (Spring 68-1)							
Alpha (gross)	1	-7.8E-01 ± 1.5E+00 <sup>(e)</sup>	NC	0	Data not available		1.5E+01
Beta (gross)	1	2.7E+00 ± 2.2E+00 <sup>(e)</sup>	NC	0	Data not available		5.0E+01

Table C.13. Radionuclide Concentrations Measured in Water Samples Collected from Shoreline Seeps along the Hanford Site (2009-2014)

Location/Radionuclide	2014			2009-2013			Washington State Ambient Surface Water Quality Standard, <sup>(d)</sup> pCi/L
	No. of Samples	Concentration, <sup>(a)</sup> pCi/L		No. of Samples	Concentration, <sup>(a)</sup> pCi/L		
		Maximum <sup>(b)</sup>	Average <sup>(c)</sup>		Maximum <sup>(b)</sup>	Average <sup>(c)</sup>	
Strontium-90	1	4.7E-03 ± 4.0E-02 <sup>(e)</sup>	NC	0	Data not available		8.0E+00
Tritium	1	2.4E+03 ± 5.1E+02	NC	1	2.9E+03 ± 6.1E+02	NC	2.0E+04
100-N Area (Spring 8-13)							
Alpha (gross)	1	6.1E-01 ± 1.0E+00 <sup>(e)</sup>	NC	5	1.0E+01 ± 4.0E+00	3.3E+00 ± 7.3E+00	1.5E+01
Beta (gross)	1	1.8E+00 ± 1.3E+00 <sup>(e)</sup>	NC	5	1.8E+01 ± 3.8E+00	5.8E+00 ± 1.2E+01	5.0E+01
Strontium-90	1	1.4E-02 ± 3.4E-02 <sup>(e)</sup>	NC	5	4.8E-02 ± 3.2E-02 <sup>(e)</sup>	2.8E-02 ± 3.4E-02 <sup>(e)</sup>	8.0E+00
Tritium	1	4.2E+03 ± 8.5E+02	NC	5	4.0E+03 ± 8.2E+02	2.5E+03 ± 2.8E+03	2.0E+04
100-N Area (Spring 89-1)							
Strontium-90	1	1.3E+01 ± 2.0E+00	NC	2	4.4E+01 ± 6.9E+00	2.4E+01 ± 3.9E+01	8.0E+00
Tritium	1	2.6E+02 ± 1.5E+02	NC	2	1.5E+03 ± 3.5E+02	1.2E+03 ± 6.1E+02	2.0E+04
300 Area (300 Area Spring 42-2 and 300 Area Spring DR 42-2)							
Alpha (gross)	2	6.6E+01 ± 7.2E+00	4.1E+01 ± 4.9E+01	5	3.1E+01 ± 6.4E+00	2.4E+01 ± 7.3E+00	1.5E+01
Beta (gross)	2	3.0E+01 ± 3.1E+00	2.2E+01 ± 1.5E+01	5	3.9E+01 ± 4.9E+00	2.0E+01 ± 1.9E+01	5.0E+01
Tritium	2	5.4E+03 ± 1.1E+03	4.9E+03 ± 9.8E+02	5	6.1E+03 ± 1.2E+03	4.3E+03 ± 1.9E+03	2.0E+04
Uranium-234	2	3.7E+01 ± 5.9E+00	2.3E+01 ± 2.7E+01	5	1.6E+01 ± 3.7E+00	1.3E+01 ± 4.9E+00	(g)
Uranium-235	2	3.0E+00 ± 5.7E-01	1.9E+00 ± 2.3E+00	5	1.7E+00 ± 5.1E-01	9.8E-01 ± 7.5E-01	(g)
Uranium-238	2	3.5E+01 ± 5.7E+00	2.2E+01 ± 2.6E+01	5	1.7E+01 ± 4.1E+00	1.2E+01 ± 6.2E+00	(g)
Hanford Townsite (Hanford Spring 25-4)							
Alpha (gross)	2	5.8E-01 ± 1.6E+00 <sup>(e)</sup>	NC	0	Data not available		1.5E+01
Beta (gross)	2	6.1E+00 ± 2.2E+00 <sup>(e)</sup>	NC	0	Data not available		5.0E+01
Strontium-90	2	5.7E-03 ± 3.4E-02 <sup>(e)</sup>	NC	0	Data not available		8.0E+00
Tritium	2	5.1E+00 ± 1.2E+02	NC	0	Data not available		2.0E+04
Hanford Townsite (Hanford Spring 28-2)							
Alpha (gross)	1	3.7E+00 ± 2.4E+00	NC	8	6.6E+00 ± 2.7E+00 <sup>(e)</sup>	2.8E+00 ± 3.2E+00 <sup>(e)</sup>	1.5E+01
Beta (gross)	1	4.7E+01 ± 4.5E+00	NC	8	4.5E+01 ± 4.8E+00	2.5E+01 ± 2.1E+01	5.0E+01
Tritium	1	2.1E+04 ± 4.1E+03	NC	8	3.7E+04 ± 7.2E+03	2.3E+04 ± 1.6E+04	2.0E+04

(a) To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.

(b) Maximum values are ± total propagated analytical uncertainty.

(c) Average values are not calculated (NC) when only one sample was analyzed. Averages are ±2 standard deviations of the mean.

(d) WAC 246-290, 40 CFR 141, and Appendix D, Table D.4.

(e) Value below the minimum detectable concentration.

(f) WAC 173-201A-250 and EPA-570/9-76-003.

(g) No concentration guides available.

*Table C.13. Radionuclide Concentrations in Columbia River Shoreline Sediment (100-D Seep)*

Radionuclide	No. of Samples	Result, pCi/g <sup>a, b</sup>
Antimony-125 <sup>c</sup>	1	0.83E-02 ± 3.8E-02
Cobalt-60 <sup>c</sup>	1	6.8E-03 ± 1.7E-02
Cesium-134	1	4.1E-02 ± 3.3E-02
Cesium-137	1	1.2E-01 ± 3.7E-02
Europium-152 <sup>c</sup>	1	4.7E-02 ± 5.4E-02
Europium-154 <sup>c</sup>	1	-4.3E-02 ± 5.6E-02
Europium-155 <sup>c</sup>	1	4.0E-02 ± 6.9E-02
Potassium-40	1	1.4E+01 ± 1.4E+00
Plutonium-238 <sup>c</sup>	1	1.7E-04 ± 1.2E-03
Plutonium-239/240 <sup>c</sup>	1	6.9E-04 ± 1.9E-03
Ruthenium-106 <sup>c</sup>	1	3.4E-02 ± 1.3E-01
Strontium-90 <sup>c</sup>	1	1.6E-03 ± 2.7E-02
Uranium-234	1	3.6E-01 ± 8.2E-02
Uranium-235	1	3.8E-02 ± 2.6E-02
Uranium-238	1	4.9E-01 ± 9.9E-02

a International System of Units conversion (dry weight): multiply pCi/g by 0.037 to obtain Bq/g.

b Values are ± total propagated analytical uncertainty (2 sigma).

c Results at or below minimum detectable concentrations.



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**Appendix D****Dose Calculations**

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## D.0 Dose Calculations

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*R. Perona and RT Ryti*

Dose calculations, based on measured and/or estimated releases from stack emissions, liquid effluents, and contaminated soils were conducted for the public and biota. These dose calculations are summarized in Section 4.2. Details of the methods and assumptions used for modeling individual and population dose for the public are provided in Section D.1. Methods and assumptions related to the calculation of biota dose are provided in Section D.2.

### D.1 Supporting Information for Calculation of Public Doses

The radiological dose that the public could have received in 2014 from the Hanford Site was calculated in terms of the *total effective dose*. The total effective dose is the sum of the effective dose equivalent from external sources and the committed effective dose equivalent for internal exposure. The effective dose equivalent is the sum of doses to organs and tissues that is weighted to account for the sensitivity of the organ or tissue to the effects of radiation and for the biological effectiveness of the type of radiation causing the dose. It is expressed in units of rem (sievert), or more typically the sub-unit millirem (millisievert)<sup>1</sup> for individuals, and in units of person-rem (person-sievert) for the collective dose received by the total population within a 50-mile (80-kilometer) radius of Hanford Site operations areas. This appendix describes how the doses summarized in Section 4.2 of this report were calculated.

Calculation of the effective dose equivalent takes into account the long-term (50 years) internal exposure from radionuclides absorbed into the body during the current year. The effective dose equivalent is the sum of individual committed (50 years) organ doses multiplied by tissue weighting factors ([ICRP 1991](#)) that represent the contribution of each organ or tissue to a person's internal radiation dose. Internal organs also may be irradiated from external sources of radiation. The external exposure received during the current year is added to the committed internal dose to obtain the total effective dose.

Releases of radionuclides from Hanford Site facilities are frequently too small for their concentrations to be accurately measured in many of the offsite environmental media of interest. Even when present in measureable amounts, it can be difficult to distinguish the small Hanford Site contributions from levels attributable to fallout from historical nuclear weapons testing and from naturally occurring radionuclides such as uranium and its decay products. Therefore, environmental radionuclide concentrations were estimated from stack effluent measurements (air pathway doses) or river water measurements (water pathway doses) by using environmental transport models. The air dose calculations employ environmental transport modeling based on measurements made at the points of release (stacks and vents). The water pathway dose calculations are based on the difference in measurements of radionuclide concentrations in the Columbia River upstream and downstream of the Hanford Site.

The transport of radionuclides in the environment to points of exposure is predicted using mathematical models of the physical processes underlying the various exposure pathways.

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<sup>1</sup> 1 rem (0.01 sievert) = 1,000 millirem (10 millisievert).

These models are used to calculate radionuclide levels in air, soil, and foods at offsite locations. Long-lived radionuclides deposited on the ground by irrigation or airborne depositions become possible sources of external exposure and uptake by agricultural products. Radionuclides taken into the body by inhalation or ingestion may be distributed among different organs and tissues and retained in the body for various lengths of times. Agricultural, behavioral, and dosimetric models were applied to calculate radionuclide intakes and radiological doses to the public from annual-average radionuclide concentrations in the exposure media. Computer programs were used to implement these mathematical models using Hanford Site-specific dispersion and uptake parameters. These programs are incorporated in a master code—*GENII - The Hanford Environmental Radiation Dosimetry Software System, Version 2.10* ([PNNL-14583](#), [PNNL-14584](#), [PNNL-19168](#))—which employs the internal dosimetry methodology described in International Commission on Radiological Protection Publication 60 ([ICRP 1991](#)) and external dose coefficients described in Federal Guidance Report 12 ([EPA 402-R-93-081](#)). GENII Version 1.485 ([PNL-6584](#), *The Hanford Environmental Radiation Dosimetry Software System*), which incorporated internal dosimetry methods of [International Commission on Radiological Protection Publication 30](#) (ICRP 1979a and 1979b) was used for dose calculations through 2008. GENII Version 2.10 is a Microsoft Windows®-based version that also incorporates some environmental modeling improvements (e.g., plume depletion during atmospheric transport) relative to Version 1.485. The modeling assumptions and radionuclide release data used in the GENII calculations are the primary focus of Section D.1. The ingestion and inhalation dose coefficients ([ICRP 1991](#)) and external dose coefficients ([EPA 1993](#)) used for the pathway dose calculations are described further in [PNNL-14584](#) and are not reproduced here.

The computer program CAP88-PC (also known as CAP-88) was used to calculate an air pathway dose to a maximally exposed individual (MEI) for compliance with *Clean Air Act* standards, as required by the EPA through [40 CFR 61](#), Subpart H from airborne radionuclide effluents (other than radon) released at DOE facilities. Technical details of the CAP88-PC calculations are provided in the *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2014* ([DOE/RL-2015-12](#)).

Calculations of radiological doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations. [DOE O 458.1](#), Chg. 2, provides requirements for demonstrating compliance with the public dose limit of 100 millirem (1 millisievert) total effective dose in a year. Relevant requirements include:

- ⊗ Compliance may be demonstrated by calculating dose to the representative person or to the MEI
- ⊗ Collective dose for members of the public should be calculated, and may be truncated, by distance (e.g., 50 miles [80 kilometers])
- ⊗ The representative person or MEI must include members of the public outside of controlled areas on DOE sites and offsite
- ⊗ Analytical models used to calculate dose must be codified or approved by DOE and must consider likely exposure pathways, including external radiation from air and soil, inhalation, and ingestion of water and terrestrial and/or aquatic foods
- ⊗ Calculations of doses to the public from exposures resulting from both routine and unplanned activities must be performed using DOE-approved dose conversion factors

- ⊗ Values of default or site-specific parameters used in the dose modeling must be included to document the calculations.

A summary of how the location of the offsite MEI was identified, and information on modeling assumptions and inputs to the GENII computer code used to conduct the MEI dose calculations, is provided in Section D.1.1. Information supporting the calculation of collective offsite dose for members of the public using the GENII computer code is provided in Section D.1.2.

### **D.1.1 Maximally Exposed Individual Dose**

The MEI is a hypothetical member of the public whose location and lifestyle make it unlikely that any actual individuals would receive higher doses. The location of the MEI can vary from year to year, depending on 1) the relative contributions of the different operational areas to radioactive emissions released to the air, 2) the contribution of radionuclide releases to the Columbia River from Hanford Site facilities, and 3) year-to-year differences in meteorology affecting wind dispersion. The following potentially significant exposure pathways are considered for identifying the location of this hypothetical individual:

- ⊗ Inhalation of airborne radionuclides
- ⊗ External exposure from submersion in airborne radionuclides
- ⊗ Ingestion of foodstuffs contaminated by radionuclides deposited on vegetation and the ground by airborne deposition and/or irrigation water drawn from the Columbia River
- ⊗ Incidental ingestion of soil and external exposure to ground contaminated by airborne deposition and/or irrigation water
- ⊗ Ingestion of drinking water drawn from the Columbia River
- ⊗ Consumption of fish from the Hanford Reach of the Columbia River
- ⊗ Recreation along the Hanford Reach of the Columbia River, including fishing, boating, swimming, and exposure to sediments during shoreline activities.

**Determination of the Location of the MEI.** Based on experience since 1990 from environmental transport modeling and environmental surveillance monitoring, four locations (Section 4, Figure 4.2) have been considered as the MEI. The distinguishing characteristics of these locations are described in the following paragraphs.

**Riverview MEI.** The Riverview area is across the Columbia River from the city of Richland. Because of its location, an individual in the Riverview area has the potential to receive the maximum exposure to waterborne effluent from Hanford Site facilities as well as some contribution from exposure to airborne emissions from the 300 Area. The Riverview location is where a small population of West Pasco residents obtain their drinking water from the river via a community water system; therefore, the domestic drinking water pathway is applied to this location. Columbia River water from just downstream of the Hanford Site is also withdrawn for irrigation of small gardens and farms at Riverview.

**Ringold MEI.** The Ringold area is along the eastern shoreline of the Columbia River 16 miles (26 kilometers) east of separations facilities in the 200 Areas. Because of its location, an individual in the Ringold area has the potential to receive the maximum exposure to airborne emissions from the

200 Areas. In addition, it is assumed that some individuals in the Ringold area may irrigate their crops with water from the Columbia River downstream of where contaminated groundwater originating from the 100 and 200-East Areas enters the river. For identifying the MEI, Hanford Site contributions to irrigation water at Ringold are protectively evaluated using the same downstream concentrations employed for Riverview. Domestic drinking water at Ringold is not obtained from the Columbia River so this exposure pathway is incomplete.

**Sagemoor MEI.** An individual in the Sagemoor area, located approximately 0.87 mile (1.4 kilometers) directly across the Columbia River from the 300 Area, frequently receives the maximum exposure to airborne emissions from the 300 Area. However, domestic water at this location comes from wells rather than from the river; as a result, the wells on the eastern side of the Columbia River are not impacted by radionuclides of Hanford Site origin. Because the farms located across from the 300 Area obtain irrigation water from the Columbia River upstream of the Hanford Site, irrigation-related exposure pathways are likely incomplete at this location. However, because some individuals may obtain much of their food from local agriculture, Columbia River irrigation pathways agricultural dose has been historically assigned to the Sagemoor area MEI. This practice protectively, but unrealistically, sums the location-specific air deposition component of food-related dose with the irrigation component from another location. The added contribution of radionuclides in the Riverview area irrigation water maximizes the calculated dose from the air and water pathways combined.

**Horn Rapids Road MEI.** Meteorological conditions in 2012 through 2014 resulted in a more southerly direction of wind dispersion than has been observed in past years. As a result, air concentrations related to 300 Area emissions were modeled to be slightly higher at a location just to the south of the Hanford Site boundary than at the Sagemoor location across the Columbia River to the east. Buildings in this area historically have been associated with commercial and industrial activities. However, in recent years, residences also have been constructed near the southern boundary of the Hanford Site south of the 300 Area. Residences in this area obtain drinking water from the city of Richland, which has an intake on the Columbia River downstream of the Hanford Site; therefore, the domestic drinking water pathway is applied to this location. Additionally, some agriculture in this area occurs on leased property that receives irrigation water from the Battelle pumping station on the Columbia River just below the 300 Area.

During the period of plutonium production at the Hanford Site, Ringold was the location of the MEI. Because of the shift in Hanford Site operations from nuclear weapons production to the current mission of managing waste products, cleaning up legacy waste, and researching new ideas and technologies for waste disposal and cleanup, the significance of air emissions from production facilities in the 200 Areas has decreased compared to emissions from research facilities in the 300 Area. For the past two decades, the hypothetical MEI has been associated with air emissions from the 300 Area.

Because the hypothetical MEI at all locations is assumed to potentially receive dose from consumption of foods raised using Columbia River irrigation water, the identification of the location of the MEI is based on the highest projected dose among the following pathways:

- ☉ Air pathways dose at Ringold (200 Area sources)

- ⊗ Air pathways dose at Sagemoor (300 Area sources)
- ⊗ Air pathways dose at Horn Rapids Road (300 Area sources) plus drinking water and irrigation pathways dose
- ⊗ Air pathways dose at Riverview (300 Area sources) plus drinking water and irrigation pathways dose.

For 2014, air-pathways radiological dose calculations conducted using CAP88-PC in support of *Clean Air Act* requirements identified Horn Rapids Road as the location with the highest MEI dose, which is 0.25 millirem per year. That dose consists of 0.28 millirem (2.8 microsievert) per year from stack emissions, 0.17 millirem (1.7 microsievert) per year from diffuse and fugitive emissions, and 0.019 millirem (0.19 microsievert) per year from radon ([DOE/RL-2015-12](#)). Air pathways calculations performed with the GENII computer code, which implements air dispersion calculations that differ slightly from CAP-88PC, indicate that Sagemoor and Horn Rapids Road MEI doses in 2014 are practically equivalent (0.10 millirem at Sagemoor and 0.11 millirem at Horn Rapids Road). Because the MEI at Horn Rapids Road also receives dose from the drinking water pathway, Horn Rapids Road was identified as the location of the hypothetical MEI in 2014 for the GENII calculations. Both Sagemoor and Horn Rapids Road MEI GENII results are shown in Section 4, Figure 4.4 for comparison.

The coordinates of the MEI location relative to each of the Hanford Site operating areas are entered in the GENII computer code to specify the location for the air pathways dose calculations. For Sagemoor, these coordinates are:

- ⊗ 100 Area: 26.874 km Easting, -30.064 km Northing
- ⊗ 200 Area: 24.954 km Easting, -20.814 km Northing
- ⊗ 300 Area: 1.35 km Easting, -0.26 km Northing
- ⊗ 400 Area: 7.909 km Easting, -6.739 km Northing.

For Horn Rapids Road, these coordinates are:

- ⊗ 100 Area: 29.1 km Easting, -29.1 km Northing
- ⊗ 200 Area: 22.6 km Easting, -22.6 km Northing
- ⊗ 300 Area: 0 km Easting, -1.80 km Northing
- ⊗ 400 Area: 7.92 km Easting, -7.92 km Northing.

**Water and Air Release Inputs Used In GENII Version 2.10.** As discussed in Section 4.2, the environmental data needed to perform the GENII dose calculations for the water pathways are differences in the measured upstream and downstream radionuclide concentrations in the Columbia River. The radionuclide releases to the Columbia River that are assumed to be the source of these differences are assigned to the 200 Areas. Measured emissions of radionuclides in stack releases are used in the GENII air pathways dose calculations. These air and water pathways data must be processed for input to the GENII computer code. GENII accepts inputs for environmental releases using dimensions of activity (e.g., Curie or Becquerel) per time for both water and air pathways.

Direct liquid effluent releases from outfalls in the 100 Areas were historically used to characterize contributions from the 100 Areas. The last operating outfall, the 1908-K Outfall in the 100-K Area,



ceased operations at the end of March 2011; therefore, no annual releases were identified from the 100 Areas in 2014. Liquid effluent discharges related to historical Hanford operations are known to enter the Columbia River by groundwater discharge at certain locations along the site shoreline from the 100-B/C Area downstream to the 300 Area. The impact of these discharges was evaluated as the difference between near-shore river water radionuclide concentrations downstream of the Hanford Site (monthly samples collected at the Richland Pumphouse, sampling location label RICH.PMPHS HRM46.4) and upstream samples collected below the Priest Rapids Dam (monthly samples collected at sampling location label PRIEST RAPIDS-RIVER). Some radionuclides are measured in both filtered samples (in solution) and in samples that capture suspended particulates (adhered to resin). These data were evaluated both separately and summed.

One-tailed paired t-tests and nonparametric Wilcoxon Rank Sum (WRS) tests were used to determine whether average downstream sample concentrations were statistically greater than upstream average concentrations, using a p-value of 0.05 as the threshold of statistical significance. The paired t-test is more powerful than the ordinary t-test when the values in the pairs correlate, or when the concentrations measured downstream tend to correlate to those upstream. The WRS test has less power than the t-test when the data originate from a normal distribution, but the assumptions under which the statistical results are valid are not as restrictive. Both statistical tests identified tritium, potassium-40, and uranium-238 as potentially Hanford-related contaminants to include in the 2014 dose assessment. Concentrations of uranium-234 were significantly greater downstream using the t-test but not based on the WRS. Uranium-234 is retained as a potentially Hanford-related contaminant for the 2014 dose assessment based on the results of the t-test. Because uranium-235 would be expected to co-occur with both uranium-234 and uranium-238, uranium-235 also was identified for inclusion in the water pathways dose assessment calculations. These liquid effluent releases were associated with the 200 Areas for reporting purposes. In addition to an evaluation of the 2014 Columbia River data, samples from 2002-2014 were evaluated to examine longer-term trends. Concentrations of tritium, uranium-234, uranium-235, and uranium-238 were clearly greater downstream compared to upstream for this longer period.

Potassium-40 is a naturally occurring radionuclide in soil, water, and the tissues of plants and animals that is routinely detected and is not known to be of Hanford origin. Potassium-40 is also naturally present in products such as potassium-containing fertilizers. A comparison of Columbia River upstream and downstream potassium-40 concentrations for the past 13 years is shown in Figure D.1. Potassium-40 concentrations were somewhat higher between 2008 and 2013 relative to the previous 7 years and, with the exception of 2008 annual-average, potassium-40 concentrations have been higher downstream of the Hanford Site throughout this 13-year period. Downstream potassium-40 concentrations were approximately the same in 2013 and 2014, but upstream concentrations were lower in 2014, resulting in the inclusion of potassium-40 in the water pathways dose calculations in 2014.

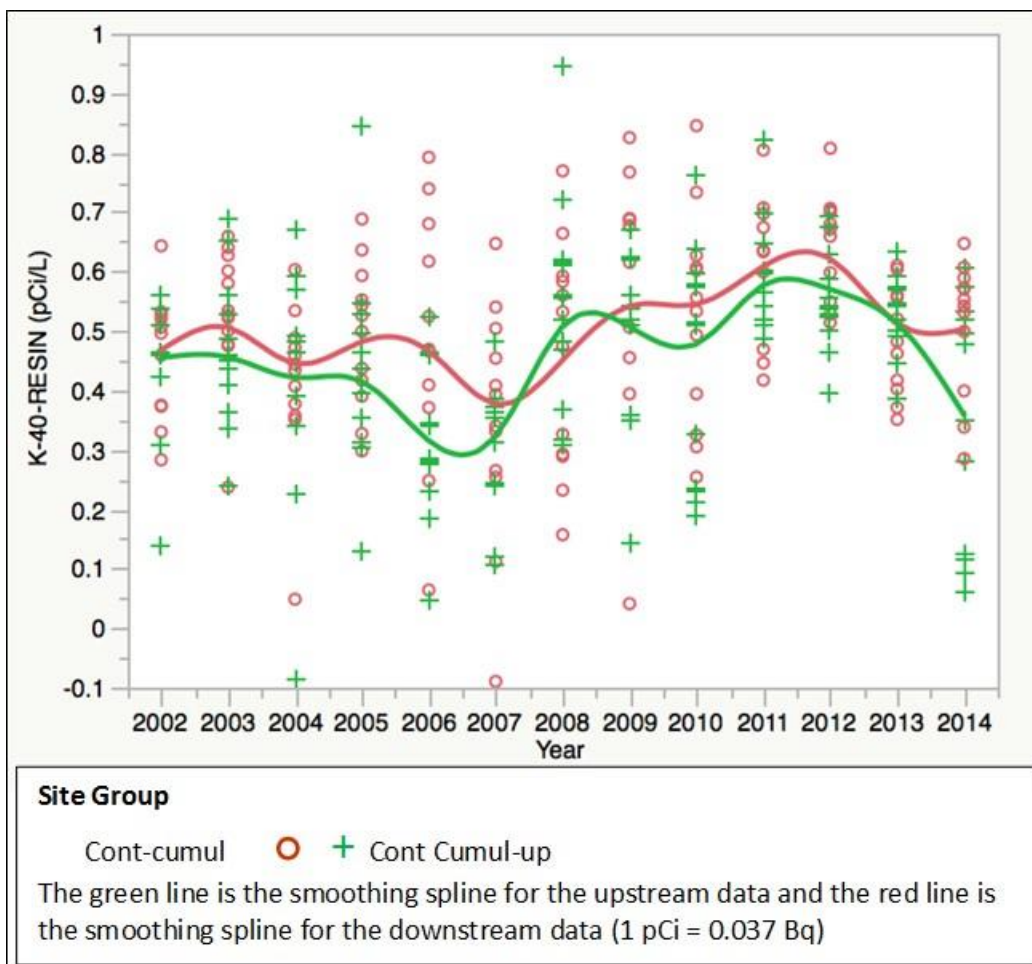
*Figure D.1 Comparison of Downstream and Upstream Potassium-40 Resin Concentrations.*

Table D.1, summarizes the mean annual differences in downstream and upstream concentrations, and calculated annual releases for the 2014 200 Areas GENII water pathways dose calculations.

*Table D.1. 200 Area Liquid Effluent Radionuclide Releases for GENII Calculations*

Radionuclide	Upstream	Downstream	Difference
<b>Columbia River Annual-Average Radionuclide Concentrations (pCi/L)</b>			
Potassium-40	3.8E-01	5.5E-01	1.6E-01
Tritium	1.6E+01	2.7E+01	1.1E+01
Uranium-234	2.4E-01	2.7E-01	3.4E-02
Uranium-235	1.0E-02	1.4E-02	3.5E-03
Uranium-238	1.9E-01	2.3E-01	4.1E-02
<b>Calculated Radionuclide Releases (Ci/year)<sup>a</sup></b>			
Potassium-40	NA	NA	1.8E+01
Tritium	NA	NA	1.2E+03
Uranium-234	NA	NA	3.7E+00
Uranium-235	NA	NA	3.9E-01
Thorium-231 <sup>b</sup>	NA	NA	3.9E-01
Uranium-238	NA	NA	4.4E+00
Thorium-234 <sup>c</sup>	NA	NA	4.4E+00
Protactinium-234m <sup>c</sup>	NA	NA	4.4E+00

a Calculated as the product of the difference in downstream and upstream radionuclide concentrations and the 2014 annual-average river flow rate of 3,447 m<sup>3</sup>/sec at Priest Rapids Dam and the number of seconds in a year.

b This short-lived progeny of uranium-235 was protectively assumed to be in secular equilibrium at the time of discharge.

c These short-lived progeny of uranium-238 were protectively assumed to be in secular equilibrium at the time of discharge.

Refer to Section 7.0 for information on Columbia River surface water sampling.

NA: Not applicable; radionuclide releases are calculated based on the difference between annual-average downstream and upstream concentrations.

1 pCi = 0.037 Bq.

Radioactive air emissions based on monitoring of stacks in the 100 Area, 200 Area, 300 Area, and 400 Area were used as the basis for the GENII air pathways dose calculations. Stack emissions are measured for specific radionuclides related to the operations at each emissions point. During the dispersion time from the stack to an offsite exposure location there is opportunity for ingrowth of short-lived radioactive progeny that are included in the GENII radionuclide inventory. A protective upper-bound dispersion time of 15 hours was estimated based on the longest dispersion distance in the collective dose calculations 50 miles (80 kilometers) and an assumed (4.9 feet/second (1.5 meters/second) average wind speed. The highest short-term (15-hour ingrowth period) concentrations of short-lived progeny that have a separate dose conversion factor were included in the GENII air emissions inventory to address their potential contribution to the inhalation dose. Ingrowth of longer-lived progeny in soil and other environmental media is accounted for within GENII.

In addition to measurement of specific radionuclides, gross alpha and gross beta measurements are also made on emissions from each operating area. Following the precedent of [DOE/RL-2015-12](#), measurements of gross alpha and gross beta radiation in stack emissions were protectively added to the measured emissions of plutonium-239/240 and strontium-90, respectively, to ensure that

contributions from any unmeasured operations-related radionuclides are incorporated in the estimated doses. These specific radionuclides were selected based on their historical association with releases in these operating areas and because of the relatively large values of their dose conversion factors. Air releases for the GENII air pathways dose calculations are summarized in Table D.2.

**Exposure Parameter Values Used in GENII Version 2.10.** GENII Version 2.10 requires input values for numerous parameters used in the environmental transport and human exposure models. Important parameters affecting the movement of radionuclides within agricultural exposure pathways such as animal dietary parameters, irrigation rates, crop yield, growing periods, and holdup periods are listed in Table D.3. The plant, animal, and aquatic foods transfer factors used for the pathway dose calculations are documented in [PNNL-14584](#) and are not reproduced here.

The offsite radiological dose is related to the extent of external exposure to, or intake of, radionuclides released from Hanford Site operations that become incorporated in exposure media such as air, water, soil, sediment, and various foodstuffs. Tables D.4 through D.6 provide the values for the diet, residency, and river recreation parameters for the MEI and collective dose (average individual) calculations.

**Meteorological Data Used in GENII Version 2.10.** GENII Version 2.10 employs an atmospheric dispersion model to calculate annual-average air concentrations and deposition rates at downwind locations based on site-specific radionuclide air emissions measurements and meteorological data ([PNNL-14583](#)). The 2014 meteorological data used in the GENII air dispersion modeling were gathered at monitoring stations in the 100 Area (station 29; 100-K), 200 Area (station 21; Hanford Meteorological Station), 300 Area (Station 11; 300 Area), and 400 Area (station 9; Fast Flux Test Facility). With the exception of the 200 Area, all meteorological data were obtained at a height of 33 feet (10 meters). In the 200 Area, where some active stacks are 200 feet (61 meters) in height, the meteorological data used were collected at 397 feet (121 meters).

Because meteorological station 29 (100-K) has been inoperable during 2013 and 2014, a meteorological file was compiled with data for years 2003 through 2012. This file represents a 10-year average of daily meteorological data at this location. 100 Area air pathways doses were calculated using this 10-year average data file, and also using 2014 meteorological data from Station 13 at 100-N. The difference in dose results was approximately 10%, with the results using the 100-K 10-year meteorological data file being slightly higher. The 10-year 100-K meteorological file was used for the protectively biased MEI dose calculations. The 2014 100-N meteorological file, which is more applicable to regional air dispersion in 2014, was used for the 100 Area population dose calculations.

Hourly meteorological data from the monitoring stations described above were formatted for use in the GENII computer code. Five meteorological files, one for each of the Hanford Site operating areas and stations described above, were created. These files were identified in the GENII Chronic Plume Air Module. A radial grid consisting of 16 directional sectors and 10 downwind distances was specified in the air module. The downwind distances were varied for each operating area to coincide with the distance to the MEI location, as defined by the Easting and Northing coordinates described above. For example, the finest resolution was entered for the distance from the 300 Area to the MEI location.

*Table D.2. Air Pathways Radionuclide Stack Emissions for GENII Modeling*

Radionuclide <sup>a</sup>	100 Area (Ci)	200 Areas (Ci)	300 Area (Ci)	400 Area (Ci)
Hydrogen-3 (elemental tritium)	NA	NA	325	NA
Hydrogen-3 (tritiated water vapor)	NA	NA	325	1.8E-03
Sodium-22	NA	NA	NA	1.4E-09
Krypton-85	NA	NA	5.6E-07	NA
Stontium-90 <sup>b</sup>	5.0E-06	3.0E-04	1.4E-06	NA
Yttrium-90 <sup>b,c</sup>	7.5E-07	4.5E-05	2.1E-07	NA
Technetium-99	NA	NA	4.1E-06	NA
Iodine-129	NA	9.8E-04	NA	NA
Cesium-137	5.5E-07	3.7E-05	1.6E-06	4.3E-07
Barium-137m <sup>c</sup>	5.5E-07	3.7E-05	1.6E-06	4.3E-07
Europium-152	NA	NA	1.6E-09	NA
Europium-154	3.7E-10	NA	5.5E-09	NA
Gadolinium-153	NA	NA	1.0E-10	NA
Radon-220	NA	NA	75.2	NA
Lead-212 <sup>c</sup>	--	--	1.1E-01	NA
Bismuth-212 <sup>c</sup>	--	--	9.0E-02	NA
Radon-222	NA	NA	2.4E-02	NA
Polonium-21 <sup>c</sup>	--	--	2.4E-02	NA
Lead-214 <sup>c</sup>	--	--	2.3E-02	NA
Bismuth-214 <sup>c</sup>	--	--	2.1E-02	NA
Radium-226	NA	NA	4.8E-10	NA
Actinium-227	NA	NA	3.3E-10	NA
Uranium-232	NA	NA	5.3E-09	NA
Uranium-233	NA	NA	1.8E-08	NA
Neptunium-237	NA	NA	2.9E-09	NA
Plutonium-238	3.3E-08	5.5E-07	3.7E-08	NA
Plutonium-239/240 <sup>d</sup>	2.1E-06	4.8E-05	1.4E-07	2.0E-07
Plutonium-241	1.1E-06	4.7E-06	3.9E-07	NA
Americium-241	3.2E-07	4.1E-06	7.7E-10	NA
Americium-243	NA	NA	8.5E-08	NA
Neptunium 239 <sup>c</sup>	--	--	1.4E-08	NA
(gross alpha)	1.8E-06	3.5E-05	1.4E-07	NA
(gross beta)	4.7E-06	2.1E-04	8.2E-07	NA

<sup>a</sup> Radionuclides in italic font are short-lived progeny of the parent listed above that may ingrow during air dispersion to offsite locations. .

<sup>b</sup> 100, 200, and 300 Area values include the addition of gross beta activity.

<sup>c</sup> Values of these short-lived progeny are the highest activity calculated within an estimated 15-hour air dispersion time period to an exposure point within a 50-mile (80-kilometer) distance.

<sup>d</sup> 100, 200, and 300 Area values include the addition of gross alpha activity.

NA – Not available. No stack emissions reported for this radionuclide.

Table D.3. Agricultural Pathway Parameters for Hanford Site Dose Calculations

	Leafy Vegetables	Root Vegetables	Fruits	Cereals	Eggs	Poultry	Beef	Milk	Hay (Beef Cattle, Milk Cows)	Pasture (Milk Cows)	Grains (Beef Cattle, Poultry)
Holdup time; day (MEI)	1	5	5	180	1	1	15	1	100	0	180
Holdup time; day (population)	14	14	14	180	18	34	34	4	100	0	180
Growing period; day	90	90	90	90	NA	NA	NA	NA	45	30	90
Yield; kg/meters <sup>a</sup>	1.5	4	2	0.8	NA	NA	NA	NA	2	1.5	0.8
Irrigation rate; cm/year	77	88	77	<sup>b</sup>	NA	NA	NA	NA	103	103	<sup>b</sup>
Irrigation period; month	6	6	6	<sup>b</sup>	NA	NA	NA	NA	6	6	<sup>b</sup>
Water intake; L/year	NA	NA	NA	NA	0.3	0.3	50	60	NA	NA	NA
Food intake; kg/day	NA	NA	NA	NA	0.12	0.12	68 / 68 <sup>c</sup>	55 / 55 <sup>d</sup>	NA	NA	NA
Contaminated fraction of diet <sup>a</sup>	NA	NA	NA	NA	1.0	1.0	0.25 / 0.75 <sup>c</sup>	0.25 / 0.75 <sup>d</sup>	NA	NA	NA
Livestock soil intake; kg/day	NA	NA	NA	NA	0.0	0.0	0.0	0.375 <sup>e</sup>	NA	NA	NA

<sup>a</sup> Pertains to animal feed. 100 percent of animal water is assumed contaminated surface water.

<sup>b</sup> No irrigation is assumed to occur for cereal crops or grains.

<sup>c</sup> First value pertains to grains, and second value pertains to hay.

<sup>d</sup> First value pertains to hay, and second value pertains to pasture grass.

<sup>e</sup> Calculated as 0.5 kilogram soil / day (EPA 2005) while grazing × 0.75 diet fraction of pasture grass.

Holdup is the time between harvest and consumption.

MEI: maximally exposed individual.

NA: not applicable.

**Table D.4. Consumption Parameters for Hanford Site Dose Calculations**

Medium	Consumption Rate <sup>a</sup>			
	Maximally Exposed Individual		Average Individual (Collective Dose)	
Leafy vegetables	30 kg/year	(66 lb/year)	15 kg/year	(33 lb/year)
Root vegetables	220 kg/year	(485 lb/year)	140 kg/year	(310 lb/year)
Fruits	330 kg/year	(728 lb/year)	64 kg/year	(140 lb/year)
Cereals	80 kg/year	(180 lb/year)	72 kg/year	(160 lb/year)
Milk	270 L/year	(71 gal/year)	230 L/year	(61 gal/year)
Beef	80 kg/year	(180 lb/year)	70 kg/year	(150 lb/year)
Poultry	18 kg/year	(40 lb/year)	8.5 kg/year	(19 lb/year)
Eggs	30 kg/year	(66 lb/year)	20 kg/year	(44 lb/year)
Fish <sup>b</sup>	40 kg/year	(88 lb/year)	— <sup>c</sup>	— <sup>c</sup>
Drinking water <sup>d</sup>	730 L/year	(193 gal/year)	440 L/year	(116 gal/year)
Inadvertent soil ingestion	36.5 g/year	(1.17 oz/year)	18.3 g/year	(0.59 oz/year)

<sup>a</sup> A transit time of 11 hours from the release to receptor locations is assumed.<sup>b</sup> A holdup time of 1 day is used for both MEI and population calculations.<sup>c</sup> Average individual consumption not identified; see text of Section D.1.2.<sup>d</sup> A holdup time of 1 day is used for the Riverview calculations for identification of the location of the MEI.**Table D.5. Residency Parameters for Hanford Site Dose Calculations**

Pathway	Exposure (hour/year)	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Air: Inhalation <sup>1, 2</sup>	24 hour/day, 365 days/year	24 hours/day, 365 days/year
Air: external (submersion) <sup>2</sup>	24 hour/day, 365 days/year	24 hours/day, 365 days/year
Soil: external (ground shine)	12 hour/day, 365 days/year	8 hours/day, 365 days/year

<sup>1</sup> Inhalation rate, adult 1.0 m<sup>3</sup>/hour (35 ft<sup>3</sup>/hour).<sup>2</sup> Dispersion time of 15 hours is protectively assumed for ingrowth of short-lived progeny during transport [50-miles (80-kilometers)] population dose radius and 4.9 feet/s (1.5 m/s) wind speed.**Table D.6. Columbia River Recreational Parameters for Hanford Site Dose Calculations**

Activity and Pathway	Exposure (hour/year) <sup>a</sup>	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Shoreline: sediment; external	5.0 hours/day, 100 days/year <sup>b</sup>	1.7 hours/day, 10 days/year <sup>b</sup>
Boating: river water; external	2.0 hours/day, 50 days/year <sup>c</sup>	0.1 hour/day, 50 days/year <sup>c</sup>
Swimming: river water; inadvertent ingestion <sup>d</sup> , external	2.0 hours/day, 50 days/year	0.2 hour/day, 50 days/year

<sup>a</sup> A transit time of 11 hours from the release to receptor locations is assumed.<sup>b</sup> A shoreline width factor of 0.2 is used.<sup>c</sup> No shielding by the boat is assumed.<sup>d</sup> Ingestion rate of 0.02 L/hour (0.68 oz/hour).



### D.1.2 Fifty-Mile (Eighty-Kilometer) Collective Population Dose

Regulatory limits have not been established for collective doses to a population; however, evaluation of the collective population doses to all residents within a 50-mile (80-kilometer) radius of Hanford Site operations is required by [DOE O 458.1](#), Chg. 2. The radiological dose to the collective population within 50 miles (80 kilometers) of site operations areas was calculated to confirm adherence to DOE environmental protection policies, and provide information to the public. The 50-mile (80-kilometer) collective dose is the sum of doses to all individual members of the public within 50 miles (80 kilometers) of the four Hanford Site operations areas (100 Area, 200 Area, 300 Area, and 400 Area).

The same exposure pathways evaluated for the MEI (Section D.1.1) were used to calculate doses to the offsite population. The primary difference between the MEI and collective dose calculations is in the values selected for certain exposure parameters. As shown in Tables D.4, D.5, and D.6, exposure parameter values for the collective dose calculations reflect an average individual rather than an MEI.

In calculating the collective dose related to water-mediated exposure pathways (drinking water, irrigated foods, Columbia River recreation, and fish consumption), estimates were made of the size of the offsite population expected to be affected by each pathway. The assumptions of population size and the calculation of collective dose for each of these four exposure pathways are described in the following paragraphs.

**Drinking Water.** The cities of Richland and Pasco obtain all or part of their municipal water directly from the Columbia River downstream from the Hanford Site; the city of Kennewick obtains its municipal water indirectly from the river from nearby wells. Approximately 182,000 people residing in the Tri-Cities<sup>2</sup> are assumed to obtain all of their drinking water directly from the Columbia River or from impacted wells adjacent to the river. Annual drinking water dose for an average individual is multiplied by the Tri-Cities population to calculate the collective drinking water dose.

**Irrigated Food.** Columbia River water is withdrawn for irrigation of small vegetable gardens and farms in the Riverview area of Pasco in Franklin County. It is assumed enough food is grown in this area to feed an estimated 2,000 people. Commercial crops are also irrigated by Columbia River water in the Horn Rapids area of Benton County. Because these crops are widely distributed, any individual in the Tri-Cities is likely to receive only negligible potential exposure. Annual irrigated foods dose for an average individual is multiplied by the estimate population of 2,000 individuals to calculate the collective irrigated foods dose.

**Columbia River Recreation.** As described in Section 4.2 and Section D.1.1, these recreational activities include fishing, swimming, boating, and shoreline recreation. It was protectively assumed that all 182,000 individuals in the Tri-Cities participated in these recreational activities. Annual recreational dose for an average individual is multiplied by the Tri-Cities population to calculate the collective recreational dose.

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<sup>2</sup> The cities of Pasco, Kennewick, and Richland—known as the Tri-Cities—are located in southeastern Washington State. Population estimates from <http://quickfacts.census.gov/qfd/index.html>.

**Fish Consumption.** Population doses from consuming fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 33,000 pounds (15,000 kilograms) per year. It was protectively assumed that 100 percent of the annual catch was consumed by individuals in the Tri-Cities area. Population dose related to fish consumption was calculated as:

$$\text{Population dose (person-rem)} = \text{MEI dose (millirem)} \times 0.001 \text{ rem/millirem} \times (\text{annual catch [kg/year]} / \text{IR}_{\text{fish}} [\text{kg/year/person}])$$

Where:

MEI dose = dose for the maximally exposed individual.

Annual catch = 15,000 kg fish/year.

IR<sub>fish</sub> = individual fish ingestion rate used in the MEI calculation (40 kg/year/person).

Collective dose related to air-mediated exposure pathways was calculated based on the geographic distribution of the population residing within a 50-mile (80-kilometer) radius of the Hanford Site operating areas, as shown in [PNNL-20631, Hanford Site Regional Population – 2010 Census](#). These distributions are based on 2010 Bureau of the Census data ([PNNL-20631](#)). These data influence the population dose by providing estimates of the number of people exposed to radioactive air emissions and their proximity to the points of release.

The air pathways collective dose calculations are based on modeled radionuclide air concentrations and deposition rates downwind of the Hanford Site operating areas coupled with the geographic population distribution in these areas. Both the meteorological data and the population distribution data are organized according to 16 directional sectors based on the four cardinal, four ordinal, and eight cross-wind directions (N, NNE, NE, ENE, etc.). These sectors were transformed into grids using concentric circles with radii of 1, 2, 3, 4, 5, 10, 20, 30, 40, and 50 miles. These radii correspond to the downwind distances specified in the GENII Chronic Plume Air Module. Population files were created based on the number of individuals located in each of the 160 grid segments centered on the 100, 200, 300, and 400 Areas, as tabulated in [PNNL-20631](#). These files were identified in the GENII Air Dose Report Module.

## D.2 Calculation of Biota Doses

The RESRAD-BIOTA computer code was used to screen the 2014 radionuclide concentrations in water and sediment to see if they exceeded the established biota concentration guides. Biota concentration guides are concentrations that could result in a dose rate of 1 rad per day for aquatic biota or 0.1 rad per day for terrestrial organisms. Table D.7 presents the Tier 1 biota concentration guides for the radionuclides evaluated. Both internal and external doses to aquatic, riparian, and terrestrial animals and plants are included in the screening process. For analyses with multiple media and multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to its corresponding biota concentration guide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded. If the initial estimated screening value (Tier 1) exceeds the dose limit (sum of fractions more than 1.0), additional screening calculations are performed (Tier 2 or Tier 3) to more accurately evaluate exposure of the biota to the radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure.

In the initial (Tier 1) screening assessment, researchers compare maximum measured concentrations to the biota concentration guides. The maximum detected concentrations evaluated for biota dose assessment are presented in Table D.8. If the sum of fractions does not exceed one, no further analysis is required. However, if the sum of fractions does exceed one, a second analysis is performed using average concentrations. For the aquatic biota dose assessment, paired sediment and water data are required. In the event that only one of these media was sampled, the other was calculated using an element-specific water to sediment partition coefficient. These coefficients are tabulated in Table D.7.

As discussed in Section 4.2.6, biota doses were evaluated for Columbia River water and sediment and West Lake water and sediment. For West Lake, the Tier 1 sum of fractions exceeded 1.0 and, therefore, Tier 2 and Tier 3 calculations were implemented using the mean water concentrations presented in Table

**Table D.7. Tier 1 Biota Concentration Guides and Water to Sediment Partition Coefficients**

Radionuclide	Water (pCi/L) <sup>a</sup>	Limiting Organism	Sediment (pCi/g) <sup>a</sup>	Limiting Organism	Default Kd (mL/g)
Hydrogen-3	2.65E+08	Riparian animal	3.74E+05	Riparian animal	0.001
Carbon-14	6.09E+02	Riparian animal	5.90E+04	Riparian animal	0.001
Strontium-90	2.78E+02	Riparian animal	5.82E+02	Riparian animal	30
Technetium-99	6.67E+05	Riparian animal	4.22E+04	Riparian animal	5
Cesium-137	4.26E+01	Riparian animal	3.12E+03	Riparian animal	500
Plutonium-239/240	1.87E+02	Aquatic animal	5.86E+03	Riparian animal	2000
Uranium-234	2.02E+02	Aquatic animal	5.27E+03	Riparian animal	50
Uranium-235	2.17E+02	Aquatic animal	3.73E+03	Riparian animal	50
Uranium-238	2.23E+02	Aquatic animal	2.49E+03	Riparian animal	50

<sup>a</sup> Biota concentration guides (pCi/L or pCi/g).

Kd = Water to Sediment Partition Coefficients (mL/g).

1 pCi = 0.037 Bq.

**D.9.** The tiered screening process is further described in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* ([DOE-STD-1153-2002](#)).

The Tier 1 and Tier 2 West Lake biota dose assessments were driven by the potential for dose from uranium isotopes in water and the assumed potential for these isotopes to accumulate in biota. Therefore, the Tier 3 West Lake biota dose calculations utilized site-specific information on bioaccumulation. As defined in [DOE-STD-1153-2002](#), bioaccumulation is the ratio of the contaminant concentration in the organism relative to the contaminant concentration in an environmental medium resulting from the uptake of the contaminant from one or more routes of exposure. The more relevant biota data collected from West Lake are the brine flies sampled in 2000 and 2007 ([PNNL-13487](#), [DOE/RL-2007-50](#)). Birds (avocets) were also sampled in 2000 and had lower concentrations than the brine flies ([PNNL-13487](#)). These birds are not year-round residents and thus have lower exposure and less potential for bioaccumulation from West Lake ([DOE/RL-2007-50](#), Appendix K).

The maximum concentration of any of the uranium isotopes in brine flies was 0.88 pCi/g for uranium-233/234 in 2007. The minimum uranium-233/234 West Lake pond water concentration was 940 pCi/L in 2007. The bioaccumulation factor is calculated by dividing the biota concentration (in pCi/g) by the water concentration (in pCi/mL), because RESRAD-BIOTA assumes that aquatic bioaccumulation occurs from water to biota. Therefore, the maximum bioaccumulation factor for uranium would be less than one (0.88 divided by 0.94). Also, as presented in Table D.10 of the 2011 report ([DOE/RL-2011-119](#), *Hanford Site Environmental Report for Calendar Year 2011*), the bioaccumulation factors for uranium isotopes based on the mean concentrations in flies and water are between 0.2 and 0.5. A bioaccumulation factor of one was used for the West Lake Tier 3 biota dose calculation as a somewhat protective measure of site-specific uranium uptake into the food chain. This same approach was used in the 2011 ([DOE/RL-2011-119](#), *Hanford Site Environmental Report for Calendar year 2011*) and 2012 ([DOE/RL-2013-18](#), *Hanford Site Environmental Report for Calendar Year 2012*) reports. The data supporting the site-specific bioaccumulation factor are presented in those reports. Table D.10 presents the Tier 3 biota concentration guides for isotopic uranium for both aquatic and riparian animals. These site-specific values were used in the RESRAD-BIOTA Tier 3 screening discussed in Section 4.2.6.

**Table D.8. Maximum Detected Concentrations Evaluated for Biota Dose Assessment**

Radionuclide	Priest Rapids Dam <sup>a</sup>	100-B Area Seeps <sup>b</sup>	100-K Area Seeps <sup>b</sup>	100-N Area Seeps <sup>b</sup>	100-D Spring Sediment <sup>a</sup>	100-D Area Seeps <sup>b</sup>	Locke Island <sup>a</sup>
Hydrogen-3	—	1030	2360	4160	—	2450	—
Carbon-14	—	—	414	—	—	—	—
Strontium-90	—	—	0.0692	12.6	—	2.71	—
Technetium-99	—	—	6.24	—	—	—	—
Cesium-137	0.23	—	—	—	0.117	—	—
Plutonium-239/240	0.0109	—	—	—	—	—	—
Uranium-234	1.35	—	—	—	0.363	1.04	1.36
Uranium-235	0.104	—	—	—	0.0377	0.0591	0.0912
Uranium-238	1.22	—	—	—	0.491	0.788	1.44

Radionuclide	White Bluffs Slough <sup>1</sup>	100-F Slough <sup>a</sup>	100-F Spring <sup>b</sup>	Hanford Slough <sup>a</sup>	Hanford Spring <sup>b</sup>	Savage Island <sup>a</sup>	300 Area Springs Seeps <sup>b</sup>
Hydrogen-3	—	—	454	—	20800	—	5370
Carbon-14	—	—	—	—	—	—	—
Strontium-90	—	—	—	—	—	—	—
Technetium-99	—	—	—	—	—	—	—
Cesium-137	0.415	0.226	—	0.26	—	0.0451	—
Plutonium-239/240	—	—	—	0.00332	—	—	—
Uranium-234	1.11	0.457	—	0.83	—	0.669	36.8
Uranium-235	0.0459	0.0646	—	0.0496	—	0.0451	3
Uranium-238	1.05	0.431	—	0.74	—	0.604	35.3

Radionuclide	McNary Dam Sediment <sup>a</sup>	West Lake Sediment <sup>a</sup>	West Lake Water <sup>b</sup>
Hydrogen-3	—	—	—
Carbon-14	—	—	—
Strontium-90	—	—	—
Technetium-99	—	—	—

Cesium-137	0.259	0.441	—
Plutonium-239/240	0.0103	—	—
Uranium-234	1.51	7.61	6580
Uranium-235	0.0969	0.323	248
Uranium-238	1.24	6.8	6380

<sup>a</sup> pCi/g.<sup>b</sup> pCi/L.

— Not detected or not measured.

1 pCi/L = 0.037 Bq.

*Table D.9. West Lake 2014 Water Samples*

Radionuclide	Water Concentration (pCi/L)		
	Pond	Seep	Average
Uranium-234	6580	62.1	3320
Uranium-235	248	3.12	126
Uranium-238	6380	58.2	3220

1 pCi/L = 0.037 Bq.

*Table D.10. Tier 3 Biota Concentration Guides*

Radionuclide	Water BCG (pCi/L)		Sediment BCG (pCi/g)	
	Aquatic Animal	Riparian Animal	Aquatic Animal	Riparian Animal
Uranium-234	202000	20200	3030000	5270
Uranium-235	217000	21700	110000	3790
Uranium-238	222000	22200	42900	2490

1 pCi/L = 0.037 Bq.

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