



DOE/RL-2017-24, Rev. 0

Hanford Site Environmental Report for Calendar Year 2016



The *Fritillaria pudica*, as shown on the front cover, is a lily found throughout the Hanford Site in a wide variety of habitats. The flower grows 1 ft high with a clear yellow, hanging, bell-like flower at the top of the flower stalk. The species name, *pudica*, refers to the shy nature of the flower, which always faces the ground. As the flower ages, the yellow bell becomes a rusty red or purplish color.



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Hanford Site Environmental Report for Calendar Year 2016

September 2017

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



ENERGY | Richland Operations
Office

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Executive Summary

Since 1959, the U.S. Department of Energy (DOE) has annually published the Hanford Site Environmental Report in accordance with [DOE O 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 2016* is to inform the public, regulators, employees, and other stakeholders of environmental and operating performance during the year.

Hanford Site operations are affected and, in many cases, regulated by numerous federal and state agencies enforcing legal requirements that address environmental compliance, remediation, planning, preservation, and waste management. For example, the DOE has sole authority to take action on matters under the [Atomic Energy Act](#) (AEA). In some cases, other federal agencies such as the Council on Environmental Quality, U.S. Environmental Protection Agency (EPA), and U. S. Fish and Wildlife Service have authority to regulate activities pursuant to the [National Environmental Policy Act](#) (NEPA); [Comprehensive Environmental Response, Compensation, and Liability Act](#) (CERCLA); [Endangered Species Act](#) (ESA); and [Migratory Bird Treaty Act](#) (MBTA). The EPA has delegated authority to the State of Washington Departments of Ecology and Health to regulate activities in accordance with the [Resource Conservation and Recovery Act](#) (RCRA), [Clean Air Act](#) (CAA), and [Clean Water Act](#) (CWA). In still other cases, state laws for licensing and permitting apply to activities and have resulted in the Hanford Site Radioactive Air Emissions License, RCRA Permit, Air Operating Permit, and State Waste Discharge Permits.

In general, the laws, regulations, and other requirements applicable to Hanford Site operations include, but may not be limited to, those that address environmental quality; air quality and noise; water resources; hazardous waste and materials management; radioactive waste and materials management; ecological resources; cultural and paleontological resources; worker safety and health; radiological safety and radiation protection; transportation; emergency planning, pollution prevention, and conservation; and environmental justice. It is DOE's policy to carry out its mission in a sustainable manner to maximize energy and water efficiency; minimize chemical toxicity and harmful environmental releases; promote renewable and other clean energy development; and conserve natural, cultural, and ecological resources while sustaining assigned mission activities.

All previous annual Hanford Site environmental reports are available online through Mission Support Alliance, LLC (MSA) at <http://msa.hanford.gov/page.cfm/enviroreports>. The following sections summarize this year's annual report.

ES.1 Section 1, Introduction

The Hanford Site encompasses approximately 581 mi² (1,505 km²) in Benton, Franklin, and Grant Counties, located in south-central Washington State within the semi-arid Pasco Basin of the Columbia Plateau (Figure ES-1). The Hanford Site was established in 1943 to provide plutonium production to fuel atomic weapons during World War II and the Cold War. The site has restricted public access and provides a buffer for areas used for former nuclear materials production, waste storage, and waste disposal. With the signing of the [Hanford Federal Facility Agreement and Consent Order](#) (Tri-Party Agreement [TPA]) in 1989 (Ecology et al. 1989a) by the Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and DOE (collectively, TPA agencies), the primary

mission shifted to developing new waste treatment and disposal technologies and characterizing and cleaning up the contamination from historical operations. The DOE is responsible for one of the largest nuclear cleanup efforts in the world, managing the legacy of five decades of nuclear weapons production. 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 (i.e., waste storage, treatment, and disposal), and related scientific and environmental research and development of waste management technologies. In addition, the recently established Manhattan Project National Historical Park, of which the B Reactor and other Hanford Site structures are a part, focuses on historic preservation and public education.

Cleanup of the Hanford Site is overseen by two DOE offices, the Richland Operations Office (DOE-RL) and the Office of River Protection (DOE-ORP). DOE-RL and the DOE-ORP jointly manage the site through several contractors and their subcontractors. The DOE-RL 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 DOE-ORP was established by Congress in 1998 as a field office to manage the retrieval, treatment, and disposal of approximately 56 million gal (204 million L) 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, DOE-ORP is responsible for the safe operation of the tank farms and 200 Area facilities, and construction and operation of the Waste Treatment Plant (WTP) located in the Central Plateau.

The DOE, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife each manage portions of the Hanford Reach National Monument.

The Manhattan Project National Historical Park, created in November 2015, is a partnership between DOE and the National Park Service. DOE continues to own, preserve, and provide public access to the five National Park facilities and areas at Hanford, while the National Park Service is responsible for interpretation of the Manhattan Project story, as well as visitor services. .

The DOE, Office of Science manages DOE's science and technology facilities, programs, goals, and objectives at the Hanford Site. Its principal laboratory is the Pacific Northwest National Laboratory (PNNL), operated by Battelle Memorial Institute for DOE since 1965.

ES.2 Section 2, Compliance Summary

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 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 with applicable environmental regulations at the Hanford Site, including the EPA, Ecology, Washington State Department of Health (WDOH), and the Benton Clean Air Agency. The EPA and Ecology are the two main

agencies who regulate Hanford cleanup as part of the TPA. In addition, the Defense Nuclear Facilities Safety Board (DNFSB) provides oversight of DOE work. Congress created the DNFSB as an independent agency within the Executive Branch to identify the nature and consequences of potential threats to public health and safety at DOE's defense nuclear facilities, to elevate such issues to the highest levels of authority, and to inform the public. During 2016, the DNFSB oversaw projects pertaining to each contractor at the Hanford Site. In addition, the TPA commits DOE to comply with the remedial-action provisions of the CERCLA and the RCRA treatment, storage, and disposal (TSD) unit regulations and corrective-action provisions.

ES.2.1 Tri-Party Agreement

From 1989 through December 31, 2016, a total of 1,286 TPA milestones were completed, and 341 target dates were met. During 2016, 38 specific cleanup milestones were scheduled for completion; of those, 14 milestones were deleted, 22 milestones were completed on time, no milestones were missed, and 2 were in negotiation. In addition, 2 target dates were met, 5 target dates were deleted, and 1 target date was in negotiation.

ES.2.2 Federal Facility Compliance Act

DOE provides mixed waste information annually as part of the Hanford Site Mixed Waste Land Disposal Restrictions Summary Reports pursuant to TPA Milestone M-026-01. In 2016, [DOE/RL-2016-08, Calendar Year 2015 Hanford Site Mixed Waste Land Disposal Restrictions Summary Report](#), met the reporting requirement.

ES.2.3 Regulatory Inspections

During calendar year (CY) 2016, 80 regulatory agency inspections were conducted at DOE facilities on the Hanford Site: Ecology conducted 39, WDOH 33, EPA (Region 10) 2, the City of Richland 1, and DOE 5.

ES.2.4 RCRA

The Ecology and EPA inspections focused on TSD unit compliance with the [Hanford Facility Dangerous Waste Permit](#) (Ecology 2012) and [WAC 173-303, "Dangerous Waste Regulations."](#) Waste accumulation and universal waste management areas were also inspected. During 2016, permit modifications were processed to change requirements for TSD units pursuant to WAC 173-303-830, "Permit Changes."

ES.2.5 CERCLA

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. During CY 2016, a draft version of the [DOE/RL-2016-01, Hanford Site Fourth CERCLA Five-Year Review Report](#), addressing 2011 through 2015 was completed and transmitted to EPA for review. Based on subsequent feedback received from EPA and other agencies, work continued on this report through the remainder of CY 2016 and into CY 2017.

ES.2.6 Hanford Site Emission Sources

In 2016, the WDOH inspections focused on compliance of major and minor stack air emission units as well as diffuse and fugitive emission sources, with the Hanford Site Air Operating Permit and Radioactive Air Emissions License (FF-01). Ecology inspections included discharge points (e.g., emergency engines/generators) and packaged boiler systems regulated under the Hanford Site Air Operating Permit. During 2016, regulatory agencies conducted 35 *Clean Air Act* inspections on the Hanford Site. A

total of four violations were alleged involving airborne radioactive materials at the 618-10 Burial Ground and failure to monitor stack air emissions continuously or operating outside sampling system design parameters at PUREX, B-Plant, and the Canister Storage Building.

ES.2.7 Environmental Occurrences

Per [DOE M 231.1-2, Occurrence Reporting and Processing of Operations Information](#), 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). During 2016, there were no events for Category 1, 2, and 3; however, 47 Category 4 events occurred as a result of the discovery of legacy contamination at the Hanford Site.

ES.2.8 Emergency Planning and Community Right to Know Act

DOE/RL-2017-12, *2016 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory*, 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 54 hazardous chemicals that exceeded the reporting thresholds.

ES.2.9 Pollution Prevention Program

In 2016, 1,284 metric tons of non-hazardous (i.e., plastic, aluminum, cardboard, paper, wood, and metal) and hazardous (i.e., antifreeze, batteries, bulbs, and oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Emissions for fiscal year (FY) 2016 decreased from FY 2015 largely due to a decrease in facility energy use and non-fleet fuel use, and an increase in waste diversion from landfills. Reported greenhouse gas emissions for FY 2016 were 46,829 metric tons of carbon dioxide equivalent compared with 102,645 metric tons carbon dioxide equivalent from the FY 2008 baseline and 71,693 metric tons carbon dioxide equivalent reported for FY 2015. There was a 34.5% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2016 from the FY 2008 baseline; emissions in FY 2016 were 27,259 metric tons carbon dioxide equivalent, whereas emissions in FY 2008 were 41,426 metric tons carbon dioxide equivalent. Greenhouse gas emissions from employee commuting, business travel, offsite wastewater treatment, and contracted solid waste disposal are primarily dependent on work locations and the number of workers employed at the Hanford Site.

ES.3 Section 3, Environmental Management System

Environmental management performance measures objectives for 2015 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. The acquisition target for alternative fuel vehicles was not met in 2016. The acquisition target for alternative fuel vehicles was not met in 2016. The alternative fuel use target was surpassed for FY 2016; however, the target for petroleum-based fuel use was missed. The target objectives for potable and non-potable water, renewable electric energy, facility fuel, facility energy, and regulated waste reduction were met in FY 2016. The target objectives for the Electronic Product Environmental Assessment Tool were exceeded in FY 2016, with 100% of the purchases meeting the requirements. More Hanford Site sanitary waste was recycled than was sent to landfills in FY 2016.

ES.4 Section 4, Radiological Protection and Doses

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 2016 monitoring efforts are provided below.

ES.4.1 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. External radiation fields were monitored in 2016 at 125 locations near Hanford Site facilities and operations. The thermoluminescent dosimeter results were used individually or averaged to determine dose rates in a given area for a specific sampling period. During 2016, 10 new thermoluminescent dosimeter monitoring locations were added.

ES.4.2 Radiological Release of Hanford Site Property

No property with detectable residual radioactivity above authorized limits was released from the Hanford Site in 2016.

ES.4.2.1 Radiological Clearance for Potentially Contaminated Personal Property with Hard-to-Detect Radionuclides. More than 19,000 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 articles such as flashlights, hard hats, radios, cameras, pens, pencils, respiratory protection, radiological control instruments, and industrial hygiene instruments. In January 2000, DOE issued a moratorium 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 2016.

ES.4.2.2 Radiological Clearance for Granular Activated Carbon for Offsite Shipment and Regeneration. Approximately 98,000 lb (44,400 kg) of granular-activated carbon was shipped offsite in 2016 for regeneration.

ES.4.3 Potential Radiological Doses to the Public and Biota

In 2016, 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. The primary sources of radionuclide contamination evaluated in the dose assessment included gaseous emissions from stacks and ventilation exhausts and contaminated groundwater seeping into the Columbia River. Potential radiological doses from 2016 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 mi (80 km) of Hanford Site operation areas

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- Doses from recreational activities, including hunting and fishing
 - Dose to a worker consuming drinking water on the Hanford Site
 - Dose to a visitor of the Manhattan Project National Historical Park
 - 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 surfacewater bodies.

Additionally, air-pathway doses from stack and fugitive emissions to offsite and non-DOE Hanford Site employees 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,”](#) were summarized.

The MEI is a hypothetical person whose location and assumed exposures are modeled in such a protective manner that it is highly unlikely any actual offsite individual would have received a higher Hanford-related dose. The dose to the MEI calculated in 2016 from Hanford Site operations was 0.12 mrem (1.2 μ Sv), which is 0.12% of the 100 mrem (1,000 μ Sv) annual public dose limit specified in DOE O 458.1. Many different exposure pathways are included in the dose calculations, but ingestion of food containing tritium from 300 Area air emissions was the single largest contributor. Collective dose was estimated for the entire population living with a 50-mi (80-km) radius of the air emissions sources and also individuals obtaining drinking water from the Columbia River downstream of the Hanford Site. A collective dose of 1.2 person-rem (0.012 person-Sv) was calculated as the sum of doses to all individual members of the exposed population.

Doses to a hypothetical individual were also calculated using measured concentrations of radionuclides in fish tissue and onsite drinking water. For recreational activities, a fish ingestion annual dose of up to 0.17 mrem (1.7 μ Sv) was estimated based on tissue samples of carp and bass collected from the Hanford Reach of the Columbia River. An annual dose of up to 0.20 mrem (2.1 μ Sv) was calculated for ingestion of Hanford Site drinking water from a 400 Area well. Lastly, annual doses were calculated for workers and visitors at the Hanford Townsite and White Bluffs Bank locations of the Manhattan Project National Historical Park (up to 0.00016 mrem (0.0016 μ Sv). Like the offsite MEI dose, these doses were far below the public dose limit. To place this information into perspective, these doses may be compared with those received from other routinely encountered sources of radiation. The 2009 National Council on Radiation Protection and Measurements report *Ionizing Radiation Exposure of the Population of the United States* (NCRP 2009) estimated that the overall annual exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv), approximately half of which is related to natural sources and the other half attributable primarily to medical procedures.

ES.5 Section 5, Environmental Restoration and Waste Management

Below is a waste summary for environmental restoration and waste management activities, including 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 describes important 2016 cleanup and remediation activities at the Hanford Site.

ES.5.1 River Corridor

The River Corridor includes the Hanford Site 100, 300, and 400 Areas that border the Columbia River. Through 2016, 100 and 300 Area transitions to MSA Long Term Stewardship are complete for 220 mi² (570 km²) of the River Corridor.

ES.5.2 100 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 2016, cleanup activities focused on completion of interim remedial actions in the 100-D, 100-H, and 100-N Areas. Waste generated from the cleanup of waste sites was disposed at the Environmental Restoration Disposal Facility (ERDF) in the 200 Areas.

ES.5.3 100-K Area

Construction was completed on the 105-K West Annex and construction activities were initiated on installing the Engineered Container Retrieval & Transfer System hardware in both the 105-K West Basin and Annex. Installation of the Engineered Container Retrieval & Transfer System hardware is forecast for April 2017. Maintenance and Storage Facility Pre-operational Acceptance Testing was completed. K-Basin Preoperational Acceptance Testing is forecast to be completed in 2017. Groundwater pump-and-treat operations continued, as well as testing systems and components to be used to remove K-Basin sludge at the Maintenance and Storage Facility located in the 400 Area prior to deployment to the K-West Basin, Annex, and its radiological environment. Remediation of waste sites to protect human health and the environment also continued.

ES.5.4 100 Areas Facilities Decommissioning

As of 2015, all deactivation, decommissioning, decontamination, and demolition activities in the 100 Area have been completed.

ES.5.5 200 Area (Central Plateau) Facilities Decommissioning

Central Plateau facilities include buildings and associated waste sites in the 200-East, 200-West, and 200-North Areas and those on the adjoining Rattlesnake Unit. The final push to prepare the four main process buildings (234-5Z, 236Z, 242Z, and 291Z) for demolition began in 2016. Two of these buildings (236Z and 242Z) were declared ready for demolition. Work at 242Z included grouting the sump pit, painting and isolating the E3 duct, and declaring 242Z and 242ZA ready for demolition. Work at 291Z included removal of process vacuum piping and asbestos abatement. The 2727Z and 2729Z Buildings were demolished and removed from the complex. The debris was removed from the site and taken to ERDF for final disposition.

ES.5.6 300 Area Facilities Decommissioning

Future activities in the 300 Area will address the 324 facility and the underlying 300-296 waste site, as well as the retained facilities and waste sites.

ES.5.7 400 Area Facilities – Fast Flux Test Facility Deactivation

The Fast Flux Test Facility remains in long-term surveillance and maintenance, and routine surveillances are performed annually.

ES.5.8 Solid Waste Management

Solid waste management includes the TSD of solid waste produced as a result of Hanford Site operations or received from offsite sources authorized to ship waste to the site. Active onsite solid waste facilities as of 2016 are described below.

ES.5.8.1 Central Waste Complex. Located in the 200-West Area, the Central Waste Complex receives waste from Hanford Site sources and any offsite sources authorized by DOE to ship waste to the site for TSD. Waste received includes low-level, transuranic, or mixed waste, and radioactive waste contaminated with polychlorinated biphenyls. Currently, the volume of waste stored in the Central Waste Complex Outside Storage Areas is approximately 162,781 ft³ (4,609 m³), with the remaining enclosed area storage totaling approximately 224,849 ft³ (6,367 m³).

ES.5.8.2 T-Plant. The T-Plant Complex is located in the 200-West Area and provides solid waste treatment, storage, and decontamination services for the Hanford Site and offsite facilities and is preparing to receive K-Basin sludge for storage.

ES.5.8.3 Canister Storage Building. Located in the 200-East Area, this 42,000-ft² (3,902-m²) 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.

ES.5.8.4 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. The first operational layer of waste packages in both trenches have been covered with compacted gravel and soil, and waste is currently being placed on the second waste layer in both Trenches 31 and 34. Trench 31 contains approximately 218,900 ft³ (6,200 m³) of waste in approximately 3,740 waste packages. Trench 34 contains approximately 187,100 ft³ (5,300 m³) of waste in 5,280 waste packages. In 2016, a total of 12,360 ft³ (350 m³) of waste was disposed of in Trenches 31 and 34. The LLBG Trench 94 received two defueled U.S. Navy reactor compartments in 2016.

ES.5.8.5 Waste Encapsulation and Storage Facility. Located in the 200-East Area, the Waste Encapsulation and Storage Facility was constructed in 1970 and 1971 on the west end of B-Plant and became active in 1974. The Waste Encapsulation and Storage Facility is operating under interim status standards. A RCRA closure plan was approved for the initial closure of Hot Cells A through F. Initial closure will consist of stabilizing the contents and contamination in these hot cells by filling them with grout. Grouting the hot cells commenced in CY 2016.

ES.5.8.6 Integrated Disposal Facility. The Integrated Disposal Facility (IDF) is an unused landfill located in the south-central part of the 200-East Area. 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) currently operating under RCRA final status standards. The IDF has a process design capacity of 2.89 million ft³ (82,000 m³).

ES.5.8.7 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, DOE and its contractors have disposed

17.9 million tons (16.2 million metric tons) of contaminated material at the ERDF since the facility began operations in 1996.

ES.5.9 Liquid Waste Management

The facilities described below are operated on the Hanford Site to store, treat, reduce, and dispose of various types of liquid effluent generated by site cleanup activities. In addition, remediation systems pump and treat contaminated groundwater in the 100-D, 100-H, and 200-West Areas.

ES.5.9.1 200 Area Effluent Treatment Facility. Located in the 200-East Area, the Effluent Treatment Facility (ETF) treats liquid w to remove toxic metals, radionuclides, and ammonia, in addition to destroying organic compounds. The treated waste is stored in tanks, sampled and analyzed, and discharged to the State-Approved Land Disposal Site (616-A Crib). The facility operated in 2016.

ES.5.9.2 200 Area Liquid Effluent Retention Facility. Across from the ETF, the Liquid Effluent Retention Facility (LERF) consists of three RCRA-compliant surface basins used to store aqueous waste. The volume of wastewater received for the LERF basin storage in 2016 was approximately 1.65 million gal (6.25 million L). The majority of wastewater received at the LERF was pipeline-transported, CERCLA-regulated leachate from ERDF, totaling approximately 0.784 million gal (2.96 million L). The other major contributor to wastewater received into LERF was approximately 0.416 million gal (1.57 million L) of process condensate from the 242-A Evaporator. Approximately 0.45 million gal (1.7 million L) of wastewater was received by tanker trucks from various other facilities. Approximately 5.17 million gal (19.6 million L) of wastewater in LERF was treated at ETF in 2016. The treated effluent was discharged to the soil at the State-Approved Land Disposal Site. The volume of wastewater being stored in the LERF at the end of 2016 was approximately 15.1 million gal (57.2 million L).

ES.5.9.3 200 Area Treated Effluent Disposal Facility. Located east of the 200-East Area, the Treated Effluent Disposal Facility is a collection and disposal system for non-RCRA waste streams and consists of approximately 11 mi (18 km) of buried pipelines connecting three pumping stations, the 6653 Building (known as the disposal sample station), and a 5-ac(2-ha) disposal ponds. The volume of unregulated effluent disposed to this facility in 2016 was approximately 305,000 gal (1,154,000 million L).

ES.5.9.4 242-A Evaporator. The 242-A Evaporator in the 200-East Area concentrates dilute liquid tank waste by evaporation, reducing the volume of liquid waste sent to double-shell tanks for storage and the potential need for other double-shell tanks. In 2016, two operating campaigns were completed at 242-A Evaporator with a volume reduction of 305,000 gal. The facility underwent upgrades in the control room in 2016.

ES.5.10 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.

ES.5.10.1 Single-shell Tank System. This system is undergoing closure, as the radioactive and hazardous waste stored in single-shell tanks is being transferred to more safe, double-shell tanks. The retrieval status is 15 of the 16 tanks are complete (one was completed in 2016, and one is in progress for CY 2017). Retrieval of C-111 was completed on March 28, 2016, and the retrieval certificate for

C-111 was submitted to the state in August 2016. Retrieval activities continue at C-105. By the end of 2016, more than 75% of the waste has been retrieved from Tank C-105.

ES.5.10.2 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 2016, there were 25.6 million gal (96.7 million L) of waste in the DSTs.

ES.5.10.3 Underground Waste Storage Tanks and Associated Facilities Progress on DNFSB.

Throughout 2016, the DOE-RL, DOE-ORP, and its contractors met with and provided information to the DNFSB and its technical staff to resolve concerns regarding the 242-A Evaporator, Low-Activity Waste (LAW) Pretreatment System, Waste Compatibility Program, 222-S Laboratory, and Recommendation 2012-2 (DOE 2013).

ES.5.10.4 Single-Shell Tank Closure and Correct Measures Program. The Single-Shell Tank (SST) Closure and Corrective Measures Program (formerly known as the Vadose Zone Program) is responsible for the closure of SST Waste Management Areas, conducting performance assessments (PAs), and performing agreed upon interim measures in and around SST waste management areas (WMAs). Closure activities in CY 2016 continued to focus on the development of closure strategies and closure documents. Work was conducted during CY 2016 to prepare PAs for WMA C, the IDF, and WMA A-AX. The WMA C and WMA A-AX PAs supports closure of WMA C and WMA A-AX, respectively, while the IDF PA supports operations of the IDF. Milestones for the construction of interim surface barriers were renegotiated during CY 2016, and construction of the SX Farm interim surface barriers is scheduled to begin in October 2017.

ES.5.11 Hanford Tank Waste Treatment and Immobilization Plant

The WTP is being built on 65 ac (26 ha) on the Central Plateau to treat radioactive and hazardous waste currently stored in 177 underground tanks. In 2016, DOE and Bechtel National Inc. (BNI) finalized modifications to the WTP contract that prioritize finishing the LAW Facility, Balance of Facilities, and Analytical Laboratory to feed waste directly from the Hanford Tank Farms to LAW under an approach called Direct Feed Low-Activity Waste.

ES.5.11.1 Pretreatment Facility. In 2016, work continued to resolve the remaining technical decisions that have impacted design and construction at the Pretreatment Facility since 2012. Significant progress on the technical decisions was made in 2016 with resolution of the three most significant ones being achieved in January 2017. In December 2016, the final phase started for full-scale testing of control equipment and systems designed to safely mix radioactive waste in Pretreatment vessels. Testing is expected to finish in late 2017.

ES.5.11.2 High-level Waste Facility. At this facility, high-level waste is combined with materials in high-temperature melters, poured into waste containers to form a solid, immobilized glass form. In 2016, experts at Mississippi State University began conducting tests of the safe change high-efficiency particulate air filters that will be used in the Pretreatment, LAW, and high-level waste facilities. Tests included studies of the filter performance under combined operating conditions that exceed the requirements for standard nuclear-grade filters.

ES.5.11.3 Low-Activity Waste Facility. In 2016, construction continued on the installation of the final pieces of major engineered equipment for the off-gas treatment system, including the Thermal

Catalytic Oxidizer, the ammonia skid, and the caustic scrubber. Crews also completed fabrication work on two 300-ton (272-metric tons) melters that will be the heart of the vitrification process in the LAW Facility.

ES.5.11.4 Analytical Laboratory. Once operational, the laboratory will process about 10,000 waste samples a year to support glass formulation and waste-form compliance. In September 2016, WTP workers brought in permanent power to Building 87, the primary electrical switchgear building. Permanent power has now been successfully distributed to three additional Balance of Facilities. This achievement represents the transition from temporary construction-phase utilities to permanent utilities that will operate WTP. Pre-construction activities began on Effluent Management Facility in 2016 and formal construction will commence in 2017, with approval of a Temporary Authorization from Ecology.

ES.5.12 Long-term Stewardship

The Hanford Site's Long-Term Stewardship (LTS) Program has responsibilities within the 220 mi² (570 km²) of the Hanford Site's River Corridor and bounded by 46 mi (74 km) of Columbia River shoreline; these responsibilities include managing post-cleanup obligations for 1,527 waste sites and 6 Manhattan Project Era production reactors that have been placed in interim safe storage. More than 24,000 cleanup and historic documents have been identified, indexed, and tagged in the LTS records and document libraries. During the 2015 and 2016 inspections of the cocooned reactors, several housekeeping tasks were identified that the LTS Program completed in 2016 and early 2017 to minimize future deterioration of the cocooned structure and improve protectiveness of human health and the environment.

ES.5.13 Scientific and Technical Contributions to Hanford Site Cleanup

The 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-Environmental Management Offices of Soil and Groundwater Remediation and Tank Waste and Waste Processing, DOE-RL, CH2M Plateau Remediation Contractor (CHPRC), DOE-ORP, Washington River Protection Solutions, and BNI. Efforts included performing scientific and technical evaluations and reviews and developing and advancing new technologies to address site cleanup challenges. 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 complex soluble species. Several candidate complexes may be present in tank wastes, and actual waste samples were secured for testing during 2016.

ES.6 Section 6, Air Monitoring

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. The natural state of air in the outdoor environment, ambient air is also monitored at site facilities, away from facilities, and offsite in nearby and distant communities.

ES.6.1 Air Emissions

Small quantities of particulate and volatilized forms of radionuclides and nonradioactive chemical pollutants are emitted to the environment from federal and state permitted emission sources. Most facility radioactive air emission units are monitored periodically or continuously if they have the potential to exceed 1% of the standard for public dose at 10 mrem (100 μ Sv)/yr. Non-radioactive constituents and parameters are monitored directly, sampled, and analyzed or estimated based on inventory usage. Air emission data collected in 2016 were comparable to those collected in 2015.

ES.6.2 Ambient Air Monitoring

A network of continuously operating samplers at 60 locations across the Hanford Site was used during 2016 to monitor radioactive airborne materials in air near site facilities and operations. Ambient air was monitored in 2016 at six locations in the 100-K Area, and analytical results showed radionuclide concentrations at or below typical Hanford Site levels. Uranium-234 and -238 were detected in approximately 20% of the samples, and tritium was detected in approximately 28% 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 2016. Generally, radionuclide levels measured in the 2016 air composite samples were similar to those measured in previous years. Uranium-234 and -238 were detected in approximately 28% of the samples. Air sampling was conducted at 23 locations in the 200-West Area during 2016. Radionuclide levels measured were similar to results for previous years. At the Treatment Effluent Disposal Facility station, components for tritium sampling were added in July. The results from these 4-week samples showed slightly lower tritium concentrations than those seen in stations located in/near the 300 Area. Air sampling was conducted at five locations at ERDF (200-West Area). Radionuclide levels measured at this site were comparable to previous years. Air monitoring was conducted at four locations at the 618-10 Burial Ground Project north of the 300 Area. Radionuclide levels measured at this site were comparable to previous years.

ES.6.3 Hanford Site and Offsite Ambient Air Monitoring

Airborne radionuclide samples were collected in 2016 by 40 continuously operating samplers at or in the vicinity of the Hanford Site. All sample results in 2016 showed very low radiological concentrations in air. All radionuclide concentrations (Appendix C, Table C-6) 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 mrem (100 μ Sv)/yr from airborne radiological material.

ES.7 Section 7, Water Monitoring

Eight DOE-owned, contractor-operated public water systems supply drinking water to DOE facilities on the Hanford Site. MSA operates six of the public water systems and the CHPRC operates two systems. The City of Richland supplies water to the 300 Area, Richland North Area, and Hazardous Materials Management and Emergency Response facility.

ES.7.1 Hanford Site Drinking Water Monitoring

Routine chemical, physical, and microbiological monitoring of Hanford Site drinking water is performed regularly as mandated by EPA's Community Water System requirements. All DOE-owned Hanford Site systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels for 2016. Contaminant concentrations measured during the year were similar to those observed in recent years.

ES.7.2 Columbia River Water Monitoring

The 2016 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years. Statistical analyses indicated that monthly tritium concentrations in river water samples at the City of Richland raw water intake facility were slightly higher than concentrations in samples from Priest Rapids Dam.

ES.7.2.1 Columbia River Water – Fixed Location Samples. Individual radiological contaminant concentrations measured in Columbia River water during 2016 were well below the DOE-derived concentration standards (Appendix D).

ES.7.2.2 Columbia River Transect Samples. The 100-N Area, Hanford Townsite, 300 Area, and City of Richland transects have higher tritium concentrations near the Hanford Site shore (Benton County) when comparing levels to the opposite shoreline. However, 2016 showed similar concentrations of tritium when comparing the City of Richland fixed station to the Benton County shoreline transect sample. Strontium-90 concentrations in Hanford Reach transect samples collected in 2016 were similar to upstream reference concentrations for most locations. Uranium concentrations in all transect samples collected during 2016 were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]). Average strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2016 were similar to those reported in previous years.

ES.7.2.3 Inorganic and Organic Chemical Results. Inorganic and organic analyses detected metals and anions in Columbia River transect samples upstream and downstream of the Hanford Site. Copper and uranium were detected in most samples while detections of arsenic, lead, nickel, and zinc were detected in a few samples. All dissolved metal concentrations in river water were less than the Washington State ambient surfacewater quality criteria for the protection of aquatic life.

ES.7.3 Columbia River Sediment Monitoring.

Samples of the surface layer of Columbia River sediment were collected at depths of 0 to 6.3 in. (0 to 16 cm) from 13 river locations that were predominantly submerged. 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. Analytical results for 2016 showed similar concentrations of cesium-137 at Priest Rapids and McNary Dam sediment collection locations. Uranium-234 concentrations were slightly elevated in the 300 Area DR-42-2 location when compared to other sediment collected from the Hanford Reach, McNary Dam, and Priest Rapids Dam samples in 2016.

ES.7.4 Columbia River Seep Water

Samples of Columbia River shoreline seep water and three associated shoreline sediment samples were collected along the Hanford Reach in 2016 and analyzed for radiological, inorganic, and organic contaminants. In 2016, 12 of 15 seeps were successfully sampled. All samples collected were analyzed for tritium. Some samples from selected seeps were analyzed for alpha, anions, beta, carbon-14, hexavalent chromium, metals, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, and volatile organic compounds.

ES.7.5 Pond Water and Sediment

West Lake is the only naturally occurring pond on the site, and the area has not received radioactive discharges for some time. The surfacewater collected within the footprint of West Lake was analyzed for tritium, uranium-234, uranium-235, and uranium-238. Tritium concentrations in surfacewater collected from West Lake in 2016 were below the laboratory-reported required detection limit. Two uranium-234 and two uranium-238 results were above applicable DOE-derived concentration standards ([DOE/EH-0676](#)) for riparian and aquatic receptors. One sample showed the highest concentrations of uranium-234 and uranium-238 compared to concentrations seen over the last few years.

ES.7.6 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 a canal east of the Columbia River and from the Horn Rapids irrigation pumping station. Most radionuclide concentrations measured in irrigation water in 2016 were at similar levels detected in Columbia River transect water samples collected upstream of the Hanford Site.

ES.7.7 Liquid Effluent Monitoring

Liquid effluent disposal is governed by applicable regulations and permits. When discharges occur, sampling and analyzing is performed to identify select radioactive parameters and nonradioactive hazardous materials. Discharge monitoring reports that contain contaminant data from these analyses are submitted to Ecology.

ES.8 Section 8, Groundwater Monitoring

During Hanford Site operations, chemical and radioactive waste was released into the environment and contaminated soil and groundwater beneath portions of the site, mostly in the 200-East, 200-West, 300, and 100 Reactor Areas along the river. Groundwater monitoring data and information on well locations, construction details, and screened intervals, are available through the DOE Environmental Dashboard Application at <https://ehs.hanford.gov/eda/> or on the PNNL-Hanford Online Environmental Information eXchange website at <http://phoenix.pnnl.gov>. The data and additional groundwater monitoring details are available in [DOE/RL-2016-67, Hanford Site Groundwater Monitoring Report for 2016](#).

ES.9 Section 9, Soil Monitoring

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. Soil samples from offsite locations are collected every 3 to 5 years and were last collected in 2015.

Radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2016 were higher than the concentrations in samples collected farther away. As expected, data also showed that concentrations of certain radionuclides in 2016 were similar or 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 Area, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas.

ES.10 Section 10, Biota Monitoring

DOE conducted agricultural monitoring at several locations that vary annually 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 are also 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.

ES.10.1 Agricultural Monitoring

Food and farm products (apricots, corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in 2016 at locations near the Hanford Site. Radionuclide concentrations in most food and farm product samples in 2016 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. Data for potassium-40 and beryllium-7 are included to show the natural radioactive elements that exist in food products relative to concentrations of potential Hanford Site-produced contaminants.

ES.10.2 Fish and Wildlife Monitoring

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during CY 2016 were smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and California quail (*Callipepla californica*). Most fish and wildlife samples are collected on and around the Hanford Site and analyzed for human-pathway exposure every 2 to 3 years. Reference samples are obtained at locations determined not to be affected by Hanford Site effluents and emissions at least every 5 years.

ES.10.2.1 Smallmouth Bass. Manmade gamma-emitting radionuclides, including cesium-137, were not detected in 2016 in any of the muscle samples analyzed. Strontium-90 was not detected in smallmouth bass samples collected in 2016 from the reference area or Hanford Reach locations. Three bass samples were analyzed for 17 different trace metal concentrations. Barium, copper, manganese, mercury, selenium, silver, and zinc were detected above the analytical detection limit.

ES.10.2.2 Common Carp. Manmade gamma-emitting radionuclides, including cesium-137, was not found in 2016 in any of the muscle samples analyzed. Strontium-90 was not detected in common carp file or carcass samples in 2016. Uranium-234 was detected in 7 of the 11 samples. Uranium-235 was detected in 4 of the 11 samples. Uranium-238 was detected in 6 of the 11 samples for 2016. This was slightly less detects than in 2014 in a similar number of samples. Barium, copper, lead, manganese, mercury, selenium, thorium, uranium, and zinc were detected above the analytical detection limit.

ES.10.2.3 Mule Deer and Elk. Cesium-137 was not detected in any of the seven muscle tissue samples collected as a Hanford sample or a reference sample. Strontium-90 was detected in all four bone samples analyzed during 2016. Ten metals (aluminum, barium, cadmium, chromium, copper, manganese, selenium, silver, thorium, and zinc) were found above analytical detection limits in 2016.

ES.10.2.4 Upland Game Birds. Manmade gamma-emitting radionuclide, cesium-137, was not detected above the detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) for any upland game bird

muscle samples analyzed in 2016. Strontium-90 concentrations were detected in two quail bone samples collected in 2016.

ES.10.3 Vegetation Monitoring

Plant populations and habitats occurring on the Hanford Site are surveyed and monitored to assess potential risks or impacts to biota. Data from Hanford Site and offsite vegetation samples are analyzed for atmospheric deposition of contaminants in and around operational areas onsite and in uncultivated areas offsite. These data provide a baseline against which unplanned releases can be compared. Radionuclide concentrations in vegetation samples collected from or adjacent to waste disposal facilities in 2016 were similar to or slightly higher than concentrations in samples collected farther away, including concentrations measured offsite in 2015. Generally, the predominant radionuclides were activation and fission products in the 100 Area, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas. Vegetation samples collected in 2016 at locations in the 100-N, 200-East, 200-West, 400, and 600 Areas were comparable to those collected in previous years. Vegetation samples collected in the 200 and 600 Areas showed concentrations of uranium-234, uranium-235, and uranium-238 that were comparable to historical data.

ES.10.3.1 Radiological Contamination. 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 45 vegetation samples surveyed during the 2016 investigations.

ES.10.3.2 Vegetation Control. Vegetation control activities help prevent, limit, or remove contaminated plants or undesirable plant species. Approximately 5,444 ac (2,203 ha) were treated with herbicides in 2016 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.

ES.10.4 Waste Site Remediation and Revegetation

In 2016, only 2 ac (0.8 ha) across the Hanford Site were planted with grass seed to stabilize areas where traffic and erosion had damaged the grass cover on waste sites. Waste sites in the 200-East and 200-West Areas were designed and constructed with a cap of perennial grass essential to performance of engineered waste sites.

ES.11 Section 11, Resource Protection

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 applicable laws, regulations, and policies (including management plans) governing DOE activities.

ES.11.1 Ecological Protection

Ecological monitoring data provide baseline information about the plants, animals, and habitats under DOE stewardship at Hanford that is required to make cleanup decisions. During 2016, 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 raptor nest monitoring, roadside and sagebrush bird surveys, mule deer, snake hibernacula, and long-billed curlews.

ES.11.2 Endangered and Threatened Species

Two endangered and threatened fish species, 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 that the species is transient. Umtanum desert buckwheat and White Bluffs bladderpod, federally listed as threatened plant species, also occur on the site. No other plants or animals known to occur on the Hanford Site are currently federally listed as threatened or endangered, though the Washington ground squirrel is a candidate for federal listing. 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 31 state-level sensitive and candidate species of animals and 17 sensitive plant species occurring or potentially occurring on the Hanford Site.

ES.11.3 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. In 2016, Hanford Site archaeologists completed 97 [National Historic Preservation Act of 1966](#) (NHPA) Section 106 cultural resources reviews. Twenty-seven undertakings had the potential to affect cultural resources. Thirty-five projects affected historic buildings and were determined exempt by Hanford Site archaeologists after meeting the DOE-approved historic buildings programmatic agreement ([DOE/RL-96-77](#)) exemption criteria following an initial review. Twenty-five projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews. Ten projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration. A total of 5,950.29 ac (2,407.99 ha) of new ground was surveyed for cultural resources from NHPA Section 106 project-specific surveys.

ES.11.4 Collection Management and Curation

The Hanford History Project provides professional curatorial and archival services for the management, conservation, and public access of the Hanford Collection, which consists of artifacts and multimedia relating to the Manhattan Project and Cold War Era. In addition to public outreach and education, Washington State University, Tri Cities (WSU-TC) provides a repository for the collection that meets the requirements of [36 CFR 79, "Curation of Federally-Owned and Administered Archaeological Collections,"](#) including protecting these resources from theft, fire, breakage, or deterioration. During 2016, five artifacts were evaluated for inclusion and picked up from Hanford Site facilities and delivered to the Hanford History Project repository at WSU-TC, leaving 26 (3.5%) of the 743 tagged artifacts scheduled for collection between 2016 and 2048. The transition of the Hanford Collection to the WSU-TC facility began in July 2015 and continued through September 2016. During 2016, the remaining 60% of the Collection was moved from the artifact staging facility on the Hanford Site to either the WSU-TC curation facility in the Innovation Center Building or to a staging room for screening prior to transition.

ES.12 Section 12, Quality Assurance

Quality assurance (QA) and quality control (QC) programs for the Hanford Site and offsite environmental surveillance were documented through project-specific QA plans and describe applicable QA elements. Several types of field QC samples are collected to ensure the validity of the sampling procedures and the resulting sample data. The potential cross-contamination between samples during the sampling process is evaluated using trip blanks and equipment blanks. Additionally, field duplicates are collected to evaluate sample matrix heterogeneity and sample collection reproducibility. In 2016, field duplicate samples were collected and analyzed for air, soil, Columbia River water, natural vegetation, milk, wine, mulberries, wildlife, irrigation water, sediment, and seep samples. The accepted method of evaluating the precision or reproducibility of duplicate samples is the calculation of the Relative Percent Difference. In 2016, Hanford Site Environmental Surveillance samples were sent to two laboratories (GEL and TARL). These laboratories participated in various independent QA and QC programs including Mixed Analyte Performance Evaluation Program (MAPEP) and DOE Consolidated Audit Program. GEL's MAPEP program radiological results were issued warnings for biased strontium-90 results in the 20 to 30% range. However, these results are considered acceptable. GEL's MAPEP results for inorganic compounds in water were issued a warning for mercury in MAPEP study 35. However, this is considered an acceptable result. TARL's MAPEP program radiological results for studies 34 and 35 in 2016 received warnings for plutonium-238 in air and technetium-99 in water. However, these results are considered acceptable. TARL had unacceptable results for technetium-99, strontium-90, and americium-241 due to false positive results.

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Acronyms

μS	microsiemens
μSv	microsievert
AEA	Atomic Energy Act of 1954
AR	Administrative Record
BNI	Bechtel National, Inc.
BOF	Balance of Facilities
BPA	Bonneville Power Administration
BRMP	Hanford Site Biological Resources Management Plan
C&D	construction and demolition
ca.	circa
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CGS	Columbia Generating Station
CHPRC	CH2M Plateau Remediation Company
CITS	Chemical Inventory Tracking System
CLUP	Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement
Council	Hanford Natural Resource Trustee Council
CSB	Canister Storage Building
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWC	Central Waste Complex
CY	calendar year
D4	deactivation, decommissioning, decontamination, and demolition
DFLAW	Direct Feed Low-Activity Waste
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOE-EA	U.S. Department of Energy, Office of Enterprise Assessments
DOE-EM	U.S. Department of Energy, Office of Environmental Management
DOE-HQ	U.S. Department of Energy, Headquarters
DOE-ORP	U.S. Department of Energy, Office of River Protection

DOE-PNSO	U.S. Department of Energy, Pacific Northwest Site Office
DOE-RL	U.S. Department of Energy, Richland Operations Office
DSA	Documented Safety Analysis
DST	double-shell tank
EA	environmental assessment
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
EMF	Effluent Management Facility
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act of 1986
EPEAT	Electronic Product Environmental Assessment Tool
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FFTF	Fast Flux Test Facility
FMEF	Fuels and Materials Examination Facility
FONSI	Finding of No Significant Impact
FY	fiscal year
GEL	General Engineering Laboratories, LLC
GIS	Geographic Information System
HAB	Hanford Advisory Board
HAMMER	Hazardous Materials Management and Emergency Response
HDPE	high-density polyethylene
HEPA	high-efficiency particulate air
HHP	Hanford History Project
HLW	high-level waste
HPMC	HPMC Occupational Medical Services
HRM	Hanford River Mile
HTO	tritiated water vapor
IAP	Injury Assessment Plan
IC	institutional control

ICRP	International Convention on Radiological Protection
IDF	Integrated Disposal Facility
IP	Implementation Plan
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
LAW	low-activity waste
LERF	Liquid Effluent Retention Facility
LIGO	Laser Interferometer Gravitational-wave Observatory
LLBG	low-level burial grounds
LLRW	low-level radioactive waste
LLW	low-level waste
LTS	Long-Term Stewardship
MAPEP	Mixed Analyte Performance Evaluation Program
MBTA	<i>Migratory Bird Treaty Act of 1918</i>
MCO	Multi-Canister Overpacks
MEI	maximally exposed individual
MOA	Memorandum of Agreement
MSA	Mission Support Alliance
MSDS	Material Safety Data Sheet
NEPA	<i>National Environmental Policy Act of 1969</i>
NHPA	<i>National Historic Preservation Act of 1966</i>
NLOP	North Load-Out Pit
NRC	U.S. Nuclear Regulatory Commission
NRDA	Natural Resource Damage Assessment
NRDWL	Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill
PA	performance assessment
PCB	polychlorinated biphenyl
PEP	Project Execution Plan
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PSRP	Public Safety and Resource Protection Program
PUREX	Plutonium Uranium Extraction Facility

QA	quality assurance
QC	quality control
RBDA	risk-based disposal approvals
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
REDOX	Reduction-oxidation
RESRAD	RESidual RADioactivity
ROD	Record of Decision
RPD	Relative Percent Difference
S&M	surveillance and maintenance
SARA	Superfund Amendments and Reauthorization Act
SDS	Safety Data Sheet
SDWA	<i>Safe Drinking Water Act of 1974</i>
SS	safety-significant
SST	single-shell tank
SVE	soil vapor extraction
SWL	Solid Waste Landfill
TARL	Test America Richland Laboratories
TLD	thermoluminescent dosimeter
TPA	Tri-Party Agreement
Tri-Cities	cities of Kennewick, Pasco, and Richland
TRIDEC	Tri-City Development Council
TSD	treatment, storage, and disposal
TTP	transition and turnover package
USFWS	U.S. Fish and Wildlife Service
VPU	vertical pipe unit
WCH	Washington Closure Hanford
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
WRAP	Waste Receiving and Processing

WRPS	Washington River Protection Solutions, LLC
WSU-TC	Washington State University, Tri-Cities
WTP	Hanford Tank Waste Treatment and Immobilization Plant
Yakama Nation	Confederated Tribes and Bands of the Yakama Nation

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1.0 Introduction

JR Draper

Since 1959, the U.S. Department of Energy (DOE) has published the annual Hanford Site Environmental Report to inform the public, regulators, stakeholders, and other interested parties of the site's environmental performance during the calendar year. This calendar year 2016 report includes a description of the Hanford Site mission; compliance with applicable federal, state, and local environmental laws, regulations, permits, executive orders, and DOE policies and directives; and descriptions of summary data from environmental programs. Previous years' annual environmental reports are available at <http://msa.hanford.gov/page.cfm/enviroreports>. The sections in this document include topics on:

- Site compliance with federal, state, and local 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 2016 monitoring efforts are provided in the latest version of [DOE/RL-91-50, Hanford Site Environmental Monitoring Plan](#).

Section 1.0 provides information about the Hanford Site location and details the environmental setting, mission, management, primary operations and activities, and climate and meteorology as well as stakeholder involvement, the role of regional Tribal governments, and Hanford regulatory oversight.

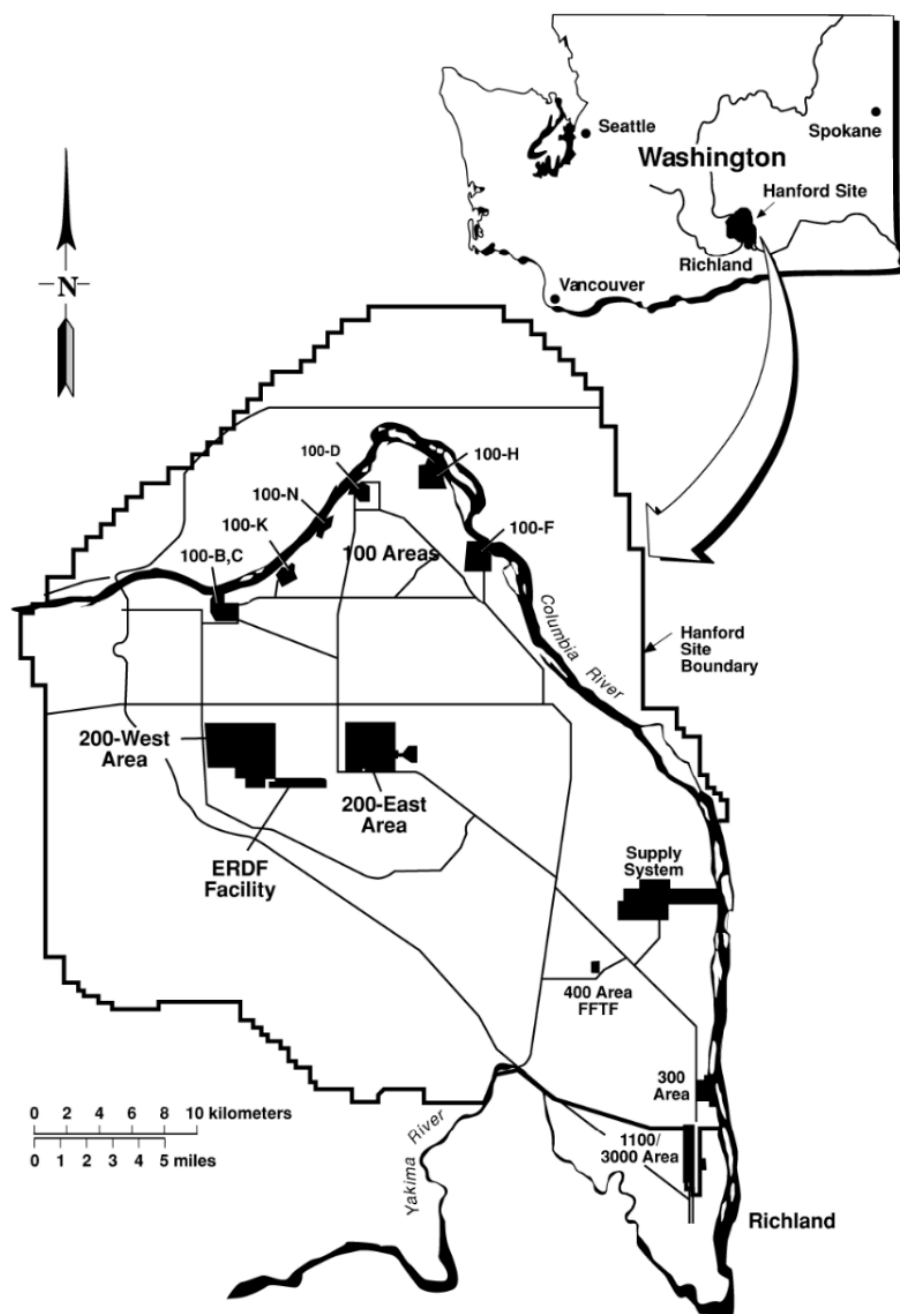
1.1 Hanford Site Location

The Hanford Site encompasses approximately 581 mi² (1,505 km²) in Benton, Franklin, and Grant Counties, located in south-central Washington State within the semi-arid Pasco Basin of the Columbia Plateau (Figure 1-1). The Hanford Site stretches approximately 30 mi (50 km) north to south and about 24 mi (40 km) east to west, immediately north-northwest of the confluence of the Yakima and Columbia Rivers, the cities of Kennewick, Pasco, and Richland (the Tri-Cities), and the City of West Richland. The Columbia River flows 50 mi (80 km) through the northern part of the Hanford Site and, turning south, forms part of the Site's eastern boundary. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge are on the southwestern and western boundaries of the Site, and Saddle Mountain is on the northern boundary. The plateau of the central portion of the Hanford Site has two small east-west ridges, Gable Butte and Gable Mountain. Lands adjoining the Hanford Site to the west, north, and east are principally range and agricultural (WCH-520). With restricted public access, the diverse geographic features and land (Figure 1-2) provide a buffer for areas used for nuclear materials production, research, and ongoing waste storage and disposal.

The climate of south-central Washington is strongly influenced by the Pacific Ocean and the Cascade Range to the west. The Rocky Mountains to the east and the north are also an important influence on

the climate of the region. Locally, the climate of the Hanford Site is influenced by the Yakima Ridge, Rattlesnake Hills, and Horse Heaven Hills to the west and south, and Saddle Mountains to the north (Figure 1-2). The relatively low annual average rainfall (6.3 in. [16 cm]) at the Hanford Site is caused in large part by the rain shadow created by the Cascade Range. Maritime influences are experienced in the Hanford Site area during the passage of strong, large-scale storm systems. Maritime air also penetrates into the region through gaps in the Cascade Range (such as the Columbia River Gorge). Continental influences are limited by the mountain ranges to the north and east of the Hanford Site. These mountains play a key role in protecting the region from the more severe winter storms and the extremely low temperatures associated with the modified arctic air masses that move southward through Canada. (WHC-SD-HWV-PSAR-001)

The Hanford Site lies within the interior, low elevation, Columbia River Basin, which is within the shrub-steppe zone. The diversity of physical features across the Hanford Site contributes to a corresponding diversity of biological communities. The majority of the Hanford Site consists of shrub-steppe habitats, but valuable riparian, wetland, and aquatic habitats are associated with the Hanford Reach of the Columbia River. The Hanford Site also contains a diversity of other rare terrestrial habitats such as riverine islands, bluffs/cliffs, basalt outcrops, swales, and sand dunes. Both shrub-steppe and riparian habitats are considered “priority habitats” by the Washington State Department of Fish and Wildlife (WDFW) ([DOE/RL-96-32](#)). Some of these areas contain species considered rare and/or declining or are of significant interest to federal, state, or Tribal governments.



E9803101.1

Figure 1-1. Location of the Hanford Site.

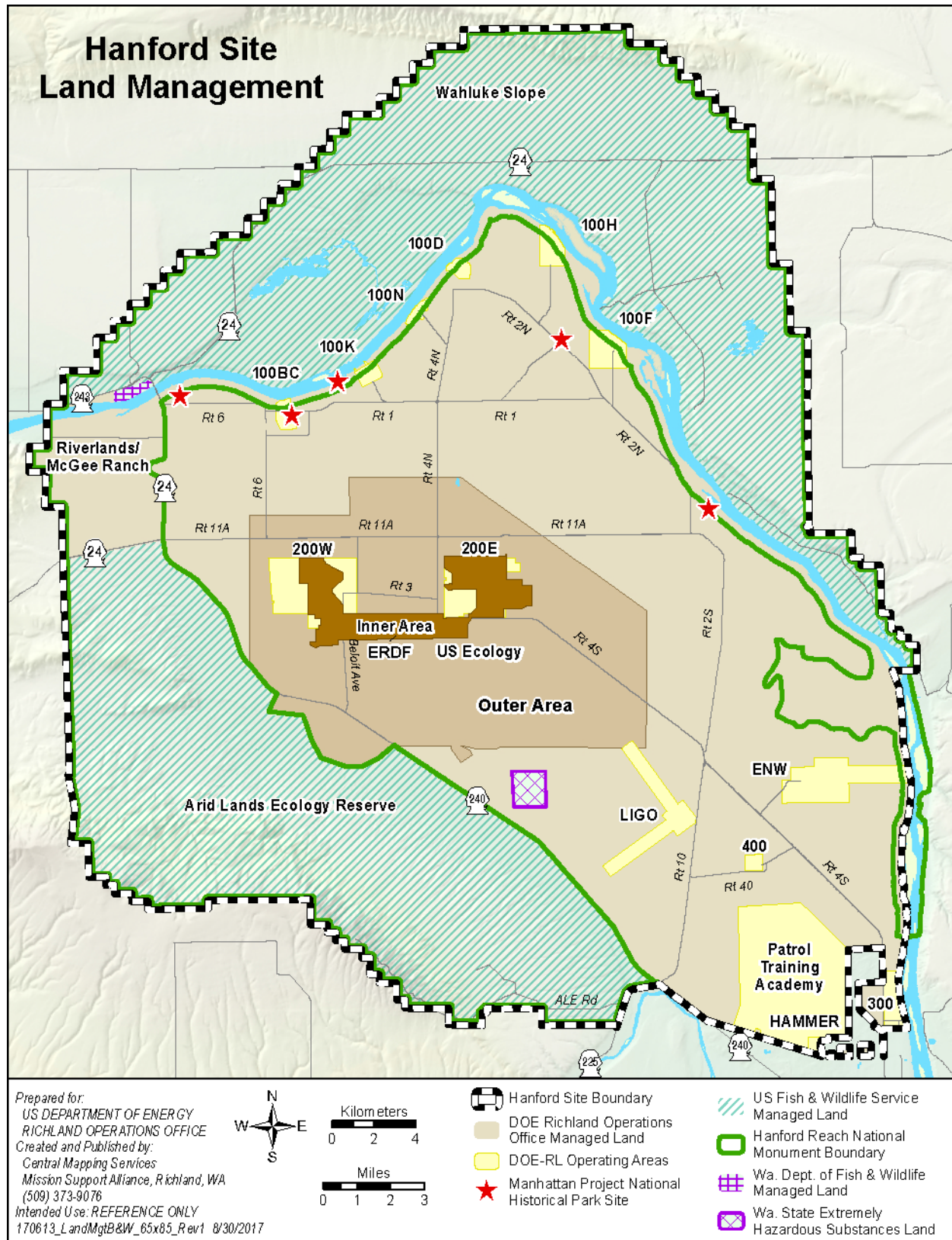


Figure 1-2. Detailed Geography of the Hanford Site, Hanford Reach National Monument, and U.S. Department of Energy Portions of the Hanford Site.

1.2 Hanford Site History and Mission

The Hanford Site opened in 1943 with nine plutonium production reactors operational along the Columbia River from 1944 to 1987 and research reactors, including the Fast Flux Test Facility (FFTF) that operated from 1982 to 1992, located in the southern portion of the Site. Hundreds of other supporting buildings and extensive infrastructure was constructed to support the program to provide plutonium to fuel atomic weapons during World War II and the Cold War (Figure 1-3) and support research into nuclear energy. Hanford manufactured the uranium metal fuel for the nuclear reactors onsite. Five chemical process plants in the center of the Hanford Site processed 110,000 tons (100,000 metric tons) of irradiated fuel from the reactors, discharging an estimated 450 billion gal of liquids to soil disposal sites and 56 million gal of radioactive waste to 177 large underground tanks.



Figure 1-3. B Reactor was the World's First Full-Scale Plutonium Production Reactor, Created as Part of the Top Secret Manhattan Project During World War II.

With the signing of the [Hanford Federal Facility Agreement and Consent Order](#) (Tri-Party Agreement [TPA]) in 1989 (Ecology et al. 1989a) by the Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and DOE (collectively, TPA agencies), the primary mission shifted to developing new waste treatment and disposal technologies, characterizing and cleaning up the contamination from historical operations, and environmental remediation. The DOE is responsible for one of the largest nuclear cleanup efforts in the world, managing the legacy of five decades of nuclear weapons production.

After more than two decades of cleanup, considerable progress has been made at Hanford, reducing risk to the health and safety of workers, the public, and the environment (Figure 1-4). Crews responsible for Hanford Site cleanup are dealing with several different kinds of waste in a number of different forms, with many of the wastes being potentially harmful to people and the environment. Precautions have been taken so that the waste does not contaminate the air, soil, groundwater, the Columbia River, the people who are doing the cleanup work, or the people and environment near the Hanford Site. 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 (i.e., waste storage, treatment, and disposal), and related scientific and environmental research and development of waste management technologies. In addition, the recently established Manhattan Project National Historical Park, of which the B Reactor and other Hanford Site structures are a part, focuses on historic preservation and public education.



Figure 1-4. The F Reactor Area is the First Reactor Area at the Hanford Site to be Remediated under a CERCLA ROD. Cleanup Consisted of Demolishing 112 Facilities, Cleaning up 88 Waste Sites, and Removing 1.5 million tons of Contaminated Material in the 2-mi² (5.18-km²) Area.

1.3 Primary Operations and Activities

The following is a list of the major DOE operational, administrative, research, and historically preserved areas in and around the Hanford Site.

1.3.1 100 Area

The 100 Area occupies 4 mi² (11 km²) and consists of six sites (100-B/C, 100-D/DR, 100-F, 100-H, 100-KE/KW, and 100-N) along the Columbia River shore in the northern portion of the Hanford Site. These sites were the location of nine nuclear reactors built between 1943 and 1965. They were constructed next to the river because of the abundance of hydro-electric power and cooling water needed by the reactors during operation. None of Hanford's ten DOE reactors are in operation any more with the last reactor, the FFTF Reactor, being shut down in 1992. A commercial NRC licensed reactor still operates on Hanford leased land for the public utility Energy Northwest near the sand dunes along the Columbia River. Beginning in the 1990s, workers began the process of "cocooning" the DOE reactors. When a reactor is cocooned, about 80% of the buildings and auxiliary structures that were needed to support the reactor during its operating days are demolished and removed. The remaining 20% of the reactor complex, including the core of the reactor itself, is enclosed in a cement and steel, structure called a cocoon. This cocoon prevents radiation or contamination left over from the nuclear operations from escaping to the environment. Ultimately, eight of the ten reactors at Hanford will be cocooned. Reactors C, D, DR, F, H, and N are already cocooned, with K-East and K-West Reactors next in line to be cocooned. B Reactor has been named a National Historic Landmark by the United States Department of the Interior and has been preserved as a museum. As the first industrial-scale nuclear reactor, B Reactor produced plutonium for the world's first nuclear detonation (Trinity Test) and the atomic bomb that was detonated over Nagasaki, Japan, in 1945.

DOE Operates five pump & treat facilities along the River Corridor. The KR4 system was the first system installed and began operation in 1997 and treats up to 330 gal/min. The KW system was the second system installed, and it began remediating hexavalent chromium in the KW Reactor area in January 2007 and treats 330 gal/min. The third and newest system (KX) began operation in February 2009 and treats 600 gal/min. The KX system is used primarily to treat hexavalent chromium in groundwater near N Reactor Area. The DX and HX pump & treat systems were designed for hydraulic control and hexavalent chromium mass removal to protect the Columbia River. Both the DX and HX pump & treat systems include an extraction well network, transfer building (the DX system has two transfer buildings), a treatment building, an injection well network. The DX system was fully operational in December 2010, and the HX system was fully operational in October 2011. The DX and HX systems are designed to provide treatment capacities of 600 gal/min each.

1.3.2 200 Areas

The 200 Areas at Hanford is known as the Central Plateau. It is the part of the DOE Industrial Hanford Site that is the highest in elevation. There are three regions associated with the 200 Areas (the 200-East Area, the 200-West Area, and the 200-North Area); each are separated from each other by several miles. The 200 Area makes up about 75 mi² (194 km²) of the Hanford Site. The plateau surface is approximately 328 ft (100 m) above the level of the Columbia River and about 280 ft (85 m) above the underlying water table. The 200 Areas contain underground waste storage tanks and housed facilities known as separations plants that extracted plutonium from dissolved irradiated fuel. Some of the most hazardous chemical and nuclear wastes were put into 177 underground storage tanks spread out into 18 groups of tanks called tank farms. The storage tanks range in size from 50,000 gal (190,000 L) of

capacity to more than 1 million gal (4 million L) of capacity. Currently at Hanford, some 56 million gal of chemical and nuclear waste remain stored in these tanks ([HNF-EP-0182](#)).

While much of Hanford's current mission revolves around the demolition of buildings and facilities, there are two construction projects underway in the 200 Areas that are critical to the safe removal of the solid and liquid wastes at Hanford. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being built to process the millions of gallons of liquid waste currently being stored in the tank farms. The process is called vitrification, where the liquid wastes are mixed with glass making materials and then heated to form a red-hot, molten substance that is poured into steel cylinders. Once the material is cooled, the waste will have been captured in a glass form that is considerably more stable than liquid wastes are. These cylinders of vitrified waste will ultimately be sent to a national repository where they will be buried permanently in a specially approved and regulated facility. The Environmental Restoration Disposal Facility (ERDF) also is located on the Central Plateau between the 200-East and -West Areas. ERDF is a massive landfill that is regulated by the EPA. ERDF accepts materials that come from building demolition projects and waste site remediation at Hanford.

Staff at Hanford's 222-S Analytical Laboratory, a Hazard Category 3 nuclear facility, receive, handle, and store up to 10,000 tank waste samples a year, performing up to 25,000 analyses of these samples, and report the results to DOE contractors. Samples handled in the lab are typically highly radioactive with dangerous waste components.

The 242-A Evaporator is currently the only operating nuclear processing facility at Hanford. The Evaporator receives radioactive liquid wastes that are pumped through underground pipes from double-shell waste storage tanks on the Hanford Site. The mission of 242-A is to take that waste, referred to as "feed", and boil off as much of the liquids as possible. The remaining waste goes back into the waste storage tanks while the water products that were removed through the Evaporator operations is sent to other facilities for treatment and safe disposal.

The Canister Storage Building (CSB) is a large, 42,000-ft² facility in Hanford's 200-East Area. The CSB stores about 2,300 tons of spent nuclear fuel packaged in approximately 400 Multi-Canister Overpacks (MCOs). The MCOs are stored in 220 carbon steel tubes within a below grade concrete vault. The MCOs will be safely stored in the tubes until they are permanently placed in a National Repository.

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 also sent to the National Repository.

The 200 West Pump & Treat facility was constructed between 2010 and 2011 to remove contaminants of concern found in the Central Plateau groundwater. The 200 West pump & treat system is designed to treat contaminated groundwater and reduce the mass of carbon tetrachloride, total chromium (trivalent and hexavalent), nitrate, trichloroethene, technetium-99, and uranium. Following treatment, the water is re-injected into the aquifer to serve as a recharge source, to promote flow-path control, and provide hydraulic containment. The central facility can treat up to 2,500 gal/min of extracted groundwater using two parallel treatment trains. The extraction and injection well network is located throughout the Central Plateau.

1.3.3 300 Area

The 300 Area is located just north of Richland and covers approximately 0.6 mi² (1.5 km²). From the early 1940s until the start of the environmental cleanup mission in 1989, hundreds of thousands of tons

of raw uranium was sent to the 300 Area to be manufactured into fuel assemblies called “rods.” These fuel rods were ultimately placed into the 100 Area reactors where a nuclear chain reaction would change the nuclear properties of the uranium into the plutonium needed for atomic weapons. The 300 Area also served to provide scientists with the laboratory facilities where they could test their theories and conduct experiments on the most efficient ways to transform the uranium into plutonium and perform materials analysis and research. Several small nuclear reactors were operated in the 300 Area in support of research. Due to the many experiments that were conducted at the 300 Area, there are also many contaminated zones associated with it. The Pacific Northwest National Laboratory (PNNL) working for the Pacific Northwest Science Office of DOE uses some of the buildings within the 300 Area under an agreement between the two DOE offices.

1.3.4 400 Area

The 400 Area is located northwest of the 300 Area and covers approximately 0.23 mi² (0.61 km²). This area includes the Fast Flux Test Facility (FFTF), the Maintenance and Storage Facility (MASF), and the Fuels and Materials Examination Facility (FMEF). Construction of FFTF was completed in 1978, and initial criticality was achieved in early 1980, with full power initiated in late 1980. Following an additional year of acceptance testing, FFTF operated successfully from 1982 to 1992 as a research facility providing the nuclear industry with advances in nuclear fuels, materials, and components; nuclear power plant operations and maintenance protocols; and reactor safety designs. During this time, FFTF also produced a wide variety of medical and industrial isotopes, made hydrogen-3 (tritium) for the U.S. fusion research program, and conducted cooperative international research work. In late 1993, DOE decided not to continue operating FFTF due to a lack of economically viable missions at that time and issued a shutdown (e.g., deactivation) order for the facility. Since that time, and after various delays temporarily stopping the deactivation work, FFTF completed deactivation activities and was placed in a long-term, low-cost surveillance and maintenance condition in 2009. MASF is periodically used to support mock ups of proposed work to ensure the workers have practiced using the tools and equipment in physical configurations they are likely to encounter doing specialized work. FMEF was intended to be a support building for the FFTF and the future Liquid Fast-Breeder Reactor Program; the FMEF was never used in a nuclear capacity. When the nation abandoned the breeder reactor program, FMEF was also left without a mission and remains unused and largely vacant today.

1.3.5 600 Area

The 600 Area consists of Hanford’s roads, railroads, fire station, an old concrete batch plant site, the former townsites of Hanford and White Bluffs, the Hanford meteorology station, the Wahluke Slope, and the Arid Lands Ecology Reserve (including Rattlesnake Mountain).

The Laser Interferometer Gravitational-wave Observatory (LIGO) is located just north of the 400 Area and is designed to detect gravitational waves originating from black holes and other astronomical phenomena. LIGO is a scientific collaboration of the California Institute of Technology and the Massachusetts Institute of Technology funded by the National Science Foundation.

An area along the river and north of the 300 Area is leased by Energy Northwest for operation of a commercial nuclear plant called the Columbia Generating Station (CGS). CGS is the only commercial nuclear energy facility in the region. Construction of the CGS began in 1973 and power was first delivered to the region in 1984.

The 618-10 and 618-11 Burial Grounds are also located within the 600 Area. The burial grounds contain wastes that were generated by activities in the 300 Area of the Hanford Site. The 300 Area was used for developing and manufacturing reactor fuel and conducting laboratory research during Hanford’s

plutonium production mission. Some of the most hazardous wastes on the Hanford Site were disposed of in the 618-10 and 618-11 Burial Grounds. Cleanup of the 618-10 Burial Ground includes remediating 94 buried vertical pipe units (VPU) that contain radioactive and chemical waste. The VPUs were constructed of 55-gal (208-L) drums welded together end to end, corrugated pipes or solid steel pipes, all buried vertically. Some of the waste disposed in the VPUs was packaged in a variety of containers ranging in size from juice cans to paint buckets. Remediation of the 618-10 Burial Ground was completed at the end of FY 2017. Nonintrusive characterization was completed in 2011 at the 618-11 Burial Ground.

1.3.6 1100 and 3000 Areas

The former 1100 Area is located between the 300 Area and Richland, covering 1.2 mi² (3.1 km²). It had no disposal locations for radioactive or mixed wastes but contained several sites for hazardous wastes including batteries and battery acid containing lead, sulfuric acid, and ethylene glycol or antifreeze. Following cleanup, EPA took the site off the National Priorities List in 1996. 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.

The former 3000 Area is located northeast of the 1100 Area and accommodated engineering and construction support facilities.

Richland North Area (offsite). This area includes the DOE and DOE contractor facilities located between the 300 Area and the City of Richland that are not in the 1100 and 3000 Areas. Located in the Richland North Area is PNNL, a DOE National Laboratory operated by Battelle for DOE's Office of Science. PNNL conducts research for national security missions, nuclear materials stewardship, non-proliferation missions, the nuclear fuel life cycle, an energy production and includes the DOE scientific user facility Environmental Molecular Sciences Laboratory. PNNL also supports the Hanford Site cleanup and River Corridor protection missions.

1.3.7 700 Area (offsite)

The 700 Area of the Hanford Site is located in downtown Richland. Called the Federal Building, DOE and site contractors occupy offices in the seven-story structure, although the majority of DOE Offices are now located in the Stevenson Center in North Richland near where the 1100 Area used to be.

1.3.8 Volpentest Hazardous Materials Management and Emergency Response Federal Training Center

Hazardous Materials Management and Emergency Response (HAMMER) is a worker safety training facility and is used by Hanford Site contractors, federal and state agencies, Tribal governments, and private industry. HAMMER is comprised of modern classrooms, specialty-training areas, and numerous life-size training props that can be configured to create a variety of situations for industrial hazards (e.g., worksite scenarios, emergency response or incident command, and hazardous materials training) (Figure 1-5). HAMMER contracts with emergency response agencies and offers classes in fire suppression, hostage rescue, high-speed pursuit, and drug enforcement. The center 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-mi² (0.31-km²) main site and a 15.6-mi² (40.4-km²) law enforcement and security training site.



Figure 1-5. Worker-trainees learn how to properly torque waste container tie-down as part of a training session at HAMMER.

1.3.9 Hanford Tank Waste Treatment and Immobilization Plant

Bechtel National, Inc. (BNI) is designing, constructing, and commissioning the world's largest radioactive waste treatment plant for the DOE. When complete, the WTP, also known as the Vit Plant, will process and stabilize 56 million gal of radioactive and chemical waste currently stored at the Hanford Site. The construction site spans 65 ac (26 ha) and includes four major nuclear facilities – Pretreatment, Low-Activity Waste Vitrification, High-Level Waste Vitrification, and the Analytical Laboratory. The plant will use vitrification technology to stabilize the waste. Vitrification involves blending the waste with glass-forming materials and heating it to 2,100 °F (1,149 °C). The molten mixture is poured into stainless steel canisters to cool and solidify. In this glass form, the waste is stable in the environment, and designed so the radioactivity will safely dissipate over hundreds to thousands of years.

1.3.10 Non-DOE Operations and Activities on Hanford Site Leased Land

Energy Northwest operates a commercial nuclear power reactor at the CGS north of the 300 Area on 1,090 ac (440 ha). The CGS nuclear facility is the third largest electricity generator in Washington and the only commercial nuclear energy facility in the region. Construction of the CGS began in 1973 and power was first delivered to the region in 1984. All of its output is provided to the Bonneville Power Administration at the cost of production under a formal net billing agreement in which Bonneville Power Administration pays the costs of maintaining and operating the facility.

The U.S. Ecology Washington operates a commercial low-level radioactive waste (LLRW) burial site located west of the 200-East Area on 99 ac (40 ha). The burial site serves commercial and government

LLRW customers in the Northwest and Rocky Mountain compact regions: Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, Wyoming, Colorado, Nevada, and New Mexico.

West of the 400 Area, the California Institute of Technology and Massachusetts Institute of Technology jointly operate the LIGO sponsored by the National Science Foundation. LIGO is a national facility for gravitational-wave research, providing opportunities for the broader scientific community to participate in detector development, observation, and data analysis.

1.3.11 Non-DOE Nuclear Operations

AREVA NP, Inc. operates a commercial nuclear fuel fabrication facility providing fuel products and related components and services for commercial pressurized water reactor (PWR) and boiling water reactor (BWR) customers worldwide.

The Perma-Fix Northwest Richland (PFNW) facility is a commercial TSD located on 35 ac (14 ha) adjacent to the DOE Hanford Site. This facility receives, manages and treats both LLRW and mixed LLRWs from the Hanford site. Westinghouse Electric Company operates the Richland Service Center. The facility can be used for a variety of fabrication projects, chemical mixing, maintenance, repair of hot equipment, and laboratory testing.

1.3.12 Hanford Reach National Monument

Designated in June 2000 by Presidential Proclamation ([65 FR 37253](#)), the Hanford Reach National Monument (Figure 1-2) covers 195,000 ac (78,900 ha) in Benton, Franklin, Grant, and Adams Counties. 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 administrative units: Rattlesnake (Fitzner/Eberhardt Arid Lands Ecology Reserve), Columbia River Corridor, Ringold, Wahluke, and Saddle Mountain (Figure 1-2). Additionally, the U.S. Fish and Wildlife Service (USFWS), WDFW, and U.S. Department of Energy, Richland Operations Office (DOE-RL) manage portions of the monument. The DOE-RL oversees a 14-mi² (36.4-km²) 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-mi (0.4-km) wide strip of land along the Hanford Reach shoreline from Vernita Bridge to north of the 300 Area. This 39-mi² (101-km²) area in Benton, Franklin, and Grant counties also includes the 9.9-mi² (25.6-km²) Hanford Site dunes north of the CGS.

1.3.13 Manhattan Project National Historical Park

Established in November 2015, one of the nation's newest national parks is located in three areas of the United States (Oak Ridge, Tennessee; Los Alamos, New Mexico; and Hanford, Washington) that played critical roles in the research and development of the first nuclear bombs used in World War II. These sites were also at the origin of developing the national laboratory system that has given rise to U.S. scientific and technological advancement and capabilities. Key structures on the Hanford Site that are part of the permanently preserved park include:

- Bruggemann's Agricultural Warehouse Complex (existed during or since approximately/circa [ca.] 1900–1943) – The last remaining building from an irrigated farm, orchard, and fruit packing and shipping facility.
- B Reactor National Historic Landmark – The B Reactor was the world's first full-scale plutonium production reactor.

- Allard (Hanford Irrigation District) Pump House (ca. 1908) – With an irrigation canal headwall, businesses such as a hotel, pharmacy, mercantile and telephone companies, and real estate office created opportunity and industry in the towns of Hanford and White Bluffs.
- First Bank of White Bluffs (ca. 1907–1909) – The first European-American settlement of the late 1800s, White Bluffs was located in what was known as Washington territory. The bank represents the last remaining building of the pre-World War II town.
- Historic Hanford High School (ca. 1916) – The building served two generations of Hanford students and doubled as a hall for public meetings and social events.

These historical buildings represent some of the only remaining evidence of the agricultural towns of Hanford and White Bluffs and offer insight into the initial original settlement of the American West.

1.4 Hanford Site Management

Cleanup of the Hanford Site is overseen by two DOE offices, the DOE-RL and the Office of River Protection (DOE-ORP). DOE-RL and the DOE-ORP jointly manage the site through several contractors and their subcontractors. Each contractor is responsible for the safe and environmentally sound maintenance of 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, USFWS, and WDFW each manage portions of the Hanford Reach National Monument, as described above. The Manhattan Project National Historical Park is a partnership between DOE, with existing and continuing oversight and management of multiple locations (including Hanford), and the U.S. Department of the Interior's National Park Service as interpreter, offering visitor services and assistance with historical preservation.

The DOE-RL is 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 following is a list of DOE-RL's principal contractors and their respective responsibilities.

- Mission Support Alliance, LLC (MSA) was awarded the Mission Support Contract for the Hanford Site in 2009. MSA is a joint venture between Leidos, 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; and environmental compliance and clean energy solutions.
- 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, 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.

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- WCH was awarded the River Corridor Closure Contract in 2005. WCH consists of AECOM (which acquired the former URS Corporation in late 2014), BNI, and CH2M (formerly CH2M HILL). 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 completed its mission for DOE-RL in September 2016. Any outstanding tasks were transferred to CHPRC.
 - HPMC Occupational Medical Services (HPMC) was awarded the occupational medical contract for the Hanford Site in 2012. HPMC is responsible for the health and safety needs of more than 8,000 Hanford workers, providing occupational medical services to DOE and Hanford employees. HPMC has clinics in Richland and the Hanford 200-West Area.

The DOE-ORP was established by Congress in 1998 as a field office to manage the retrieval, treatment, and disposal of approximately 56 million gal (204 million L) 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, DOE-ORP is responsible for the safe operation of the tank farms and 200 Area facilities, and construction and operation of the WTP located in the Central Plateau. The following is a list of DOE-ORP's principal contractors and their responsibilities at the Hanford Site.

- Wastren Advantage, Inc. (WAI) was awarded the Laboratory Analytical and Testing Services contract in 2014. WAI operates, manages, and maintains the Analytical Services functions of the Hanford 222-S Laboratory.
- BNI was awarded the contract to design, construct, and commission the WTP in 2000. When complete, the WTP will process and stabilize radioactive and chemical waste currently stored at the Hanford Site. The WTP will cover 65 ac (26 ha) with four nuclear facilities (Pretreatment, High-Level Waste Vitrification, Low-Activity Waste Vitrification, and an Analytical Laboratory), as well as operations and maintenance buildings, utilities, and office space.
- Washington River Protection Solutions, LLC (WRPS) was awarded the Tank Operations Contract in 2008. It is WRPS' responsibility to maintain and operate the Tank Farms, 242-A Evaporator, and supporting Tank Farm infrastructure. WRPS is owned by AECOM and Atkins with AREVA as the primary subcontractor. WRPS is responsible for safely managing the underground waste storage tanks and preparing the systems to feed waste to the WTP for immobilization. The waste is stored in 149 single-shell tanks and 28 double-shell tanks located in the 200 Areas. The 242-A Evaporator is located in the 200-East Area of the Hanford Site and is critical to the safe management of Hanford's tank waste. It began operating in 1977 to reduce the volume of waste stored in Hanford's underground tanks.
- The DOE Office of Science manages DOE's science and technology programs, goals, and objectives at the Hanford Site. Its principal contractor is PNNL, operated by Battelle Memorial Institute for DOE since 1965. As one of 10 DOE national laboratories, 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 also the U.S. Department of Homeland Security; National Nuclear Security Administration; and other government agencies, universities, and industries. PNNL is home to DOE's Environmental Molecular Sciences Laboratory, a national

scientific user facility leading molecular-level discoveries for DOE's Office of Biological and Environmental Research.

1.5 Climate and Meteorology

GE Gutierrez, PJ Perrault

The Hanford Meteorology Station is located on the Hanford Site's Central Plateau. Meteorologists 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 meteorological and climatological data. This data is used by a broad range of scientific and clean-up endeavors across site. 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 members rely on data provided by the Hanford Meteorological Monitoring Network, which consists of 29 remote monitoring stations that transmit data to the Hanford Meteorology Station through radio telemetry every 15 minutes. There are three towers that are 10 ft (3 m) high, 22 towers that are 30 ft (9 m) high, 3 towers that are 200 ft (61 m) high, and 1 tower that is 400 ft (121 m) high. Meteorological information collected at these stations includes wind speed, wind direction, temperature, precipitation, atmospheric pressure, dewpoint temperature, wet-bulb global temperature, solar radiation, relative humidity, and subsurface soil temperature; however, not all data are collected at all stations. Other specialized meteorological data such as cloud height, visibility, present weather, and freezing rain detection is collected at select sites.

Regional temperatures, precipitation, and winds are affected by mountain barriers. Beyond the city of Yakima to the northwest, the Cascade Mountain Range greatly influences the climate of the Hanford Site because of its rain-shadow effect. The Rocky Mountains and mountain 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 on the Central Plateau is from the northwest all year long, with a secondary wind 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 wind speeds are lowest during winter months, averaging about 6 to 7 mph (3 m/s), and highest during summer, averaging about 8 to 9 mph (4 m/s). Wind speeds well above average are usually associated with southwesterly winds. However, summer drainage winds are generally northwesterly and frequently exceed 30 mph (13 m/s). These winds are most prevalent over the northern portion of the Hanford Site. Figure 1-6 shows the 2016 wind roses, diagrams showing direction and frequencies of wind, measured at a height of 30 ft (9 m) for 28 meteorological monitoring stations. Note: Stations 19, 29, and 32 are 10 ft (3 m) tall, leading to small changes in wind data.

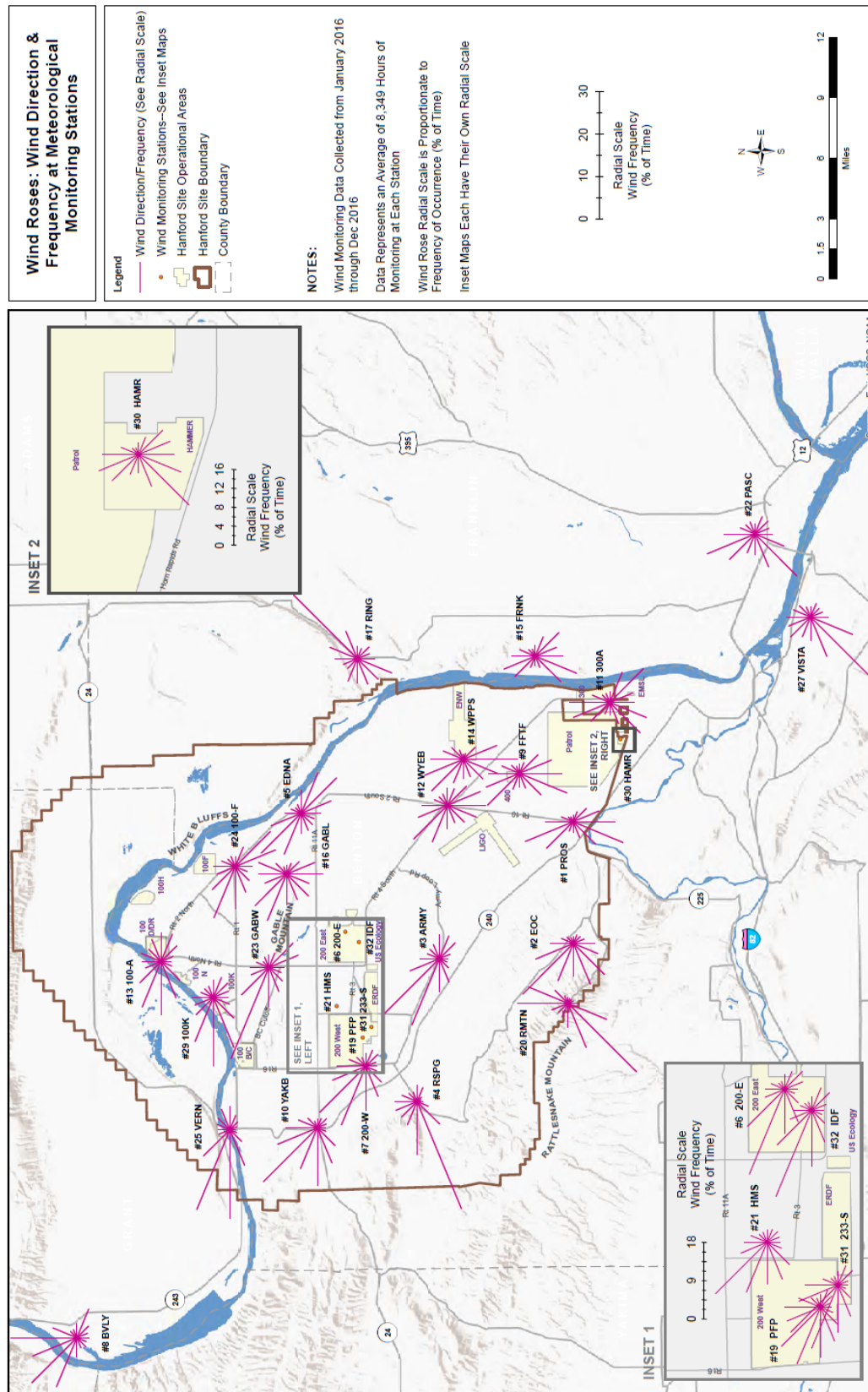


Figure 1-6. Meteorological Monitoring Network Wind Roses from 2016
NOTE: Measured at a height of 30 ft (9 m).

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% 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% 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

Table 1-1 shows the climatological information for the Hanford Meteorological Station from 1945 through 2016.

Table 1-1. Hanford Meteorological Station Climatological Information for 1945 through 2016.

	Normal annual	Highest monthly average	Lowest monthly average	Record highest monthly average	Record lowest monthly average	Highest daily	Lowest daily
Temperature °F (°C)	53.9 (12.2)	77.1 (25.1)	31.1 (-0.5)	82.8 (28.2)	12.1 (-11.1)	113 (45)	-23 (-31)
Rel Humidity %	55.3	77.2	36.5	90.5	21.9	100	6
Precipitation in. (cm)	7.08 (17.98)	-	-	12.31 (31.23) ^a	2.99 (7.59) ^a	1.91 (4.9)	-
Snowfall in. (cm)	-	-	-	56.1 (142.5) ^b	0.3 (0.8) ^b	12.4 (31.5)	-
Wind Speed mph (m/s)	7.6 (3.4)	9.0 (4.0)	5.9 (2.6)	11.1 (5.0)	2.9 (1.3)	33.7 (15.1)	0.3 (0.1)
Pressure in./Hg (mb)	29.213	29.329	29.129	29.638	28.999	30.23 (1053.8)	28.10 (977.3)

- Not reported

^a Precipitation records are for a year

^b Snowfall records are for a season

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 [PNNL-15160, Hanford Site Climatological Summary 2004 with Historical Data](#).

1.5.2 Meteorological Monitoring

The average temperature for 2016 was 56 °F (13.3 °C), which was 2.1 °F (1.2 °C) above normal. During 2016, 9 months were warmer than normal, 3 months were cooler than normal, and April had the greatest positive departure at 7.5 °F (4.2 °C) above normal. The months of April and November 2016 both broke records for highest mean monthly temperature for their respective month. December had the greatest negative departure at 3.8 °F (2.1 °C) below normal.

Precipitation totaled 7.65 in. (19.43 cm), which is 108% of normal precipitation (7.08 in. [17.98 cm]). Greatest monthly total of precipitation was 2.59 in. (6.58 cm) in October, and lowest monthly total was a trace in August. October 9th and 10th had the greatest 24-hour precipitation at 1.14 in. (2.9 cm). Snowfall for 2016 totaled 28 in. (71.1 cm), which was 183% of normal (15.3 in. ([38.6 cm])).

Average wind speed was 8.2 mph (3.7 m/s), which was 0.6 mph (0.3 m/s) above normal. Occurring on March 1, the peak gust for the year was 55 mph (24.6 m/s). Peak gusts of 51 mph (22.8 m/s) and 50 mph (22.3 m/s) were recorded in November and October, respectively.

The growing season was 236 days in 2016. This made 2016 the longest growing season on record. The last frost in spring was March 26, and the first frost in fall was November 17. This is the latest first frost on record. The shortest growing season was 1974 at 142 days.

Monthly and annual climatological data collected at the Hanford Meteorology Station is provided in Table 1-2. Real-time and historical data from the Hanford Meteorology Station are available at <http://www.hanford.gov/hms>, which includes hourly weather observations, 15-min data, monthly climatological summaries, and historical data.

1.6 Stakeholder Involvement

JR Draper

DOE encourages information exchange and public involvement in discussions and decision making regarding Hanford Site cleanup and remediation actions. Participants help guide cleanup decisions and post-cleanup outcomes, these participants include the public; Indian Tribes; federal, state, and local government agencies; advisory boards; activist groups; and other entities in the public and private sectors. The roles and involvement of select stakeholders are described in the following sections.

1.6.1 Role of Native American Tribes

JA Conrad

The role of Indian 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 policy and consultation guidance in working with Indian Tribes. DOE will consult with any American Indian or Alaska Native Tribal governments 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 Indian Tribes and commits the agency to institute government-to-government relations with the Tribes. DOE O 144.1 Attachment 3, "Office of Environmental Management, Office of Nuclear Energy, Office of Science, and the National Nuclear Security Administration Framework to Provide Guidance for Implementation of DOE's American Indian and Alaska Native Tribal Government Policy," provides additional guidance on how Tribal consultation is to be conducted.

Table 1-2. Meteorology Station ^a Monthly and Annual Climatological Data.

Month	Temperature (°F)								Precipitation (in.)				Relative Humidity (%)		15-m Wind ^b				
	Averages				Extremes				Total	Departure ^c	Snowfall		Average	Departure ^c	Average Speed (mph)	Departure ^c	Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure ^c	Highest	Date	Lowest	Date			Total	Departure ^c					Speed (mph)	Direction	Date
Jan	40.2	29.3	34.7	+1.3	57	22	11	2	1.47	+0.53	3.5	-1.1	86.4	+6.6	5.6	-0.7	33	WSW	29
Feb	53.1	33.6	43.4	+5.2	66	27	24	3 ^d	0.27	-0.43	0.2	-2.1	71.2	+0.5	7.1	+0.2	53	WSW	28
Mar	59.5	36.4	48.0	+1.5	75	31	28	18	1.01	+0.44	0	-0.4	57.6	+0.4	9.3	+1.4	55	W	1
Apr	75.2	46.7	61.0	+7.5	89	20	37	6	0.34	-0.21	0	0	42.4	-5.9	8.9	+0.4	43	WSW	4
May	79.3	50.9	65.1	+3.0	91	3	44	28	0.20	-0.31	0	0	40.7	-2.5	9.5	+0.7	46	NW	26
Jun	86.8	56.8	71.8	+2.2	106	6	42	19 ^d	0.38	-0.13	0	0	33.1	-6.5	9.6	+0.6	43	NW	29
Jul	90.4	63.1	76.7	-0.4	106	29	53	5	0.27	+0.09	0	0	34.2	+0.1	10.3	+1.7	43	NW	4
Aug	92.6	61.3	77.0	+1.2	101	14	51	31	T	-0.18	0	0	28.5	-7.2	8.0	+0.1	39	NW	5
Sep	80.1	51.2	65.7	-0.7	94	10	42	14	0.08	-0.23	0	0	40.1	-2.8	8.0	+0.7	40	NNW	8
Oct	63.1	45.3	54.2	+1.1	77	8	33	12	2.59	+2.10	0	0	67.1	+11.0	8.2	+1.5	50	SW	14
Nov	55.7	38.9	47.3	-6.8	69	12	28	17	0.57	-0.38	0	-2.0	76.0	-2.1	7.3	+0.6	51	S	24
Dec	34.8	19.9	27.3	-3.8	56	3	-4	17	0.47	-0.73	4.1	+1.1	76.4	-4.8	6.4	+0.5	36	W	27
Year ^e	67.6	44.5	56.0	+2.1	106	Jul 29 ^d	-4	De 17	7.65	+0.57	7.8	-7.5	54.5	-0.8	8.2	+0.6	55	W	Mar 1

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

^a The Hanford Meteorology Station is 25 mi (40 km) northwest of Richland, WA at latitude 46°34'N, longitude 119°35'W, elevation 733 ft (223 m)

^b Measured on a tower 50 ft (15 m) above ground

^c Departure columns indicate positive or negative departure of meteorological parameters from 30-year (1981–2010) climatological normal.

^d Latest of multiple occurrences

^e 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 Indian Tribes on certain issues include the [American Indian Religious Freedom Act of 1978](#) (42 U.S.C. 1996), the [National Environmental Policy Act of 1969](#) (NEPA; 42 U.S.C. 4321 et seq.), [Archaeological Resources Protection Act of 1979](#) (16 U.S.C. 470), [National Historic Preservation Act of 1966](#) (NHPA; 54 U.S.C. 300101 et seq.), and the [Native American Graves Protection and Repatriation Act of 1990](#) (Public Law 101-601).

As Hanford Site cleanup progresses, Indian 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 The Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and Confederated Tribes and Bands of Yakama Nation (Yakama Nation), all of with whom the U.S. government negotiated treaties ([Treaty with The Nez Percés](#) [U.S. Government 1855a]; [Treaty of Walla Walla](#) [U.S. Government 1855b]; [Treaty with The Yakama](#) [U.S. Government 1855c]) in 1855. Each Treaty included provisions that reserved the rights of Indian 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. Located in Priest Rapids, the Wanapum, which once resided on lands that are now the Hanford Site with historic ties to the area, has a long-standing relationship with DOE. Additionally, DOE provides financial assistance through cooperative agreements with the Nez Perce Tribe, CTUIR, and Yakama Nation, and supports Tribal involvement in decisions made at Hanford. Funding enables Indian Tribes to retain staff to facilitate reviews and comment onsite-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 Program is available at <http://www.hanford.gov/page.cfm/inp>.

1.6.1.1 2016 Activities. In 2016, the Office of Access and Use was introduced to each of the Tribes, with a description of the Office's anticipated interactions with Tribes regarding Tribal access of the Hanford Site. To further their mission, a new Tribal Specialist was added to the DOE team.

As part of mitigations agreed upon with the Wanapum for the transfer of land out of federal control, unsightly debris was removed from a Traditional Cultural Property, a cleanup project not required by the [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (CERCLA) and in a significant cultural area. That location was featured in a tour by the Assistant Secretary for Environmental Management.

The DOE-RL Manager agreed to be part of the USFWS's Working Group. This group was formed to address motorized public access to the Summit of Rattlesnake Mountain – another Traditional Cultural Property identified by the Yakama Nation. Early in the year, Tribes participated in a "Priorities Workshop" where DOE-RL and DOE-ORP outlined projects and budget numbers and Tribes shared their priorities and values.

For the first time at Hanford, Yakama Nation students toured cultural sites on the Hanford Reservation, accompanied by Tribal cultural experts who could explain the importance of such sites to a new generation. The DOE-RL Manager also spoke to the Yakama Tribal School, encouraging students to seek careers in math and science.

The Tribal Program also conducted several annual events, such as Tribal training for DOE and Contractor managers; HAMMER Tribal Subcommittee participation; and participation in the bi-annual State and Tribal Government Working Group, the annual Environmental Management Tribal Leader Dialogue, and the Secretary of Energy's Tribal Summit. As an outcome of a meeting, DOE-RL hosted a Long-Term Stewardship Workshop to discuss Tribal questions, issues, and future vision for Long-Term Stewardship at Hanford.

1.6.2 Cultural and Historic Resource Consultations

MK Wright

The NHPA (54 U.S.C. 300101 et seq.) requires federal agencies to consult with Indian Tribes, the Advisory Council on Historic Preservation, State Historic Preservation Officers, local government representatives, and the interested public on cultural and historic resource matters. The NHPA implementing regulations (36 CFR 800) require that DOE consider the effect of its actions on significant cultural and historic resources in consultation with consulting parties. DOE-RL solicits and gathers input from Indian Tribes, interested parties, and the Washington State Historic Preservation Officer to identify and evaluate cultural and historic resources within its areas of potential effect. DOE-RL assesses the impacts of its activities on significant resources and seeks concurrence with the Washington State Historic Preservation Officer.

DOE-RL's Cultural and Historic Resource Program consults with the Washington State Historic Preservation Officer, the Yakama Nation, the CTUIR, the Nez Perce Tribe, and the Wanapum through monthly and individual meetings and discussions, field walkdowns, and project comment resolution. Tribal cultural experts discuss project scope and design on a monthly basis with DOE-RL, the State Historic Preservation Officer, Tribal representatives, and other interested parties.

The Program also consults with other parties that express an interest in cultural and historic resources located on the Hanford Site, including groups such as the Benton County Historical Society, East Benton County Historical Museum, the Franklin County Historical and Museum Society, and the Reach Museum.

The [*Hanford Cultural Resources Management Plan*](#) (DOE/RL-98-10) provides guidance on cultural and historic resources, cultural materials, and archaeological resources. The Plan also contains guidance on consultation in accordance with other statutes including, but not limited to, the *Native American Graves Protection and Repatriation Act* and the *Archaeological Resources Protection Act of 1979*, as amended (16 U.S.C. 470aa-470mm; Public Law 96-95).

[*DOE P 141.1, Department of Energy Management of Cultural Resources*](#), ensures that DOE-RL integrates cultural resources management into its mission and activities. Consultation with affected stakeholders is pivotal to maintaining the cultural and historical values associated with identified cultural resources for future generations and implementing all stewardship responsibilities.

1.6.2.1 2016 Activities. In 2016, the Cultural and Historic Resources Program focused on more than 150 proposed projects. DOE-RL hosted 11 monthly meetings with Tribal representatives and participated in 4 individual meetings with historic societies, museums, and educational institutions. DOE-RL consulted on one Memorandum of Agreement (MOA) and initiated the signature process during this year. New technologies were added to the Section 110 monitoring program in consultation with Tribes to document cultural resources during routine monitoring activities.

1.6.3 Hanford Natural Resource Trustee Council

SA Boynton

The CERCLA (42 U.S.C. 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 must 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 DOE-administered land, 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) from contaminant release. Federal, state, and Tribal entities are authorized to act as trustees pursuant to CERCLA, Section 301(c), which covers Natural Resource Damage Assessments (NRDAs). 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
- Nez Perce Tribe
- CTUIR
- Yakama Nation.

Established in 1996 via an MOA, the Hanford Natural Resource Trustee Council (Council) is a voluntary association of trust organizations. Members collaborate and coordinate on 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.

1.6.3.1 2016 Activities. Hanford NRDA work in fiscal year (FY) 2016 was focused on 11 injury/restoration studies that are in various stages of completion. The studies are based on the Injury Assessment Plan (IAP) approved by the Council in 2013. The Council's goal is to complete the injury assessment and prepare a Restoration Plan by 2024. Planning efforts resulted in an update of the Hanford NRDA Project Execution Plan (PEP). The PEP 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 PEP is a "living document" that is updated annually based on actual budgets and new information gained from the injury assessment process. Actual funding over the last few years has been less than requested, which has constrained the assessment process.

The Council has prioritized the list of studies from the IAP, which are subject to funding availability. Implementation of the IAP is a dynamic, iterative process and the list of studies is subject to change as additional data becomes available during the injury assessment process.

Initial injury studies are in various stages of completion. Final reports summarizing results of a Groundwater Contaminant Plume Mapping Study and Mussel Toxicity Study conducted by the United States Geological Survey are in the process of being finalized. A terrestrial disturbance inventory geodatabase and report were completed for two operable units (100-F and 100-B/C). Other studies that are in various stages of completion include: Three Tribal Service Loss Studies; Near Shore Aquatic; Evaluation of Contaminant Concentrations in Soils of Non-process Areas; Habitat Recovery Analysis/Restoration Planning; and Groundwater Policy/Injury.

A revised MOA was approved by the Trustees in FY 2016. The MOA supersedes the 1996 Hanford Site Trustee MOA. The MOA provides the framework for coordination and cooperation of the Trustees in conducting the NRDA at Hanford.

The Council continued to meet on a monthly basis to plan, organize, implement, and direct Hanford NRDA activities. The Administrative Record (AR) Procedures Manual was revised to be more consistent with regulations and their intent.

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

RD Buel

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

Previously known as the *Community Relations Plan*, the *Hanford Public Involvement Plan* (TPA 2012) serves as the overall guidance document for public participation and outreach activities at Hanford. The document outlines the public participation processes used by the TPA agencies and offers ways in which the public can be involved in Hanford Site cleanup decision-making processes. The first plan was developed and approved with public input in 1990 and was last revised in June 2017. During CY2016, the Hanford Site worked to the November 2012 Plan (TPA 2012). With the update of the plan, CY2017 work will coincide with TPA 2017.

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 about upcoming public involvement and participation opportunities, including, but not limited to, the following:

- Listserv Notices and Printed Mailings. The TPA agencies use a Listserv to communicate electronically about upcoming public involvement activities along with information on ways to be involved in Hanford cleanup decisions. To be added to the Listserv or to the printed mailing list, visit the Listserv website to subscribe or send an email to Hanford@ecy.wa.gov.
- Hanford Site Public Involvement Activities. Available at <http://www.hanford.gov/pageAction.cfm/calendar>, the Hanford Site Events 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.
- TPA Agencies Public Involvement Calendar for the Hanford Site. Available on the Ecology website (<http://www.ecy.wa.gov/programs/nwp/public.htm>), a public involvement calendar is available that frequently provides upcoming key public activities, including Hanford Advisory Board (HAB) meeting dates and locations.
- TPA Agencies Public Involvement Summary. Each year since the early 2000s the TPA agencies have distributed an annual survey to encourage feedback, share information, and provide education about the Hanford Site cleanup. What began as a challenging, hand-written response interpretation and information gathering at biennial meetings has become an annual electronic survey. This publication is available for review (TPA 2016a) and promotes and encourages the sharing of links through a wide variety of online media. Previous years public involvement summary reports can be found online at https://issuu.com/hanford_edoutreach.
- Hanford Site Informational Links. Information concerning Hanford Site events, issues, cleanup activities, and public involvement opportunities is available at <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 also available at the DOE Public Reading Room (Washington State University Tri-Cities Consolidated Information Center, 2710 University Dr., Richland, Washington); on the TPA AR Public Information Repository website (<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.cfm/TriParty/ModificationsforPublicComment>.
- Informational Public Meetings. All TPA quarterly public involvement planning, semiannual, and special meetings and workshops are open to the public. In addition, the TPA 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 AR Public Information Repository website (<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, [Resource Conservation and Recovery Act of 1976](#) (RCRA), and NEPA; HAB meetings; Hanford presentations; and other Hanford Site-related public involvement and information meetings, workshops, or activities.

For more information about Hanford Site cleanup activities, contact the TPA agencies at the following contact numbers:

DOE-RL	(509) 376-7501
DOE-ORP	(509) 376-9292
Ecology	(509) 372-7950
EPA	(509) 376-6865

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

1.6.5 State of Oregon

RD Buel

DOE recognizes Oregon's unique role and interests at the Hanford Site and its concerns with protecting Columbia River resources. In 2004, DOE-RL and DOE-ORP updated a 1986 Memorandum of Understanding (DOE-RL and DOE-ORP 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

KL Holmes

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 TPA agencies created the HAB in 1994 and was 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 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 Advice and Responses website at <http://www.hanford.gov/?page=453>. Additional information about the HAB, including its charter (operating ground rules), is available at <http://www.hanford.gov/?page=449>.

In 2016, the HAB provided DOE-RL with a significant amount of advice regarding several TPA milestone changes affecting future work on Hanford's Central Plateau. The advice influenced the creation of a new milestone to remove the high-radiation portion of the 324 waste site, a new milestone for submittal of a data quality objectives report assessing the structural integrity of the Plutonium Uranium Extraction Facility tunnels 1 and 2, and suggestions for improving public involvement materials. It also guided

DOE and the regulatory agencies to publish an actual milestone date instead of “to be determined” for a particular milestone.

1.7 Hanford Site Regulatory Oversight

JR Draper

Several federal, state, and local regulatory agencies are responsible for monitoring and enforcing compliance with applicable environmental regulations at the Hanford Site, including the EPA, Ecology, Washington State Department of Health (WDOH), and the Benton Clean Air Agency. The EPA and Ecology are the two main agencies who regulate Hanford cleanup as part of the TPA. In addition, the Defense Nuclear Facilities Safety Board (DNFSB) provides oversight of DOE work.

1.7.1 Environmental Regulations

Before 1986 environmental laws only regulated private industry and state and local governments. Ecology and the EPA had to decide how to apply environmental regulations to a federal agency (DOE) at Hanford. Instead of lengthy litigation, these three agencies agreed to manage cleanup under the Hanford Federal Facility Agreement and Consent Order, also known as the TPA. Signed in 1989, the original agreement had a schedule to clean up Hanford over a 30-year period. It defines roles and responsibilities between Ecology and EPA for regulating hazardous waste sites.

EPA's purpose is to ensure that:

- All Americans are protected from significant risks to human health and the environment where they live, learn, and work
- National efforts to reduce environmental risk are based on the best available scientific information
- Federal laws protecting human health and the environment are enforced fairly and effectively
- Environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade, and these factors are similarly considered in establishing environmental policy
- All parts of society (e.g., communities; individuals; businesses; and state, local and Tribal governments) have access to accurate information sufficient to effectively participate in managing human health and environmental risks
- Environmental protection contributes to making our communities and ecosystems diverse, sustainable, and economically productive
- The United States plays a leadership role in working with other nations to protect the global environment.

When Congress writes an environmental law, EPA implement it by writing regulations. Often, EPA sets national standards that states and Tribes enforce through their own regulations. If they fail to meet the

national standards, EPA can help. EPA also enforces regulations and helps companies understand the requirements.

Ecology's Nuclear Waste Program focuses on keeping people and the environment safe from the dangers of mixed radioactive and chemically hazardous waste by:

- Enforcing regulatory compliance and cleanup at the Hanford Site and at other facilities managing nuclear waste statewide
- Promoting public involvement and community outreach and education in order to enhance nuclear waste management, compliance, and cleanup of the Hanford Site
- Ensuring appropriate oversight for the safe management and disposal of radioactive hazardous wastes at the Richland commercial LLRW disposal site.

The designation of lead regulatory agency and regulatory process for each operable unit, treatment, storage, and disposal (TSD) group/unit, or milestone at Hanford is determined through a change process. EPA and Ecology have joint authority to determine the choice of lead regulatory agency and regulatory process in consultation with DOE.

The WDOH's Hanford Environmental Radiation Oversight Program provides oversight of DOE's radiation monitoring programs. DOE's environmental radiation monitoring programs determine the impact of Hanford releases on the environment and the public. The WDOH program independently verifies the quality of DOE's program. The objectives of the oversight program are to:

- Independently verify the quality of DOE's monitoring programs at the Hanford Site by conducting sampling at locations having the potential to release radionuclides to the environment or areas where releases may have an impact.
- Use data from DOE and WDOH to assess the potential impact on people by comparing radionuclide concentrations in samples with background samples. Note that WDOH's monitoring program is intended to be oversight and not a program that finds and reports the highest levels of environmental contaminants.
- Address public concerns about environmental radiation at the Hanford Site.

1.7.2 Hanford Federal Facility Agreement and Consent Order

SW Davis, SL Brasher

The TPA is an agreement (Ecology et al. 1989a) among the TPA agencies to achieve environmental regulation compliance on the Hanford Site with CERCLA and RCRA 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 [RCW 70.105, "Hazardous Waste Management,"](#) 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 (Ecology et al. 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 TPA 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. 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 Dr., 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 (509) 372-7950 or e-mail to Hanford@ecy.wa.gov.

1.7.2.1 TPA Milestone Status. The TPA commits DOE to comply with the remedial action provisions of CERCLA, as well as with RCRA (42 U.S.C. 6901) TSD unit regulations and corrective action provisions, including Washington State's implementing regulations ([WAC 173-303, "Dangerous Waste Regulations"](#)).

From 1989 through December 31, 2016, a total of 1,286 TPA milestones were completed and 341 target dates were met. During 2016, 38 specific cleanup milestones were scheduled for completion; of those, 14 milestones were deleted, 22 milestones were completed on time, no milestones were missed, and 2 were in negotiation. In addition, 2 target dates were met, 5 target dates were deleted, and 1 target date was in negotiation.

1.7.2.2 TPA-Approved Modifications. During 2016, 26 negotiated change control forms to the TPA were approved and can be viewed on the TPA website at <http://www.hanford.gov/c.cfm/tpa/>.

1.7.3 Defense Nuclear Facility Safety Board

JR Draper

Congress created the DNFSB as an independent agency within the Executive Branch to identify the nature and consequences of potential threats to public health and safety at DOE's defense nuclear facilities, to elevate such issues to the highest levels of authority, and to inform the public. During 2016, the DNFSB oversaw projects pertaining to each contractor at the Hanford Site (e.g., Waste Encapsulation and Storage Facility, Plutonium Finishing Plant, WTP, and Tank Farms). Reports produced by the DNFSB reporting on Hanford Site projects can be viewed at <https://www.dnfsb.gov/documents>.

2.0 Compliance Summary

JR Draper

For the protection of human health and the environment through safe operations, the Hanford Site has compliance programs designed to meet federal, state, and local environmental laws, regulations, and requirements and comply with the U.S. Department of Energy (DOE) orders, notices, directives, policies, and guidance (see Section 2.9). These measures include specific requirements, actions, plans, and schedules identified in the [Hanford Federal Facility Agreement and Consent Order](#) (Tri-Party Agreement [TPA]) (Ecology et al. 1989a) and other compliance or consent agreements. The U.S. Department of Energy, Richland Operations Office (DOE-RL) and Office of River Protection (DOE-ORP) recognize the importance of maintaining a proactive program of self-assessment and regulatory reporting to ensure that environmental compliance is achieved and maintained at the Hanford Site. This report fulfills reporting requirements for the annual compliance status under the environmental standards specified in [DOE O 231.1B, Chg 1, Environmental, Safety and Health Reporting](#). The Order addresses DOE/National Nuclear Security Administration receiving timely, accurate information about events that have affected or could adversely affect the health, safety, and security of the public or workers, the environment, the operations of DOE facilities, or the credibility of DOE.

Section 2.0 summarizes the laws and regulations that govern Hanford Site activities with regard to federal environmental protection statutes and associated state and local environmental regulations. This section discusses both permits required under specific environmental protection regulations and the U.S. Environmental Protection Agency (EPA) or Washington State Department of Ecology (Ecology)-issued notices of violation or non-compliance. Notices of violation are the regulatory means of informing organizations that their work activities are not meeting requirements; notices of non-compliance 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

SW Davis, SL Brasher

Enacted by Congress on October 6, 1992, the [Federal Facility Compliance Act of 1992](#) (Public Law 102-386) amends Section 6001 of the [Resource Conservation and Recovery Act of 1976](#) (RCRA) to specify that the U.S. waives sovereign immunity from civil and administrative fines and penalties for RCRA violations. In addition, the 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-026-01. In 2016, [Calendar Year 2015 Hanford Site Mixed Waste Land Disposal Restrictions Summary Report](#) (DOE/RL-2016-08) 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](#) (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 treatment, storage, and disposal (TSD). The Hanford Site dangerous waste activities are subject to applicable provisions of [WAC 173-303, "Dangerous Waste Regulations,"](#) including provisions in the WAC 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, though there are numerous TSD units spread over large geographic areas. The permit is issued to the following seven permittees:

- DOE-RL and DOE-ORP as the owners/operators
- Five of DOE's contractors
 - Bechtel National, Inc.
 - CH2M Plateau Remediation Company (CHPRC)
 - Mission Support Alliance, LLC (MSA); the permit identifies MSA as a permittee but not a co-operator
 - Pacific Northwest National Laboratory
 - Washington River Protection Solutions, LLC (WRPS).

Washington state dangerous waste regulations (WAC 173-303) require Ecology to reissue a permit after a term of up to 10 years. The initial permit was issued on September 27, 1994, for a 10-year term. DOE submitted a permit renewal application on March 30, 2004. The permit 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 \(RCRA\) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste](#) (Hanford Facility Dangerous Waste Permit; Ecology 1994).

In May 2012, Ecology issued a draft renewal permit ([Ecology 2012](#)). Ecology received more than 4,000 comments on the draft renewal 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 the DOE. Issues raised during the comment period identified substantial new questions; as a result, Ecology plans to make revisions and reopen the public comment period for the draft renewal permit. Ecology expects this process to take several years. The process will include 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.

Ecology has completed activities associated with the first bullet above. Activities associated with the second bullet are underway.

During 2016, permit modifications were processed to change requirements for the following TSD units pursuant to WAC 173-303-830, "Permit Changes":

- Liquid Effluent Retention Facility and 200 Areas Effluent Treatment Facility (Operating Unit Group 3)
- 242-A Evaporator (Operating Unit Group 4)
- 325 Hazardous Waste Treatment Unit (Operating Unit Group 5)
- Hanford Tank Waste Treatment and Immobilization Plant (WTP) (Operating Unit 10)
- Integrated Disposal Facility (IDF; Operating Unit 11)
- 400 Area Waste Management Unit (Operating Unit Group 16)
- 207-A South Retention Basins
- 225B Waste Encapsulation and Storage Facility
- Low-level burial grounds.

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 managed by the DOE-RL, DOE-ORP, and Pacific Northwest Site Office (DOE-PNSO). 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 calendar year (CY) 2016, 80 regulatory agency inspections were conducted at DOE facilities on the Hanford Site: Ecology - 39, WDOH- 33, EPA - 2, the City of Richland - 1, and DOE - 5.

Ecology inspections were conducted by the Nuclear Waste Program Office located in Richland, Washington. EPA Region 10 inspections focused on air quality at the 618-10 Burial Ground and PUREX pathways 1 and 8 including oversight of Ecology and WDOH inspections under EPA-delegated authority. WDOH inspections were performed primarily by the Office of Radiation Protection, Richland, Washington. The WDOH Office of Drinking Water in Spokane, Washington, also performed a sanitary survey of the 300 and 400 Area drinking water systems. The City of Richland inspection focused on the 300 Area of the Hanford Site to evaluate compliance with Industrial Wastewater Discharge Permit (CR-IU-010) requirements, including the monitoring of wastewater discharges to the publicly owned treatment works. DOE-RL, DOE-ORP, and DOE-PNSO facility inspections are performed in accordance with the terms and conditions of the Air Operating Permit, Radioactive Air Emissions License, Wastewater Discharge Permits and RCRA permit. Inspections are supported by the Hanford Site contractors responsible for the facilities being inspected.

Regulatory agency inspections can result in alleged violations of regulations and other concerns. If deemed appropriate, regulatory agencies may initiate a variety of enforcement and compliance actions, which are discussed further in Section 2.9.

RCRA Inspections. The Ecology inspections focused on TSD unit compliance with the Hanford Facility Dangerous Waste Permit (Ecology 1994) and WAC 173-303. The TSD units and other facilities inspected during 2016 included the following:

- 200 Areas Effluent Treatment Facility
- Waste Encapsulation Storage Facility
- 222-S Laboratory
- 400 Area Waste Management Unit
- 207-A Retention Basin
- 242-A Evaporator
- 325 Building
- 204-AR Waste Unloading Facility
- B-Plant
- Liquid Effluent Retention Facility
- 600 Area Fuel Station
- Hexone Storage and Treatment Facility
- Central Waste Complex
- Low-level Burial Grounds Trenches 31 and 34
- Plutonium Finishing Plant
- Plutonium Uranium Extraction Facility (PUREX)/PUREX Storage Tunnel
- Double-shell tank and single-shell-tank tank farms
- T-Plant
- Waste Receiving and Processing Facility
- 90-day accumulation areas
- Satellite accumulation areas
- Universal waste management operations.
- Nonradioactive Dangerous Waste Landfill
- Groundwater Monitoring Network Wells
- 100-DR Cocooned Reactor
- Low-level Burial Grounds Green Islands.

Section II.O of the RCRA permit addresses general inspection requirements required in accordance with WAC 173-303-320. General inspections are conducted in addition to the TSD unit inspections specified in Parts III, V, and 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 by DOE-RL and Hanford contractors to identify and correct potential malfunctions, deterioration, operator errors, and discharges that may cause or lead to the release of dangerous waste constituents to the environment or that threaten human health. In accordance with RCRA permit requirements, Ecology is notified of the general inspections at least 7 days in advance to allow their participation. RCRA permit general inspection summary reports are maintained in the Hanford Facility Operating Record and Regulatory Agency Inspection Database.

Clean Air Act Inspections

JW Cammann and CJ Perkins

In 2016, the WDOH inspections focused on compliance of major and minor stack air emission units as well as diffuse and fugitive emission sources, with the Hanford Site Air Operating Permit and Radioactive Air Emissions License (FF-01). Ecology inspections included discharge points (e.g., emergency engines/generators) and packaged boiler systems regulated under the Hanford Site Air Operating Permit.

During the period from March through September 2016, the WDOH Radioactive Air Emissions Section inspected the compliance of the Hanford air sample collection process, tracking, analysis, verification, validations, and reporting to determine compliance with the Radioactive Air Emissions license (RAEL FF-01) and WAC 246-247 (specifically, 40 CFR 61, Appendix B, Method 114). The inspection consisted of document review, witnessing of sample handling and tracking, laboratory visits, and finalization of the reported data.

Items recognized as good practice regarding the Environmental Surveillance ambient air sampling program included good contamination control during sample collection and transport, thorough verification of field information, excellent data verification, and validation processes.

2.1.2.3 RCRA Groundwater Monitoring

MJ Hartman

The Soil and Groundwater Remediation Project (see Section 8) monitors 25 RCRA units on the Hanford Site. LERF (Section 5.3.4.2) and IDF (Section 5.3.3.7) operate under Part III of the RCRA permit (WA7890008967). The other TSD units monitored under RCRA are scheduled to be closed under Part V of the RCRA permit (WA7890008967). Section 8 includes a summary of groundwater monitoring activities for the RCRA units during 2016. [DOE/RL-2016-66, Hanford Site RCRA Groundwater Monitoring Report for 2016](#), includes detailed groundwater monitoring information.

2.1.3 Comprehensive Environmental Response, Compensation, and Liability Act of 1980

JW Cammann, GT Berlin

In 1980, Congress passed the [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (CERCLA) to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. Because the operation of nuclear production and disposal facilities at the Hanford Site has 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 Section 121. The CERCLA Five-Year Review Report documents the methods, findings, and conclusions of the 5-year reviews, which can require institutional controls (ICs) and/or National Resource Damage Assessment and Restoration Program mitigation. The results of the four 5-year reviews conducted since 2000 are documented in the [USDOE Hanford Site First Five-Year Review Report](#) (EPA 2001a); [DOE/RL-2006-20, Second CERCLA Five-Year Review Report for the Hanford Site](#); [DOE/RL-2011-56, Hanford Site Third CERCLA Five-Year Review Report](#); and [DOE/RL-2016-01, Hanford Site Fourth CERCLA Five-Year Review Report](#).

On September 29, 2016, a draft version of the Hanford Site Fourth CERCLA Five-Year Review Report (DOE/RL-2016-01, Draft A, Rev 1) addressing 2011 through 2015 was completed and transmitted to EPA for review (16-AMRP-0284). Based on subsequent feedback received from EPA and other agencies, work continued on this report through the remainder of CY 2016 and into CY 2017. This report aligns with EPA's latest guidance on 5-year review reports, as well as recent training provided to multi-federal agencies as they strive for more consistent reports and the use of substantive tables and figures to more concisely present information that supports the protectiveness statements. On March 27, 2017, the DOE-RL transmitted the final Hanford Site Fourth CERCLA Five-Year Review Report to the EPA ([17-AMRP-0127](#)). On May 4, 2017, the EPA sent a letter to DOE-RL approving the Hanford Site fourth CERCLA five-year review report.

This latest CERCLA 5-year review report evaluates the protectiveness of 30 operable units with remedies that have been documented in interim or final Records of Decision (RODs). Approximately 16 operable units that have been documented in interim or final RODs do not have remedies at this time. They will be addressed in future 5-year review reports as additional RODs are issued. A breakdown of the source and groundwater operable units that are in scope and out of scope for Hanford's fourth CERCLA 5-year review report is provided below.

- In scope (operable units with interim or final RODs):
 - Source operable units: 100-BC-1, 100-BC-2, 100-FR-1, 100-FR-2, 100-IU-2, 100-IU-6, 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-NR-1, 300-FF-1, 300-FF-2, 200-CU-1, 200-CU-3, 200-DF-1, 200-CW-5, 200-PW-1, 200-PW-3, 200-PW-6, 1100-EM-1.
 - Groundwater operable units: 100-FR-3, 100-HR-3, 100-KR-4, 100-NR-2, 300-FF-5, 200-UP-1, 200-ZP-1.
- Out of scope (operable units without RODs):
 - Source operable units: 100-OL-1, 200-BC-1, 200-CB-1, 200-CP-1, 200-CR-1, 200-CW-1, 200-DV-1, 200-EA-1, 200-IS-1, 200-OA-1, 200-SW-1, 200-SW-2, and 200-WA-1.
 - Groundwater: 100-BC-5, 200-BP-5, and 200-PO-1.

2.1.3.1 Superfund Amendments and Reauthorization Act of 1986. The [Superfund Amendments and Reauthorization Act of 1986](#) (SARA; Public Law 107-377) amended CERCLA on October 17, 1986. SARA reflected EPA's experience in administering the complex Superfund program during its first 6 years and made the following important changes and additions to the program:

- 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 tools

- 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 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.

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 EPRCA during 2016.

Table 2-1. Emergency Planning and Community Right-to-Know Act Requirements Summary. (2 Pages)

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
302	40 CFR 355, "Emergency Planning and Notification"	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
		Change occurring at a facility that is relevant to emergency planning.	Within 30 days after change has occurred	Local Emergency Planning Committee
304		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 min of knowledge of reportable release). Written follow-up within 14 days of release.	Local Emergency Planning Committee; State Emergency Response Commission

Table 2-1. Emergency Planning and Community Right-to-Know Act Requirements Summary. (2 Pages)

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
311	40 CFR 370, "Hazardous Chemical Reporting"	The presence at any one time at a facility an OSHA hazardous chemical in quantity $\geq 10,000$ lbs (4,500 kg) or an extremely hazardous substance in quantity equal to or greater than threshold planning quantity or 500 lbs (230 kg), 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		The presence at any one time at a facility an OSHA hazardous chemical in quantity equal to or greater than 10,000 lbs (4,500 kg), or an extremely hazardous substance in quantity equal to or greater than threshold planning quantity or 500 lbs (230 kg), whichever is less.	Annually by March 1	Local Emergency Planning Committee; State Emergency Response Commission; Local Fire Departments
313	40 CFR 372, "Toxic Chemical Release Reporting"	Manufacture, process, or use at a facility, any listed Toxic Release Inventory chemical in excess of threshold amount during a CY. Thresholds are 25,000 lbs (11,300 kg) for manufactured or processed or 10,000 lbs (4,500 kg) for otherwise used except for persistent, bio-accumulative, toxic chemicals with thresholds under 100 lbs (45 kg).	Annually by July 1	EPA; State Emergency Response Commission
OSHA = Occupational Safety and Health Administration				

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	

The 2016 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory (DOE/RL-2017-12) 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 54 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 2016.

Table 2-3. Average Quantity of the 10 Hazardous Chemicals Stored in Greatest Quantities.

CAS#	Chemical	TPQ	Average Amount (lb/kg)
7647-14-5	Sodium Chloride	10,000	4,291,036 /1,946,381
7440-23-5	Sodium	10,000	4,624,378 /2,097,583
8012-95-1	Mineral Oil	10,000	1,163,719 /527,854
00-00-0	Diesel fuel (Grades 1 and/or 2)	10,000	1,004,894/455,812
65997-15-1	Portland Cement	10,000	642,992 /291,656
68131-74-8	Fly Ash (Class F)	10,000	430,000/195,045
7664-93-9	Sulfuric Acid	500	336,481/152,625
00-00-0	Lead Acid Batteries	500	260,054/117,959
14808-60-7	Silica, Crystalline-Quartz	10,000	268,372/121,731
1305-78-88	Calcium Oxide	10,000	255,300/115,802

The 2016 Hanford Site Toxic Chemical Release Inventory report (DOE/RL-2017-36) was submitted to EPA and Ecology before the annual July 1 deadline. During CY 2016, the Hanford Site exceeded activity thresholds for lead, naphthalene, propylene, toluene, and xylene. Information concerning these chemicals is described in Table 2-4.

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 sitewide
Xylene	1330-20-7	Gasoline used for stationary equipment
Toluene	108-88-3	Gasoline used for stationary equipment

2.1.5 Reportable Releases

ME Carlson

Federal regulations establish reporting requirements for certain environmental releases that must be reported to the National Response Center. The National Response Center is the central point of contact for reporting hazardous substance 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 and Discharges into 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 none of these events required notification to Ecology. These relatively minor spill events primarily involved petroleum products from leaking equipment and vehicles (e.g., hydraulic fluid, diesel fuel, and motor oil). These spills have all been logged per Contractor Requirements Document 436.1. All of these spilled products were cleaned up and all resulting materials (e.g., absorbents and impacted soils) were processed for disposal 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; Public Law 94-469) requirements that primarily involve regulation of polychlorinated biphenyls (PCBs). TSCA also regulates other constituents, such as asbestos, lead-based paint, and radon. The applicability of TSCA to the management of these constituents at the Hanford Site is discussed below:

- Lead-based Paint
 - The TSCA regulations for lead-based paint are applicable to residential and child-occupied facilities and do not apply to Hanford activities.
- Radon
 - The radon regulations in TSCA pertain to schools and public or assisted-housing and do not apply to Hanford activities.
- Asbestos
 - Asbestos at the Hanford Site is primarily regulated by the Clean Air Act (CAA) and Occupational Safety and Health Administration (OSHA).
 - However, TSCA accreditation and training requirements provided in 40 CFR 763, Appendix C - Asbestos Model Accreditation Plan are applicable and Hanford must comply with minimum training standards for personnel engaged in asbestos abatement activities.
- PCBs – 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.

- Signed on August 31, 2000, [*The Hanford PCB Framework Agreement 8/31/00: Framework Agreement for Management of Polychlorinated Biphenyls \(PCBs\) in Hanford Tank Waste*](#) (EPA et al. 2000) resulted in the TPA 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.
- DOE-RL submitted the [*2015 Polychlorinated Biphenyl Annual Report*](#) (DOE/RL-2016-39) and [*2015 Hanford Site Polychlorinated Biphenyl Annual Document Log*](#) (DOE/RL-2016-40) to EPA on June 28, 2016, 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 2016, including but not limited to single-shell tank waste retrieval activities in accordance with EPA Phase I and II RBDAs for the use of double-shell tank 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.
- Work was performed at the 242-A Evaporator under the RBDA for the 200 Areas Liquid Waste Processing Facilities.
- 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 2016, 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

ES Pennala

The [*National Environmental Policy Act of 1969*](#) (NEPA) is the basic national charter for protection of the environment. It establishes policy, sets goals, and provides means for carrying out the policy. It contains “action-forcing” provisions to ensure that federal agencies act according to the letter and spirit of the Act [40 CFR 1500.1(a)]. NEPA requires federal agencies to assess the environmental consequences of proposed actions prior to making decisions that may have environmental effects. The Council on Environmental Quality (CEQ) regulations that implement NEPAs (40 CFR 1500-1508) and

DOE’s NEPA implementing regulations (10 CFR 1021) ensure compliance with the letter and spirit of NEPA.

Proposed actions are evaluated in accordance with CEQ regulations and DOE NEPA implementing regulations to determine whether an EIS or EA is required; or the proposed action is categorically excluded (CX) from preparation of an EIS or EA. This section provides the status of NEPA documentation

(EISs, EAs, and CXs) completed or underway at the Hanford Site during CY 2016. NEPA documentation completed in early CY 2017 is also mentioned, where applicable. Hanford Site NEPA documentation is available online at <http://www.hanford.gov/page.cfm/Documents>.

2.1.7.1 Hanford Site Environmental Impact Statements. This section summarizes the status of EISs completed or underway at the Hanford Site during CY 2016.

Natural Gas Pipeline EIS (DOE/EIS-0467). On January 23, 2012, DOE published a ["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, Washington, and Notice of Floodplains and Wetlands Involvement \(DOE/EIS-0467\)"](#) in the *Federal Register* (77 FR 3255). 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 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 run westerly across non-DOE lands 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.

DOE postponed preparation of the EIS in 2015 to better align the completion of the EIS with planned future operations of facilities on Hanford's Central Plateau. In the spring of 2016, DOE began evaluating steps to continue preparation of the EIS and is currently working on a schedule for publication of a Draft EIS for public review.

2.1.7.2 Hanford Site Environmental Assessments. Hanford Site EAs that were completed in CY 2016 or underway are described in the following section.

Final Environmental Assessment for Proposed Conveyance of Land at the Hanford Site, Richland, Washington (DOE/EA-1915). 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 approximately 1,641 ac of land located in the southeastern corner of the Hanford Site near the City of Richland in Benton County, Washington, for economic development purposes. DOE prepared an EA and issued a Final EA and FONSI on September 30, 2015.

The significance of potential environmental impacts was considered based on "context and intensity" per the CEQ regulations (40 CFR 1508.27). No potentially significant impacts were identified in the EA; however, DOE committed to implement the mitigation measures in a Mitigation Action Plan (MAP) to better achieve an environmentally-preferable outcome. The [Mitigation Action Plan Annual Report Calendar Year 2016](#) (DOE/EA-1915) was issued with a date of December 2016.

Final Environmental Assessment for Expansion of Borrow Areas on the Hanford Site (DOE/EA-1934-FEA-2013). The *Environmental Assessment for Expansion of Borrow Areas on the Hanford Site* (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 established one new borrow area source in the 100 Area for ongoing construction activities and fill material following remediation activities.

The significance of potential environmental impacts was considered based on "context and intensity" per the CEQ regulations (40 CFR 1508.27). No potentially significant impacts were identified in the EA; however, DOE committed to implement the mitigation measures in a Mitigation Action Plan (MAP) to better achieve an environmentally-preferable outcome. The [2016 Annual Report for Mitigation Action Plan](#) (DOE/EA-1934) was issued with a date of February 2017.

Environmental Assessment for Rebuild of the North Loop 230-kV Electrical Transmission Line (DOE/EA-2033). A portion of the electric power needs at Hanford is provided from the North Loop electrical transmission line, which is part of an existing system that was built in the 1940s. Because of the age of the system and deteriorating condition of the conductors, hardware, and support structures, the existing system will not support the continued long-term cleanup mission of the Hanford Site Central Plateau, which is projected until at least 2060.

To provide reliable power, DOE proposes to rebuild approximately 28 miles of the North Loop transmission line in the northern part of the Hanford Site with approximately 20 miles of single- and double-circuit line. The North Loop line would be reduced by approximately 8 miles. The proposed project would require reconfiguring switching stations and substation components, installing equipment and conductors, building and reconditioning access roads, removal of structures, and other ancillary activities. DOE made a determination to prepare an EA for the rebuild-of the transmission line on February 1, 2016. Preparation of the EA is ongoing.

Environmental Assessment for Benton-Othello 115-kV Transmission Line Rebuild Project (DOE/EA-2038). DOE is preparing an EA to assess potential environmental effects of Avista Utilities' (Avista) proposal to rebuild 12.6 miles of the Benton-Othello Switching Station (Benton-Othello) electrical transmission line on the Hanford Site. Sections of the electrical transmission line were built in the 1920s and 1940s, and most of the structures, conductor, and associated components are physically worn posing risks to safety and reliability. The upgrade would begin 0.5 miles south of State Route 24, on the Hanford Site. The northern 10.6 miles of the electrical transmission line crosses the Monument, which is managed jointly by DOE and the US Fish and Wildlife Service (USFWS).

DOE made a determination to prepare an EA for the rebuild of the transmission line on April 6, 2016. A Public Scoping Notice to prepare an EA was issued on January 3, 2017. Avista, in coordination with DOE and other agencies with jurisdiction, has been conducting field studies and preparing a Biological Evaluation, Wetland Assessment, Floodplain Assessment, and Cultural Resources Report.

Environmental Assessment Energy Northwest WNP-1/4 Lease Renewal (DOE/EA-2044). In 1975, the Washington Public Power Supply System (now known as Energy Northwest) obtained a lease from the U.S. Government for Washington Nuclear Projects Number 1 and Number 4 (WNP-1/4), which included options for renewing the lease. DOE's proposed action, was renewal of an existing lease, and the EA analyzed activities authorized by the proposed lease amendment.

Activities that were authorized included subleasing office and warehouse space, and transitioning from groundwater wells to surface water to supply Energy Northwest's Industrial Development Complex (IDC) with potable water. The existing water distribution system would be used to transport water from the Columbia River to the IDC.

DOE made a determination to prepare an EA on June 15, 2016. The EA and FONSI were issued on January 6, 2017.

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 the environment and for which neither an EA nor an EIS is required (10 CFR 1021).

The DOE NCO approved a total of 38 categorical exclusions during CY 2016. Of these, 36 were annual categorical exclusions, to cover routine and recurring work activities planned to be performed during FY 2017 at the Hanford Site (Mission Support Alliance – 21, CH2M Plateau Remediation Company – 8, and Pacific Northwest National Laboratory – 7). The two remaining categorical exclusions were activity-specific to cover the “National Park Service Centennial Bike Ride” and the “Plutonium Man Bike Race” on the Hanford Site. Annual and activity-specific categorical exclusions approved by the DOE NCO may be viewed at <http://www.hanford.gov/page.cfm/CategoricalExclusions>.

2.1.8 Institutional Controls Plan

R Ranade

The MSA Long Term Stewardship (LTS) program is responsible for managing ICs along the River Corridor with the exception of a portion of the 100-K Area. CHPRC is responsible for the ICs associated with groundwater. 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 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. The selected remedies chosen may include ICs and the CERCLA decision documents identify the specific requirements for these controls.

ICs 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 residual contaminants. Active ICs, such as controlling access to the Hanford Site or activities that may affect remedial action, are generally employed during remediation. After remediation is completed, passive ICs are employed such as permanent markers, retaining public records and archives, or sustaining regulations regarding land or resource use. ICs such as drilling and excavation restrictions for waste sites with contamination below 15 ft, monitoring and controlling access to the area, and warning signs also may be employed after remediation is completed.

As required by DOE-RL-2001-41, ICs are assessed annually as required by the CERCLA and/or RCRA decision. Hanford Site contractors provide an annual update on the effectiveness of the ICs to EPA and Ecology at the area unit managers meetings each September. Minutes from the unit managers’ meeting are available on the TPA Administrative Record Public Information Repository website (<http://pdw.hanford.gov/arpir/>). The Hanford Site CERCLA 5-year review also includes a rollup of the issues/actions noted during of the annual assessments.

The MSA LTS organization is responsible for managing ICs related to Hanford Site access control and the wastes sites in the River Corridor area. The IC assessments conducted in FY 2016 found the following:

- Warning signs along the Hanford Site boundary and at the entrance of the River Corridor areas where cocooned reactor buildings are located were in place and visible.
- The fence along State Route 240 was found to have broken wire strands in four places. The broken wire strands were replaced. Other fencing was intact.
- Eighty “No Trespassing” signs were missing, damaged, and/or could not be seen from the Columbia River. MSA LTS has initiated a project to identify and replace the missing signs.
- The Excavation Permits and Site Evaluation Processes were used successfully to ensure compliance with ICs, which require the restriction of drilling or excavating into the deep zone (below 15 ft [4.6 m]).
- Five reportable trespassing incidents occurred from October 2015 to September 2016 and were reported to the Benton County Sheriff’s office.
- The 300 Area Fire Station is in compliance with the final 300 Area ROD ICs and DOE directives regarding fire hydrant testing.

Operable units in the Central Plateau of the Hanford Site also have a number of ICs in both interim and final ROD documents. In CY 2016, an assessment of ICs at 200-UP-1 Operable Unit, 221-U Facility, and 200-ZP-1 Operable Unit identified no deficiencies.

2.1.9 Federal Insecticide, Fungicide, and Rodenticide Act

JM Rodriguez

EPA administers the [Federal Insecticide, Fungicide, and Rodenticide Act](#) (7 U.S.C. 136 et seq.). The Washington State Department of Agriculture administers standards to regulate implementation of the Act in the state, including [RCW 15.58, “Washington Pesticide Control Act,”](#) [RCW 17.21, “Washington Pesticide Application Act,”](#) 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

W Boyd

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

To ensure proper management of radioactive materials, the [Atomic Energy Act of 1954](#) (AEA; 42 U.S.C. 2011 et seq.) 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, 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 technical standards may be accessed via the DOE Office of Environment, Health, Safety & 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 and the International Commission on Radiological Protection); 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 National Council on Radiation Protection and Measurements and International Commission on Radiological Protection, 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 goals 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 concentrations 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 concentrations are based on a committed dose standard of 100 mrem (1 millisievert [mSv]) 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.

**Table 2-5. Radiation Standards for Public Protection
from All Routine DOE Concentrations.**

All Pathways (DOE O 458.1)		
Effective dose equivalent for any member of the public from all routine DOE operations ^a shall not exceed values below.		
	Effective Dose Equivalent^b	
	mrem/yr	mSv/yr
Routine public dose	100	1
Potential authorized temporary public dose ^c	500	5
Dose to Native Aquatic Animal Organisms from Liquid Discharges (DOE O 458.1)		
Radioactive material in liquid waste discharged to natural waterways shall not cause an absorbed dose ^d to native aquatic animal organisms that exceed 1 rad (10 milligray [mGy]) per day.		
Drinking Water Pathway Only: 40 CFR 9, 141, and 142 (65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule"); WAC 246-290, "Group A Public Water Supplies;" and DOE O 458.1		
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 mrem (0.04 mSv)/yr. DOE operations shall not cause private or public drinking water systems downstream of the facility discharge to exceed the radiological drinking water limits in 40 CFR 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> .		
Air Pathways Only (40 CFR 61, "National Emission Standards for Hazardous Air Pollutants")		
Public dose limit at location of maximum annual air concentration as a consequence of routine DOE operations ^a	Effective Dose Equivalent^a	
	mrem/year	mSv/year
	10	0.1
NOTE: 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.		
^a Routine DOE operations imply normal, planned activities and do not include actual or potential accidental or unplanned releases.		
^b Effective dose equivalent is expressed in rem (or mrem) and Sv (or mSv).		
^c Authorized temporary annual dose limits may be greater than 100 mrem (1 mSv)/yr but cannot exceed 500 mrem (5 mSv)/yr if unusual circumstances exist that make avoidance of doses impracticable to the public. DOE-RL 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.		
^d Absorbed dose is expressed in rad (or millirad) with the corresponding value in gray (or mGy) in parentheses.		
mrem = millirem		
mSv = millisievert		
rem = roentgen equivalent in man		
Sv = sievert		

2.2.3 DOE O 435.1, Radioactive Waste Management

OA Farabee, JA Reddick

The purpose of DOE O 435.1 is to establish requirements to manage high-level waste, transuranic waste, and low-level waste, including the radioactive component of mixed waste (high-level waste, transuranic waste, and low-level waste 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 10 CFR 835; [DOE O 440.1B, Worker Protection Program for DOE \(Including the National Nuclear Security Administration\) Federal Employees](#); and [DOE O 458.1, Radiation Protection of the Public and the Environment](#). For facilities undergoing CERCLA removal actions or CERCLA remedial actions DOE O 435.1 may not be Applicable or Relevant and Appropriate Requirements (ARARs).

2.3 Air Quality Statutes and Regulations

RA Kaldor

Below is 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. Originally passed in 1963, the law has been revised extensively on numerous occasions. The most recent revision, the [Clean Air Act Amendments of 1990](#) (Public Law 101-549) 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 federal changes. EPA provides high-level programmatic oversight of the air quality program on the Hanford Site and has delegated authority for implementing applicable *Clean Air Act* regulations to designated state and local regulatory agencies.

WDOH regulates radioactive air emissions on the Hanford Site by enforcing applicable federal requirements in [40 CFR 61, "National Emission Standards for Hazardous Air Pollutants,"](#) Subparts A and H; 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, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities."](#)

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 Ozone";](#) 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 air pollutants are other chemical contaminants as regulated by Washington State.

The Benton Clean Air Agency regulated 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 regulates outdoor burning activities at the Hanford Site in accordance with state requirements in [WAC 173-425, "Outdoor Burning."](#)

2.3.2 Air Permits

RA Kaldor, JW Cammann

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 DOE-RL Hanford Site, License FF-01 issued by the WDOH in February 2012. The FF-01 license is a compilation of all applicable radioactive air emission requirements and is renewed every 5 years. For each emission unit, the FF-01 license includes either an approval to modify/construct or 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 mrem (100 microsievert [μSv])/yr 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-2017-17, Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2016](#)).

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 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 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 2016, regulatory agencies conducted 35 *Clean Air Act* inspections on the Hanford Site. A total of four violations were alleged involving airborne radioactive materials at the 618-10 Burial Ground and failure

to monitor stack air emissions continuously or operating outside sampling system design parameters at PUREX, B-Plant, and the Canister Storage Building (Section 2.1.2.2.).

2.4 Water Quality Statutes and Regulations

M Kamberg

This section provides information on federal, state, and local requirements and permits for water quality protection.

2.4.1 Federal Permit – Discharges to Columbia River

The [Clean Water Act of 1977](#), as amended, applies to discharges to surfacewaters in the United States. At the Hanford Site, regulations are applied through [40 CFR 122, “EPA Administered Permit Programs: The National Pollutant Discharge Elimination System.”](#) 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, all held by DOE, were in effect during 2016: ST-4500, ST0004502, ST0004511, and ST0045514. Ecology’s wastewater discharge permits page 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 (and issued to Bechtel National Inc.) during 2016: WAG-50-5180 and WAG-50-5181. 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 Chapter 17.30, Richland Pretreatment Act](#). DOE holds Permit No. CR-IU010, which allows discharges from the 300 Area facilities. The current Permit was renewed in 2016 and will expire November 30, 2021.

2.4.4 Safe Drinking Water Act of 1974

BR Stenson

The [Safe Drinking Water Act of 1974](#) (SDWA; 42 U.S.C. 300f) 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 in 1986 and became formally registered as public under WDOH jurisdiction in 1987.

The SDWA was amended in 1986 and 1996 (Public Law 104-182). Although 1986 amendments included provisions that emphasized treatment to ensure safe drinking water, 1996 amendments focused on

source water protection, water system improvements funding, operator training, public information, and strengthening EPA's scientific work, including a risk and cost benefit analysis in establishing drinking water standards. 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 new treatment technologies to comply with the increasingly complex requirements.

The EPA's microbial and disinfection byproduct rules include nine drinking water regulations, address acute threats from microbial contamination, and address chronic threats from disinfectant residuals and disinfection byproducts. Disinfection byproducts are sometimes formed when an oxidizing agent like chlorine is added to water during the water treatment process to kill or inactivate harmful organisms that may cause various diseases. Chlorine is a very active substance and reacts with naturally occurring substances, like organic material and bacteria, to form compounds known as 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 2016, 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 worker health using public water supplies on the Hanford Site, water systems were monitored during 2016 for microbiological, chemical, physical, and radiological constituents. There were no microbiological detections during the 2016 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 2016 radiological monitoring are summarized in Section 7.1.3.

Table 2-6. Selected Drinking Water Standards. (2 Pages)

Constituent	DWS ^a		Agency ^b
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 ^c	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 ₃ ⁻	10 mg/L	10 ppm	EPA, WDOH
Nitrite, as NO ₂ ⁻	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 ^d	11.1 Bq/L	EPA
Beta particle and photon activity	4 mrem/yr ^e	40 µSv/yr	EPA, WDOH

Table 2-6. Selected Drinking Water Standards. (2 Pages)

Constituent	DWS ^a		Agency ^b
Carbon-14	2,000 pCi/L ^d	74.1 Bq/L	EPA
Cesium-137	200 pCi/L ^d	7.4 Bq/L	EPA
Cobalt-60	100 pCi/L ^d	3.7 Bq/L	EPA
Iodine-129	1 pCi/L ^d	0.037 Bq/L	EPA
Ruthenium-106	30 pCi/L ^d	1.11 Bq/L	EPA
Strontium-90	8 pCi/L ^d	0.296 Bq/L	EPA, WDOH
Technetium-99	900 pCi/L ^d	33.3 Bq/L	EPA
Total alpha (excluding uranium)	15 pCi/L ^d	0.56 Bq/L	EPA, WDOH
Tritium	20,000 pCi/L ^d	740 Bq/L	EPA, WDOH
Uranium	30 µg/L	0.03 ppm	EPA, WDOH

^a Maximum contaminant level for drinking water supplies.

^b WDOH at WAC 246-290; EPA at 40 CFR 141, "National Primary Drinking Water Regulations;" 40 CFR 143, "National Secondary Drinking Water Regulations;" and *Drinking Water Regulations and Health Advisories* (EPA 1996).

^c Standard is for total trihalomethanes.

^d 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 1963, as amended).

^e 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

DWS = drinking water standards

L = liter

Mg = milligrams

pCi = picocuries

ppm = parts per million

µg = micrograms

yr = year

2.4.5 Surface Water Standards

The state of Washington has established surface water quality standards to protect public health and public enjoyment of the waters and for the propagation and protection of fish, shellfish, and wildlife. The standards apply to all surface water and water courses within the jurisdiction of the state of Washington. For the Hanford area, this primarily encompasses the Columbia River. The standards are contained within WAC 173-201A.

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

The [Hanford Site Biological Resources Management Plan](#) (BRMP; DOE/RL-96-32) requires that all Hanford Site projects with the potential to affect biological resources adversely 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 U.S.C. 1531), the [Migratory Bird Treaty Act of 1918](#) (MBTA; 16 U.S.C. 703), and the [Bald and Golden Eagle Protection Act](#) (16 U.S.C. 668–668c) as well as [Executive Order 11988, “Floodplain Management,”](#) and [Executive Order 11990, “Protection of Wetlands.”](#) 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 158 ecological compliance reviews requested during FY 2016, including 143 reviews to support general Hanford Site activities and 15 reviews for River Corridor environmental restoration activities. By comparison, 188 ecological compliance reviews were performed in 2015 including 155 reviews to support general Hanford Site activities and 33 reviews for River Corridor environmental restoration activities.

2.5.1.1 Endangered Species Act of 1973 (16 U.S.C. 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 U.S.C. 1531) as either threatened or endangered ([50 CFR 17, “Endangered and Threatened Wildlife and Plants,”](#) Subpart B, “Lists”) and occur onsite. Critical habitat for these species has been designated within the Hanford Reach. The bull trout (*Salvelinus confluentus*) is also listed under 16 U.S.C. 1531 and may occasionally occur in the Hanford Reach; critical habitat for bull trout was designated in the Hanford Reach in 2010 (USFWS 2010). The [Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout](#) (DOE/RL-2000-27) is in place for all three fish species. Two plant species, the Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Physaria douglasii* ssp. *tupleshensis*) are now listed under 16 U.S.C. 1531. Other species on the Hanford Site are listed by the WDFW as endangered, threatened, or sensitive (see Section 11.2).

2.5.1.2 Migratory Bird Treaty Act (16 U.S.C. 703). The MBTA prohibits taking or disturbing listed migratory birds or their feathers, eggs, or nests. Over 200 species of birds that regularly occur on the Hanford Site are protected under this Act. 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 BRMP (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. Hanford Site biologists maintain migratory bird permits issued by the USFWS that allow for certain MBTA-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 U.S.C. 668). 16 U.S.C. 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. The [Bald Eagle Management Plan for the Hanford Site, South](#)

[Central Washington](#) (DOE/RL-94-150) directs 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 and establishes guidelines for the protection of perches, roosts, and 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.

2.5.1.4 Executive Orders 11988 and 11990. Executive Order 11988 and Executive Order 11990 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* (33 U.S.C. 1251), 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

CD Currie

The [Department of Energy Management of Cultural Resources](#) (DOE P 141.1) requires compliance with cultural resource-related laws and regulations to include the [Antiquities Act of 1906](#) (54 U.S.C. 320301-320303), [Historic Sites Act of 1935](#) (54 U.S.C. 320301-320303; 18 U.S.C. 1866(b)), [National Historic Preservation Act of 1966](#) (54 U.S.C. 300101), NEPA (42 U.S.C. 4321 et seq.), [Archaeological and Historic Preservation Act of 1974](#) (54 U.S.C. 312501-312508), [American Indian Religious Freedom Act of 1978](#) (42 U.S.C. 1996), [Archaeological Resources Protection Act of 1979](#) (16 U.S.C. 470aa-mm), and [Native American Graves Protection and Repatriation Act](#) (Public Law 101-601).

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

Executive orders applicable to cultural resources include [Executive Order 11593, “Protection and Enhancement of the Cultural Environment”](#); [Executive Order 13007, “Indian Sacred Sites”](#); [Executive Order 13175, “Consultation and Coordination with Indian Tribal Governments”](#); [Executive Order 13287, “Preserve America”](#); and [Presidential Proclamation 7319, Establishment of the Hanford Reach National Monument](#) (65 FR 37253). Refer to Section 11.3 for details regarding the Hanford Site Cultural and Historic Resources Programs.

2.6 Sustainability Statutes

JR Draper

The federal government is committed to avoiding the depletion of natural resources. Federal requirements and guidance have been initiated for agencies to follow. The following are additional statutes implemented at the Hanford Site.

2.6.1 Chemical Management Systems

ML Hermanson

Each Hanford Site contractor maintains a formal program to manage chemicals used by their respective contracts. These chemical management programs apply to the acquisition, use, storage, transportation, and final disposition of all chemicals used at Hanford. A central sitewide information system (The Safety Data Sheets-Material Safety Data Sheets [SDS-MSDS] Database), used by all Hanford Site contractors, maintains an inventory of chemical product SDS and MSDS. The SDS-MSDS Database is available to all Site employees with access to the Hanford Local Area Network. An information only copy of the SDS-MSDS Database has been made available outside the Hanford Local Area Network in a public domain. This public domain copy makes the manufacturers SDS and MSDS documents available to public emergency responders, should the need arise, when any chemicals managed by a Hanford contractor are shipped offsite. The SDS-MSDS Database is also the information point of entry for the Hanford Site's Chemical Inventory Tracking System (CITS).

Each chemical product is entered into the CITS Database and is profiled identifying information such as the percentage of pure chemical constituents; Specific Gravity; flash point; physical state; National Fire Protection Association (NFPA) 704 classification; Occupational Safety and Health Administration [29 CFR 1910.1200, "Hazard Communication"](#); hazard class; and category. Codes are applied to each chemical constituent that identify reporting requirement categories.

Hanford Site contractors assign personnel to enter information into CITS to track the inventory of their company's chemicals from acquisition, use, storage, and transportation through final disposition. Using the CITS inventory quantity and location data combined with the chemical product profile information, data sets are generated to support company hazard communication and required reporting such as EPCRA Toxic Release Inventory, NFPA 1 Maximum Allowable Quantity (MAQ) limitations, and DOE Sustainable Environmental Stewardship goals.

2.6.2 Pollution Prevention Program (42 U.S.C. 133)

MM Rehberg

The [Pollution Prevention Act of 1990](#) (42 U.S.C. 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 Sustainability Plan (HNF-54800) was created to promote sustainability, natural and cultural resource preservation, and the integration of sustainable practices into management functions and mission activities. DOE is responsible for the Hanford Site Sustainability Plan and provides the Site Sustainability Guidance to Hanford Site contractors to build a comprehensive approach to site sustainability. This plan provides goals and expectations for the implementation of energy conservation opportunities, water conservation initiatives, greenhouse gas emission reductions, waste minimization, and pollution prevention.

DOE O 436.1, *Departmental Sustainability*, establishes pollution prevention and environmental stewardship requirements. In accordance with these requirements, pollution prevention and waste minimization activities are documented, tracked, and reported. Table 2-7 summarizes Hanford Site pollution prevention and waste minimization quantities recycled in FY 2016.

Table 2-7. Recycle Quantities.

Material	FY 2016 Total (metric tons)
<i>Non-hazardous Solid Wastes</i>	
Cardboard	89.10
CI Shredded Paper	616.26
Furniture	142.80
Plastic Bottles	36.39
Tires	42.51
Wood Pallets	60.85
Activated Carbon	36.29
Ferrous Metal	124.18
Non-ferrous Metals	18.60
Software/Media	3.62
Aluminum Cans	2.36
MSA Zero Waste Picnic	0.16
Subtotal	1173.12
<i>Regulated Solid Wastes</i>	
Aerosol Cans	0.00
Antifreeze	2.81
Antifreeze – Fleet	2.28
Ballasts	2.14
Batteries	3.89
Fluorescent Bulbs	9.11
Lamps	0.00
Lead Acid Batteries	24.20
Lead Acid Batteries (Fleet)	11.65
PCB Waste Oil <50ppm	4.33
Toner Cartridges	5.35
Used Engine Oils (Fleet)	17.97
Used Oil	27.13
WCH Cartridge	0.58
Subtotal	111.44
TOTAL	1284.45

2.6.2.1 Pollution Prevention and Waste Minimization Accomplishments and Awards. The Hanford Site received one DOE, federal agency, state agency, or industry-sponsored award for pollution prevention and waste minimization accomplishments in CY 2016. The Green Electrics Council notified The Hanford Site that they received a three-star 2017 Electronic Product Environmental Assessment Tool (EPEAT) Purchasers Award for the combined application MSA submitted on behalf of MSA, CHPRC, and WRPS for CY 2016 (Figure 2-1). The goal of the EPEAT Purchaser Awards is to recognize excellence in the procurement of green and sustainable electronics among a wide range of organizations. The EPEAT-registered product categories are computers and displays, imaging equipment, and televisions with rating tiers of gold, silver, and bronze. EPEAT Purchasers earn one star for each product category for

which they have a written policy in place that requires the purchase of EPEAT-registered electronics registered in the EPEAT green-rating system. For 2016, those who received EPEAT Awards were collectively responsible for more than \$16.8 million in energy savings, greenhouse gas reductions equivalent to removing 29,786 passenger cars from the road for a year, and a reduction of more than 702 metric tons of hazardous waste.



Figure 2-1. The 2017 EPEAT Purchaser Awards Reception Featuring Representatives from DOE, EPEAT, Green Electronics Council, MSA, and Other Award Winners.

2.6.2.2 Accomplishments. The Hanford Site has recycled 85% of non-hazardous solid waste and certain hazardous waste, excluding construction and demolition (C&D) debris. In 2016, 1,284 metric tons of non-hazardous (i.e., plastic, aluminum, cardboard, paper, wood, and metal) and hazardous (i.e., antifreeze, batteries, bulbs, and oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Along with material recycling and diversion, the Site strives to reduce greenhouse gases Scopes 1, 2, and 3. Emissions for FY 2016 decreased from FY 2015 largely due to a decrease in facility energy use and non-fleet fuel use, and an increase in waste diversion from landfills. Reported greenhouse gas emissions for FY 2016 were 46,829 metric tons of carbon dioxide equivalent compared with 102,645 metric tons carbon dioxide equivalent from the FY 2008 baseline and 71,693 metric tons carbon dioxide equivalent reported for FY 2015. There was a 34.5% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2016 from the FY 2008 baseline; emissions in FY 2016 were 27,259 metric tons carbon dioxide equivalent, whereas emissions in FY 2008 were 41,426 metric tons carbon dioxide equivalent. Greenhouse gas emissions from employee commuting, business travel, offsite wastewater treatment, and contracted solid waste disposal are primarily dependent on work locations and the number of workers employed at the Hanford Site.

During FY 2016, contractors at the Hanford Site continued to divert C&D from landfill disposal. The Hanford Site diverted approximately 59% (2,028 metric tons) of C&D debris from the inert landfill. Hanford continues to make efforts to divert C&D materials suitable for reuse and recycle from landfills. One of the larger contributors of C&D diversion in FY 2016 was from utilizing road repair debris for structural base and wood utility poles for fence posts as part of the Hanford Site's footprint reduction

scope of work. The following are some ongoing Hanford Site projects and operations expected to increase the generation of C&D debris in FY 2017:

- Eleven miles of electrical distribution line removal
- Rebuild of 1st St. from Canton Ave. to the IDF entrance
- Pump-and-treat filter upgrades
- Land clearing operations for construction
- Reducing waterline pipe size and runs.

2.6.3 Environmental Orders

One DOE order and one Presidential Executive Order address sustainability and are complied with at the Hanford Site.

Executive Order 13693 superseded Executive Order 13423 and 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 13693 superseded Executive Order 13514 and 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 stormwater 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 Hanford 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 integrated with the Hanford Site operational plans. In addition, the Order requires developing an EMS certified to or conforming with the ISO 14001:2015 standard, submittal of sustainability goal data and reports as well as EPCRA reporting. Implementation of DOE orders and executive orders by Hanford Site contractors is addressed in Section 3.0.

As the Hanford Site services and infrastructure contractor, MSA updated the sustainability plan (HNF-54800) for the Hanford Site in 2016 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 2016, 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

ME Carlson

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 2016. 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 a

Category 4 occurrence with potential environmental implications that occurred on the Hanford Site during the reporting period and the discoveries of legacy contamination.

2.7.4.1 Discovery of Legacy Contamination. Each year on the Hanford Site, legacy contamination is spread from 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 deposit contaminated feces outside of the contaminated area. Birds build nests and occasionally use materials from contaminated areas, resulting in contamination transfer to uncontaminated areas. Of these three biological vectors, contaminated tumbleweeds occur most frequently and have the potential to transfer contamination the farthest distance from the original locations. High winds may contribute to the spread of legacy contamination beyond posted areas. Reports of legacy contamination that are discovered throughout the year are consolidated into quarterly reports. In 2016, there were 47 documented occurrences of legacy contamination.

2.8 Standards and Permits

JK Perry, RA Kaldor, M Kamberg, 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 2-8.

Table 2-8. Environmental Permits. (3 Pages)

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 (Ecology 2012). 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 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 FF-01) is issued to RL by WDOH. 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 and is incorporated into the Hanford Site Air Operating Permit as an Attachment, pursuant to WAC 246-247-060(7).

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 2-8. Environmental Permits. (3 Pages)

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 DOE-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. This permit expires November 30, 2021.
HAN002 through HAN075 permit onsite sewage systems to operate on the Hanford Site. WDOH issues these permits.
Permit ST-0004500, State Waste Discharge Permit, allows treated wastewater from the Effluent Treatment Facility to be discharged to the State-Approved Land Disposal Site. This permit is effective until December 31, 2019.
Permit ST0004502, State Waste Discharge Permit, allows treated effluent from the 200-East and 200-West Areas to be discharged to the 200 Areas Treated Effluent Disposal Facility. This permit is effective until June 30, 2017. ST0004502 requires reapplication for permit renewal by June 30, 2016. The permit renewal application was verified as having been received by Washington State Department of Ecology on June 28, 2016.
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 stormwater discharges at the Hanford Site. This permit expires December 31, 2018.
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 provides domestic wastewater treatment for the 200-West and 600 Areas, and treatment for domestic wastewater hauled from the 200-East Area and other locations within the Hanford 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 stormwater associated with Ready Mix Concrete operations. Bechtel National is the permit owner. This permit expires March 31, 2021.
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 Bechtel National, Inc. as owner/operator. The Pit 30 Quarry supports the construction of the WTP, and the primary function is making construction sand and gravel. This permit expires March 31, 2021.
Wildlife Permits
Permit MB60138B-1, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to DOE-RL, authorizes the collection of migratory birds for ecological monitoring, and danger to human safety and health including control of contamination. This permit expires March 31, 2018.
Permit MB05788C-0, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to DOE-RL, authorizes the trimming and maintenance of a Bald Eagle nest located on a Bonneville Power Administration Tower. This permit expires December 31, 2017.
Review Reference Number 13260-2009-I-0121, Federal Fish and Wildlife Section 10 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 15-221a, Scientific Collection Permit issued by WDFW to MSA for May 2015 through May 2016 (extended through June 2016), authorizes food fish, shellfish, game fish, and wildlife collection for research purposes. This permit is renewed annually.
Permit 16-250, Scientific Collection Permit issued by WDFW to MSA for June 2016 through June 2017, authorizes the collection of food fish, shellfish, game fish, and wildlife for research purposes. This permit is renewed annually.

Table 2-8. Environmental Permits. (3 Pages)

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 Ave. Seattle, WA 98101	U.S. Department of Energy Richland Operations Office 825 Jadwin Ave. Richland, WA 99352
U.S. Fish and Wildlife Service Migratory Bird Permit Office 911 NE 11th Ave. Portland, OR 97232-4181	Washington State Department of Health P.O. Box 47890 Olympia, WA 98504-7890	

2.9 Environmental Noncompliance

JW Cammann

Hanford Site operations are affected and, in many cases, regulated by numerous federal and state agencies enforcing legal requirements that address environmental compliance. For example, the DOE has sole authority to take action on matters under the AEA. In some cases, other federal agencies such as the Council on Environmental Quality, EPA, and U. S. Fish and Wildlife Service have authority to regulate activities pursuant to the NEPA; CERCLA; *Endangered Species Act*; and MBTA. The EPA has delegated authority to the State of Washington Departments of Ecology and Health to regulate activities in accordance with the RCRA, *Clean Air Act*, and *Clean Water Act*. In still other cases, state laws for licensing and permitting apply to activities and have resulted in the Hanford Site Radioactive Air Emissions License, RCRA Permit, Air Operating Permit, and State Waste Discharge Permits.

In general, the laws, regulations, and other requirements applicable to Hanford Site operations include, but may not be limited to, those that address environmental quality; air quality and noise; water resources; hazardous waste and materials management; radioactive waste and materials management; ecological resources; cultural and paleontological resources; worker safety and health; radiological safety and radiation protection; transportation; emergency planning, pollution prevention, and conservation; and environmental justice. It is DOE's policy to carry out its mission in a regulatory compliant and sustainable manner to maximize energy and water efficiency; minimize chemical toxicity and harmful environmental releases; promote renewable and other clean energy development; and conserve natural, cultural, and ecological resources while sustaining assigned mission activities. This section discusses the environmental noncompliances alleged by regulatory agencies at the Hanford Site during CY 2016.

2.9.1 Regulatory Agencies

During CY 2016, there were 27 regulatory agency compliance actions filed against the DOE and its contractors for alleged violations of regulatory requirements (1 by WDOH, 25 by Ecology, and 1 by EPA Region 10) or other enforceable agreements. Twenty-four of the 27 compliance actions resulted from regulatory agency inspections of DOE facilities on the Hanford Site (see Section 2.1.2.2). The compliance actions resulted in 128 concerns and 66 compliance actions. DOE-RL was fined \$50,000 for alleged improper container labeling, inadequate waste designations, incomplete waste inventory records, noncompliant inspection logs, failure to conduct weekly inspections, and universal waste accumulation at T-Plant. On September 12, 2016 DOE-RL's Plateau Remediation Contractor appealed the \$50,000 fine to the Pollution Control Hearing Board. On June 29, 2017 DOE-RL's Plateau Remediation Contractor and

Ecology signed a [“Settlement Agreement and Joint Motion to Dismiss”](#) (CHPRC-1702829). The agreement requires establishment of a 90-day hazardous waste accumulation area at the T-Plant Complex and complete waste designation within defined time periods. The agreement also requires updating of the facility operating record for the T-Plant Complex.

Table 2-9 summarizes the alleged environmental noncompliances by program area. Table 2-10 summarizes the 27 alleged environmental noncompliances filed against the DOE and its contractors during CY 2016 including a description of the alleged noncompliances. Figure 2-2 shows alleged environmental noncompliance concerns, violations, and associated fines.

Table 2-9. Alleged Environmental Noncompliance Summary by Program Area, 2010–2015.

Program Area	2011	2012	2013	2014	2015	2016
CAA	0	0	4	2	3	1
CWA	0	0	0	0	1	0
RCRA	1	2	4	7	16	22
CERCLA	0	3	1	0	0	1
Others	1	2	1	1	7	3
Total Notices of Violation	2	7	10	10	27	27

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2016. (4 Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
Ecology	2017-05	ECOLOGY NOTICE OF DEFICIENCY REGARDING CLOSURE NOTICE FOR CONTAINER STORAGE AREAS LOCATED IN 400 AREA WASTE MANAGEMENT UNIT	Failure to submit closure notice for 400 Area Waste Management Unit (WMU) Interim Storage Facility (ISA) and Fuel Storage Facility (FSF) per WAC 173-303-610(3)(c) and RCRA Permit.
Ecology	2017-04	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE VIOLATIONS BASED ON 6/7-9/2016 GROUNDWATER OPERATION AND MAINTENANCE INSPECTION	Incomplete inspection records, no specific conductance exceedances confirmation sampling, failure to sample for ICP metals (mercury, selenium, and lead), failure to implement groundwater QA program.
Ecology	2017-03	ECOLOGY WARNING LETTER FOR ALLEGED DANGEROUS WASTE VIOLATIONS AT PUREX PLANT AND PUREX TUNNELS BASED ON 4/28/2016 INSPECTION	Failure to determine whether a white powder discovered during the 2015 annual surveillance of the PUREX Plant and PUREX Tunnels designates as dangerous waste under WAC-173-303.
Ecology	2017-02	ECOLOGY WARNING LETTER FOR ALLEGED DANGEROUS WASTE VIOLATIONS AT LLBG MIXED WASTE TRENCHES 31/34 BASED ON 5/11/2016 INSPECTION	Dangerous waste containers not properly marked/labeled with major risks, full printed names on inspection logs, fire extinguisher locations and evacuation routes in Contingency Plan.
Ecology	2017-01	ECOLOGY WARNING LETTER FOR ALLEGED VIOLATIONS OF DANGEROUS WASTE REGULATIONS AT CENTRAL WASTE COMPLEX BASED ON INSPECTION ON 6/13/2016	Transfer dangerous waste stored in Container #Z7610-210 to a container that is in good condition or overpack Container #Z7610-210 into a container that is in good

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2016. (4 Pages)

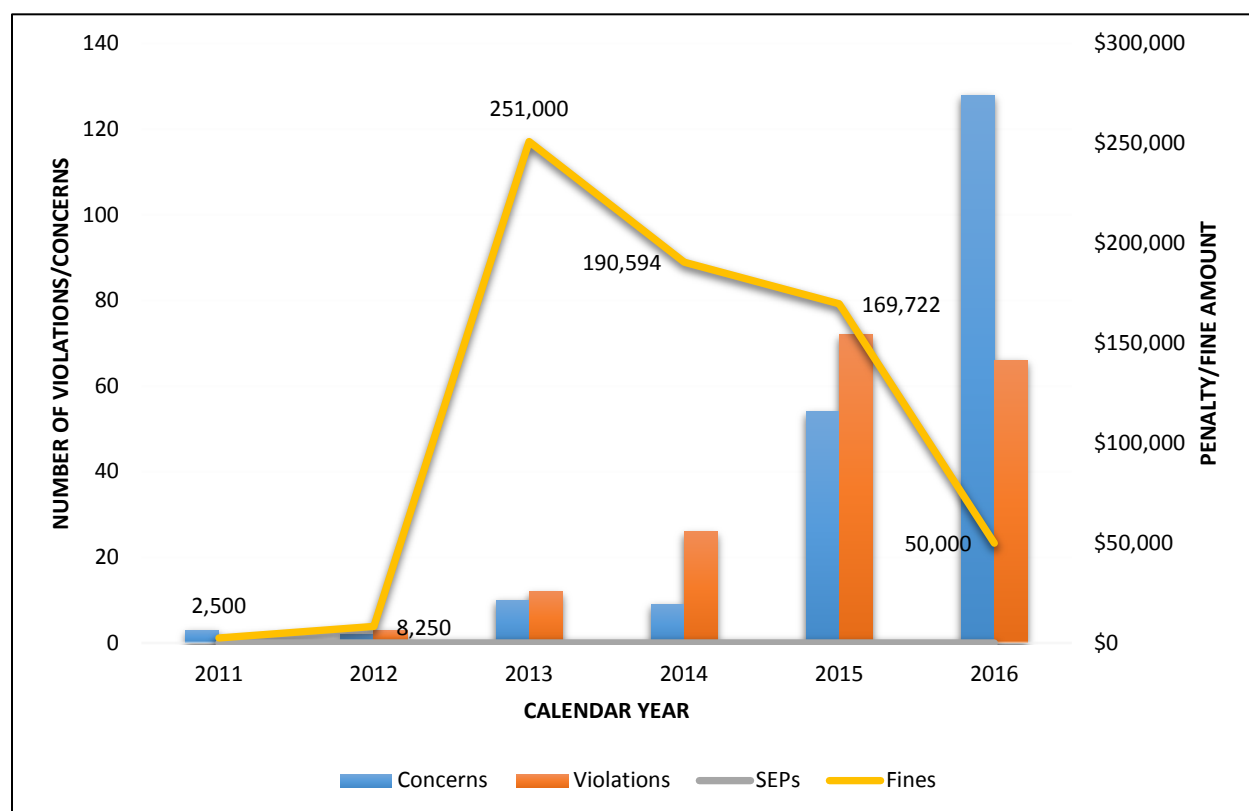
Agency	Document Number	Title	Alleged Noncompliance Description
			condition; container labeling with major risks.
Ecology	2016-28	ECOLOGY WARNING LETTER BASED ON INSPECTION OF B-PLANT ON 4/28/2016	Failure to place time of inspection on round sheets; failure to use full printed name and signature on round sheets.
Ecology	2016-27	INITIATION OF DISPUTE RESOLUTION PER TPA ACTION PLAN SECTION 9 REGARDING NEED FOR PUREX CANYON CLOSURE PLAN	Failure to develop and maintain a closure plan for PUREX Canyon in the operating record in accordance with 40 CFR 265 Subpart G and 265.197.
Ecology	2016-26	ECOLOGY WARNING LETTER BASED ON SITEWIDE INSPECTION OF DANGEROUS WASTE TRAINING PROGRAM ON 1/12/2016	Develop Dangerous Waste Training Plans for 183-H Solar Evaporation Basins and 300 Area Process Trenches, place in operating record. Revise TFC-PLN-07 Dangerous Waste Training Plan to include missing job titles/descriptions.
Ecology	2016-25	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT WESF ON 5/26/2016	Inspection records without dates, times, and printed name and handwritten signature of the inspector per WAC 173-303-320(2)(d).
Ecology	2016-24	ECOLOGY COMPLIANCE INSPECTION REPORT, ADMINISTRATIVE ORDER, AND NOTICE OF PENALTY FOR DANGEROUS WASTE REGULATION VIOLATIONS AT T-PLANT	Improper container labeling, inadequate waste designations, incomplete waste inventory records, noncompliant inspection logs, failure to conduct inspections weekly, universal waste accumulation exceeding 1 year allowed.
Ecology	2016-23	ECOLOGY WARNING LETTER BASED ON 3/23/2016 DANGEROUS WASTE COMPLIANCE INSPECTION AT WASTE RECEIVING AND PROCESSING FACILITY	Within 60 days provide documentation that the roof leaks in 2404-WB have been repaired or placed on a schedule for remedy.
Ecology	2016-22	NOTICE OF CORRECTION FOR 241-AZ-301 CONDENSATE WASTE DESIGNATION AND LOADING STATION	Correct the designation of the AZ-301 condensate and provide Ecology with a revised designation.
Ecology	2016-21	ECOLOGY WARNING LETTER BASED ON DANGEROUS WASTE COMPLIANCE INSPECTION AT 242-A EVAPORATOR ON SEPTEMBER 23, 2015	Inadequate dangerous waste signage on loading room rollup door; incomplete dangerous waste inspection reports; missing fire system inspections; inadequate personnel training.
Ecology	2016-20	WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION ON 3/24/2016 AT THE 241-CX TANK SYSTEM	Incomplete inspection log sheets.
Ecology	2016-19	DISAPPROVAL OF HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER CHANGE CONTROL FORM M-89-16-01	Ecology disapproval of TPA Change Control Form M-89-16-01 regarding TPA Milestone M-089-06 for the 324 Building Closure Plan.
Ecology	2016-18	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT ETF/LERF ON JUNE 25, 2015	Well identification tags lacking, Groundwater Monitoring Plan updates, permit modifications lacking, inspection log deficiencies, operating record deficiencies,

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2016. (4 Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
			missing integrity assessments, and improper DW accumulation.
Ecology	2016-17	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT HEXONE STORAGE AND TREATMENT FACILITY ON 3/14/16	Incomplete information on Hexone Storage and Treatment Facility inspection record; missing time of inspection.
Ecology	2016-16	ECOLOGY NOTICE OF CONCERNS BASED ON CENTRALIZED CONSOLIDATION/RECYCLE CENTER INSPECTION ON 11/17/2015	No regulatory noncompliances. Ecology identified three concerns that do not require a response including UW accumulation longer than 1 year at CCRC, information on bill of lading, and need to update CCRC management plan.
Ecology	2016-15	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT 222-S LABORATORY DANGEROUS-MIXED WASTE STORAGE AREAS ON 9/22/2015	Noncompliance with dangerous waste regulations regarding inspection reports and inclusion of printed name of inspector, signature, notation of observations, date, and nature of repairs or remedial actions.
Ecology	2016-14	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT SINGLE SHELL TANK FARM SYSTEM ON 7/28/2015	Violation of dangerous waste regulations regarding proper filling out of hazardous waste manifests with physical site address and failure to conduct inspections every 7 days.
Ecology	2016-13	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT SOLID WASTE OPERATIONS COMPLEX ON 10/22/2014	Missing CWC annual ignitable/reactive inspection records for 2009; inspections not being performed annually; incomplete inspection records missing time of inspection; DWMUs not authorized to treat/store dangerous/mixed waste.
Ecology	2016-12	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT PUREX PLANT AND STORAGE TUNNELS ON 3/12/2015	Noncompliance with dangerous waste regulations involving inspection record deficiencies, Building Emergency Plan deficiencies, inadequate tank signage/labeling, inadequate inspections.
WDOH	2016-11	GENERAL NOTICE OF POTENTIAL VIOLATION OF CODE OF FEDERAL REGULATIONS 40 CFR 61.93 AND HANFORD RADIOACTIVE AIR EMISSIONS LICENSE FF-01	Failure to continuously monitor stack air emissions or operating outside of sampling system design parameters at emission units 291-A-1, 296-B-1, and 296-H-212.
EPA	2016-10	FAILURE TO COMPLY WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS) AT THE 618-10 BURIAL GROUND	Failure to comply with Applicable or Relevant and Appropriate Requirements (ARARs) at the 618-10 Burial Ground leading to release of radioactive contaminants into areas accessible by the public.
Ecology	2016-09	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT DOUBLE-SHELL TANKS SYSTEM ON 6/30/2015	Lack of closure schedule for 204-AR WUS tank system; incomplete inspection records missing name of inspector, date/time of inspection, observations, and remedial/repair actions.

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2016. (4 Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
Ecology	2016-08	INITIATION OF DISPUTE RESOLUTION ON DISAPPROVAL OF TPA CHANGE CONTROL FORMS M-47-15-01 AND M-90-15-01	This involves initiation of dispute resolution to address DOE-ORP proposed changes to TPA milestones that were disapproved by Ecology.
Ecology	2016-07	ECOLOGY WARNING LETTER FOR DANGEROUS WASTE COMPLIANCE INSPECTION AT CENTRAL WASTE COMPLEX ON 4/1/2015	Violations of WAC 173-303 relating to documentation for disposal, containers in poor condition, inability to inspect containers, containers lacking accumulation start dates, and incomplete inspection records.

**Figure 2-2. Alleged Environmental Noncompliance Violations, Concerns, and Associated Fines Summary.**

NOTE 1: Supplemental environmental projects (SEPs) performed to benefit the local community in lieu of a penalty payment.

NOTE 2: The \$50,000 fine in CY 2016 was appealed to the Pollution Control Hearing Board. On June 29, 2017, DOE-RL's Plateau Remediation Contractor and Ecology signed a "Settlement Agreement and Joint Motion to Dismiss" (CHPRC-1702829).

To avoid litigation expense and to settle administrative or judicial claims or causes of action a regulatory agency may have against them, DOE and its contractors, without admitting fault or liability, may enter into Agreed Orders and other negotiated regulatory agreements to resolve regulatory agency allegations asserted therein. Nothing in the agreements or in the execution and implementation of the terms and conditions of the agreements shall be taken as an admission of liability by DOE and its contractors, and DOE and its contractors neither admit nor deny the specific factual allegations contained therein. Regulatory agencies progress through a variety of tools to gain compliance, usually starting with a warning letter or letter of noncompliance. If the warning does not result in compliance, then enforcement actions can escalate to notices, orders, or civil penalties issued by the Washington State Attorney General. Although DOE and its contractors may receive warning letters from regulatory agencies, such letters do not constitute formal enforcement actions represented by notices, orders, or civil penalties issued by the Washington State Attorney General that may be appealed.

2.9.2 Waste Water Permit Deviations

M Kamberg

During CY 2016, there were 11 non-compliances reported to regulatory agencies for wastewater permit deviations (2 to WDOH, 9 to Ecology). Of the 11 events, 9 of them involved State Waste Discharge Permits, and 2 of involved Large Onsite Sewage System permits. In all cases, the required actions to stop and correct the non-compliant conditions were taken and regulatory notifications were made in accordance with the applicable permit requirements. Table 2-11 shows the dates of non-compliance, applicable Permit Numbers, Regulatory Agencies and Reasons for each deviation.

Table 2-11. CY 2016 Wastewater Permit Deviations.

Date	Permit Number Deviated	Reported To	Reason(s)
March 9	ST0004502	Ecology	Exceeded monthly chloroform average in February and March 2016.
April 15	ST0004502	Ecology	Missed performing required pH and conductivity surveillances from April 15 through 18, 2016, due to power outage.
April 23	ST0004511	Ecology	Outside water faucet with hose attached at MO-412 200W was left on.
June 17	ST0004500	Ecology	Leaking air vacuum relief valve in manhole MH-ETF-09.
June 20	HAN 011	Health	Lift station overfilled (2607-Z) 200-West.
September 5	ST0004502	Ecology	Leaking air vacuum relief valve in manhole TL-01.
September 12	HAN 049	Health	Air vent seepage due to blockage in distribution line between 6607-18 and 2607-EP.
October 1	ST0004502	Ecology	Unauthorized discharge of chemical rinsate from WESF to TEDF.
November 4	ST0004511	Ecology	Unplanned release during hydrotest of WTP Plant Cooling Water lines exceeded Condition S1.B.2 instantaneous flow rate limit of 150 gallons per minute.
December 14	ST0004502	Ecology	Leaking air vacuum relief valve in manhole TL-04.
December 28	ST0004502	Ecology	Nitrate analysis not performed within required hold time in December 2016.

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3.0 Environmental Management System

SL Vaughn

The U.S. Department of Energy (DOE) requires Hanford Site contractors to develop and operate under an Integrated Safety Management System (ISMS). In accordance with contract obligations, contractors maintain an Environmental Management System (EMS) that is consistent with ISO 14001, *Environmental Management Systems*, standard. In 2015, all but one Hanford Site contractor 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 applicable DOE orders and their approval dates.

Performance related to EMS must be reported annually to DOE Headquarters (DOE-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 DOE Richland Operations Office (DOE-RL) and Office of River Protection.

Table 3-1. DOE Contract Actions and Contractor Implementation. (2 Pages)

Actions, Implementation	Richland Operations Office				Office of River Protection		
	HPMC	CHPRC	MSA	WCH	WHL	BNI	WRPS
Contractor Start Date	Oct 1, 2012	Oct 1, 2008	Aug 24, 2009	Aug 27, 2005	Nov 22, 2015	Dec 11, 2000	Oct 1, 2008
DOE Approval of Contractor ISMS	NA	Nov 2009	Jan 2011	Nov 2007	Oct 2016	Feb 2003	Sept 2009
Direction to Implement DOE EO 13423	Oct 2012	Oct 2008	Aug 2009	June 2009	Nov 2015	NA	Oct 2008
Direction to Implement DOE EO 13514	NA	June 2012	May 2011	Oct 2012	Nov 2015	NA	Mar 2011
Direction to Implement DOE O 430.2B	NA	June 2009	Aug 2009	June 2009	NA	NA	Oct 2008
Direction to Cancel DOE O 430.2B	NA	July 2012	July 2012	Oct 2012	NA	NA	Sept 2014
Direction to Implement DOE O 450.1A	Oct 2012	June 2009	Aug 2009	June 2009	NA	NA	Oct 2009
Direction to Cancel DOE O 450.1A	Oct 2012	July 2012	Dec 2012	Oct 2012	NA	NA	Sept 2014
Direction to Implement DOE O 436.1	Sept 2014	July 2012	July 2012	Oct 2012	Nov 2015	NA	Oct 2013
Contractor EMS Established	Oct 2012	Nov 2009	Dec 2009	Sept 2009	Sept 2016	NA	Sept 2009

Table 3-1. DOE Contract Actions and Contractor Implementation. (2 Pages)

Actions, Implementation	Richland Operations Office			Office of River Protection			
	HPMC	CHPRC	MSA	WCH	WHL	BNI	WRPS
ISO 14001 Certification	NA	Jul 2012/ 2015	Sept 2011/ 2014	NA	NA	NA	NA
DOE Declared DOE O 450.1A Conformance	NA	Dec 2009	Dec 2009	Nov 2009	NA	NA	Sept 2009
Most Recent Declaration of Conformance	March 2016	Jul 2015	Sept 2014	Sept 2015	Sept 2016	NA	Sept 2015
Contractor EMS Scorecard Rating	Green	Green	Green	Green	Green	Red	Green
EMS Scorecard for 2015	Green			Yellow			

BNI=Bechtel National, Inc.

CHPRC=CH2M Plateau Remediation Company

EMS=Environmental Management System

HPMC=HPMC Occupational Medical Services

MSA=Mission Support Alliance, LLC

WCH=Washington Closure Hanford, LLC

WHL=Wastren Advantage, Inc.

WRPS=Washington River Protection Solutions, LLC

Table 3-2. DOE Order and Executive Order Issuance.

Order	Approval Date
DOE Order 450.1	January 15, 2003
Executive Order 13423	January 26, 2007
DOE Order 430.2B	February 27, 2008
DOE Order 450.1A	June 4, 2008
Executive Order 13514	October 8, 2009
DOE Order 436.1	May 2, 2011
Executive Order 13693	March 25, 2015

As the services and infrastructure contractor for the Hanford Site, Mission Support Alliance (MSA) developed a sustainability plan (HNF-54800) for the Hanford Site in 2016 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, Departmental Sustainability](#). Environmental objectives were established and maintained in 2016, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship. Sustainability plans from fiscal year (FY) 2001 through present are available on the MSA website.

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 3-3. Hanford Site Environmental Management System Internet Links.

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

3.1 Environmental Performance Measures

In consultation with DOE and other Hanford Site prime contractors, MSA tracks environmental performance measures for the Hanford Site. Performance measures address the goals of DOE O 436.1 and [Executive Order 13693, “Planning for Federal Sustainability in the Next Decade.”](#) The measures developed in response to these 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 DOE-HQ.

3.1.1 Fleet Management

The acquisition target for alternative fuel vehicles was not met in 2016 (Figure 3-1). DOE requires that a minimum of 75% of all non-mission critical light-duty vehicles purchased during FY 2016 be alternative fuel vehicles (DOE O 436.1).

3.1.2 Alternative Fuel Use

The alternative fuel use target was surpassed for FY 2016; however, the target for petroleum-based fuel use was missed (Figure 3-2). Mission and contract structure changes since 2005 continue to challenge target achievement. 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 annually by 20% by FY 2015 or 2% annually relative to a FY 2005 baseline and maintain that level thereafter, and increase the amount of alternative fuels used annually by 10% or 2% annually by FY 2015 relative to a FY 2005 baseline and maintain that level thereafter.

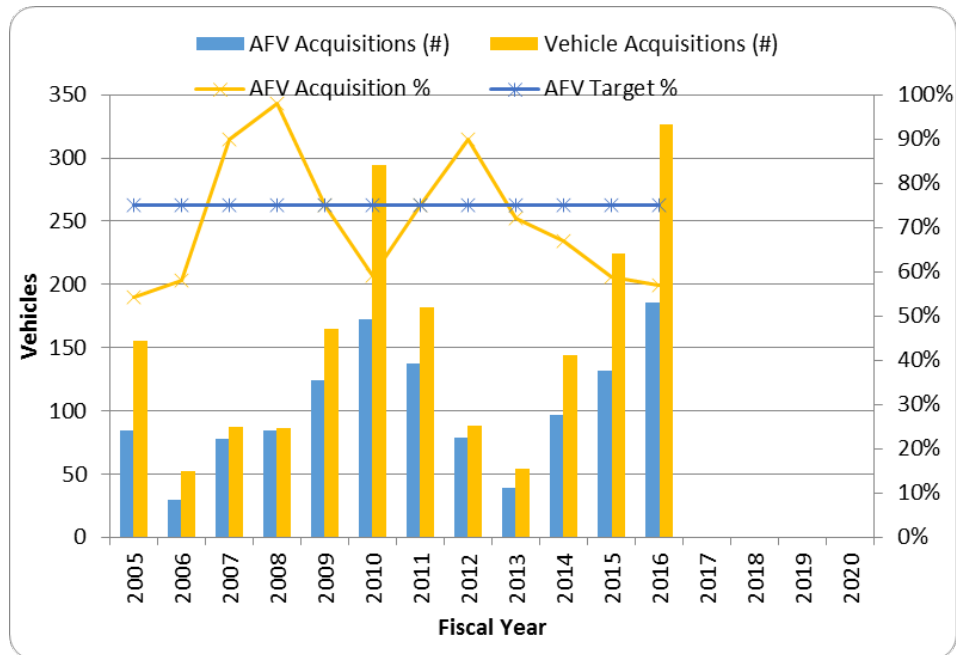


Figure 3-1. Fleet Management – Acquisitions FYs 2005–2016 with Target Objectives through 2020.

NOTE: AFV stands for alternative fuel vehicle

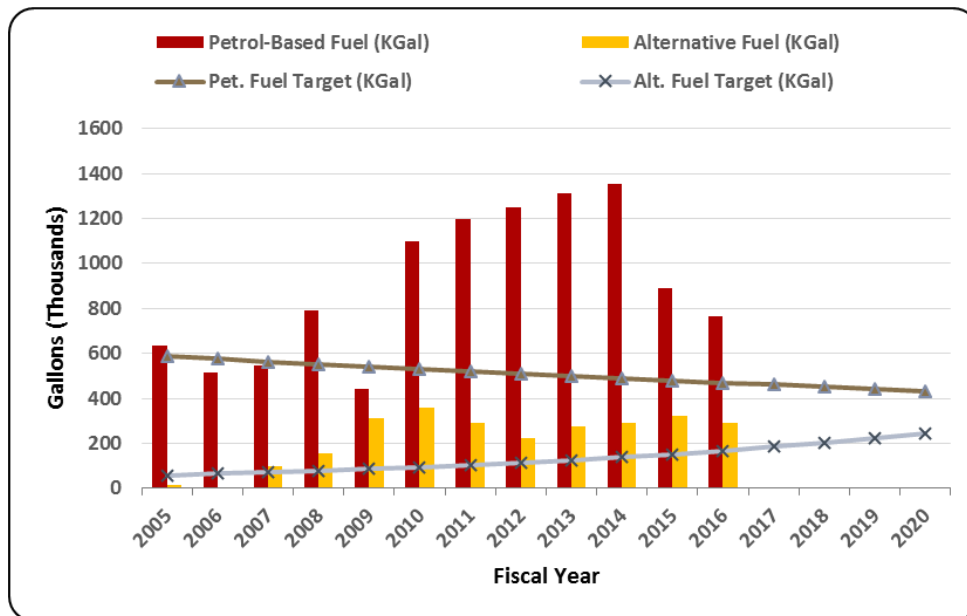


Figure 3-2. Vehicle Fuel Use – FYs 2005–2016 with Target Objectives through 2020.

3.1.3 Potable and Non-potable Water Use

The target objectives for potable and non-potable water were met in FY 2016 (Figure 3-3). As specified by Executive Order 13693, water use requirements stipulate the reduction of potable water consumption intensity by 2% annually through FY 2025 or 36% by the end of FY 2025, relative to a baseline of water consumption in FY 2007. Correspondingly, there is a requirement to reduce non-potable water use by 2% annually through the end of FY 2025 or 30% by the end of FY 2025 relative to a FY 2010 baseline.

3.1.4 Electricity Use

As directed by Executive Order 13693, this metric has changed to track renewable electric energy as a percentage of the total electricity usage. Requirements call for renewable electric energy account for not less than 10% of the total electricity use in FY 2016 to 2017 and working towards 30% of total usage by FY 2025. The target objective for renewable electric energy was met in FY 2016 (Figure 3-4) representing 28.6% of total electricity usage. Renewable electric energy is defined in Executive Order 13693 as electricity produced or displaced by solar, wind, biomass, landfill gas, ocean, geothermal, geothermal heat pumps, microturbines, municipal solid waste, or new hydroelectric generation.

3.1.5 Facility Fuel Use

The target objectives for facility fuel use were met in FY 2016 (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% annually (or 45% through the end of FY 2020) relative to the FY 2003 baseline.

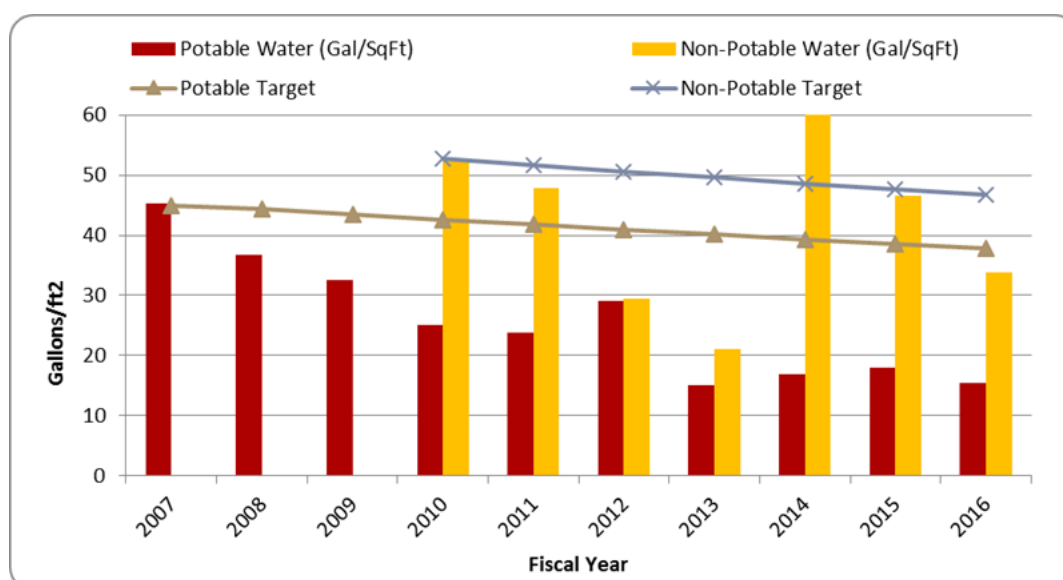


Figure 3-3. Water Use – FYs 2007–2016.

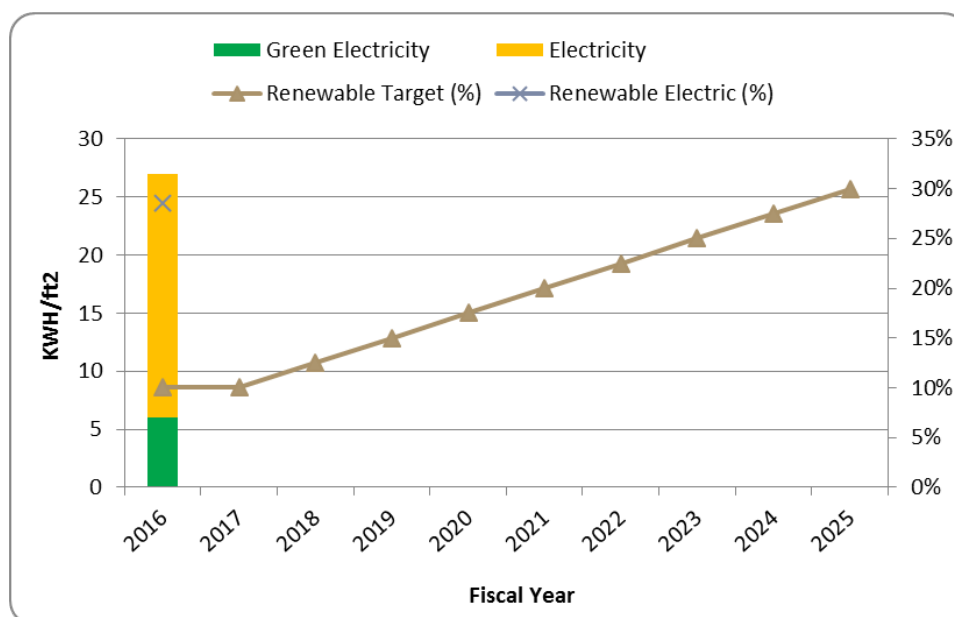


Figure 3-4. Electricity Use – FY 2016 with Target Objectives through 2025.

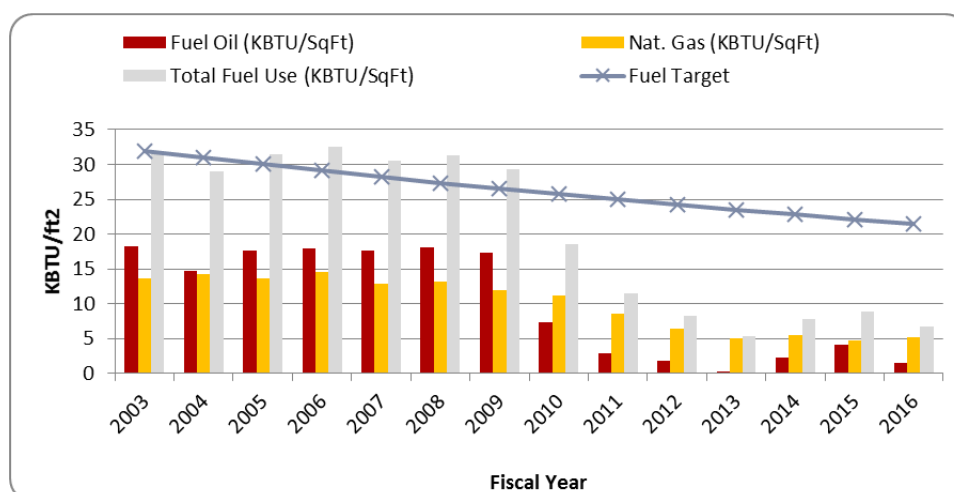


Figure 3-5. Facility Fuel Use – FYs 2003–2016.

NOTE: KBTU stands for one thousand British thermal units

3.1.6 Facility Energy Use

The target objective for facility energy use has been extended per Executive Order 13693. Requirements call for the reduction of energy use (a combination of electricity, fuel oil, and natural gas) by 25% by the end of FY 2025 or 2.3% annually relative to the FY 2015 baseline. The target objective was met in FY 2016 (Figure 3-6).

3.1.7 Electronic Product Environmental Assessment Tool (EPEAT)

The target objectives for the EPEAT were exceeded in FY 2016, with 100% of the purchases meeting the requirements (Figure 3-7). The requirements in Executive Order 13693 specify 95% of procured electronic assets (i.e., notebooks, computers, tablets, and monitors) must comply with the standard in

an effort to reduce or eliminate the environmental impacts of electronic assets by incorporating electronic stewardship practices.

3.1.8 Sanitary Waste Reduction.

The target objective for sanitary waste reduction requires the diversion of post-consumer materials suitable for reuse and recycling from landfills to a target of 50% annually by FY 2015 based on an FY 2009 baseline (Figure 3-8) and maintain that level thereafter. More Hanford Site sanitary waste was recycled than was sent to landfills in FY 2016.

3.1.9 Regulated Waste Reduction.

The target objective for regulated waste reduction was met in FY 2016 (Figure 3-9). Objectives for regulated waste reduction on the Hanford Site include eliminating or minimizing regulated waste generation 5% annually (based on FY 2009 generation) through source reduction, including segregation, substitution, and reuse. Regulated waste includes waste such as hazardous, universal, special, and state-regulated industrial 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 decreased in FY 2016 (Figure 3-10).

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

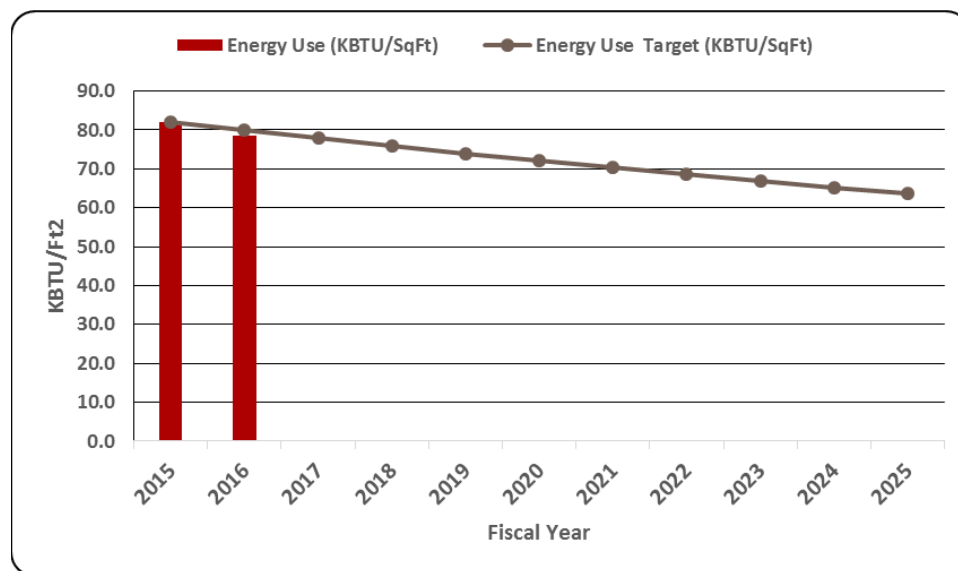


Figure 3-6. Facility Energy Use – FYs 2015-2016 with Target Objectives through 2025.

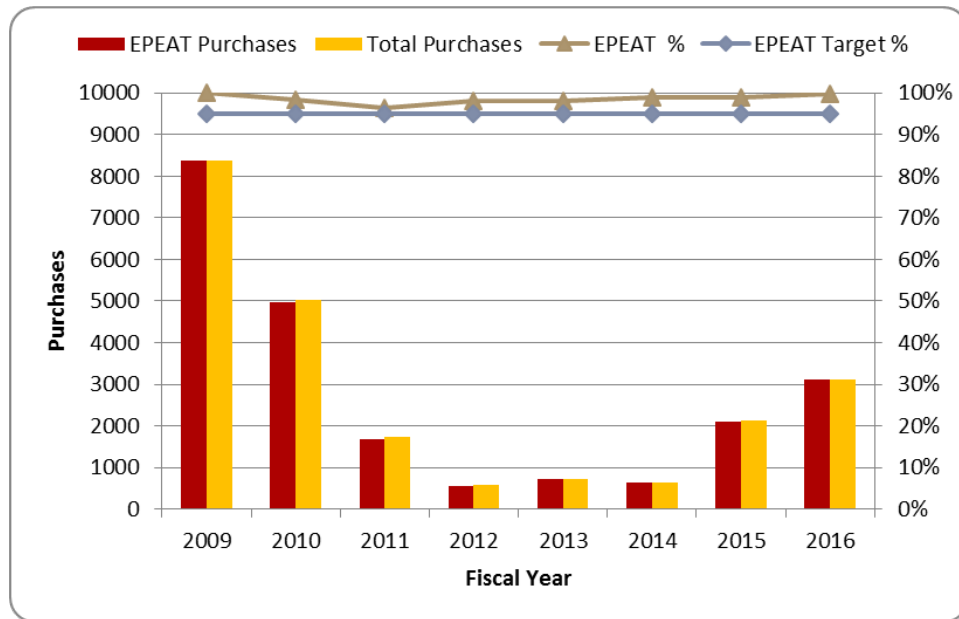


Figure 3-7. Electronic Product Environmental Assessment Tool Standards Compliance – FYs 2009–2016

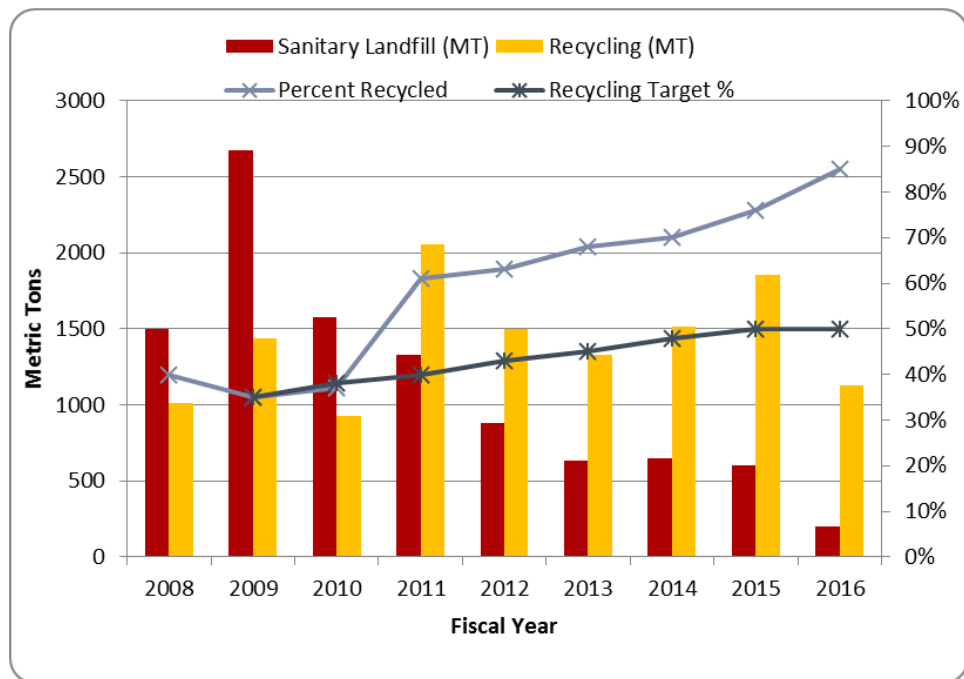


Figure 3-8. Sanitary Waste Reduction – FYs 2008–16.

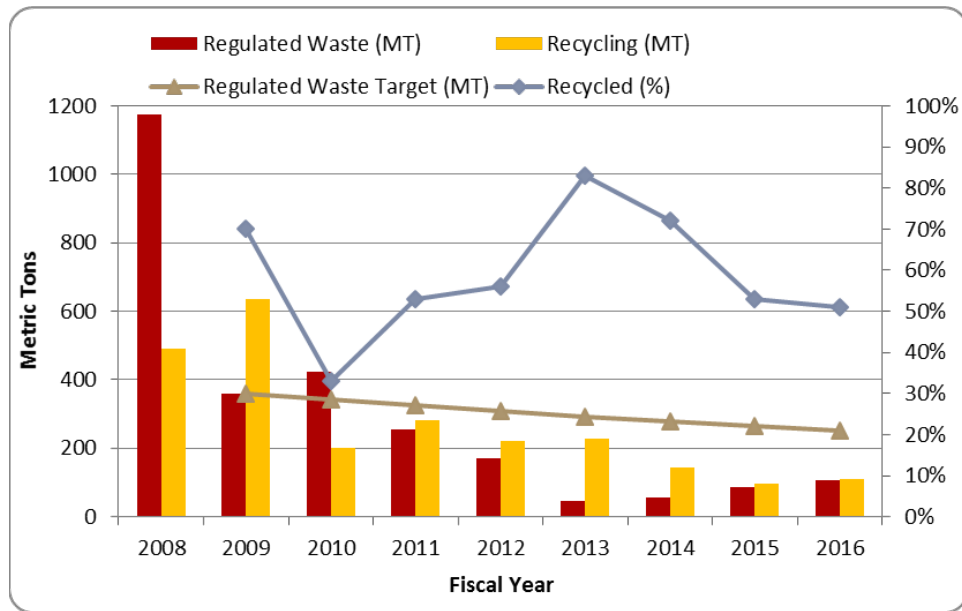


Figure 3-9. Regulated Waste Reduction – FYs 2008–2016

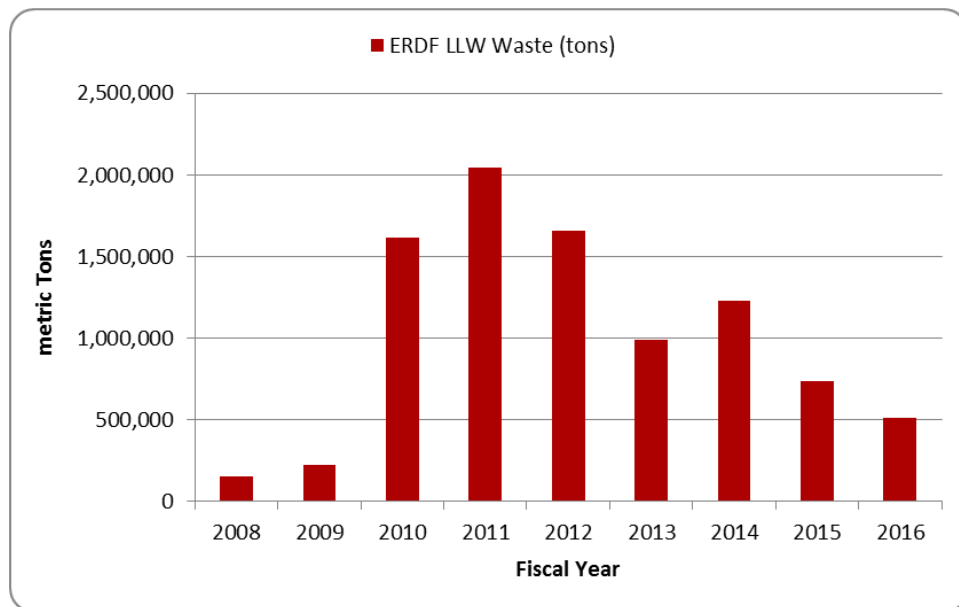


Figure 3-10. Onsite Waste Disposal – FYs 2008–2016 at the Environmental Restoration Disposal Facility.

3.2 Hanford Site Awards and Recognition

MM Rehberg

3.2.1 HPMC Occupational Medical Services

HPMC OMS self-declared conformance to ISO 14001:2004 on March 17, 2016. DOE-RL conducted the external audit on March 21, 2016. This contract requirement due April 30, 2016, was completed ahead of schedule.

3.2.2 CH2M Plateau Remediation Company

The Environmental Compliance & Quality Assurance Organization conducted an independent assessment to review implementation of CH2M Plateau Remediation Company's (CHPRC) EMS as described in PRC-MP-EP-40182, *Environmental Management System Manual*, and its conformance with ISO 14001:2004. Employee awareness of CHPRC's Environmental Policy and environmental roles and responsibilities was assessed, and an effectiveness review of FY 2015 EMS audit corrective actions was conducted. CHPRC's internal audit was followed up by a required external surveillance audit. NSF-International Strategic Registrations, Ltd., an American National Standards Institute National Accreditation Board-accredited certification body for the international standard ISO 14001, conducted its annual surveillance audit of the CHPRC EMS June 20–23, 2016. Two auditors reviewed CHPRC documents, visited four CHPRC Projects, interviewed CHPRC workers to discuss CHPRC implementation of the International Organization for Standardization (ISO) core elements, and met with CHPRC senior staff members to gauge management commitment. Five "system strengths" were noted. No non-conformances and two opportunities for improvement were issued, and no Corrective and Preventative Action Plan was necessary. The auditors concluded that CHPRC remains compliant with the ISO 14001 standard and recommended continuation of ISO 14001 certification for another year.

3.2.3 Mission Support Alliance, LLC

MSA completed its required surveillance audit for FY 2016 to maintain its ISO 14001:2004 registration with a follow up surveillance audit and reassessment audit in FY 2017 to the ISO 14001:2015 revision. MSA's EMS coordinator also presented the 2016 Environmental Leadership Award. The award was established to recognize outstanding environmental performance by employees. This year's winner was the MSA Asphalt Reuse Team.

Two road projects used pulverized, existing asphalt and recycled it for new road base. These projects established MSA's efforts in diverting construction and demolition waste from landfill as a regular practice on the Hanford Site. With about 960 and 1,900 tons of material diverted from the construction and demolition landfill, the benefits went beyond landfill diversion and demonstrated opportunities in cost savings and resource conservation.

The Hanford Site was selected recently as an honorable mention by DOE for its submission for the 2017 Presidential Migratory Bird Federal Stewardship Award. Managed by contractor MSA, Hanford's avian protection program was recognized for monitoring key avian species, evaluating potential cleanup activity impacts and taking active protective measures where needed, as well as training Site personnel about migratory bird protection and protecting and enhancing important migratory bird habitats for FY 2016. The program focused on key species including ferruginous hawks, burrowing owls, American white pelicans, bald eagles, and sage-steppe passerines (including the sagebrush sparrow).

At more than 375,000 ac (151,757 ha), the Hanford Site represents one of the largest remaining native shrub-steppe communities; with diverse habitats including cliffs and riverine, the site provides permanent or transitory habitat for more than 200 bird species. Strong relationships with agencies, such as the U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife (WDFW), and Bonneville Power Administration, led to the Hanford Site becoming a leader in developing monitoring and compliance expectations for migratory birds.

Responsible for ecological monitoring at Hanford, DOE contractor MSA was a major contributor to the 2016 Ferruginous Hawk Survey program initiated by the WDFW and the Sagebrush Songbird Survey Program, run by WDFW and the Washington Audubon Society. The company also works with local agencies, including Blue Mountain Wildlife, to rehabilitate injured birds and release of a rehabilitated owl in October 2016.

3.2.4 Washington River Protection Solutions, LLC

In 2016 and 2017 the Washington River Protection Solutions (WRPS) Quality Assurance Organization conducted an independent assessment to review implementation of WRPS's EMS as described in TFC-PLN-123, *EMS Description*, and its conformance with ISO 14001:2004. The Quality Assurance Organization performs annual independent assessments of the WRPS EMS and divides the elements of ISO evenly over a 3-year time period so that all the elements of ISO have been thoroughly assessed between the required External Independent Triennial Audits for Declaration of Conformance to the ISO 14001 Standard. The last triennial conformation audit was held in July 2015. There were no non-conformances found in either of the internal independent assessments or the 2015 triennial external audit.

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4.0 Radiological Protection and Doses

This section provides information on the Hanford Site radiological program and doses as well as cleanup activities as the U.S. Department of Energy (DOE) progresses toward site closure and the likely transfer of property to other entities. Additional information on radiation, dose rates, and dose terminology can be found in Appendix A, Helpful Information and Appendix B, Glossary.

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 from 15 to 25% at any location because of changes in soil moisture and snow cover (NCRP 1975).

The Harshaw^{TM1} thermoluminescent dosimeter (TLD) system is used to measure external radiation on the Hanford Site. This type of TLD measures very low dose rates only and is not suitable for use for personnel monitoring. 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 (mrem/day) at each location were converted to annual dose equivalent rates (mrem/yr) by averaging the daily dose rates and multiplying by 365 days/yr. The TLDs were positioned approximately 3.3 ft (1 m) above ground and were collected and read quarterly.

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.

4.1.1 External Radiation Measurements

External radiation fields were monitored in 2016 at 125 locations (Table 4-1) 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.

¹ Harshaw is a trademark of Thermo Fisher Scientific, Inc., Waltham, Massachusetts.

During 2016, 10 new TLD monitoring locations were added. These included:

- Three locations added in the 100/600 Areas to replace retired/retiring air sampling locations
- Three locations added at onsite air sampling locations supporting the Waste Treatment Plant (WTP)
- Three locations added at offsite (perimeter) air sampling locations supporting the WTP
- One reference location in Yakima.

Table 4-1. Thermoluminescent Dosimeter Locations, 2016.

Location	No. of Dosimeters
100-K Area	14
100 Area	4
200-Eastast Area and WTP	45
200-Westest Area	24
200-Northorth Area	1
300 Area	14
400 Area	7
618-10 Burial Ground	4
CVDF	4
ERDF	3
IDF	1
Perimeter	3
Reference	1
Total	125
CVDF=Cold Vacuum Drying Facility (100 K Area) ERDF=Environmental Restoration Disposal Facility (200-Westest Area) IDF=Integrated Disposal Facility (200-Eastast Area) TEDF=300 Area Treated Effluent Disposal Facility WTP= Waste Treatment Plant	

In 2015, the Hanford External Dosimetry Program's (HEDP) laboratory was relocated from its long-time location near the 300 Area to a location between the 200-East and 200-West Areas. This relocation introduced two substantial variances.

One significant difference was the higher background dose rate levels (approximately 50% higher) attributable to elevated radon levels inherent within the new HEDP facility (Figure 4-1). These background values are subtracted from the ambient dose rate levels measured in the environs to determine site-specific dose rate levels above background. This simple calculation, produced artificially, decreased dose rate values for 2015 when compared to previous years' values.

The second significant difference that occurred during 2015 was the material used for shielding the dosimeters during their residency in the HEDP facility. Prior to 2015, the shielding material used was lead, which is substantially better than the steel shielding used in 2015. The effect of this change was to

expose the dosimeters to the significantly higher background levels, discussed in the previous paragraphs, and ultimately cause a higher dose rate reading.

Due to the complexities and uncertainties imparted on the TLD data by these changes at the HEDP facility, definitive annual data comparisons for the 2016 data are impractical.

The average dose rate levels measured in the operational areas during 2016 were comparable to the previous years' levels (Figure 4-1). Individual TLD results and detailed maps of monitoring locations are available upon request.

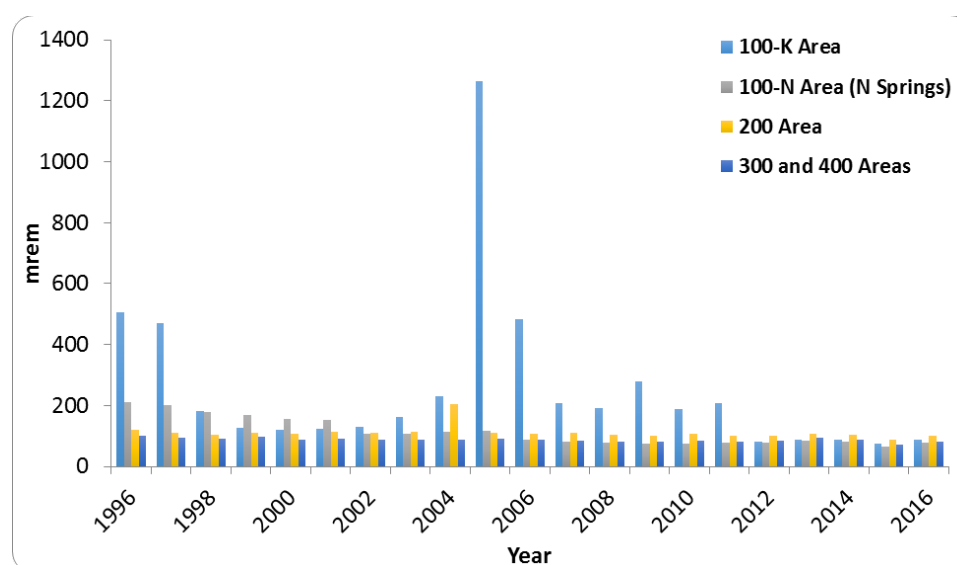


Figure 4-1. Average Thermoluminescent Dosimeter Results (mrem/year) in Selected Operational Areas.

4.1.1.1 100-K Area. As in years past, the 2016 dose rate levels 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 was transported, were noticeably higher than other TLD locations at 100-K.

4.1.1.2 100 Areas. Dose rates measured along the Columbia River shoreline in the 100-N Area (N Springs) continued to decrease during 2016. Three new locations along the river corridor were established during September to provide continued radiological monitoring at air sampling locations that were retired (100-F and Hanford Townsite), or are expected to be retired in the near future (100-D).

4.1.1.3 200-East Area. Dose rate levels measured during 2016 near the "A" and "C" Tank Farms were higher than other 200-East Area locations. Three new locations in support of the WTP were added at air sampling locations "200 ESE" (N920), "B Pond" (N924), and "WTP New Station" (N584).

4.1.1.4 200-West Area. Dose rate levels measured during 2016 near the “S” and “T” Tank Farms and at the Solid Waste Operations Complex were higher than other 200-West Area locations.

4.1.1.5 200-North. Dose rates measured in 2016 were low, and all four quarterly measurements were similar.

4.1.1.6 300 Area. Dose rate levels measured during 2016 at locations in the southern portion of the 300 Area were slightly higher (5-10%) than at other 300 Area locations.

4.1.1.7 400 Area. Dose rates measured in 2016 at all seven monitoring locations were low and similar.

4.1.1.8 Environmental Restoration Disposal Facility (ERDF). Dose rates measured in 2016 at all three monitoring locations were low and similar.

4.1.1.9 618-10 Burial Ground. Dose rates measured in 2016 at all four monitoring locations were low and similar.

4.1.1.10 Integrated Disposal Facility. Dose rates measured in 2016 were low and all four quarterly measurements were similar.

4.1.1.11 Perimeter Locations. Three locations (Ringold, west end of Fir Road, and Dogwood Met Tower) were established in January 2016 and all four quarterly measurements were similar to each other and to onsite levels.

4.1.1.12 Reference Locations. One new location was added during September to provide a reference (aka, background) dose rate level station at the Yakima airport.

4.1.2 Waste Disposal Sites Radiological Surveys

JW Wilde

During 2016, 1,149 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 along ERDF haul routes. 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.

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 in. [0.6 cm]). 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, RT Ryti, AG Fleury

Potential radiological doses to the public and biota from Hanford Site operations in 2016 were evaluated to determine compliance with pertinent regulations and limits. Potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, 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 total annual dose to a hypothetical, maximally exposed individual (MEI) in 2016 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.12 mrem (1.2 μ Sv). This dose is 0.12% of the 100 mrem (1000 μ Sv) per year public dose limit specified in [DOE O 458.1, Radiation Protection of the Public and the Environment](#). For context, a 2009 National Council on Radiation Protection and Measurements report estimated that the overall annual exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv), approximately half of which is related to natural sources and the other half attributable primarily to medical procedures.

The offsite MEI dose is one of eight radiological impacts of Hanford Site operations that are assessed in this chapter:

- 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 mi (80 km) of Hanford Site operation areas (Section 4.2.2)
- Dose for air pathways calculated using regulation-specified U.S. Environmental Protection Agency (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)

-
- Dose 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)
 - Dose to a visitor of the Manhattan Project National Historical Park (Section 4.2.4.3)
 - Dose 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 surfacewater 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 from Hanford Site sources are too small to be measured in environmental media after they are 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 onsite and offsite locations near the 300 Area, radionuclide concentrations may be distinguishable from background levels; 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 International Convention on Radiological Protection (ICRP) Publication 2 ([Permissible Dose for Internal Radiation](#) [ICRP 1959]). In the 1970s, the annual reports began to follow the newer recommendations in [ICRP Publication 26](#) (ICRP 1977) and Publication 30 ([Limits for Intakes of Radionuclides by Workers, Part 1](#) [ICRP 1979a] and [Supplement to Part 1](#) [ICRP 1979b]) incorporated in the dose factors from the EPA in Federal Guidance Reports 11 and 12 (EPA 1988 and EPA 1993, respectively). The GENII Version 1 computer code at the Hanford Site beginning in 1988 used ICRP Publications 26 and 30 as well as EPA dose factors. The GENII Version 2 computer code for the annual report dose calculations beginning in 2009 uses ICRP Publication 60 methods (ICRP 1991) and updated EPA dose factors (EPA 1999).

Offsite dose for an MEI (Section 4.2.1) and collective dose for population residing within 50 mi (80 km) 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 Areas for tabulation of radiological dose. No direct discharge of radioactive materials from the 100 or 300 Areas to the Columbia River was reported during 2016. 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 measured in the Columbia River downstream of the Hanford Site (Richland Pump house station, HRM 46.4) in 2016 at low concentrations that were nevertheless 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 2.10.1 ([PNNL-14583](#)) 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 2016. 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 person. 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 offsite MEI (Figure 4-2). The Ringold location receives maximal air pathway impacts from the 200 Areas. Depending on annual 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 obtain their drinking water from the Riverview location via a community water system; 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; 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.

Dose calculations for 2016 releases indicate that the MEI is located in the vicinity of the Pacific Northwest National Laboratory (PNNL) Laboratory Support Warehouse, 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 radiological dose was modeled using the aforementioned Columbia River and air emissions data for the following exposure routes:

- 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 (i.e., fishing, boating) and inadvertent ingestion of water while swimming
- Consumption of locally caught Columbia River nonmigratory 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 2.10.1 (PNNL-14583) is provided in Figure 4-3. Additional information related to selection of the MEI location for releases is included 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 2016 was calculated to be 0.12 mrem (1.2 μ Sv)/yr (Table 4-2; Figure 4-4). This dose is 0.12% of the 100 mrem (1000 μ Sv) per year public dose limit specified in DOE O 458.1 and 0.48% of the 25-mrem (250- μ Sv)/yr threshold where a supplemental assessment of dose to the lens of the eye, skin, and extremities is required. Air pathway contributions from sources in the 300 Area contributed approximately 83% of the total dose of 0.12 mrem (1.2 μ Sv)/yr, with the remaining dose related to water pathway exposures.

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

- **Air Releases.** Consumption of food products containing tritium released from the 300 Area contributed approximately 72% of the total air pathways dose of 0.10 mrem (1.0 μ Sv)/yr.
- **Water Releases.** Consumption of fish from the Columbia River contributed 0.014 mrem (0.14 μ Sv) or 54% of the total water pathways dose of 0.026 mrem (0.26 μ Sv)/yr. Consumption of food grown using Columbia River water withdrawn downstream from the Hanford Site contributed approximately another 32% of the total water pathways dose, and drinking water ingestion contributed the remaining 14%. Isotopes of uranium and their progeny, particularly uranium-234 and uranium-238, contribute approximately 97% of the total water pathways dose of 0.026 mrem (0.26 μ Sv)/yr. Most of the remaining 3% of the water pathways dose is related to tritium.

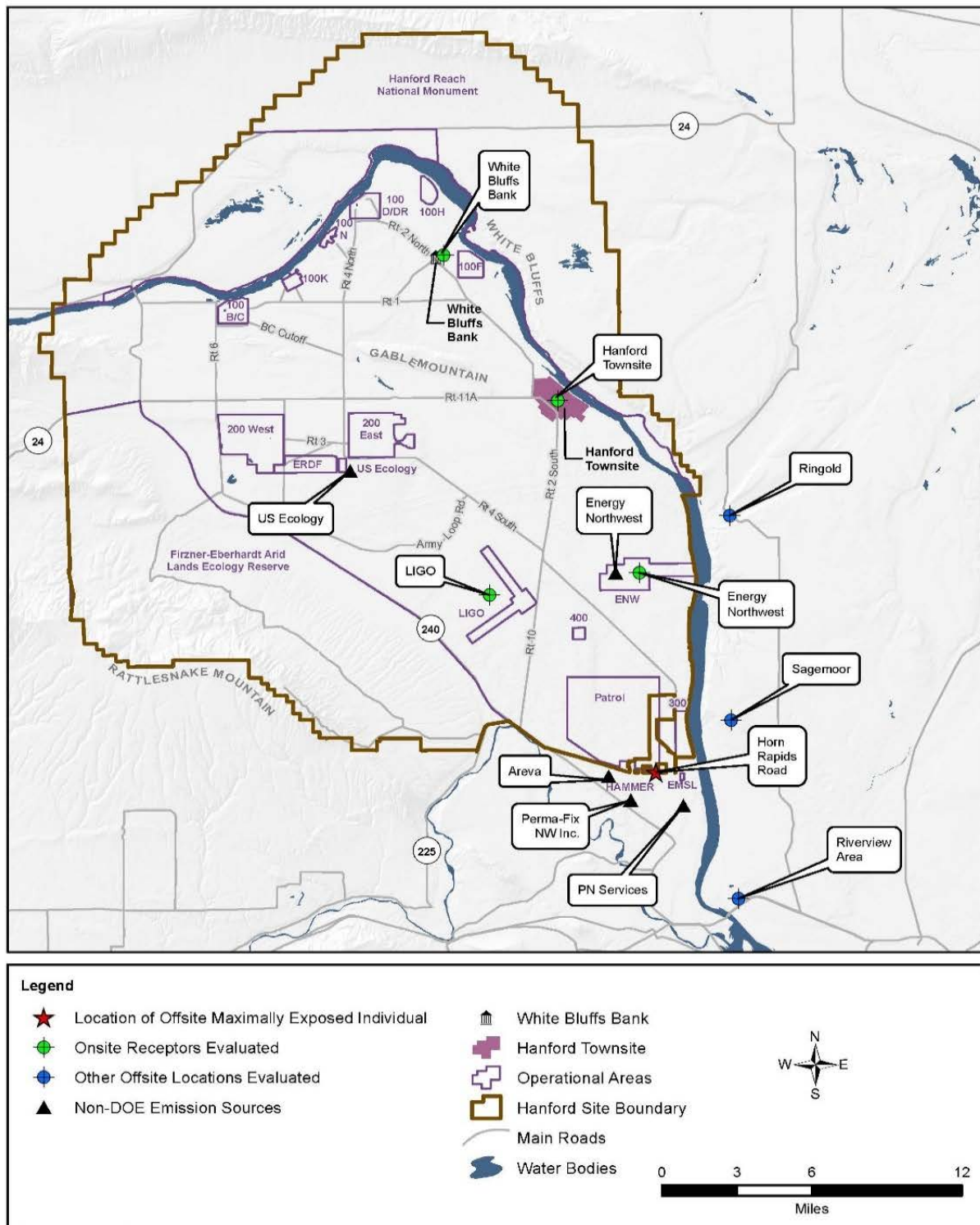


Figure 4-2. Locations Evaluated for Onsite and Offsite Receptors.

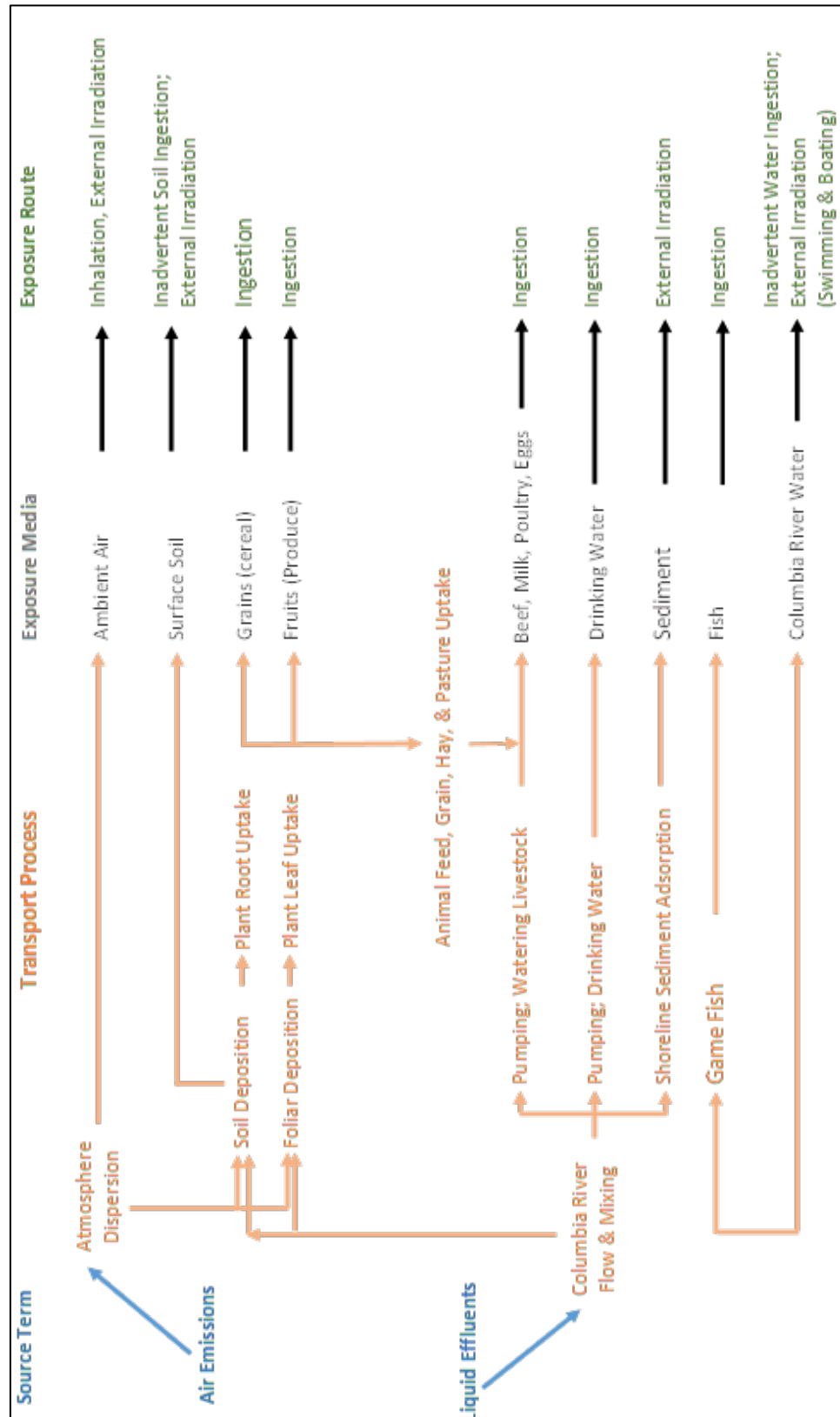


Figure 4-3. Conceptual Site Model of Exposure Pathways Evaluated in Dose Calculations (Horn Rapids Road MEI).

Table 4-2. Pathway Doses for the Hypothetical MEI Residing at Horn Rapids Road.

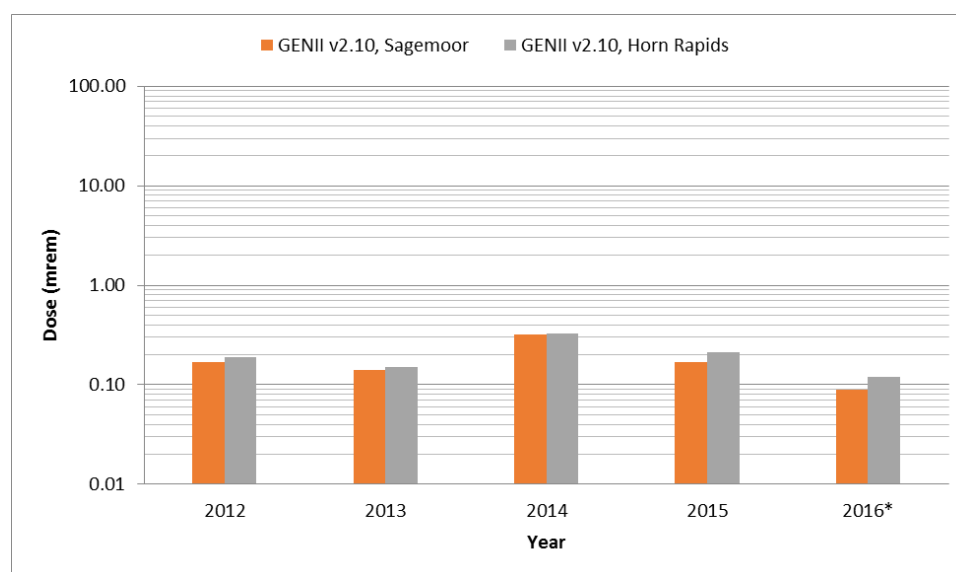
Release Type	Exposure Pathway	Dose Contributions from Operational Areas (mrem) ^a				
		100 Area	200 Areas	300 Area	400 Area	Pathway Total
Air	Food Ingestion	4.5E-07	1.4E-04	0.069	9.8E-07	0.069
	Inhalation	3.3E-06	4.5E-05	0.027	2.9E-06	0.027
	External, Soil Ingestion	4.2E-09	1.6E-07	0.0004	9.7E-09	0.00042
	Subtotal Air	3.8E-06	1.8E-04	0.10	3.9E-06	0.10
Water	Irrigation (food and soil ingestion; external)	NA ^b	0.0083 ^c	NA	NA	0.0083
	Drinking Water Ingestion	NA ^b	0.0040 ^c	NA	NA	0.0040
	Recreation (river water, sediments; external, ingestion)	NA ^b	5.0E-05 ^c	NA	NA	5.0E-05
	Fish Ingestion	NA ^b	0.014 ^c	NA	NA	0.014
	Subtotal Water	NA	0.026	NA	NA	0.026
Air + Water Total		3.8E-06	0.026	0.10	3.9E-06	0.12

^a To convert mrem to International System dose units (μSv), multiply by 10.

^b No measured releases; the last 100 Area NPDES-permitted outfall (1908-K Outfall) ceased releases in March 2011.

^c Integrates releases from all operational areas based on difference between down 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 Areas.

**Figure 4-4. Total Dose for the Hypothetical MEI Over Time.**

NOTE: 2016 doses calculated using GENII v2.10.1

4.2.1.1 MEI Dose Discussion. The MEI dose in 2016 of 0.12 mrem (1.2 μ Sv) is below the 0.21 mrem (2.1 μ Sv) MEI dose calculated in 2015 ([DOE/RL-2016-33, Hanford Site Environmental Report for Calendar Year 2015](#)). The difference between the 2016 and 2015 dose estimates is mostly attributable to larger 2015 releases of tritium and radon-220 from the 300 Area, and higher 2015 downstream concentrations of uranium-238 in the 2015 water pathways dose calculations.

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, gross alpha and gross beta radiation measurements in stack emissions from the 100, 200, and 300 Areas were protectively added to the measured emissions of plutonium-239/-240 (an alpha-emitting radionuclide related to Hanford operations) and cesium-137 (a beta-emitting radionuclide related to Hanford operations), respectively. The actual measured total air releases of plutonium-239/-240 and cesium-137 are a small fraction (23 and 11%, respectively) of assumed releases that include the contribution of gross radioactivity values. Although gross alpha and gross beta levels in stack emissions are similar to ambient air background levels, the addition of these values ensures that possible contributions from any unmeasured operations-related radionuclides are protectively incorporated in the estimated doses.

In the irrigation pathways calculations, all produce eaten by the MEI was protectively assumed to be locally grown and 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 carp and bass.

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 2016 modeled annual average air concentrations of tritiated water vapor (HTO) at the Horn Rapids Road MEI location and 2016 annual averages based on measured values at two offsite locations south and east of the 300 Area (Battelle Complex and Byers Landing) and two onsite locations near the southern border of the 300 Area northeast of the Horn Rapids Road MEI location. Measured monthly tritium concentrations vary substantially at each monitoring location. The 95% upper and lower confidence intervals of the annual average values are shown on Figure 4-5 in addition to the annual average.

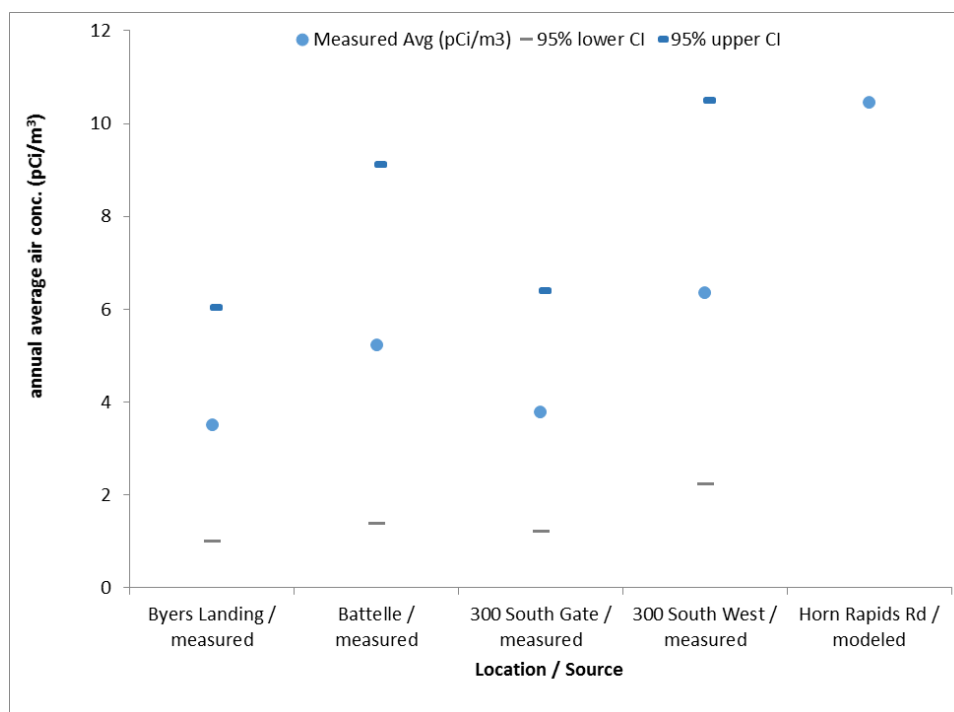


Figure 4-5. Comparison of Measured and Modeled Tritium Air Concentrations Near the 300 Area.

NOTE: Error bars are 95% confidence intervals of the mean

The modeled annual-average tritium concentration at the Horn Rapids Road MEI location is above the range of the 95% upper and lower confidence interval of the mean of the measured values at the two nearby offsite monitoring locations and the 300 South Gate onsite location. The Horn Rapids Road modeled annual-average tritium concentration is approximately equal to the 95% upper confidence interval of the mean of the measured values at the 300 South West monitoring station. A relationship between 300 Area monthly tritium air emissions and onsite 300 Area 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. Figure 4-5 shows that the modeled MEI tritium air concentration is higher than the upper 95% confidence interval annual-average tritium concentrations measured at Battelle Complex (near the Horn Rapids Road MEI Location) and Byers Landing (near the Sagemoor MEI location) stations. This suggests that modeled tritium air concentrations may overestimate actual annual-average levels at these offsite locations.

Note that 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. However, the modeled tritium values do not account for regional background levels of tritium, which would add between 1.5 and 4 pCi/m³ to the modeled values (Figure 11 in Barfuss 2007) and exacerbate the difference between modeled and measured tritium values at offsite locations near the 300 Area.

Samples of locally raised foodstuffs were collected in 2016 from four locations including the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. Sampled foodstuffs included fruits (apricots, melons, and tomatoes), leafy vegetables, potatoes, corn, milk, and wine. Gamma-emitting radionuclides and

strontium-90 were measured in all foodstuffs, and tritium was measured in tomatoes and milk. Gamma-emitting radionuclides and tritium were measured in wine. Carbon-14 was measured in melons, corn, and leafy vegetables. Measured concentrations of the Hanford-related radionuclides carbon-14, cesium-137, and tritium in foods were compared to modeled concentrations calculated for the MEI receptor using the GENII computer code. These comparisons encompassed fruits, leafy vegetables, grain (corn), root vegetables (potatoes), and milk. Modeled concentrations of carbon-14, tritium and cesium-137 are related primarily to air emissions, whereas modeled concentrations of strontium-90 are related to irrigation with Columbia River water. The following observations are drawn from the comparisons:

- Carbon-14 was detected in only one of the 14 samples of melons, corn, and leafy vegetables collected from the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. This measured concentration of 0.592 pCi/g in corn from Sunnyside was up to about one-third higher than the nondetect values (0.436, 0.454, and 0.480 pCi/g) reported for the three other corn samples. The modeled carbon-14 concentration in grain grown at the MEI location of Horn Rapids Road is approximately 1E-05 pCi/g, reflecting how naturally-occurring levels of carbon-14 in the environment are far higher than worst-case levels related to the carbon-14 stack emissions of 0.00012 Ci in 2016 (see Table D-2.)
- Cesium-137 was not detected in any food sample. Analytical detection limits were approximately a factor of 1,000 to 10,000 times larger than the worst-case modeled concentrations but comparable to or below environmental surveillance project dose-based reporting limits (DOE/RL-91-50) calculated using a 1 mrem (10 μ Sv)/yr threshold. Cesium-137 routine air releases are far below levels of detection or radiological concern in foodstuffs.
- Strontium-90 was detected only in two leafy vegetable samples from the Riverview and East Wahluke areas. The Riverview and East Wahluke areas had strontium-90 concentrations of 0.01 pCi/g and 0.007 pCi/g, respectively. Strontium-90 was not elevated in downstream Columbia River water samples in 2016 and therefore was not included in the water pathways dose calculations. Low levels of strontium-90 in the environment are widespread due to past above-ground weapons testing, and measured concentrations in leafy vegetables from the Sagemoor, Sunnyside, and East Wahluke areas are consistent with trends based on observations in offsite vegetation samples ([PNNL-20577, Radionuclide Concentrations in Terrestrial Vegetation and Soil Samples On and Around the Hanford Site, 1971 Through 2008](#)). Detected concentrations of approximately 0.01 pCi/g in leafy vegetables are almost 100 times below the environmental surveillance project dose-based reporting limit (DOE/RL-91-50).
- Tritium was measured in samples of tomatoes from the Sunnyside and Riverview areas but was not detected at either location with analytical detection limits of approximately 0.1 and 0.2 pCi/g, respectively. Tritium was detected in samples of milk at average concentrations of approximately 32 pCi/L (Sunnyside), 30 pCi/L (East Wahluke), and 38 pCi/L (Sagemoor). The relative tritium concentrations in milk from these three locations is consistent with expectations for air dispersion from releases in the 300 Area. However, these concentrations are well below the modeled worst-case tritium concentration in milk for cows grazing at the MEI location of Horn Rapids Road (approximately 480 pCi/L) and far less than the environmental surveillance project dose-based reporting limit of 17,000 pCi/L (DOE/RL-91-50).

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 2016 Hanford Site operations was estimated by calculating the radiological dose to the population residing within a 50-mi (80-km) radius of onsite operating areas (DOE O 458.1; 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 to coincide with air dispersion and deposition modeling conducted within the GENII Version 2.10.1 computer code (PNNL-14583).

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 2016 was 1.2 person-rem (0.012 person-Sv)/yr (Table 4-3), below the collective dose calculated in 2013-2015 and approximately equal to that calculated in 2012 (Figure 4-6). Air pathway contributions from releases in the 300 Area contributed approximately 60%, and water pathway contributions assigned to the 200 Areas contributed approximately 40% to the total collective dose of 1.2 person-rem (0.012 person-Sv) in 2016.

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 approximately 67% of the of the air pathways collective dose of 0.72 person-rem (0.0072 person-Sv). The remaining air pathways collective dose is primarily related to inhalation. About 60% of these food and inhalation air pathways doses are due to releases of tritium from the 300 Area. Approximately another 20% of the total air pathways collective dose is associated with inhalation of the radioactive progeny of radon-220 released from the 300 Area. Air releases from the 100, 200, and 400 Areas had negligible contributions to the air pathways collective dose.
- **Water Releases.** Consumption of drinking water drawn from the Columbia River downstream of the Hanford Site contributed approximately 97% of the total water pathways collective dose of 0.45 person-rem (0.0045 person-Sv). Two isotopes of uranium (-234 and -238) and their progeny from releases assigned to the 200 Areas were the largest contributors (approximately 88%) to the drinking water collective dose.

The collective dose in 2016 of 1.2 person-rem (0.012 person-Sv) is below the 1.7 person-rem (0.017 person-Sv) collective dose calculated in 2015 (DOE/RL 2016 33) and approximately equal to

the 2012 collective dose. There is no specific collective dose metric analogous to the 100 mrem (1,000 mSv) per year public dose limit for individual exposures described in Section 4.2.

Table 4-3. Collective Pathway Doses within a 50-mi (80-km) Radius.

Release Type	Exposure Pathway	Dose Contributions from Operational Areas, person-rem ^a				
		100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	Food Ingestion	7.9E-05	0.013	0.48	4.4E-05	0.50
	Inhalation	0.0012	0.007	0.21	1.8E-04	0.22
	External, Soil Ingestion	9.3E-07	1.3E-05	0.0027	3.7E-07	0.0027
	<i>Subtotal Air</i>	<i>0.0012</i>	<i>0.020</i>	<i>0.7</i>	<i>2.2E-04</i>	<i>0.72</i>
Water	Irrigation (food and soil ingestion; external)	NA ^b	0.0086 ^c	NA	NA	0.009
	Drinking Water Ingestion	NA ^b	4.9E-04 ^c	NA	NA	4.9E-04
	Recreation (river water, sediments; external, ingestion)	NA ^b	0.0053 ^c	NA	NA	0.0053
	Fish Ingestion	NA ^b	0.44 ^c	NA	NA	0.44
	<i>Subtotal Water</i>	<i>NA</i>	<i>0.45</i>	<i>NA</i>	<i>NA</i>	<i>0.45</i>
	Air + Water Total	0.0012	0.47	0.7	2.2E-04	1.2

^a To convert person-rem to International System dose units (person-Sv), divide by 100.

^b No measured releases; the last 100 Area NPDES-permitted outfall (1908-K Outfall) ceased releases in March 2011.

^c Integrates releases from all operational areas based on difference between down- and upstream Columbia River radionuclide concentrations.

NA = not applicable. All liquid discharges reflected in difference between up- and downstream radionuclide concentrations assigned to 200 Areas.

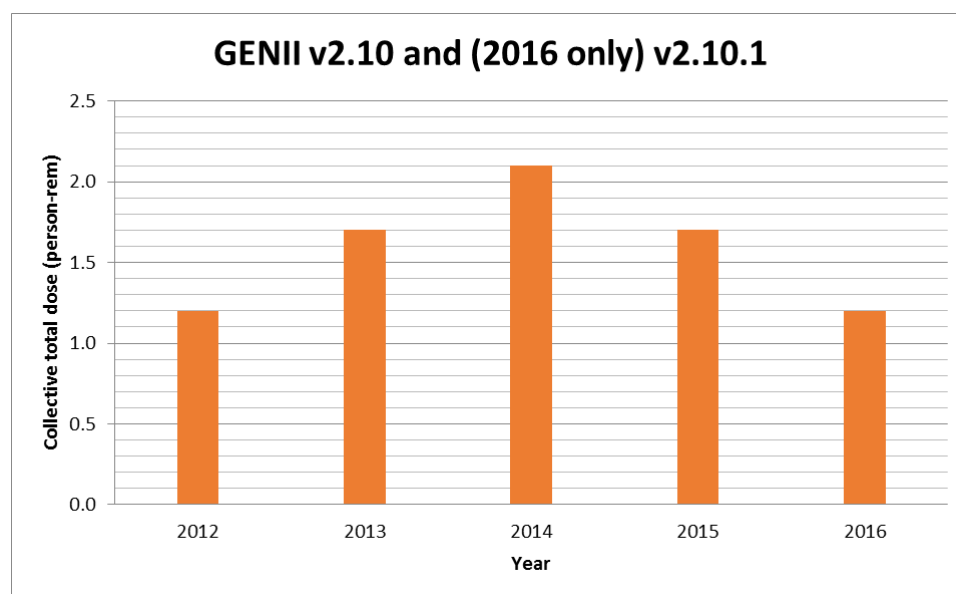


Figure 4-6. Collective Total Dose within a 50-mi (80-km) Radius.

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; 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 and is calculated using

the GENII computer code as described in Section 4.2.1 of this report. This calculation considers all potential environmental exposure pathways (e.g., from releases to both air and water) that maximize a hypothetical offsite individual's exposure to the Hanford Site's radiological liquid effluents and air emissions. A second estimate of MEI air pathways dose is required by the *Clean Air Act* and must be calculated using an EPA air dispersion and dose modeling computer code (CAP-88; EPA 2000) or other methods accepted by the EPA under the *Clean Air Act* to demonstrate compliance with 40 CFR 61, Subpart H requirements. This regulation specifies that no member of the public shall receive a dose greater than 10 mrem (100 μ Sv)/yr from exposure to airborne radionuclide emissions (other than radon) released at DOE facilities. 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.

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 2016 air emissions at the Hanford Site, refer to DOE's report to EPA (DOE/RL-2016-10).

4.2.3.1 Dose from Stack Emissions to an Offsite Maximally Exposed Individual. Using CAP-88, the offsite MEI for air pathways in 2016 was at the PNNL Richland Campus' Laboratory Supply Warehouse, an offsite business located in north Richland, Benton County, Washington, directly south of the Hanford Site 300 Area and proximal to the Horn Rapids Road MEI location (Figure 4-2). The potential air pathway dose from stack emissions to an MEI at that location calculated using the CAP-88 computer code was determined to be 0.038 mrem (0.38 μ Sv)/yr, less than 1% of the EPA standard of 10 mrem (100 μ Sv)/yr. The CAP-88 result is approximately one-half of the air pathway dose of 0.10 mrem (1.0 μ Sv) for stack emissions calculated with GENII (Table 4-2).

Dose related to radon-220 is not included in the dose calculated for EPA compliance in 40 CFR 61, Subpart H but is regulated by the 10-mrem (100- μ Sv)/yr standard established in [WAC 246-247, "Radiation Protection – Air Emissions."](#) A release of 178 curies of radon-220 was calculated from engineering estimates for stack emissions from the 325 Building in the 300 Area. A radon-220 dose of 0.026 mrem (0.26 μ Sv)/yr was calculated using the CAP-88 computer code for the Laboratory Supply Warehouse MEI, far below the WAC 246-247 standard. The sum of MEI dose for radon-220 and dose calculated for compliance with 40 CFR 61, Subpart H using the CAP-88 computer code is approximately 0.064 mrem (0.64 μ Sv), which is about 60% of the total Horn Rapids Road air pathways MEI dose of 0.10 mrem (1.0 μ Sv) calculated using the GENII computer code.

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-2016-10). Modeled contributions from monitored stack emissions and contributions from background levels of radionuclides are subtracted from perimeter ambient air concentrations measured for each radionuclide and positive differences are attributed to a virtual fugitive source located near the center of the Hanford Site.

The Laboratory Supply Warehouse 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-2016-10). The estimated dose from diffuse emissions to an MEI was calculated using the CAP-88 computer code to be 0.0060 mrem (0.060 μ Sv)/yr. Therefore, the potential combined dose from stack emissions, radon-220 emissions, and diffuse emissions (excluding radon) during 2016 at the Laboratory Supply Warehouse location was 0.070 mrem (0.70 μ Sv)/yr, far below the 10 mrem (100 μ Sv) per year federal and state standards described above.

4.2.3.3 Maximum Dose to Non-U.S. Department of Energy Workers at the Hanford Site. DOE allows private businesses to locate their activities and personnel on some regions of the Hanford Site. The EPA Region 10 Office and the Washington State Department of Health provided guidance to the U.S. Department of Energy, Richland Operations Office (DOE-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 situation has created the need to calculate a maximum dose for an onsite individual employed by a non-DOE business who 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 2016 EPA air emissions report (DOE/RL-2016-10) as possible MEI locations. Included in these locations were the Columbia Generating Station operated by Energy Northwest and Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California (Figure 4-2). The non-DOE worker dose due to stack emissions at these facilities was calculated using the CAP-88 computer code assuming full-time occupancy because EPA guidance does not allow for adjustment of such doses to account for less than full-time occupancy. The highest estimated dose to a member of the public from fugitive emissions was at LIGO. The total dose attributable to 2016 stack emissions, fugitive source emissions, and radon-220 at LIGO was calculated using CAP-88 to be 0.026 mrem (0.26 μ Sv; DOE/RL-2016-10). Even assuming that a LIGO employee is continuously present, the estimated total dose to non-DOE onsite workers in 2016 was lower than the 0.070 mrem (0.70 μ Sv)/yr total dose calculated with CAP-88 to an offsite MEI at the Laboratory Supply Warehouse.

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. Three such scenarios include an outdoor recreationalist who consumed meat from contaminated wildlife that migrated from the Hanford Site; an individual who drank water from one of four DOE-owned water treatment facilities at the Hanford Site; and a visitor to the Manhattan Project National Historical Park. 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. An outdoor recreationalist is also potentially exposed to contaminated soil and sediment along the river corridor if they access this area from the Columbia River.

Concentrations of radionuclides measured in soil (cesium-137, plutonium-238, plutonium-239/-240, and strontium-90) at far field sampling locations are not readily distinguishable from background levels, and soil concentrations are less susceptible to yearly variation than sediment and wildlife. An evaluation of radionuclide soil concentrations and trends over time is provided in PNNL-20577. Review of the 2016 sediment data indicates that concentrations of key radionuclides frequently detected in sediment (including cesium-137, plutonium-239/-240, and uranium isotopes) have approximately equal concentrations at upstream (Priest Rapids Dam) and downstream (McNary Dam) locations. Also, sediment concentrations at the dam locations are generally as large as or larger than concentrations at slough locations along the Hanford Site near White Bluff and the Hanford Townsite. The 2016 sediment data do not indicate the presence of a Hanford contribution to sediment radionuclide concentrations. Therefore, the screening assessment of outdoor recreationalist dose will focus on wildlife samples obtained in 2016.

Gamma-emitting radionuclides were analyzed in muscle tissue samples collected in 2016 from elk, mule deer, and quail. In addition to muscle tissue, samples of liver tissue were obtained from elk and mule deer and analyzed for gamma-emitting radionuclides and isotopic plutonium. Bone samples were also collected from elk, mule deer, and quail and analyzed for strontium-90, a radionuclide that accumulates in bone tissue. For estimating dose from ingestion of game meat, radionuclide concentrations in muscle tissue are most applicable. The only radionuclide detected in the muscle and liver tissue of any animal was potassium-40, a naturally occurring primordial radioisotope not of Hanford Site origin.

Fillet tissue and carcass samples were obtained from carp and bass in two river sections of the Hanford Reach in 2016. Fillet samples were analyzed for gamma-emitting radionuclides, tritium, strontium-90, and isotopes of plutonium and uranium. Carcass samples were only analyzed for strontium-90. Detected radionuclides in fillet samples were limited to potassium-40, uranium-234, uranium-235, and uranium-238. Potassium-40 is a naturally occurring radionuclide that is not of Hanford Site origin. However, uranium isotopes are associated with Hanford Site operations.

Uranium-234 was detected in three carp fish fillet samples from the 100 Area, three fillet samples from the 300 Area, and one fillet sample from the reference area. Uranium-235 was detected in two carp fish

fillet samples from the 300 Area and two fillet samples from the reference area. Uranium-238 was detected in two carp fish fillet samples from the 100 Area, two fillet samples from the 300 Area, and two fillet samples from the reference area. Both average and maximum isotopic uranium concentrations detected in the reference area carp fillet samples were higher than the values detected in the 100 Area fillet samples. Average reference area carp fillet concentrations of uranium-234 and uranium-235 were higher than those from 300 Area fillet samples, but uranium-238 concentrations were lower than those from the 300 Area fillet samples. In terms of maximum values, the reference area fillet samples were all lower than the 300 Area fillet samples. As a result of the variability in the isotopic uranium concentrations in carp fish fillets between the 300 Area and the reference area, the potential radiation dose from consumption of carp fish fillets with isotopic uranium concentrations were examined for the 300 Area.

These uranium-234 and uranium-235 results for carp are similar to the respective uranium isotopes in whitefish fillet samples collected in 2015. The uranium-238 results for carp are similar to sampling results for uranium-238 in carp fillet samples collected in 2014, where concentrations were observed to increase in carp fillet samples with downstream distance from an upstream reference area from the 100 Area to the 300 Area. Differences in sampling locations and species may explain these differences between 2014 carp and 2015 whitefish fish fillet results; Hanford Site uranium releases to the Columbia River estimated from downstream and upstream river concentrations were approximately equivalent in these 2 years.

Isotopic uranium concentrations in bass fish fillet samples were detected in the 100 Area, 300 Area, and reference area. One bass fillet sample was collected for each area and uranium-234, uranium-235, and uranium-238 were all found within each sample. Uranium-235 concentrations detected in the reference area bass fillet samples were all higher than the values detected in the 100 and 300 Area fillet samples. Uranium-234 and uranium-238 concentrations detected in the reference area bass fillet samples were all lower than the values detected in the 100 and 300 Area fillet samples. These uranium isotope results for bass are similar to sampling results for uranium-234 and uranium-238 in carp fillet samples collected in 2014. The potential radiation dose from consumption of bass fish fillets with the measured isotopic uranium concentrations were examined for the 100 and 300 Areas.

The potential radiation dose received from consumption of fish fillets with isotopic uranium concentrations measured in bass in 2016 would be negligible. Assuming annual fish consumption of 88 lb (40 kg) for an MEI (Table D-4), the annual radiation dose related to fish ingestion for bass that contains isotopic uranium is estimated to be 0.17 mrem (1.7 μ Sv) in the 100 Area and 0.16 mrem (1.6 μ Sv) in the 300 Area.

The potential radiation dose received from consumption of fish fillets with average isotopic uranium concentrations measured in carp from the 300 Area in 2016 would also be negligible. Assuming annual fish consumption of 88 lb (40 kg) for an MEI (Table D-4), the annual radiation dose related to fish ingestion for carp is estimated to be 0.064 mrem (0.64 μ Sv).

The dose estimate for carp ingestion was derived using the average value from 300 Area fillet samples for each isotopic uranium concentration and an ingestion dose factor of 1.8×10^{-4} mrem/pCi (4.9×10^{-2} μ Sv/Bq) for uranium-234, 1.7×10^{-4} mrem/pCi (4.6×10^{-2} μ Sv/Bq) for uranium-235, and 1.7×10^{-4} mrem/pCi (4.6×10^{-2} μ Sv/Bq) for uranium-238 from ICRP Publication 72 (ICRP 1995) in the following manner:

$$((0.0047 \text{ pCi uranium-234/g} \times 1.8 \times 10^{-4} \text{ mrem/pCi}) + (0.0018 \text{ pCi uranium-235/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi}) + (0.0027 \text{ pCi uranium-238/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi})) \times 40 \text{ kg/yr} \times 1,000 \text{ g/kg} = 0.064 \text{ mrem (0.64 } \mu\text{Sv)/yr}$$

The dose estimate for ingestion of bass fillets was derived using the measured value for each isotopic uranium concentration and an ingestion dose factor of 1.8×10^{-4} mrem/pCi (4.9×10^{-2} μ Sv/Bq) for uranium-234, 1.7×10^{-4} mrem/pCi (4.6×10^{-2} μ Sv/Bq) for uranium-235, and 1.7×10^{-4} mrem/pCi (4.6×10^{-2} μ Sv/Bq) for uranium-238 from ICRP Publication 72 (ICRP 1995) in the following manner:

- 100 Area

$$((0.011 \text{ pCi uranium-234/g} \times 1.8 \times 10^{-4} \text{ mrem/pCi}) + (0.0060 \text{ pCi uranium-235/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi}) + (0.0069 \text{ pCi uranium-238/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi})) \times 40 \text{ kg/yr} \times 1,000 \text{ g/kg} = 0.17 \text{ mrem (1.7 } \mu\text{Sv)/yr}$$

- 300 Area

$$((0.011 \text{ pCi uranium-234/g} \times 1.8 \times 10^{-4} \text{ mrem/pCi}) + (0.0047 \text{ pCi uranium-235/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi}) + (0.0069 \text{ pCi uranium-238/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi})) \times 40 \text{ kg/yr} \times 1,000 \text{ g/kg} = 0.16 \text{ mrem (1.6 } \mu\text{Sv)/yr}$$

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 2016 in accordance with applicable regulations (40 CFR 141); water samples were collected from the 100-K Area, 200-West Area, and three sources in the 400 Area (a primary well and two emergency backup wells). 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).

A comparison of analytical results for the 100-K, 200, and 400 Areas drinking water samples to state and federal standards is provided in Section 7.1. 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 in this section by evaluating drinking water data for tritium and strontium-90.

Strontium-90 was analyzed in one sample from each of the five drinking water sources in 2016 and was not identified above its analytical detection limit in any drinking water sample. Tritium was analyzed in one sample from both the 100-K and 200-West Areas and was not detected above its analytical detection limit 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 also in two samples from backup wells P-14 and P-15. Based on the four quarterly samples from the primary well, the annual average 400 Area drinking water tritium concentration was 2,223 pCi/L (82 Bq/L). Assuming a consumption rate of 0.26 gal (1 L)/day for 250 working days at the Fast Flux Test Facility in the 400 Area, the potential annual worker dose in 2016 would be approximately 0.037 mrem (0.37 μ Sv). The single tritium samples collected at each of the backup wells are independently assessed for worker dose because it is unlikely that both backup wells would be active at the same time and the water supply blended. The drinking water tritium concentration at backup well P-14 was 12,000 pCi/L. Based on this single measurement, an annual worker drinking water dose for water obtained exclusively from the backup P-14 well would be 0.20 mrem (2.0 μ Sv). The drinking water tritium concentration at backup well P-15 was 2320 pCi/L

resulting in an annual worker drinking water dose of 0.039 mrem (0.39 μ Sv). These estimates are well below EPA's drinking water dose limit of 4 mrem (40 μ Sv)/yr for beta-emitting radionuclides in public drinking water supplies.

The dose estimate for the primary 400 Area drinking water source was derived using a tritium ingestion dose factor of 6.7×10^{-8} mrem/pCi (1.8×10^{-5} μ Sv/Bq) from ICRP Publication 72 (ICRP 1995) in the following manner:

$$2,223 \text{ pCi tritium/L} \times 1 \text{ L/day} \times 250 \text{ d/year} \times 6.7 \times 10^{-8} \text{ mrem/pCi} = 0.037 \text{ mrem/yr}$$

4.2.4.3 Manhattan Project National Historical Park Visitor Dose. The Manhattan Project National Historical Park at Hanford includes guided tours of the B Reactor as well as access to several pre-Manhattan Project locations, two of which (Hanford Townsite and White Bluffs Bank) are situated to the east of the 100-K and the 200 Areas. These historical locations are geographically closer to these air emissions sources than the offsite MEI locations evaluated in Section 4.2.1. However, unlike an offsite residential MEI receptor, visitors to these locations would not be exposed from agricultural and drinking water exposure pathways, nor would they be continually exposed over the course of a year, as might be anticipated for some residents. For these reasons, potential doses at these locations are likely to be considerably below those calculated for the hypothetical offsite MEI.

Inhalation dose related to 100-K and 200 Areas stack emissions was calculated for a hypothetical individual at the Hanford Townsite and White Bluffs Bank locations using the GENII Version 2.10.1 computer code. Although Historical Park visitors would be present only briefly and on a single occasion at these locations, individuals conducting tours could be present for greater lengths of time. Additionally, these locations are adjacent to the Columbia River where recreationalists might be exposed while boating, fishing, or engaging in other activities. For this screening calculation, continuous exposure at the Hanford Townsite and White Bluffs Bank locations was assumed. The results of these dose calculations are presented in Table 4-4.

Table 4-4. Annual Doses for a Hypothetical Individual at the Hanford Townsite and White Bluffs Bank Locations (2015).

Release Type	Exposure Pathway	Location	Dose Contributions from Operational Areas, mrem ^a		
			100 Area	200 Areas	Pathway Total
Air	Inhalation	Hanford Townsite	4.6E-05	8.1E-05	1.3E-04
		White Bluffs Bank	1.0E-04	5.9E-05	1.6E-04

^aTo convert mrem to International System dose units (μ Sv), multiply by 10.

Radiological doses assuming continuous inhalation exposure at either the Hanford Townsite or White Bluffs Bank locations are far below the hypothetical offsite MEI air pathways dose of 0.10 mrem (1.0 μ Sv; Table 4-2) at Horn Rapids Road.

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

Doses from non-DOE sources were not quantified in 2016 because the MEI dose of 0.12 mrem (1.2 μ Sv)/yr from DOE-related sources (Section 4.2.1) was far below the threshold of 25 mrem

(250 μ Sv)/yr at which the contribution of non-DOE sources must be included. DOE O 458.1 paragraph 4.e(1)(c) states that dose evaluations to demonstrate compliance with the public dose limit must include:

[t]he 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 mrem (250 μ Sv) in a year or less. If the DOE-related dose is greater than 25 mrem (250 μ Sv) 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 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 the Washington State Department of 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 Perma-Fix Northwest, Inc. (Figure 4-2). The total individual dose from non-DOE source activities in 2010 was conservatively estimated at about 0.004 mrem (0.04 μ Sv)/yr (PNNL-20548).

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, soils (near facilities), 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 requirement for management and control of liquid discharges and air emissions. The current dose limit for aquatic animal organisms is 1 rad (10 milligray [mGy]) per day. Rad is a unit of absorbed dose of ionizing radiation equal to an energy of 100 ergs/g of irradiated material. In addition to the dose limit for aquatic organisms, there is a dose limit for riparian or terrestrial wildlife of 0.1 rad (1 mGy)/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 soil, water, or sediment concentrations of a radionuclide that would produce 1 rad (10 mGy)/day for aquatic biota or terrestrial plants or 0.1 rad (1 mGy)/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 2016 from on and around the Hanford Site.

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, cobalt-60, cesium-137, plutonium-239/-240, strontium-90, tritium, uranium-234, uranium-235, and uranium-238. Beryllium-7 was detected but is of cosmogenic origin and is not associated with the Hanford Site. Potassium-40 was also detected in sediments upstream, onsite, and downstream of the Hanford Site. Potassium-40 is a naturally occurring radionuclide and is not associated with releases from the reactors or any groundwater plumes entering the Columbia River. Therefore, dose associated with potassium-40 is not included in the biota dose assessment. 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; 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. For an initial screen of ecological populations, the sediment and water data were split into five subareas: upstream, 100 Area, Hanford Townsite, 300 Area, and downstream and the maxima concentrations evaluated in these locations. If risks to biota were identified in the initial screen, then further assessments using average concentration over smaller spatial units would be evaluated. The results of the screening calculations listed in Table 4-5 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). Most of the estimated dose in the 100 Area is from carbon-14 (70%) and strontium-90 (26%) and dose in the 300 Area is basically entirely associated with uranium isotopes. Biota doses upstream at the Hanford Townsite and downstream were all similar and likely related to background concentrations in water and sediment. Further documentation of the Columbia River biota dose calculations is provided in Appendix D.

Biota dose calculations also were completed for West Lake, 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 Areas 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 [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (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 2016 and data tabulated (Appendix C, Tables C-2, C-3, and C-4).

The results of the 2016 screening calculations listed in Table 4-6 show the West Lake sediment and water concentrations failed the Tier 1 and 2 screens. The Tier 1 screen was based on the maximum concentration, and the Tier 2 screen was based on the average concentrations of five water and three sediment 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.

Table 4-5. Estimated Doses to Biota Associated with Columbia River Sediment and Water^a.

Location	Media Sampled for Key Radionuclides ^b	Tier 1 Screen Sum of Fractions ^c		Pass or Fail
		2015	2016	
Upstream	Sediment, Water	0.015	0.018	Pass
100 Area	Sediment, Water	0.64	0.71	Pass
Hanford Townsite	Sediment, Water	0.016	0.014	Pass
300 Area	Water	0.30	0.25	Pass
Downstream	Sediment, Water	0.016	0.015	Pass

^a Using RESRAD-BIOTA 1.8 computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

^b 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 3) is required. The sum of fractions has been rounded to two figures with a maximum of three decimal points. Maximum concentrations and the Biota Concentration Guides are presented in Appendix D.

^c 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 was estimated. See Appendix D for details on what was measured.

Table 4-6. Estimated Doses to Biota Associated with West Lake^a.

Tier	Exposure Assumptions	Sum of Fractions ^b		Pass or Fail
		2015	2016	
1	Maximum Sediment, Water Concentration and Default Bioaccumulation	16	115	Fail
2	Average Sediment, Water Concentration and Default Bioaccumulation	3.7	41	Fail
3	Average Sediment, Water Concentration and Site-specific Bioaccumulation	0.05	0.49	Pass

^a Using RESRAD-BIOTA 1.8 computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

^b 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 3) is required.

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 was similar to those calculated for 2014, but the 2016 doses were about 10 times greater than those calculated for 2015 (Table 4-6). The reason is that the maximum concentrations in West Lake pond water samples varied quite widely, and isotopic uranium is typically detected in West Lake pond water. The isotopic ratios of uranium indicate a natural source (PNL-7662). The last 3 years of concentrations were 2014 (uranium-234 at 6,580 pCi/L, uranium-235 at 248 pCi/L, uranium-238 at 6,380 pCi/L); 2015 (uranium-234 at 1,650 pCi/L, uranium-235 at 87.1 pCi/L, uranium-238 at 1,570 pCi/L); and 2016 (uranium-234 at 10,700 pCi/L, uranium-235 at 43.5 pCi/L, uranium-238 at 13,700 pCi/L). The maximum concentration measured in 2016 was about 8 times greater than that measured in 2015. Further documentation of the West Lake biota dose calculations, including the Tier 3 Biota Concentration Guides, is provided in Appendix D.

Biota dose calculations were implemented for terrestrial biota based on exposures to soils collected on the Hanford Site. The RESRAD-BIOTA computer code evaluates potential effects on biota from the maximum concentrations of radionuclides measured in near field soil samples as tabulated in Appendix C. The radionuclides evaluated in soil are cesium-137, plutonium-238, plutonium-239/240, strontium-90, uranium-234, uranium-235, and uranium-238. The results of 2016 screening calculations listed in Table 4-7 show the near-field soil concentrations passed the Tier 1 screen, based on the maximum concentration. Basically, the entire estimated dose for near-field locations is from cesium-137 (84%) and strontium-90 (16%). See PNNL-20577 for a long-term trend in soil concentrations and associated biota doses on and off the Hanford Site.

Table 4-7. Estimated Doses to Terrestrial Biota Associated with On- and Offsite Soil^a.

Location	Tier 1 Screen Sum of Fractions ^b		Pass or Fail
	2015 ^b	2016	
Near field	0.72	0.57	Pass
Far field	0.024	Not measured ^c	--

^a Using RESRAD-BIOTA 1.8 computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

^b 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 3) is required. The sum of fractions has been rounded to two figures with a maximum of three decimal points. Maximum concentrations and the Biota Concentration Guides are presented in Appendix D.

^c Far field soil samples are collected approximately every 3 to 5 years and are planned for collection in 2018.

In addition to the dose assessments related to soils, sediments, and water, there are also fish and wildlife collected from the Hanford Site and reference locations. Although none of the biota dose assessments (except for West Lake) required any additional tiers of analyses, these supplemental calculations characterize more realistic doses based on measured concentrations. Dose to aquatic animals based on the maximum concentrations of strontium-90 (0.113 pCi/g), uranium-234 (0.0111 pCi/g), uranium-235 (0.00741 pCi/g), and uranium-238 (0.00693 pCi/g), in fish was 0.0001 rad/day. Internal dose to terrestrial plants based on the maximum concentrations of cesium-137 (0.13 pCi/g), plutonium-238 (0.00046 pCi/g), plutonium-239/-240 (0.021 pCi/g), strontium-90 (1.3 pCi/g), uranium-234 (0.14 pCi/g), uranium-235 (0.081 pCi/g), and uranium-238 (0.12 pCi/g), in plants was 0.002 rad/day. Dose to terrestrial animals based on the maximum concentration of strontium-90

(0.163 pCi/g) in deer bone was 0.000009 rad/day. Using the measured tissue data leads to lower doses than using the default bioaccumulation information assumed in the Tier 1 RESRAD-BIOTA calculations.

4.2.7 Radiological Dose in Perspective

The dose for the MEI in 2016 was 0.12 mrem (1.2 μ Sv; Section 4.2.1). The average individual dose from Hanford Site operations in 2016, based on the 50-mi (80-km) radius population exposed to air emissions and the Tri-Cities populations exposed to water pathways releases to the Columbia River, was approximately 0.0042 mrem (0.042 μ Sv). 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 and Measurement report *Ionizing Radiation Exposure of the Population of the United States* (NCRP 2009) estimated that the overall average exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv) per year. Approximately 50% of the 620 mrem (6,200 μ Sv)/yr average annual dose is related to natural sources, with the remaining 50% 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 mrem [190 μ Sv]), cosmic background radiation (30 mrem [300 μ Sv]), and radon (radon-222) and thoron (radon-220) gases (230 mrem [2,300 μ Sv]) are shown relative to Hanford Site operational doses in Figure 4-8. The calculated radiological doses from Hanford Site operations in 2016 were a small percentage of national average annual doses from these natural background sources. Note that annual dose is shown on a linear scale in Figure 4-8, and Hanford-related doses are too small to be observed. For example, the national annual average radiation dose from natural terrestrial sources (approximately 19 mrem [190 μ Sv]) is approximately 160 times larger than the 2016 Hanford Operations dose to the MEI receptor (0.12 mrem [1.2 μ Sv]).

Scientific studies (*Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII 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). 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, natural biochemical body reactions), some scientists doubt that the risk from low-level radiation exposure can be proven conclusively. In developing *Clean Air Act* regulations, EPA used a probability of approximately 4 per 10 million (4×10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem ($10 \mu\text{Sv}$; EPA 1989). Additional data 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 (National Research Council 2006). Guidance from the Interagency Steering Committee on Radiation Standards (ISCORS 2002) recommends that agencies assign a risk factor of 6 per 10 million (6×10^{-7}) for developing a fatal cancer after receiving a dose of 1 mrem ($10 \mu\text{Sv}$).

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 4-8 compares the estimated risks from various radiological doses to the risks of some activities encountered in everyday life.

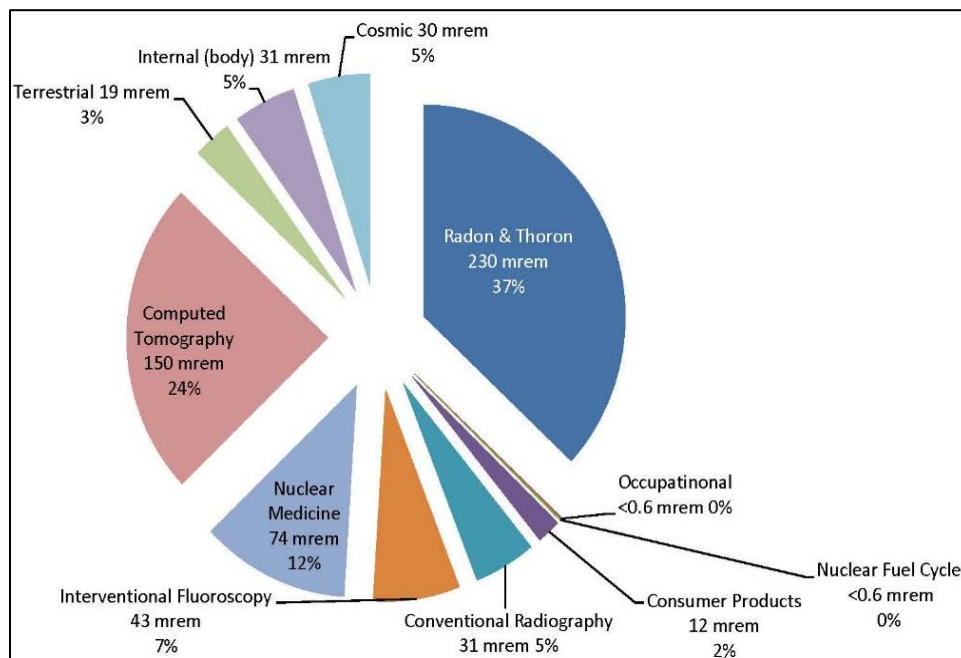


Figure 4-7. U.S. Annual Average Radiological Doses from Various Sources (2009 National Council on Radiation Protection and Measurements).

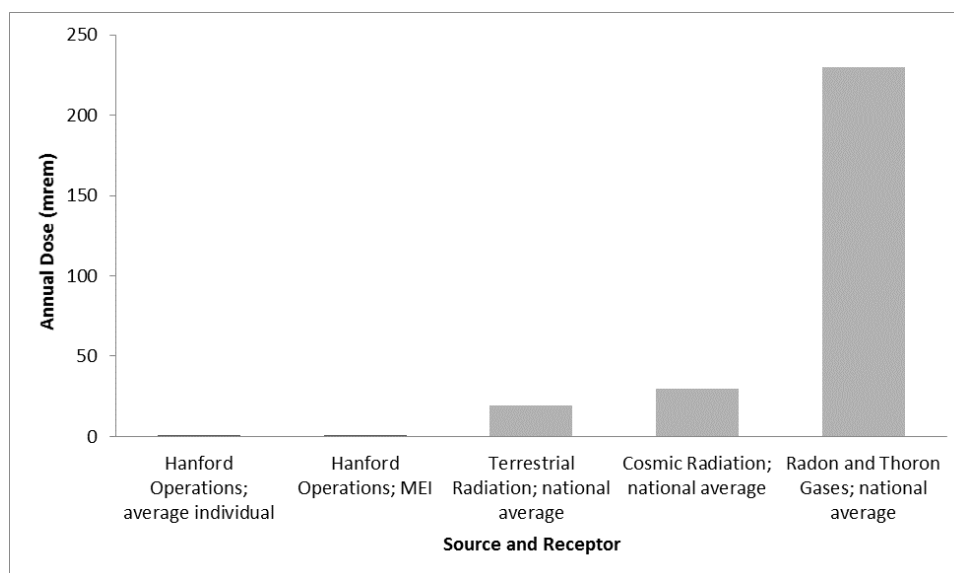


Figure 4-8. Radiological Doses from Hanford Site Operations Compared to Annual Average from Natural Sources.

Table 4-8. Estimated Risk from Various Activities and Exposures.

Activity or Exposure Per Year	Risk of Fatality
Home accidents	100×10^{-6a}
Firearms (sporting accidents)	10×10^{-6a}
Flying as an airline passenger (cross-country roundtrip – accidents)	8×10^{-6a}
Recreational boating (accidents)	6×10^{-6a}
Riding or driving 300 mi (483 km) in a passenger vehicle	2×10^{-6a}
Dose of 1 mrem (10 μ Sv) for 70 yrs	$0 \text{ to } 0.6 \times 10^{-6b}$
Natural background radiological dose (310 mrem [3,100 μ Sv]) for 70 yrs	$0 \text{ to } 200 \times 10^{-6b}$
Dose to hypothetical MEI (2016 rate) of 0.12 mrem (1.2 μ Sv)/yr living near Hanford Site for 70 yrs	$0 \text{ to } 0.1 \times 10^{-6b}$

^a Real actuarial values.

^b Upper bound calculated using 6×10^{-7} risk of developing a fatal cancer after receiving a 1 mrem (10 μ Sv) dose (ISCORS 2002).

4.3 Radiological Clearance of Hanford Site Property

W. Boyd

Principal requirements for the control and clearance of DOE property containing residual radioactivity are found in DOE O 458.1. 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 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.

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 19,000 items of personal property were cleared 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 clearance criteria and, therefore, did not require additional radiological controls post-survey. In January 2000, DOE issued a moratorium 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 2016.

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 Central Waste Complex in the 200-West Area. Personal property that has contamination levels below approved DOE control and clearance 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, a request to DOE in May 2006 was submitted by Washington Closure Hanford (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 mrem (10 mSv) in any year to the MEI and a collective dose of less than 10 person-rem (0.1 person-Sv) to any exposed population. These authorized limits (Table 4-9) were reviewed by DOE-RL and U.S. Department of Energy, Headquarters (DOE-HQ) personnel and approved for use by WCH in May 2007. In 2008, DOE-RL provided conditional approval to CH2M Plateau Remediation Company (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 cm² removable limit and 5,000 dpm/100 cm² total contamination limit). In June 2009, Washington River Protection Solutions submitted a request to the U.S. Department of Energy, Office of River Protection (DOE-ORP) for approval to use these hard-to-detect authorized limits. DOE-ORP provided conditional approval for this request in June 2009. Mission Support Alliance submitted a request to DOE-RL in October 2009 for approval to use these hard-to-detect authorized limits. DOE-RL provided conditional approval for this request in November 2009.

Table 4-9. Approved Release Criteria (Authorized Limits) for Select Hard-to-Detect Radionuclides^a for Residual Beta-Gamma Surface Contamination.

Average	Maximum	Removable
50,000 dpm/100 cm ²	150,000 dpm/100 cm ²	10,000 dpm/100 cm ²
^a Carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155		

4.3.2 Granular Activated Carbon for Offsite Shipment and Regeneration Radiological Clearance

Carbon tetrachloride was found in the unconfined aquifer beneath the 200-Westest 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-Westest 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 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 DOE-RL and DOE-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 4-10). This modification to the authorized limits does not change the expected dose to the public. Approximately 98,000 lb (44,400 kg) of granular-activated carbon was shipped offsite in 2016 for regeneration.

Table 4-10. 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
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 Land Conveyance

There were no land conveyances in 2016.

5.0 Environmental Restoration and Waste Management

Environmental restoration and waste management activities continued on the Hanford Site during 2016. 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 Hanford Tank Waste Treatment and Immobilization Plant (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-mi² (570-km²) River Corridor includes the Hanford Site's 100, 300, and 400 Areas that border the Columbia River. The River Corridor includes nine deactivated plutonium production reactors, numerous support facilities, and liquid and solid waste disposal sites. The U.S. Department of Energy's (DOE) focus is to complete source cleanup actions in the 100 and 300 Areas with the following principal goals:

- Deactivation, decommissioning, decontamination, and demolition (D4) of 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 current cleanup criteria in protecting human health and the environment
- Prepare the River Corridor for transition to the U.S. Department of Energy, Richland Operations Office (DOE-RL) Long-Term Stewardship Program (surveillance and maintenance [S&M]).

In 1991, the [*Hanford Federal Facility Agreement and Consent Order Action Plan*](#) (Tri-Party Agreement [TPA] Action Plan) agencies (Ecology et al. 1989c) agreed 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 records of decision (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 DOE-RL Long-Term Stewardship Program. Through 2016, transitions have been completed for 217 of the 220 mi² (570 km²) of the River Corridor.

In parallel with continued cleanup activities, the remedial investigation/feasibility study 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 and EPA 2013) for the 300 decision area and in September 2014 (DOE and EPA 2014) for the 100-F/IU-2/IU-6 decision area. Completion of remedial investigation/feasibility study reports, public review of proposed actions, and development of RODs for the remaining four decision areas are anticipated to be completed between 2017 and 2019.

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-H, and 100-N Areas Waste Sites

JA Lerch

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 Area began in 1996. In 2016, cleanup activities focused on completion of the remaining interim remedial actions in the 100-D, 100-H, and 100-N Areas. Waste generated from the cleanup of waste sites was disposed at the Environmental Restoration Disposal Facility (ERDF) in the 200 Area.

A total of 17,988 tons (16,318 metric tons) of contaminated soil and debris from 100 Area remediation activities were disposed at ERDF in 2016.

5.1.2.2 100-K Basins

KR Thompson

The 100-K Area remediation activities included facility demolition, waste site remediation, cleanout of the 105-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 ft³ (28 m³) of sludge. Currently, the sludge is stored in underwater engineered containers in the K West Basin for subsequent removal and disposition. The project's [*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*](#) (CERCLA) remedial design documentation will describe the means of sludge treatment and location of the national repository for sludge disposal. 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 (i.e., uranium oxides, hydrates, and hydrides), ion-exchange resin beads, polychlorinated biphenyls (PCBs), and fission products. Sludge has been defined as any material that is less than or equal to 0.25 in. (0.64 cm) in size.

100-K Area Remediation Progress and Accomplishments (2016)

- Completed construction of the 105-K West Annex and initiated construction activities on installing the Engineered Container Retrieval & Transfer System hardware in both the 105-K West Basin and Annex. Installation of the Engineered Container Retrieval & Transfer System hardware is forecast for April 2017.
- Completed Maintenance and Storage Facility Pre-operational Acceptance Testing, also known as “cold testing.” K-Basin Preoperational Acceptance Testing is forecast to be completed in 2017.
- Continued groundwater pump-and-treat operations.
- Continued testing systems and components to be used to remove K-Basin sludge at the Maintenance and Storage Facility located in the 400 Area prior to deployment to the K-West Basin, Annex, and its radiological environment.
 - Many systems and components moved from the 400 Area to the K-West Basin and Annex.
- Continued remediation of waste sites to protect human health and the environment.
 - Completed excavation on wastes sites 100-K-14, K-25, 27, 35, 50, 79, 98, and 101; 120-KE-1, 2, 3, 4, 5, 6, and 9; 126-KE-2; and 1607-K2 in AB waste site area. Closure documentation is scheduled to be completed in 2017.
 - Waste site 100-K-105 was closed and backfilled in fiscal year 2016.

K-Basins Progress on Defense Nuclear Facilities Safety Board Recommendations

ET Glossbrenner, RA Quintero

For calendar year (CY) 2016, there were no Staff Issue Reports or letter correspondence between the Defense Nuclear Facilities Safety Board (DNFSB) and the Hanford Site K-Basin Closure Sludge Treatment Project.

By issuing the [*26th Annual Report to Congress \[for Calendar Year 2015\]*](#) in March 2016 (DNFSB 2016), the DNFSB resolved all previously identified issues for the Hanford Site K-Basin Closure Sludge Treatment Project as summarized below.

The Board transmitted two letters to DOE on August 21, 2015, regarding the revised Preliminary Documented Safety Analysis (DSA) that DOE approved on February 5, 2015, with three conditions of approval. One letter communicated a safety issue regarding the project’s removal of a specific administrative control to protect the public by controlling public access to portions of the Columbia River during sludge transfers (DNFSB 2015b). On November 18, 2015, DOE responded to the Board’s letter on public access to the Columbia River during sludge transfers, indicating that the specific administrative control was no longer considered necessary (DNFSB 2015c).

The Board’s second letter identified deficiencies in the methodology used to determine the uranium metal concentration in one of the sludge storage containers (DNFSB 2015a). Recognizing that these deficiencies may be addressed as the project works to close DOE’s conditions of approval, the letter was sent for DOE’s consideration.

5.1.3 200 Areas – Central Plateau

PA Burke

The Central Plateau is a 75-mi² (194 km²) region near the center of the Hanford Site and 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 mi² (52 km²) 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 Areas' National Priorities List 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 TPA agencies developed changes to the TPA that reflect the path forward for Central Plateau cleanup. The Central Plateau includes two principal cleanup locations: the Inner and Outer Areas.

5.1.3.1 Inner Area. The Inner Area 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 sections below.

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 the Plutonium Finishing Plant (PFP) and the Plutonium Uranium Extraction (PUREX) Plant. Specific sites are listed in TPA Action Plan (Ecology et al. 1989c). At the U.S. Environmental Protection Agency's (EPA) request, the TPA 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).

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 et al. 2011) was issued in September 2011. The [Remedial Design/Remedial Action Work Plan for the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units](#) (DOE/RL-2015-23) and the [Sampling and Analysis Plan for the 200-CW-5, 200-PW-1, and 200-PW-6 Operable Units](#) (DOE/RL-2015-22) was approved by DOE-RL and EPA on May 19, 2016.

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 removing a portion of contaminated soil, structures, settling tanks, and associated debris; treating these removed wastes as required to meet disposal requirements at ERDF (Section 5.4.3.7) or waste acceptance criteria for offsite disposal at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico; and 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.

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	No change		EPA
200-WA-1 200-BC-1	Soil waste sites located in the 200-West Inner Area 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 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

Also known as the High-Salt Waste Group, three of the six 200-PW-1 waste sites will use the remove, treat, and dispose approach to excavate the highest concentrations of contaminated soils located up to 2 ft (0.6 m) below the bottom of the 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.** Also known as the Cesium-137 Waste Group, this operable unit will require additional backfill for three of the five waste sites to achieve coverage of a depth of at least 15 ft (4.57 m). Contamination at the other two waste sites is deeper than 15 ft (4.57 m) 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 (~90%) of the contaminated soils to a depth of 33 ft (10 m) below ground surface and dispose at ERDF or WIPP, as appropriate. An evapotranspiration barrier will be constructed over the remaining waste at these sites. A soil vapor extraction (SVE) system was used to remove and treat carbon tetrachloride contamination at waste sites in the High-Salt Waste Group. During SVE operations, vapor-phase carbon tetrachloride was extracted through multiple vadose zone wells and adsorbed onto granular activated carbon before the treated, clean vapor was released to the atmosphere. Between 1992 and 2012, (the last year of SVE operation), 80,107 kg of carbon tetrachloride were removed from the vadose zone. This remedy was evaluated using the process outlined in [PNNL-21843, Soil Vapor Extraction System Optimization, Transition, and Closure Guidance](#); and [DOE/RL-2014-18, Path Forward for Future 200-PW-1 Operable Unit Soil Vapor Extraction Operations](#). In November 2015, EPA concurred that the SVE remedy met the remedial action objectives in the ROD and that SVE activities could be ended. EPA concurrence with the response action report ([DOE/RL-2014-48, Response Action Report for the 200-PW-1 Operable Unit Soil Vapor Extraction Remediation](#)) in August 2016 closed out the SVE portion of the 200-PW-1 Operable Unit remedy in the ROD and initiated activities to terminate SVE operations and vadose zone monitoring. 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.

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 et al. 1989c); 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 January 2017. In addition, DOE obtained approval of the [216-U-8 Crib and 216-U-12 Crib Vadose Zone Characterization Sampling and Analysis Plan](#) (DOE/RL-2009-94), which supports the 200-WA-1 Operable Unit remedial investigation.

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, 200-IS-1 waste sites, 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 et al. 1989c); 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 use 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 been initiated.

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 that are not included in the canyon area operable units (200-EA-1, 200-WA-1, 200-SW-2) or in the tank farm WMAs. Specific sites are listed in the TPA Action Plan (Ecology et al. 1989c).

The TPA agencies agreed to use a coordinated CERCLA remedial action and [Resource Conservation and Recovery Act of 1976](#) (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. The work plan is undergoing revision and finalization.

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 et al. 1989c). Portions of the burial grounds listed in the RCRA Permit (WA7890008967) include treatment, storage, and disposal (TSD) facilities. DOE is working with the Washington State Department of Ecology (Ecology) to remove unused areas from the permit scope.

The TPA agencies agreed to use a coordinated CERCLA remedial action and RCRA corrective action process for cleanup decisions in the 200-SW-2 Operable Unit. [DOE/RL-2004-60, 200-SW-2 Radioactive Landfills Group Operable Unit RCRA Facility Investigation/Corrective Measures Study/Remedial Investigation/Feasibility Study Work Plan](#), was issued in June 2016 and mobilization of field activities to conduct the remedial investigation was initiated. A helicopter radiological survey was completed over the majority of the inner area and a summary report is being finalized to present the findings of the survey.

200-DV-1 Operable Unit (Deep Vadose Zone). This operable unit includes 43 soil waste sites located in the Inner Area that were previously located in the 200-TW-1, 200-TW-2, and 200-PW-5 Operable Units. Specific sites are listed in the TPA Action Plan (Ecology et al. 1989c). 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) was approved by Ecology on September 13, 2016. 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. Field activities associated with the remedial investigation continued and are expected to be completed in 2018.

200-CB-1 Operable Unit (B-Plant Canyon). This operable unit includes the B-Plant Canyon Building (221-B) and the Waste Encapsulation and Storage Facility (WESF), along with exterior ventilation system components for each structure (e.g., high-efficiency particulate air [HEPA] filters and sand filter) and 17 soil waste sites within the vicinity. Specific sites are listed in the TPA Action Plan (Ecology et al. 1989c); 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 are in the process of being reassigned to the 200-CB-1. Additionally, sites 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 TPA agencies.

Cesium and strontium capsules located in the WESF are not included in the scope of the 200-CB-1 Operable Unit.

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 2005). The U-Plant Canyon Disposition Initiative is a pilot project for disposition of the five canyon buildings in the 200-East and West Areas. Implementation of the selected remedial action (close in place – partially demolished structure) began in 2009.

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 et al. 1989c); 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 determined to require additional evaluation or remediation following demolition of a structure). Sites near the PUREX currently assigned to the 200-EA-1 Operable Unit are in the process of being reassigned to the 200-CP-1 Operable Unit. Additionally, sites 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 TPA agencies.

The 200-CP-1 work plan has not been initiated.

200-CR-1 Operable Unit (REDOX Canyon). This operable unit includes the Reduction-oxidation (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 et al. 1989c); 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 TPA 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 mi² (168 km²) 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.

200-CW-1, 200-CW-3, and 200-OA-1 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 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 (e.g., 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** – 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 processes, and cost information will support developing a final remedial action for the Outer Area of the Hanford 200 Areas' National Priorities List site.

Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill. The Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill (NRDWL) and Solid Waste Landfill (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, asbestos waste through 1988, and sanitary solid waste in 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 to early 1996. The SWL also received up to 1.3 million gal (5 million L) of sewage and 100,000 gal (380,000 L) of garage wash water. Because the NRDWL is a RCRA-permitted TSD site, closure is being managed in accordance with WAC 173-303 "Dangerous Waste Regulations"; the Solid Waste Landfill is regulated under [WAC 173-350, "Solid Waste Handling Standards."](#)

5.1.4 300 Area

JA Lerch

In 2016, remediation of the 300-FF-2 Operable Unit waste sites continued with a focus on the 300-288:2 waste site and the 618-10 Burial Ground (Figure 5-1). Waste generated from the cleanup of waste sites in the 300-FF-2 Operable Unit was disposed at the ERDF, located on the Central Plateau, and other EPA-approved disposal facilities. In 2016, approximately 300,820 tons (272,899 metric tons) of contaminated soil from the 300-FF-2 Operable Unit were disposed at the ERDF.



Figure 5-1. Aerial View of the 618-10 Burial Ground.

5.2 Facility Decommissioning Activities

This section provides information regarding the transition of Hanford Site facilities from stabilization to S&M 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

As of 2015, all D4 activities in the 100 Area have been completed.

5.2.2 200 Areas – Central Plateau

Central Plateau facilities include buildings and waste sites in the 200-East, 200-West, and 200-North Areas and those on the adjoining Rattlesnake Unit (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

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. The DOE issued a shutdown order for PFP in 1990. In 1996, DOE 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; 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 2016. The following sections describe the significant accomplishments at PFP during 2016 (Figure 5-2).



Figure 5-2. Aerial View of the Plutonium Finishing Plant.

Plutonium Finishing Plant Complex. The final push to prepare the four main process buildings (234-5Z, 236Z, 242Z, and 291Z) for demolition began in 2016. Two of these buildings (236Z and 242Z) were declared ready for demolition. Work at 242Z included grouting the sump pit, painting and isolating the E3 duct, and declaring 242Z and 242ZA ready for demolition. Work at 291Z included removal of process vacuum piping and asbestos abatement. The 2727Z and 2729Z Buildings were demolished and removed from the complex. The debris was removed from the site and taken to ERDF for final disposition.

234-5Z, Plutonium Finishing Plant

The following activities were completed in 2016:

- Drained waterwalls used for shielding
- Prepared for and initiated grouting floor trenches
- Prepared for removal of HA-7A, HC-7C, and HC-18M gloveboxes
- Continued asbestos abatement, removal of E4 ducting, and removal of process vacuum lines.

236Z, Plutonium Reclamation Facility

The following activities were completed in 2016:

- Removed the Miscellaneous Treatment and Column gloveboxes
- Grouted exhaust duct extension to 291Z
- Declared ready for demolition and initiated demolition.

The Plutonium Reclamation Facility column and miscellaneous treatment gloveboxes were sent to PermaFix Northwest for size reduction and returned to the Central Waste Complex (CWC) for storage until such time as they can be sent to WIPP for final disposition.

242Z, Americium Facility

The following activities were completed in 2016:

- Isolated 242Z tanks from E4 ventilation
- Continued efforts to ready the 242Z facility for demolition.

5.2.2.2 Canyon Disposition Initiative

D Singleton

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 a pilot project for the Canyon Disposition Initiative. The remaining canyon buildings are to be addressed individually, 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 an ROD (DOE et al. 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 (i.e., 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). Due to the concerted effort to remove PFP, no action has been taken on this initiative since 2011.

5.2.3 300 Area

JA Lerch and BL Lawrence

Future activities in the 300 Area will address the 324 facility and the underlying 300-296 waste site as well as retained facilities discussed in the RDR and RAWP

5.2.4 400 Area

SA McMahan

FFTF is a formerly operating 400-megawatt (thermal) liquid-metal cooled (sodium) research and test reactor located in the 400 Area (Figure 5-3). 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 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 S&M condition, all of which was completed in June 2009. FFTF remains in long-term S&M, and routine surveillances are performed annually.

The FFTF decommissioning was included in [DOE/EIS-0391, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington](#), issued on November 12, 2012, and the supplement analysis, [DOE/EIS-0391D-SA-01](#) issued in February 2012, concluded that there were no substantial changes. The DOE issued the final ROD on FFTF decommissioning on December 13, 2013 (78 FR 75913). The decision established that DOE will implement 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 the Integrated Disposal Facility (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.

Also at the 400 Area (outside the FFTF Property Protected Area) is a mammoth structure called the Fuels and Materials Examination Facility (FMEF). Although the FMEF was intended to be a support building for the FFTF and the future Liquid Fast-Breeder Reactor Program, the FMEF was never used in any kind of a nuclear capacity. When the nation abandoned the breeder reactor program, FMEF was also left without a mission, and remains unused and largely vacant today.

Future activities will address demolition of 400 Area surplus facilities.



Figure 5-3. Aerial View of the Fast Flux Test Facility.

5.3 Waste Management Activities

WE Toebe

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

5.3.1 Waste Classifications

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 considered dangerous (i.e., hazardous) 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, high-level waste (HLW), or low-level waste (LLW) under the [Atomic Energy Act of 1954](#) (AEA) (42 U.S.C. 2011). 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 (DSTs). 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. DOE/RL-2016-06, *Hanford Site Annual Dangerous Waste Report*, lists the dangerous and mixed wastes that are generated, treated, and disposed of onsite or shipped offsite. Dangerous and mixed wastes are treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site is shipped offsite 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 offsite 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 of at municipal or commercial solid waste disposal facilities. 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-regulated 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 the 100 Area decommissioning projects was buried in situ (in place) or in designated disposal locations on the Hanford Site. Unregulated medical waste is similar to typical household waste consisting of papers and plastics that are categorized as non-infectious. Regulated medical waste is waste that may transmit infection from a virus, bacteria, or parasite to humans. Since 1996, medical waste found at Hanford has been shipped to a commercial medical waste treatment and disposal facility.

5.3.2 Solid Waste Inventories

JF Berger, 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 CH2M Plateau Remediation Company (CHPRC), Mission Support Alliance (MSA), and Washington River Protection Solutions, LLC (WRPS). The database includes all waste necessary for all annual reporting requirements from DOE. The database does not include high-level radioactive waste volumes managed at Hanford Site tank farms.

As of December 31, 2016, 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. All data is as of December 31, 2016.

Table 5-2. Solid Waste^a Quantities Generated on the Hanford Site.

Waste Category		2011	2012	2013	2014	2015	2016
Mixed	Tons	522	305	206	140	657	609
	Metric tons	474	277	187	127	596	552
Radioactive	Tons	4,022	343	513	572	1550	665
	Metric tons	3,649	311	465	519	1408	603

^a Solid waste includes containerized liquid waste.

Table 5-3. Solid Waste^a Quantities Received on the Hanford Site from Offsite Sources.

Waste Category ^b		2011	2012	2013	2014	2015	2016
Mixed	Tons	320	66	36.5	38.4	97.9	105
	Metric tons	290	60	33	35	88.9	95.3
Radioactive	Tons	257	82	62.8	57	91.4	113
	Metric tons	233	74	60	52	82.9	102

^a Solid waste includes containerized liquid waste. Solid waste quantities do not include U.S. Navy reactor compartments.

^b 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^a Quantities Shipped Off the Hanford Site.

Waste Category		2011	2012	2013	2014	2015	2016
Containerized (DW Only)	Tons	53	18	65.4	103	76.8	69.4
	Metric tons	48 ^b	16.3 ^b	59.3 ^b	93.4 ^b	69.7 ^b	63.0
Containerized (MW Only)	Tons	43	91	50.6	33.7	65.7	69.7
	Metric tons	39 ^c	82.5 ^c	45.9 ^c	30.6 ^c	59.6 ^c	63.2
Bulk Solids (DW Only)	Tons	26	3	—	22.1	—	—
	Metric tons	23.6	2.7	—	20.1	—	—
Bulk Solids (Non-Rad/Non-DW)	Tons	120	17	—	—	—	—
	Metric tons	108.9	15.4	—	—	—	—
Bulk Liquids (DW Only)	Tons	—	—	—	22	—	1
	Metric tons	—	—	—	20	—	1.36
Bulk Liquids (Non-Rad/Non-DW)	Tons	—	—	—	—	—	—
	Metric tons	—	—	—	—	—	—
Totals	Tons	242	129	116	181	142	140
	Metric tons	219	117	105	164	129	127

^a Does not include *Toxic Substances Control Act* waste

^b Dangerous waste only

^c Mixed waste (radioactive and dangerous)

— = no data met the criteria

DW = dangerous waste

MW = mixed waste

5.3.3 Solid Waste Management

S Kosjerina

Solid waste management includes treatment, storage, and disposal of solid waste produced during Hanford Site operations or received back from offsite sources authorized by DOE to ship waste to the site (e.g., Perma-Fix Northwest, U.S. Navy). 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. A solid waste storage facility located in the 200-West Area (Figure 5-4), the CWC 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 ft³ (20,800 m³) 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. As of December 31, 2016, the volume of waste currently stored in the CWC Outside Storage Areas is approximately 165,767 ft³ (4,694 m³) and the volume of waste currently stored at CWC is approximately 391,145 ft³ (11,076 m³). All data is as of December 31, 2016.



Figure 5-4. Aerial View of the Central Waste Complex.

5.3.3.2 Waste Receiving and Processing Facility. The Waste Receiving and Processing (WRAP) Facility began operating in 1997 with the mission to analyze, characterize, and prepare drums and boxes of low-level, mixed, and transuranic wastes for disposal (Figure 5-5). The 52,000-ft² (4,800-m²) facility, along with two 21,500-ft² (2,000-m²) storage buildings, are located north of the CWC in the 200-West Area. The WRAP Facility is operating under interim status standards specified in the RCRA Permit (WA7890008967), WRAP Facility Part A Form.

Waste destined for the WRAP Facility includes stored and newly generated waste from current Hanford Site cleanup activities consisting of primarily contaminated cloth, paper, rubber, metal, and plastic (i.e., debris). Processed materials that qualify as low-level radioactive waste and meet disposal requirements are buried at the Hanford Site. Low-level radioactive waste not meeting burial requirements was processed at the WRAP Facility for onsite burial or prepared for future treatment at

other TSD facilities. Waste determined to be transuranic was 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.



Figure 5-5. A worker loads 65 drums of mixed low-level waste debris for shipment from the Waste Receiving and Processing Facility to Perma Fix Northwest.

5.3.3.3 T-Plant Complex. The T-Plant Complex (Figure 5-6) 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, and is preparing to receive K-Basin sludge for storage.



Figure 5-6. Aerial View of the T-Plant Complex.

5.3.3.4 Canister Storage Building

DJ Watson

The Canister Storage Building (CSB) is a large 42,000-ft² (3,902-m²) facility located in the 200-East Area. The facility stores approximately 2,300 tons (2,086 metric tons) of spent nuclear fuel packaged in about 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.

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

S Kosjerina, DE Nester

The low-level burial grounds (LLBG) consist of eight separate burial areas regulated under the AEA: two are located in the 200-East Area and six are located in the 200-West Area. 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). Located in the 200-West Area, the 218-W-5 Burial Ground contains Trenches 31 and 34; in the 200-East Area, the 218-E-12B Burial Ground contains Trench 94, which 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 and Dumps Group and 200-SW-2 Radioactive Landfills and Dumps Group Operable Unit Remedial Investigation/Feasibility Study Work Plan](#).

Low-level Waste Burial Ground 218-W-5, Trenches 31 and 34

Trenches 31 and 34 (Figure 5-7) are rectangular landfills with approximate base dimensions of 250 by 100 ft (76 by 30 m), with a variable depth of 30 to 40 ft (9 to 12 m). The 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; however, 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 in both trenches have been covered with compacted gravel and soil, and waste is currently being placed on the second waste layer in both Trenches 31 and 34.

As of December 31, 2016, Trench 31 contains approximately 218,900 ft³ (6,200 m³) of waste in approximately 3,740 waste packages. Trench 34 contains approximately 187,100 ft³ (5,300 m³) of waste in 5,280 waste packages. In 2016, a total of 12,360 ft³ (350 m³) of waste was disposed of in Trenches 31 and 34.



Figure 5-7. Trenches 31 (left) and 34 (right) are Used to Store and Dispose of Dangerous and Mixed Waste from Hanford Site Work.

Low-Level Waste Burial Ground, Trench 94

The LLBG Trench 94 received two defueled U.S. Navy reactor compartments in 2016. The total number of reactor compartments received into Trench 94 (218-E-12B Burial Ground) is 129 as of December 31, 2016. 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 ft (10 m) in diameter, 47 ft (14.3 m) long, and weigh between 1,000 and 1,500 tons (900 and 1,400 metric tons). Decommissioned cruiser reactor compartments are approximately 33 ft (10 m) in diameter, 42 ft (12.8 m) high, and weigh approximately 1,500 tons (1,362 metric tons).

5.3.3.6 Waste Encapsulation and Storage Facility

DJ Watson

Located in the 200-East Area, the WESF was constructed in 1970 and 1971 on the west end of B-Plant and became active 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. The water provides cooling and shielding for the capsules that are considered sealed sources.

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 current mission of WESF is safe storage of the cesium and strontium capsules. The facility is a two-story, 20,000-ft² (1,860-m²) building that is 157 ft (48 m) long and 40 ft (12 m) 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. A RCRA closure plan was approved for the initial closure of Hot Cells A through F. Initial closure stabilized the contents and contamination in these hot cells by filling them with grout. Grouting the hot cells commenced in CY 2016 and was completed in CY 2017. Only Cell G remains active for supporting cesium and strontium capsule storage and eventual removal. The operating areas and other building service areas associated with the hot cells and pool cell provide areas for instrumentation monitoring, utility support, or manipulator repair as required.

5.3.3.7 Integrated Disposal Facility

S Kosjerina

The IDF (Figure 5-8) is an unused landfill located in the south-central part of the 200-East Area. 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) currently operating under RCRA final status standards. The landfill is divided lengthwise (north to south) into two distinct cells: the east cell (cell 2) is for disposal of low-level radioactive waste (non-RCRA permitted) and the west cell (cell 1) 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 ft³ (82,000 m³). The IDF is referenced in DOE/EIS-0391 as a future disposal option for Hanford Site wastes.



Figure 5-8. Aerial View of the Integrated Disposal Facility.

5.3.3.8 Environmental Restoration Disposal Facility

MA Casbon

The ERDF (Figure 5-9) is the largest disposal facility in the DOE cleanup complex. The massive landfill located near the 200-West Area covers 107 acres and has a current capacity of approximately 21 million tons (19.1 million metric tons).



Figure 5-9. The Environmental Restoration Disposal Facility Covers an Area the Size of 52 Football Fields.

Regulated by the EPA, 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 CERCLA regulations. The total available expansion area of the ERDF site was authorized in a 1995 ROD (EPA et al. 1995) to cover as much as 1.6 mi² (4.1 km²). To provide a barrier preventing contaminant migration into the vadose zone from the in-ground facility, the ERDF was constructed to RCRA Subtitle C minimum technology requirements, which includes a double-liner and leachate collection system (40 CFR 264.301, Subpart N, "Landfills"). The lower liner of the double-liner system is a 3ft (0.9-m) thick layer of clay covered with high-density polyethylene (HDPE) plastic. A gravel or geocomposite drainage layer lies immediately above the lower liner. A second liner consisting of HDPE plastic sits on top of the drainage layer and is covered with another 1-ft (0.3-m)-thick gravel drainage layer. The topmost layer is 3 ft (0.9 m) of soil to protect the underlying layers of the liner system. 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 500 ft (152 m) wide, and 1,456 ft (444 m) long. A more recent configuration, the supercell, has the dimensions and capacity of a pair of the original sized cells. There are currently 10 cells at ERDF, 8 original and 2 supercells. In January 2016, ERDF began placing waste in its vertical expansion, a 20-ft vertical expansion over existing filled cells that will eliminate the need for one supercell. A permanent 15-ft (5-m)-thick RCRA Subtitle-C cap will be placed over the facility when Hanford cleanup is complete.

As of December 31, 2016, DOE and its contractors have disposed 17.9 million tons (16.2 million metric tons) of contaminated material at the ERDF since the facility began operations in 1996 (Figure 5-10). The disposed quantity 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 mi² (570 km²) River Corridor located along the banks of the Columbia River. The LLW consists mainly of soil contaminated during operations of Hanford's nine plutonium production reactors and support facilities from 1943 to 1987, as well as contaminated rubble from building demolition. In addition, ERDF receives cleanup waste from other Hanford locations.



Figure 5-10. Soil Contaminated with Concentrated Chromium is Treated Before Disposal at the Environmental Restoration Disposal Facility.

5.3.4 Liquid Waste Management

JA McLain

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 federal and state regulations and facility permits.

5.3.4.1 200 Area Effluent Treatment Facility. The 200 Area Effluent Treatment Facility (ETF) (Figure 5-11) 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 150 gal (570 L) 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 Areas 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), an underground drain field located just north of the 200-West Area. Percolation rates for the field were 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 200 Area ETF operated in 2016.



Figure 5-11. The Effluent Treatment Facility Receives Liquids from the Liquid Effluent Retention Facility.

5.3.4.2 Liquid Effluent Retention Facility. Across from the ETF, the Liquid Effluent Retention Facility (LERF) (Figure 5-12) consists of three RCRA-compliant surface impoundments to store process condensate from the 242-A Evaporator, groundwater from various operable unit pump-and-treat systems, leachate from ERDF and 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 gal (29.5 million L) and is constructed of two flexible, HDPE 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 the other liners fail. Each basin has a floating membrane cover constructed of low-density polyethylene to keep out windblown soil and weeds and minimize evaporation of organic compounds and tritium that may be present in the basin contents. The facility began operating in April 1994 and received liquid waste resulting from RCRA- and CERCLA-regulated cleanup activities. Historically, RCRA and CERCLA wastewaters were segregated in the surface basins and processed with different disposal destinations; however, this process became unnecessary after the ROD for ERDF was amended to allow receipt of all RCRA and CERCLA waste (DOE 2007); thus, segregation is no longer required.

The volume of wastewater received for the LERF basin storage in 2016 was approximately 1.65 million gal (6.25 million L). The majority of wastewater received at the LERF was pipeline-transported, CERCLA-regulated leachate from ERDF, totaling approximately 0.784 million gal (2.96 million L). The other major contributor to wastewater received into LERF was approximately 0.416 million gal (1.57 million L) of process condensate from the 242-A Evaporator. Approximately 0.45 million gal (1.7 million L) of wastewater was received by tanker trucks from various other facilities. Approximately 5.17 million gal (19.6 million L) of wastewater in LERF was treated at ETF in 2016. The treated effluent was discharged to the soil at the State-Approved Land Disposal Site. The volume of wastewater being stored in the LERF at the end of 2016 was approximately 15.1 million gal (57.2 million L).



Figure 5-12. The Liquid Effluent Retention Facility is Located in the Central Part of the Hanford Site.

5.3.4.3 200 Areas Treated Effluent Disposal Facility. Located east of the 200-East Area, the 200 Area' Treated Effluent Disposal Facility (Figure 5-13) is a collection and disposal system for non-RCRA waste streams. Individual waste streams must be treated or otherwise comply with best available technology and all known available and reasonable treatment methods in accordance with [WAC 173-240, "Submission of Plans and Reports for Construction of Wastewater Facilities,"](#) 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 Treated Effluent Disposal Facility consists of approximately 11 mi (18 km) of buried pipelines connecting three pumping stations, the 6653 Building (known as the disposal sample station) and two 5-ac (2-ha) disposal ponds. The facility began operating in April 1995 and has a capacity of 3,400 gal (12,900 L)/min. The volume of non-radioactive, non-dangerous waste is disposed to this facility in 2016 was approximately 96 million gallons (363,360,000 million L).



Figure 5-13. 200 Areas' Treated Effluent Disposal Facility Ponds A and B.

5.3.4.4 242-A Evaporator. Located in the 200-East Area, the 242-A Evaporator 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 DSTs for storage and reduces the potential need for additional tanks.

In 2016, two operating campaigns were completed at 242-A Evaporator with a volume reduction of 305,000 gal (1,154,000 million gal). The facility underwent upgrades in the control room in 2016.

5.3.5 Underground Waste Storage Tanks

Hanford's 56 million gal (212 million L) of highly radioactive and chemical waste is stored in 177 underground tanks until it is prepared for disposal (Figure 5-14). 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 single-shell tanks (SSTs) (16 of which are declared retrieval completed [HNF-EP-1082]) and 28 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 2015 related to their operation and closure.



Figure 5-14. Aerial Over of the 200 Areas Tank Farms.

5.3.6 Single-Shell Tank System

The SST system includes 149 tanks that were constructed between 1943 and 1964 to store mixed waste generated on the Hanford Site; 61 of the tanks are assumed to have leaked. 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 in accordance with TPA Appendices H and I and currently operates under interim status standards. In 2016, 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 (Figure 5-15). C Farm is one of 18 tank farms located on the Hanford Site. The retrieval status is 15 of the 16 tanks are complete (one was completed in 2016, and one is in progress for CY 2017). Retrieval of C-111 was completed on March 28, 2016, and the retrieval certificate for C-111 was submitted to the state in August 2016. Retrieval activities continue at C-105. By the end of 2016, more than 75% of the waste has been retrieved from Tank C-105 using the Mobile Arm Retrieval System, 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. C-105 retrieval was suspended in September 2015 pending the installation of a third technology retrieval system. Retrieval Operations are scheduled to resume during summer 2017.



Figure 5-15. Work Continues at the C Farm.

5.3.7 Double-shell Tank System

The DST system includes 28 DSTs (25 tanks in 200-East Area and 3 in 200-West Area) located in six 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 31.5 million gal (119 million L) of radioactive and chemical waste. DST space is being managed to store waste pending treatment by the WTP and includes emergency pumping space available at all times of 1.27 million gal (4.8 million L).

At the end of 2016, there were 25.6 million gal (96.7 million L) of waste in the DSTs. Quantities of liquid waste generated in 2016 and stored in underground storage tanks are provided in the [Hanford Site Annual Dangerous Waste Report: Calendar Year 2016](#) (DOE/RL-2017-15). Table 5-5 summarizes the waste retrieved and stored in the DST system from 2009 through 2016.

Table 5-5. Tank Farm System Quantities of Waste^a Retrieved and Stored. (2 Pages)

Type of Waste	Units ^b	2009	2010	2011	2012	2013	2014	2015	2016
DSTs year-end volume ^c	gal	25,971	25,835	25,948	26,580	26,733	26,575	25,791	25,542
	L	98,311	97,796	98,224	98,000	101,195	100,597	97,630	96,676
242-A Evaporator volume evaporated	gal	960	548	0	0	0	793	1,329	305
	L	3,634	2,074	0	0	0	3,002	5,031	1,154
Single-shell tanks volume pumped ^d	gal	102	240	560	238	70	262	78	21
	L	386	909	2,120	900	263	991	295	79

Table 5-5. Tank Farm System Quantities of Waste^a Retrieved and Stored. (2 Pages)

^a Quantity of waste is defined as 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.

^b Multiply volumes shown by 1,000. 1 gallon = 3.785 liters.

^c Includes other miscellaneous additions or reductions (e.g., dilution and flush waters and corrosion controls) not represented elsewhere on this chart

^d Volume does not include dilution or flush water.

5.3.8 Underground Waste Storage Tanks and Associated Facilities Progress on Defense Nuclear Facilities Safety Board

R Hyson

Throughout 2016, the U.S. Department of Energy, Office of River Protection (DOE-ORP) and its contractors met with and provided information to the DNFSB and its technical staff to resolve concerns regarding the following Hanford Site Tank Farm projects:

- 242-A Evaporator
- Low Activity Waste Pretreatment System
- Waste Compatibility Program
- 222-S Laboratory
- Recommendation 2012-2.

5.3.8.1 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 2013) to the DNFSB. Implementation Plan actions completed and provided to the DNFSB included:

- Action 1-1 and 4-1, implementation of the DOE-approved DSA 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.
- Action 5-1, evaluation of potential means to reduce the inventory of retained flammable gases in DSTs in a controlled manner, completed February 2015.
- Action 1-2, development of a streamlined approach to implementing the planned improvements for upgrading the DST tank ventilation systems to meet safety-significant requirements, completed October 2015.

On March 24, 2016, DOE delivered a letter from the Secretary of Energy that revised the Implementation Plan (IP) for DNFSB recommendation 2012-2, *Hanford Tank Farms Flammable Gas Safety Strategy*. The revision to the IP on March 24, 2016, described a more efficient approach pertaining to the deployment of safety-significant portable exhauster units for use during off-normal events and the actions completed to date that have been incorporated into the Tank Farms DSA. The margin of safety at the Tank Farms will be further improved as IP actions are completed. The implementation of safety-significant real-time flow monitoring will be of particular benefit, adding both defense-in-depth and a simplified control strategy.

The Board responded to the Department via letter on September 16, 2016, concluding that the proposed safety-significant portable exhauster concept was consistent with the Board's recommendation and acknowledging appreciation of the updated deliverable schedule contained in the IP. The Department will continue to work with the Board to keep them apprised of ongoing IP efforts for Recommendation 2012-2, currently scheduled for completion in December 2018.

On December 27, 2016, DOE delivered a letter from the Assistant Secretary for Environmental Management that revised the expected completion date for DNFSB recommendation 2012-2, Action 3-1, *Provide [safety-significant (SS)] annulus level detectors in each of the [double shell tank (DST)] annuli where the flammable gas hazard exists*.

Work will continue in 2017 on implementing Action 2-2, installation of safety significant instrumentation for real-time monitoring of the ventilation exhaust flow from each DST. Once complete, the selected air flow meter will be used to monitor DST ventilation exhaust flow in real time.

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>.

5.3.9 Single-Shell Tank Closure and Corrective Measures Program

P Rutland

The SST Closure and Corrective Measures Program (formerly known as the Vadose Zone Program) is responsible for the closure of SST WMAs, conducting performance assessments (PAs), and performing agreed upon interim measures in and around SST WMAs. Current efforts are focused on the development of closure documentation for WMA C; conducting PAs for WMA C, WMA A-AX, and the IDF; and project activities necessary to support the design and construction of additional interim surface barriers. Additional activities include documenting past characterization work, planning for future interim measures, and monitoring the performance of implemented interim measures.

5.3.9.1 Closure of WMAs. Closure activities in CY 2016 continued to focus on the development of closure strategies and closure documents. Closure documents were prepared to meet the requirements of [DOE O 435.1, *Radioactive Waste Management*](#), and the RCRA and to be consistent with the CERCLA. Closure documents prepared during CY 2016 include a draft DOE O 435.1 Tier 1 Closure Plan for WMA C, a draft Waste Incidental to Reprocessing evaluation document for WMA C, a draft RCRA Tier 2 Closure Plan for WMA C, a draft RCRA Tier 3 Closure Plan for the 241-C-200 series tanks, a Phase 2 RCRA Facility Investigation Report for WMA C, and a RCRA Corrective Measures Study Report for WMA C.

The purpose of the closure documents is to reach agreement with regulatory agencies on closure requirements for WMA C, and to enable closure activities to proceed.

5.3.9.2 Performance Assessments. Work was conducted during CY 2016 to prepare PAs for WMA C, the IDF, and WMA A-AX. The WMA C and WMA A-AX PAs support closure of WMA C and WMA A-AX, respectively, while the IDF PA supports operations of the IDF.

A PA for WMA C was completed in September 2016 to support DOE-ORP efforts to close WMA C. This work is being performed to meet federal and state requirements along with the requirements in the TPA (Ecology et al. 1989a), Appendix I. To meet these requirements, DOE-ORP released a set of four complementary reports, each focusing on specific requirements for addressing impacts of individual contamination sources that will remain in WMA C after closure (i.e., existing contamination in the vadose zone, past tank leaks and unplanned releases, and tank residuals [radionuclides/hazardous chemicals]). Review of the WMA C PA documentation by Ecology was initiated in October 2016.

A PA for the IDF was under development in CY 2016. This PA will address the requirements outlined in DOE Order 435.1. The overall objective of this PA is to provide a basis for making informed decisions pertinent to final closure of the IDF.

The development of preliminary PA for WMA A-AX was initiated during the last quarter of CY 2016 and is being prepared to meet federal, state, and the TPA (Ecology et al. 1989a), Appendix I requirements. The initial work performed supports risk assessment and modeling efforts needed to help guide retrieval and RCRA Facility Investigation /Corrective Measures Study characterization activities.

5.3.9.3 Interim Surface Barriers. Interim surface barriers were constructed at T and TY Tank Farms in 2008 and 2010, respectively. The effectiveness of the two interim surface barriers is being assessed through an ongoing barrier-monitoring program, and monitoring results are reported annually. Monitoring indicates that the barriers are effective in drying of the vadose zone beneath the barriers. Two additional interim surface barriers have been designed to be placed over portions of the SX Tank Farm; those designs have been approved for construction. The SX Tank Farm interim surface barriers will be constructed of modified asphalt, and a single evapotranspiration basin, located south of SX Tank Farm, will be used to dispose of water collected by the barriers. Milestones for the construction of interim surface barriers were renegotiated during CY 2016, and construction of the SX Farm interim surface barriers is scheduled to begin in October 2017.

5.4 Hanford Tank Waste Treatment and Immobilization Plant

K Henckel, BA Walker

The WTP is being built on 65 ac (26 ha) in the 200-East Area to treat radioactive and hazardous waste stored in 177 underground tanks on the Central Plateau. The WTP comprises four major facilities (Pretreatment Facility, HLW Facility, Low-Activity Waste [LAW] Facility, and Analytical Laboratory) along with support buildings and associated infrastructure (Balance of Facilities [BOF]). Construction of the WTP is managed in accordance with the RCRA Permit. In 2016, DOE and Bechtel National Inc. (BNI) finalized modifications to the WTP contract that prioritize finishing the LAW Facility, BOF, and Analytical Laboratory to feed waste directly from the Hanford Tank Farms to LAW under an approach called Direct Feed Low-Activity Waste (DFLAW). The DFLAW calls for the treatment of tank waste in LAW as soon as 2022. The DFLAW approach also calls for a capability called the Effluent Management Facility (EMF).

A description of the WTP facilities and the progress at each facility in 2016 is provided in the following sections.

5.4.1 Pretreatment Facility

The Pretreatment Facility is where waste will be received from the Tank Farms and separated into low-activity and HLW streams for transport to the LAW and HLW facilities for processing. In 2016, work continued to resolve the remaining technical decisions that have impacted design and construction at the Pretreatment Facility since 2012. Significant progress on the technical decisions was made in 2016 with resolution of the three most significant ones being achieved in January 2017. In December 2016, the final phase started for full-scale testing of control equipment and systems designed to safely mix radioactive waste in Pretreatment vessels. Testing is expected to finish in late 2017.

5.4.2 High-Level Waste Facility

The HLW Facility is where HLW from the Pretreatment 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. In 2016, experts at Mississippi State University began conducting tests of the safe change HEPA filters that will be used in the Pretreatment, LAW, and HLW facilities. Tests included studies of the filter performance under combined operating conditions that exceed the requirements for standard nuclear-grade filters. The tests specifically challenge the filters' abilities to withstand accident conditions, such as an earthquake or fire. The HLW team and Mississippi State University completed testing of the safe change filters in September 2016. This represents a significant step toward ensuring that qualified HEPA filters are available to support the WTP mission.

5.4.3 Low-Activity Waste Facility

The LAW Facility is where low-activity waste will be mixed with glass-forming materials in high-temperature melters, poured into canisters, and allowed to cool to form a solid, immobile glass form. In 2016, construction continued on the installation of the final pieces of major engineered equipment for the off-gas treatment system, including the Thermal Catalytic Oxidizer, the ammonia skid, and the caustic scrubber. Crews also completed fabrication work on two 300-ton (272-metric tons) melters that will be the heart of the vitrification process in the LAW Facility.

5.4.4 Analytical Laboratory

Once operational, the Analytical Laboratory will process about 10,000 waste samples annually to support glass formulation and waste-form compliance.

5.4.5 Balance of Facilities

The WTP's Balance of Facilities is made up of 22 facilities that provide utilities and services to operate the LAW, HLW, Analytical Laboratory, and Pretreatment facilities. The support utilities include: electrical power distribution system; backup power systems; compressed air; chilled, process, potable, and fire water and steam systems; and communication and control systems. Turnovers from construction to startup began in 2016 and will continue through 2019. The BOFs are non-nuclear industrial buildings constructed in the 2004 to 2016 period. Final checks are underway system-by-system with formal transfers to the Waste Treatment Completion Company startup organization. Once complete with component and system testing, the systems and facilities will be transferred to Commissioning where integrated testing will be performed. In September 2016, WTP workers brought in permanent power to Building 87, the primary electrical switchgear building. Permanent power has now been successfully

distributed to three additional BOFs. This achievement represents the transition from temporary construction-phase utilities to permanent utilities that will operate WTP. As the remaining checks and punch list closeout for the infrastructure facilities is completed, the facilities will be tested for DFLAW operations and declared ready for integrated system testing.

5.4.6 Effluent Management Facility

JA Joyner

Pre-construction activities began on EMF in 2016 and formal construction will commence in 2017, with approval of a Temporary Authorization from Ecology. EMF will involve four structures: the main processing facility, a utility building, an electrical building, and the low point drain building. During the LAW vitrification process, effluent – or liquid secondary waste – is created and will be transferred to the EMF for treatment and disposition. Design is approximately 80% complete and bulk and equipment procurements are underway. Placement of concrete for the floor slab of the utility and process buildings is now underway and installation of equipment structures will commence in 2017. Construction of the EMF is scheduled to be completed in late 2019.

5.4.7 Waste Treatment and Immobilization Plant Progress on Defense Nuclear Facilities Safety Board Recommendations Board

R Hyson

Throughout 2016, DOE-ORP and its contractors met with and provided information to the DNFSB and its technical staff to update and review WTP technical topics. The DOE-ORP provided responses in 2016 to address topics of concern at WTP in the areas of 1) potential criticality in process vessels; 2) generation and accumulation of hydrogen in process vessels; 3) pulse jet mixer control; 4) hydrogen, piping, and ancillary vessels; 5) spray leak methodology; 6) heat transfer analyses for process vessels; 7) safety controls for ammonia hazards; 8) volcanic ash fall hazard; 9) hydrogen control strategy for the High-Level Waste Facility; 10) unanalyzed melter accidents; and 11) seismic categorization of safety controls. The DOE-ORP continues to work with DNFSB and the contractor to provide resolutions and a path forward on technical issues.

5.4.7.1 Defense Nuclear Facilities Safety Board Recommendation 2011-1. The DNFSB issued Recommendation 2011-1, *Safety Culture at the WTP*, on June 9, 2011. The U.S. Department of Energy, Office of Enterprise Assessments (DOE-EA) conducted a follow-up assessment in December 2014 through February 2015 on WTP safety culture. The follow-on review was similar to the 2011 independent oversight review and the 2014 follow-up assessment. The final report was transmitted on June 24, 2015, by DOE-EA. The report noted both DOE-ORP and BNI have made improvements since the 2014 assessment.

On July 21, 2015, U.S. Department of Energy, Office of Environmental Management (DOE-EM) completed Action 2-13 by transmitting to the DNFSB the Program Secretarial Officer approval of site-specific safety culture sustainment tools.

On August 26, 2015, the DNFSB held a Public Hearing in Richland, Washington, on Safety Culture at the WTP. The DOE panel members included the Director of DOE-EA, the Principal Deputy Assistant Secretary for Environmental Management, the DOE-ORP Manager, and the DOE-ORP WTP Federal Project Director.

The DOE-ORP Safety Culture Sustainment Plan, updated in September 2015, identified improvement actions related to Organizational Culture, Safety Culture, and Safety Conscious Work Environment with special emphasis in the areas of Leadership, Employee Engagement, and Organizational Learning. Highlights included strengthened federal oversight processes (BNI's Management Improvement Plan, contract incentives), completion of self-assessments (internal assessment, safety culture self-assessment), clarified employee expectations (ABC TV), internal assessments (self-assessments), and establishment of performance metrics/measurements (Federal Employee Viewpoint Survey analysis for organizational culture, questioning attitude metrics). In addition, Safety Culture Refresher Training was provided to all DOE-ORP federal and contractor staff in March 2016.

The DOE-ORP has completed Action 1-6. The Waste Treatment and Immobilization Plant Direct Feed Low-Activity Waste/Analytical Laboratory and Balance of Facilities Baseline Change Proposal and associated contract modification 384 of the Bechtel National, Inc., Waste Treatment and Immobilization Plant contract was approved on December 15, 2016. The contract modification included a clause requiring the contractor to establish, maintain, and promote a safety conscious work environment and provide the proper programs, policies, and enforcement of policies to ensure compliance.

DNFSB is scheduled to assess DOE-ORP and the safety culture at WTP in the summer of 2017.

All related information for recommendation 2011-1, is available on the DNFSB website at:

<https://www.dnfsb.gov/index.php>.

5.5 Long-Term Stewardship

R Ranade

The Hanford Site's Long-Term Stewardship (LTS) Program has responsibilities within the 220 mi² (570 km²) of the Hanford Site's River Corridor and bounded by 46 mi (74 km) of Columbia River shoreline (Figure 5-16); these responsibilities include managing post-cleanup obligations for 1,527 waste sites and 6 Manhattan Project Era production reactors that have been placed in interim safe storage. More than 24,000 cleanup and historic documents have been identified, indexed, and tagged in the LTS records and document libraries. The LTS program manages and provides S&M of facilities and Institutional Controls and all associated monitoring to ensure continued protectiveness of human health and the environment once cleanup actions have been completed.

Since 2010, through collaborative efforts with DOE and its prime contractors, cleaned-up waste sites and other facilities in 14 geographic areas and six cocooned reactor facilities were transitioned (mid-contract) from the River Corridor Closure Contractor to MSA's LTS program via contract modification, which included the preparation of a transition and turnover package (TTP). This documentation was prepared for each segment or area transitioned to LTS.

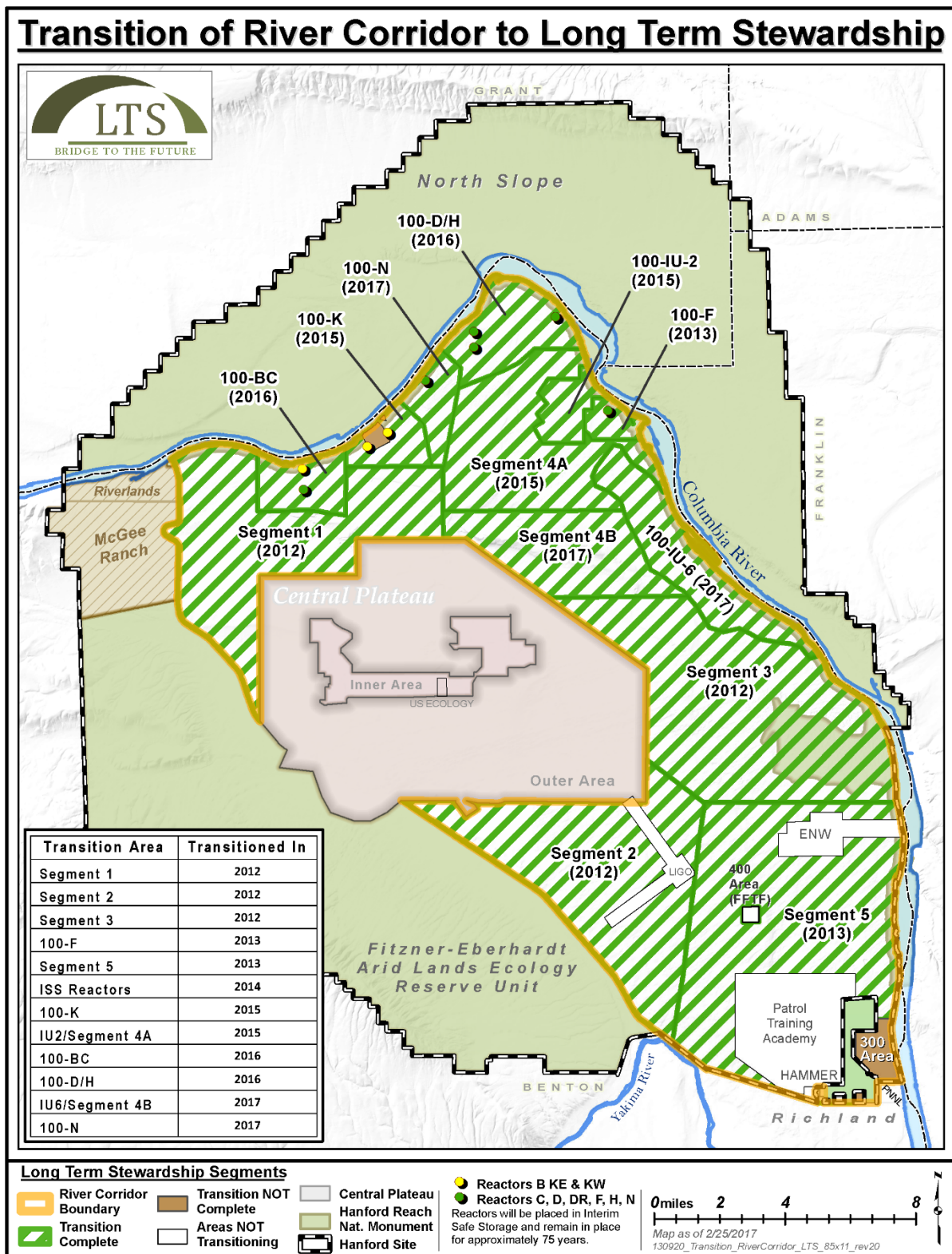


Figure 5-16. Long-Term Stewardship Managed Areas.

The TTP was used to document the condition of the land at the time of transition and to convey relevant information about the area. Topics include site assessments, record of cleanup activities, as-left conditions, remaining regulatory actions, resource management, information management, and ongoing S&M requirements. Information management activities continue during the entire process to ensure that documents cited in the TTP are identified, located, stored, protected, and made accessible.

The LTS program has conducted inspection and S&M activities for the reactors placed in Interim Safe Storage, also known as cocooning (the 105-F Reactor in October 2014 and the other five reactors in 2015 and 2016). Interim Safe Storage is designed to protect the reactor for 75 years while radioactive decay continues, ultimately making the structures safe for demolition and removal. Reactor entries and internal inspections typically are conducted at 5-year intervals to assess the condition of the structures and evaluate potential deterioration of the reactor core, shield walls, and roof.

During the 2015 and 2016 inspections of the cocooned reactors, several housekeeping tasks were identified that the LTS Program completed in 2016 and early 2017 to minimize future deterioration of the cocooned structure and improve protectiveness of human health and the environment (Figure 5-17). The tasks included, but were not limited to, the following:

- Welding steel access plates to prevent unauthorized human intrusion
- Grading the surface and removing vegetation for wildfire protection
- Removing contaminated swallow nests at the 105-N Reactor facility
- Installing stainless steel screen material over small openings in the siding to prevent bats from roosting in the cocooned facilities
- Installing bat houses on the sides of the facilities to mitigate loss of roosting locations
- Evaluating remaining transformers in facilities for PCBs.

Completing the “housekeeping” tasks was part of the negotiations with the TPA agencies to extend the inspection period from 5 to 10 years. The next inspections will be conducted in 2025. The monitoring for internal temperature and flood level in each reactor building was determined to be unnecessary and has been discontinued; changes were approved by EPA and Ecology and are documented in TPA change notices. These changes will result into considerable savings for DOE-RL.

Hanford’s LTS program is successfully shifting from a program focused on transitioning land and waste sites to a program focused on data management of S&M activities for those buildings and waste sites within the program and which require Institutional Controls.

The LTS program maintains an internal library of documents referenced in the TTPs and additional information that may be relevant to the closure history. These are the documents that tell the story. The majority of these documents are in the Hanford Administrative Record; however, the LTS library also includes Official Use Only documents that have not yet been released to the public and those that were only placed in DOE’s Integrated Document Management System (IDMS). Currently in the LTS

information systems there are over 24,000 documents and 22,000 photos; more are added as the program continues to evolve.

Near the end of the River Corridor Closure Contract (August 2016), MSA and WCH worked together to transfer the WCH Stewardship Information System, a data management tool, to the LTS program. The system has been installed on the Hanford Local Area Network. The Stewardship Information System provides historical information on the closure process and easy access to CERCLA investigation, guidance, and decision documents that contain regulatory signatures of approval. This type of closure information is critical to LTS in the CERCLA post-closure world. The ability to quickly and confidently answer the questions of 1) what was there 2) What was removed and 3) what is left are central tenants the LTS information management approach.

Stainless Steel Screen Installed



Non-PCB Transformers



Removing Contaminated Bird Nests



Workers Install Stainless Screens



Local Bat Population



Figure 5-17. Housekeeping Activities.

5.6 Scientific and Technical Contributions to Hanford Site Cleanup

MD Freshley, RA Peterson

The Pacific Northwest National Laboratory (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 Offices of Soil and Groundwater Remediation and Tank Waste and Waste Processing, DOE-RL, CHPRC, DOE-ORP, WRPS, and BNI. Efforts included performing scientific and technical evaluations and reviews and developing and advancing new technologies to address site cleanup challenges.

5.6.1 Waste Processing and Tank Waste Management

Contributions to waste processing and tank waste management during 2016 include continuing support to engineering development in support resolution of mixing issues associated with the WTP. This activity included working with BNI to identify necessary and sufficient testing to demonstrate single high solids vessel full-scale mixing and developing the simulants required for this testing. In addition, PNNL provided leadership in resolution of technical issues associated with pulse-jet mixing operations within the WTP.

WRPS continued design efforts for the Low-activity Waste Pretreatment System, which PNNL is supporting by testing filtration and ion exchange systems to demonstrate operability over a wide range of conditions. In addition, researchers are performing work to confirm gas generation, retention, and release rates in the ion exchange columns planned for Low-activity Waste Pretreatment System.

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. Several candidate complexes may be present in tank wastes, and actual waste samples were secured for testing during 2016.

Researchers at PNNL continued to support the advancement of glass formulations for both WTP low-activity and HLWs. Significant advancements have been made in waste loading and melting rate, including increasing the aluminum oxide and chromium(III) oxide concentrations in glass from 13 to greater than 26 wt% and from 0.5 to 1.5 wt%, respectively. These advancements provide the opportunity to reduce (if not eliminate) planned pretreatment options associated with caustic or oxidative leaching. In addition, the advanced glass formulations will lead to a significant reduction in glass canister/container counts and increased waste throughput, which ultimately will have a significant impact on reducing overall mission life for the WTP.

In support of WRPS efforts to test and evaluate a tank farm vapor monitoring and detection system, researchers at PNNL designed and initiated integrated outdoor testing of commercial instruments and software to detect, quantify, model, and predict vapor plume migration. The testing supports technology maturation in preparation for subsequent evaluation in an actual tank farm environment.

5.6.2 Soil and Groundwater Remediation

The Deep Vadose Zone Applied Field Research Initiative focused on improving best practices to enhance current baseline remediation technologies being deployed for soil and groundwater remediation at the Hanford Site, conducting high impact research to define alternatives to the current baseline, and

developing next generation solutions. The Applied Field Research Initiative is 1) developing the technical basis for remediation of vadose zone and groundwater contaminants, 2) developing and implementing systems-based approaches for remediation that provide alternatives to the current baseline, and 3) implementing systems-based characterization and monitoring of contaminant sources and residual vadose zone contamination. Specifically, PNNL contributed to the areas detailed below in 2016.

5.6.2.1 Technical Basis for Remediation. Researchers at PNNL completed revision of a technology evaluation plan (PNNL-24825), updating the conceptual model and an approach for evaluating technologies for remediating iodine-129 in the subsurface at the 200-UP-1 Operable Unit. Iodine-129 is a key contaminant of concern at Hanford because of its long half-life, high mobility in groundwater, and long-term risk to human health and the environment. PNNL addressed review comments from the regulatory agencies. Results from ongoing investigations were summarized in a conceptual model update (PNNL-25872).

Researchers at PNNL evaluated the biogeochemistry of iodine-129 in Hanford groundwater, focused on determining how microbial reduction can provide a technical basis for remediation or natural attenuation approaches. Biogeochemical analysis of core samples from the 200-UP-1 Operable Unit were evaluated to address possible remediation approaches for mixtures of contaminants (including technetium-99, uranium, iodine-129, and nitrate) when provided with various carbon and electron sources. Results from these studies provide the technical basis for remediation approaches for 200-UP-1 groundwater.

Researchers applied understanding of microbial communities to continue optimization of fluidized bed reactor performance in the 200-West pump-and-treat system for treating carbon tetrachloride and nitrate. The project evaluated issues with reinjection wells.

A final report was published on performance of the Prototype Hanford Barrier from 1994 to 2015 (DOE/RL-2016-37). The report summarizes performance of the surface barrier over time and addresses uncertainties to facilitate implementation of surface barriers as a remedy for deep vadose zone contamination.

5.6.2.2 Systems-Based Assessment of Remediation. The Hanford Site is applying pump-and-treat remediation to control and diminish contaminant plumes. In the future, remedial decisions will need to be made to transition from pump-and-treat to remediation closure or another approach to complete remediation (i.e., transition to natural attenuation). The recent document [*Performance Assessment for Pump-and-Treat Closure or Transition*](#) (PNNL-24696) provides a structured approach to assess pump-and-treat systems and support remedy decisions. A document was published (PNNL-25875; <https://informationrelease.pnl.gov/release/cleared/251630>) to identify how elements of the pump-and-treat PA document can be applied to address PA needs for Hanford Site pump-and-treat systems. The focus was on pump-and-treat assessment for transition to natural attenuation because 1) the 200-ZP-1 and 200-UP-1 Operable Unit pump-and-treat systems are part of remedies where transition to natural attenuation is identified in the [*Record of Decision Hanford 200 Area 200-ZP-1 Operable Unit Superfund Site, WA*](#) (EPA et al. 2008) and 2) the 100 Area systems target chromium plumes that are being diminished and are receding from the river such that natural attenuation may become a suitable polishing step to meet both aquifer concentration objectives and the more stringent river-protection standards.

Following a Remedial Investigation Work Plan (DOE/RL-2012-64), researchers characterized the extent of lead and arsenic in surface soils across 5,000 ac (2,023 ha) of historical orchard lands within the 100-OL-1 Operable Unit. The project summarized results of the remedial investigation in a report (DOE/RL-2016-54).

5.6.2.3 Systems-Based Monitoring. Researchers continued 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 over 50% by establishing monitoring requirements driven by technical objectives, knowledge of plume behavior, and integration with remedial actions.

PNNL completed performance monitoring for DOE/RL-2016-37, which reviewed and summarized over two decades of data. The report provides a technical basis for future surface barrier deployment.

6.0 Air Monitoring

CJ Perkins, SJ Johnson

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 to calculate the doses to humans, plants, and animals. Measured and calculated results are compared with the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and/or Washington State Department of Health (WDOH) standards. This report presents 2016 measurement results.

6.1 Effluent Monitoring of Stack Air Emissions

SJ Johnson

Hanford Site contractors monitor airborne emissions from site facilities to determine compliance with federal and state regulatory requirements and 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 sampled either continuously or periodically. Airborne emissions with 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 current and other reports, all of which are available to the public. For example, DOE annually submits the Radionuclide Air Emissions Report for the Hanford Site (e.g., DOE/RL-2017-17) a report of Hanford Site radionuclide air emissions in compliance with [40 CFR 61, Subpart H, 61.94, "Compliance and Reporting"](#) and [WAC 246-247, "Radiation Protection – Air Emissions."](#) The Radionuclide Air Emissions Report for the Hanford Site for the prior year's sampling effort is due annually to EPA and WDOH no later than June 30.

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 and vents) during routine operations. The isotopes most commonly measured include: tritium (i.e., hydrogen-3), strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, americium-241, and protactinium-231. Emission points are monitored continuously if they have the potential to exceed 1% of the public dose limit of 10 mrem/yr or 100 microsievert (μSv)/yr.

Distinguishing Hanford Site-produced radionuclides in the environment is challenging because concentrations of site stack emissions 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 more than 30 years ago in 1987 when the Site's current mission of environmental cleanup and remediation was initiated.

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. Other factors that are considered include removal of the calculated effect of pollution-abatement equipment, 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, and 400 Areas. The prime sources of emissions and the number of emission points by operating area are as follows:

- In the 100 Area, two radioactive emission points were active in 2016. Emissions originated from cleanup activities at the 100-K West Fuel Storage Basin, which in previous years contained irradiated nuclear fuel, and from the Cold Vacuum Drying Facility.
- In the 200 Areas, 35 radioactive emission points were active in 2016. The primary locations of these emission points were the Plutonium Finishing Plant, T Plant, B Plant, Waste Encapsulation and Storage Facility, underground tanks storing high-level radioactive waste, a waste evaporator (242-A Evaporator), the Waste Receiving and Processing Facility, 222-S Laboratory, and Plutonium Uranium Extraction Facility.
- In the 300 Area, four radioactive emission points were active in 2016. 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 in 2016; however, these sources have been shut down. Emission point locations in the 400 Area include: Fast Flux Test Facility, Maintenance and Storage Facility, and the Fuels and Materials Examination Facility.

Air emission data collected in 2016 were comparable to those collected in 2015. Table 6-1 summarizes Hanford Site radioactive airborne emissions in 2016.

Table 6-1. Hanford Site Radioactive Airborne Emissions in Calendar Year 2016. (2 Pages)

Radionuclide	Half-Life ^b	Calendar Year 2016 Releases, Ci ^a				
		100 Area	200-East Area	200-West Area	300 Area	400 Area
Actinium-227	21.6	NA	NA	NA	3.1×10^{-10}	NA
Alpha (gross) ^c	NA	1.0×10^{-05}	1.6×10^{-06}	2.7×10^{-05}	1.0×10^{-07}	7.5×10^{-07}
Americium-241	432.2	2.7×10^{-06}	1.2×10^{-07}	2.1×10^{-06}	4.8×10^{-10}	NA
Americium-243	7,380	NA	NA	NA	4.8×10^{-08}	NA
Beta (gross) ^d	NA	1.3×10^{-05}	5.7×10^{-05}	5.5×10^{-06}	4.9×10^{-06}	1.9×10^{-06}

Table 6-1. Hanford Site Radioactive Airborne Emissions in Calendar Year 2016. (2 Pages)

Radionuclide	Half-Life ^b	Calendar Year 2016 Releases, Ci ^a				
		100 Area	200-East Area	200-West Area	300 Area	400 Area
Carbon-14	5,730	NA	NA	NA	1.2×10^{-04}	NA
Cesium-134	2.1	ND	ND	ND	NA	NA
Cesium-137	30	2.6×10^{-06}	7.7×10^{-06}	ND	1.2×10^{-08}	1.1×10^{-11}
Cobalt -60	NA	NA	NA	NA	9.7×10^{-08}	NA
Curium-243/244	29.1	NA	NA	NA	ND	NA
Europium-152	13.5	ND	ND	ND	1.9×10^{-09}	NA
Europium-154	8.6	ND	ND	ND	1.1×10^{-08}	NA
Gadolinium-153	240.4 days	NA	NA	NA	8.0×10^{-11}	NA
Iodine-129	16,000,000	NA	9.8×10^{-04}	NA	NA	NA
Krypton-85	10.7	NA	NA	NA	2.8×10^{-07}	NA
Neptunium-237	2,144,000	NA	NA	NA	1.4×10^{-08}	NA
Plutonium-238	87.7	5.0×10^{-07}	ND	1.4×10^{-07}	3.7×10^{-08}	NA
Plutonium-239/240	24,110	2.9×10^{-06}	3.2×10^{-08}	9.0×10^{-06}	2.1×10^{-09}	2.3×10^{-13}
Plutonium-241	14.4	8.8×10^{-06}	ND	9.9×10^{-08}	ND	NA
Protactinium-231	32,760	NA	ND	NA	NA	NA
Radium-226	1,600	NA	NA	NA	3.7×10^{-10}	NA
Radon-220	55.6 sec	NA	NA	NA	$1.8 \times 10^{+02}$	NA
Ruthenium-106	373.6 days	ND	ND	ND	1.3×10^{-09}	NA
Sodium-22	2.6	NA	NA	NA	NA	2.1×10^{-10}
Strontium-90	29.1	3.2×10^{-06}	2.2×10^{-05}	4.2×10^{-07}	1.7×10^{-07}	NA
Technetium-99	211,100	NA	NA	NA	4.1×10^{-06}	NA
Tritium (elemental)	12.3	NA	NA	NA	$2.4 \times 10^{+01}$	NA
Tritium (tritiated water vapor)	12.3	NA	NA	NA	$2.4 \times 10^{+02}$	1.6×10^{-02}
Uranium-232	68.9	NA	NA	NA	8.6×10^{-09}	NA
Uranium-233	159,200	NA	NA	NA	2.7×10^{-08}	NA

^a To convert to the International System of Units; multiply pCi/g by 0.037 to obtain Bq/g.^b In years, unless otherwise specified.^c For dose modeling, gross alpha is assumed to be plutonium-239/240.^d For dose modeling, gross beta is assumed to be cesium-137.

NA = Not Applicable

ND = Not Detected

6.1.2 Criteria and Toxic Air Pollutants

Criteria and toxic air pollutants emitted from chemical-processing and electricity-generating engines fueled by petroleum and/or propane gas are monitored when activities known to release nonradioactive pollutants of concern (i.e. particulate matter, sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead) occur. 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 and propane fuel consumed at multiple emission units locations from across the Site, annual emissions are either measured or calculated using EPA-approved formulas ([Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources](#) [EPA 1995]). 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	2016 Releases	
	lb	kg
Criteria Pollutants		
Particulate matter-total	0	0
Particulate matter-10	4,000	1,814
Particulate matter-2.5	0	0
Lead	0	0
Nitrogen oxides	30,000	13,608
Sulfur oxides	0	0
Carbon monoxide	14,000	6,350
Volatile organic compounds	10,000	4,536
Ammonia	4,000	1,814
Toxic Air Pollutants		
Acetic acid	0	0
Acetone	2	1
Benzene	0	0
1-Butanol	1	0.5
Carbon tetrachloride	5	2.3
Chloroform	0	0
Dichloromethane	0	0
1,1,1-Trichloroethane	0	0
Trichloroethylene	0	0
Trichlorofluoromethane	0	0

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, offsite around

the 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 the [Hanford Site Environmental Monitoring Plan](#) (DOE/RL-91-50).

Comparing measured radionuclide concentrations from locations on and around the Hanford Site with those 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 60 locations across the Hanford Site was used during 2016 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 ft (500 m) 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 2016 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.

**Table 6-3. Hanford Site Monitoring Locations and Analyses
for Ambient Air Monitoring Samples. (2 Pages)**

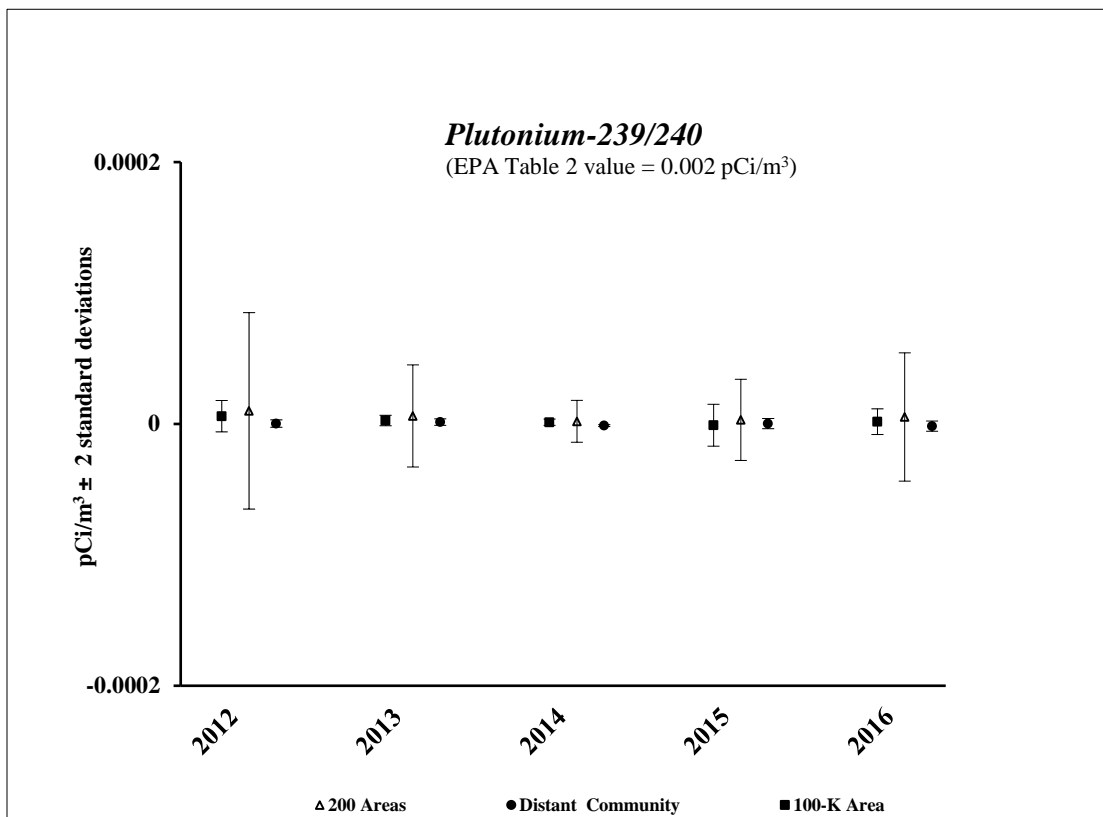
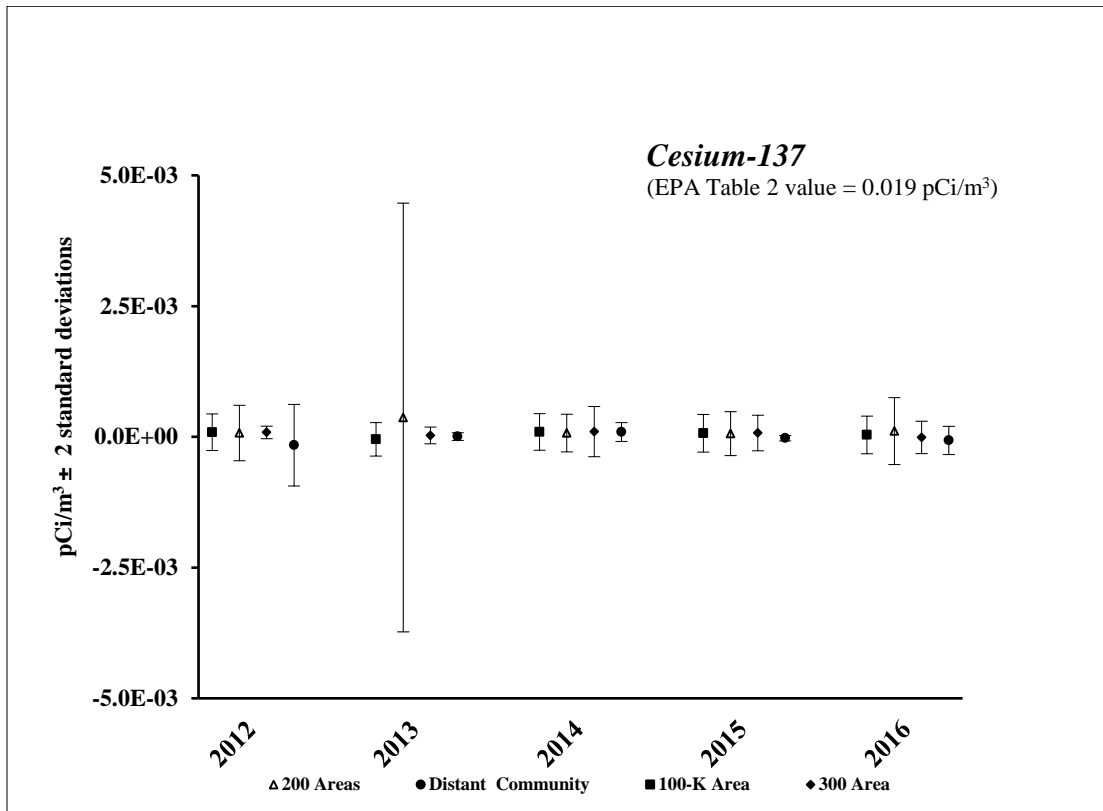
Air Monitoring Locations	Number of Samplers	EDP Codes	Analyses		
			Bi-Weekly	Monthly	Semi-Annual Composite
100-K Area	6	N476, N534, N535, N575, N576 ^a , N578	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA
200-East Area	18	N019, N158, N498, N499 ^a , N582, N957, N967, N968, N969, N970, N972, N973, N976, N977, N978, N984, N985, N999	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Canister Storage Building (200-East)	2	N480, N481	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA
Integrated Disposal Facility (200-East)	2	N532, N559	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
200-West Area	16	N161, N168, N200, N304, N441, N442, N449, N456, N457, N956, N963, N965, N966, N974, N987, N994	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Plutonium Finishing Plant (200-West Area)	7	N155, N165 ^a , N433, N554 ^a , N555 ^a , N964, N975 ^a	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA

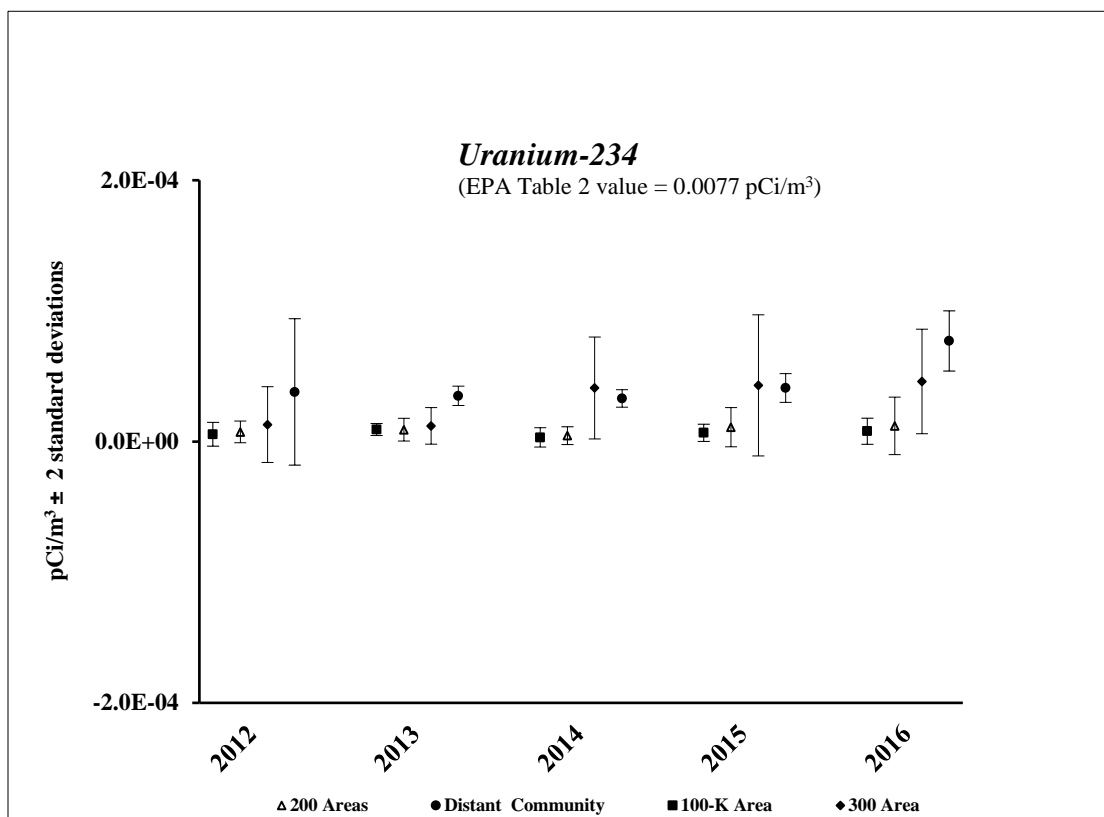
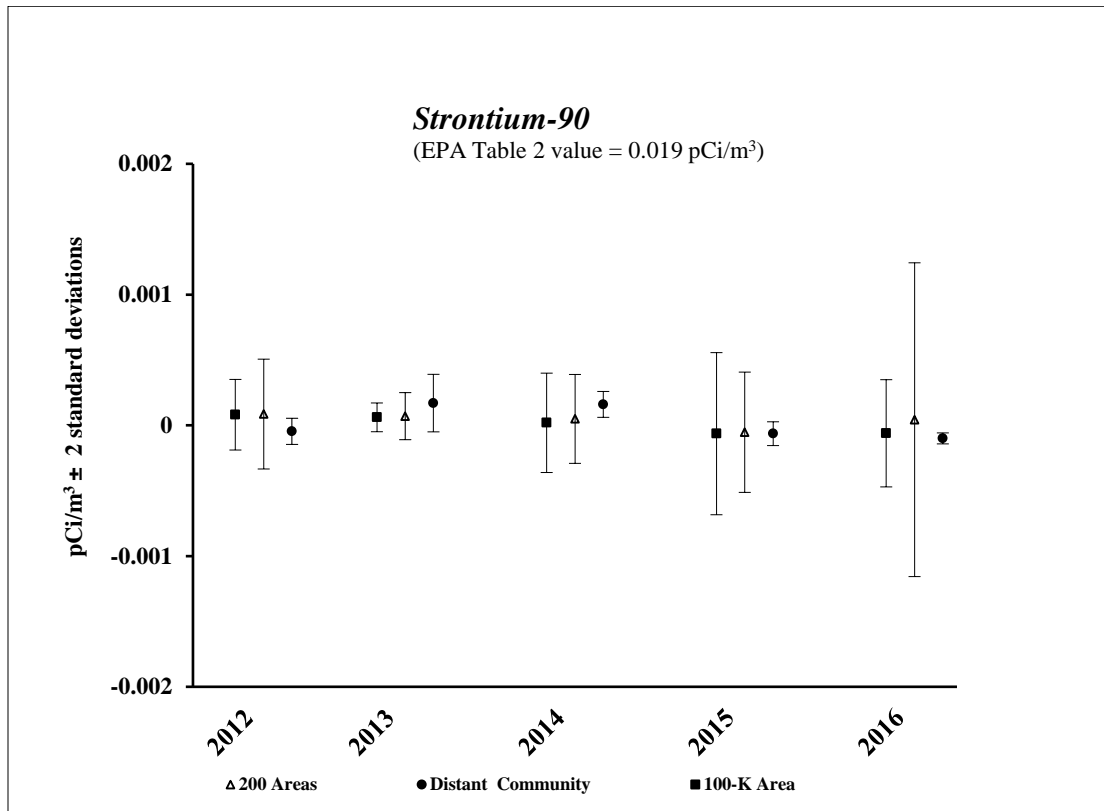
**Table 6-3. Hanford Site Monitoring Locations and Analyses
for Ambient Air Monitoring Samples. (2 Pages)**

Air Monitoring Locations	Number of Samplers	EDP Codes	Analyses		
			Bi-Weekly	Monthly	Semi-Annual Composite
300 Area	1	N130	Alpha, Beta	Tritium	⁹⁰ Sr, Pu-iso, U-iso, GEA
618-10 Burial Ground	4	N548 ^a , N549, N579, N580	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Environmental Restoration Disposal Facility (ERDF)	3	N482 ^a , N517, N518	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Wye Barricade	1	N981 ^a	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
^a Collocated sampling location with WDOH					
GEA = Gamma Energy Analysis					

For most specific radionuclide analyses, radioactive material collected on a single filter during a 2-week period was too small to be measured accurately. Individual samples collected at each location were combined into semiannual, location-specific composite samples (Table 6-3) to increase accuracy. 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. 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 mrem (100 μ Sv)/yr under conditions of continuous exposure. The 2016 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. Data also show that concentrations of certain radionuclides were higher and widely variable within different Hanford Site operational areas. Appendix C, Table C-4 shows the annual average and maximum concentrations of radionuclides in air samples collected near Hanford Site facilities and operations during 2016.





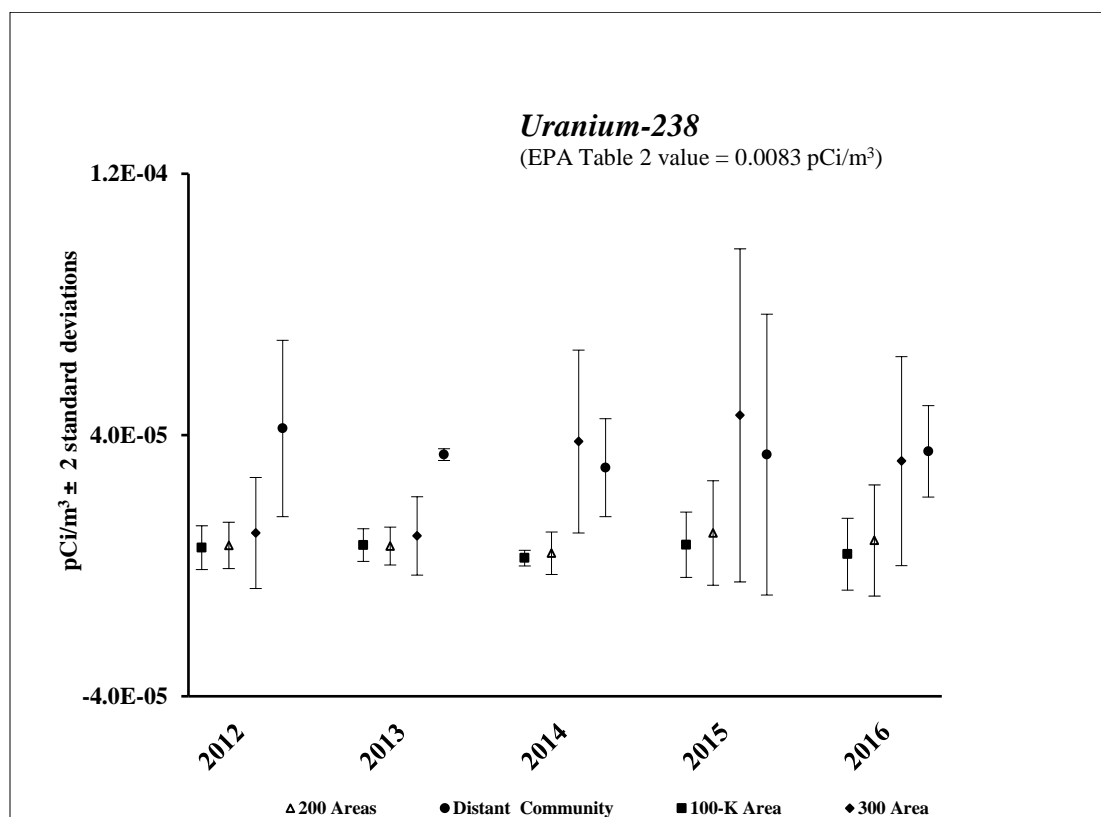


Figure 6-1. Hanford Site Average Radionuclide Concentrations in Ambient Air Samples Compared to Distant Community Samples.

NOTE: Because of figure scale, some uncertainties (error bars) are concealed by the point symbol

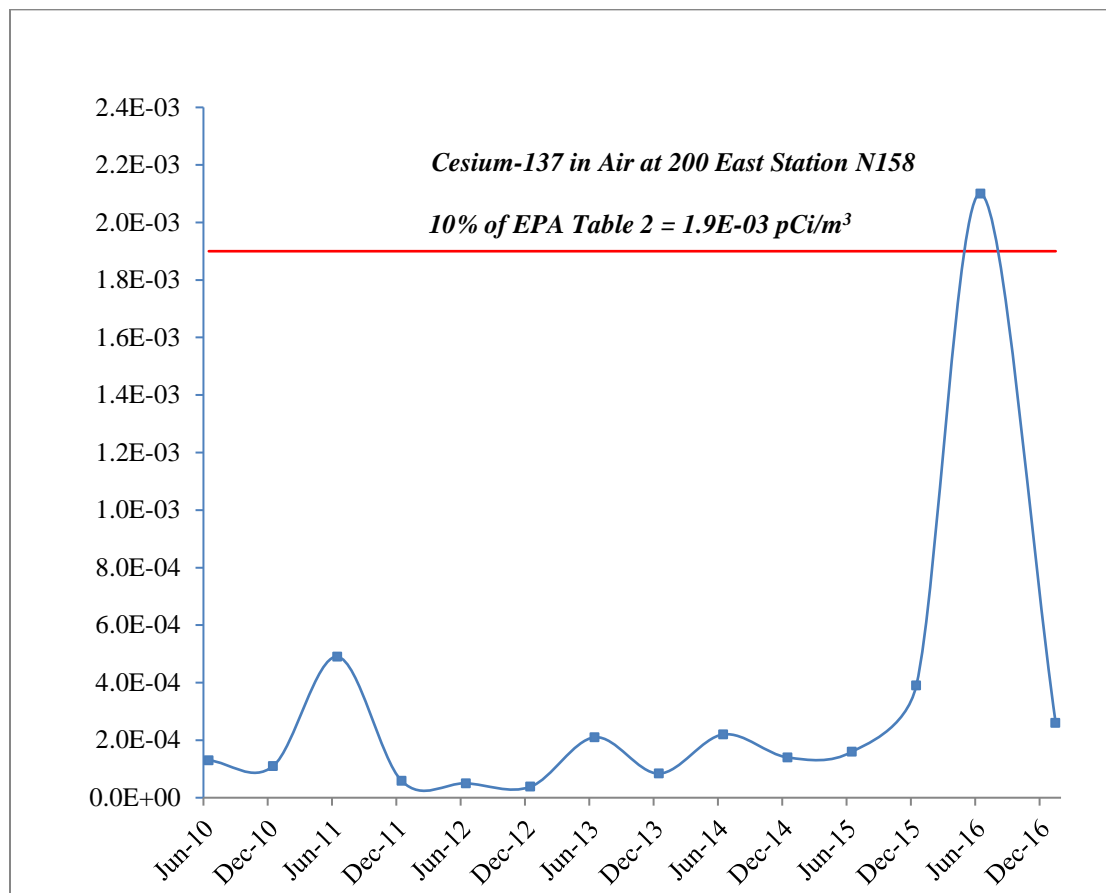
Ambient air was monitored in 2016 at six locations in the 100-K Area, and analytical results showed radionuclide concentrations at or below typical Hanford Site levels. Uranium-234 and -238 were detected in approximately 20% of the samples, and tritium was detected in approximately 28% of the samples. All other radionuclides of concern were below analytical detection limits.

Air sampling was conducted at 21 locations in the 200-East Area during 2016. Generally, radionuclide levels measured in the 2016 air composite samples were similar to those measured in previous years. Uranium-234 and -238 were detected in approximately 28% of the samples. Air sampling station N158, located east of the 241-AX Tank Farm, showed air monitoring results for cesium-137 during the first half of 2016 and for strontium-90 during the second half of the year (see Figure 6-2), greater than 10% of EPA's concentration values (40 CFR 61, Appendix E, Table 2). Both instances may have been attributable to minor fugitive releases during radioactive waste transfer activities that were conducted throughout the year. As required by the Hanford Site Radioactive Emissions License (#FF-01), both elevated air sample results were reported to the WDOH.

Air sampling was conducted at 23 locations in the 200-West Area during 2016. Radionuclide levels measured were similar to results for previous years. Uranium-234 and -238 were detected in approximately 26% of the samples. Plutonium-239/240 was detected in approximately 5% of the samples. Air sampling station N165, located near the 216-ZPIC trench southeast of the Plutonium

Finishing Plant, showed one air monitoring result for plutonium-239/240 during the second half of 2016 (see Figure 6-2), greater than 10% of EPA's concentration values (40 CFR 61, Appendix E, Table 2). This was likely attributable to resuspension of radioactive materials believed to be contained in the surface soils along back roads near the facility that saw increased vehicle traffic in support of decommissioning activities that began in late summer. As required by the Hanford Site Radioactive Emissions License (#FF-01), this elevated air sample result was reported to the WDOH. At the 300 Treatment Effluent Disposal Facility station, components for tritium sampling were added in July. The results from these 4-week samples showed slightly lower tritium concentrations than those seen in stations located in/near the 300 Area. Air sampling was conducted at five locations at ERDF (200-West Area). Radionuclide levels measured at this site were comparable to previous years.

Air monitoring was conducted at four locations at the 618-10 Burial Ground Project north of the 300 Area. Radionuclide levels measured at this site were comparable to previous years.



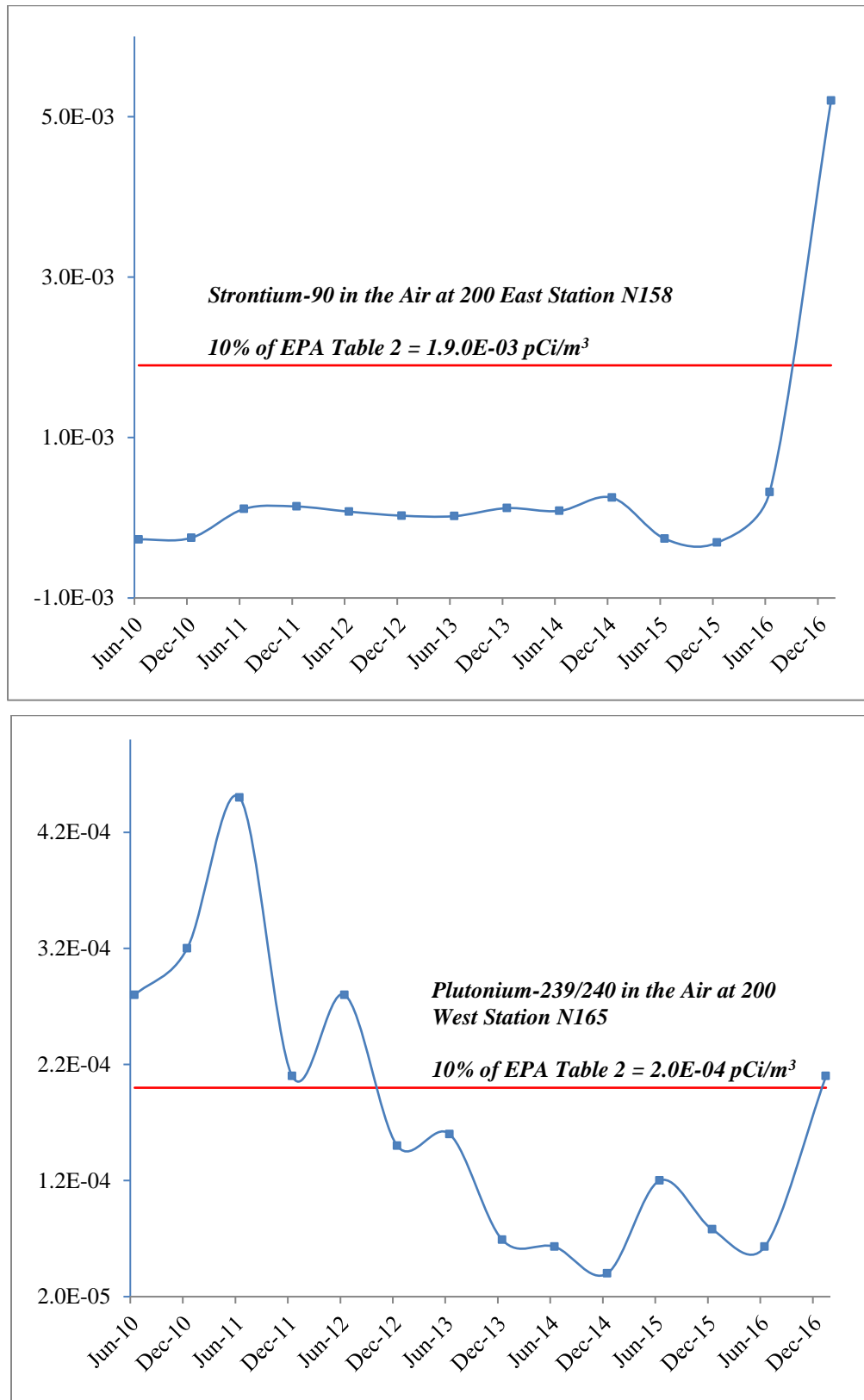


Figure 6-2. Ambient Air Sample Results Above Reporting Thresholds in 2016.

6.2.2 Hanford Site and Offsite Ambient Air Monitoring

Airborne radionuclide samples were collected in 2016 by 40 continuously operating samplers at or in the vicinity of the Hanford Site. The stations were grouped into four location categories: Hanford Site (21 stations), perimeter (11 stations), nearby Hanford Site communities (7 stations), and distant community (1 station; Figure 6-3; Appendix C, Table C-5). Hanford Site air samplers were located primarily around major operational areas to maximize the ability to detect radiological contaminants resulting from site operations. Perimeter samplers were located around the site boundary with emphasis on 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.

As a result of infrastructure reduction measures at the Hanford Site that resulted in removal of old electrical power lines, two onsite sampling stations (“100-F Met Tower” [N921] and “Hanford Townsite” [N922]) located in the River Corridor area were retired from service in August 2016. Dose rate monitoring with environmental thermoluminescent dosimeters was established during September 2016 to provide continued radiological monitoring at these two locations.

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, Rev. 2, *Hanford Site Environmental Surveillance Master Sampling Schedule Calendar Year 2016*). Airborne particle samples were collected biweekly at each location by continuously drawing air through a glass-fiber filter. The samples were transported to an analytical laboratory and stored for at least 72 hrs, allowing 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, with select filters analyzed for gross alpha radiation. For most radionuclides, the amount of radioactive material collected on a filter, historically during a 2-week period, has been too small to analyze accurately. 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. Composite samples were analyzed as shown in Table 6-4.

Atmospheric water vapor was collected for tritium analysis at 20 locations in 2016 by continuously drawing air through multi-column samplers containing adsorbent silica gel. The water-vapor samplers were exchanged every 4 weeks to prevent sample loss 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.

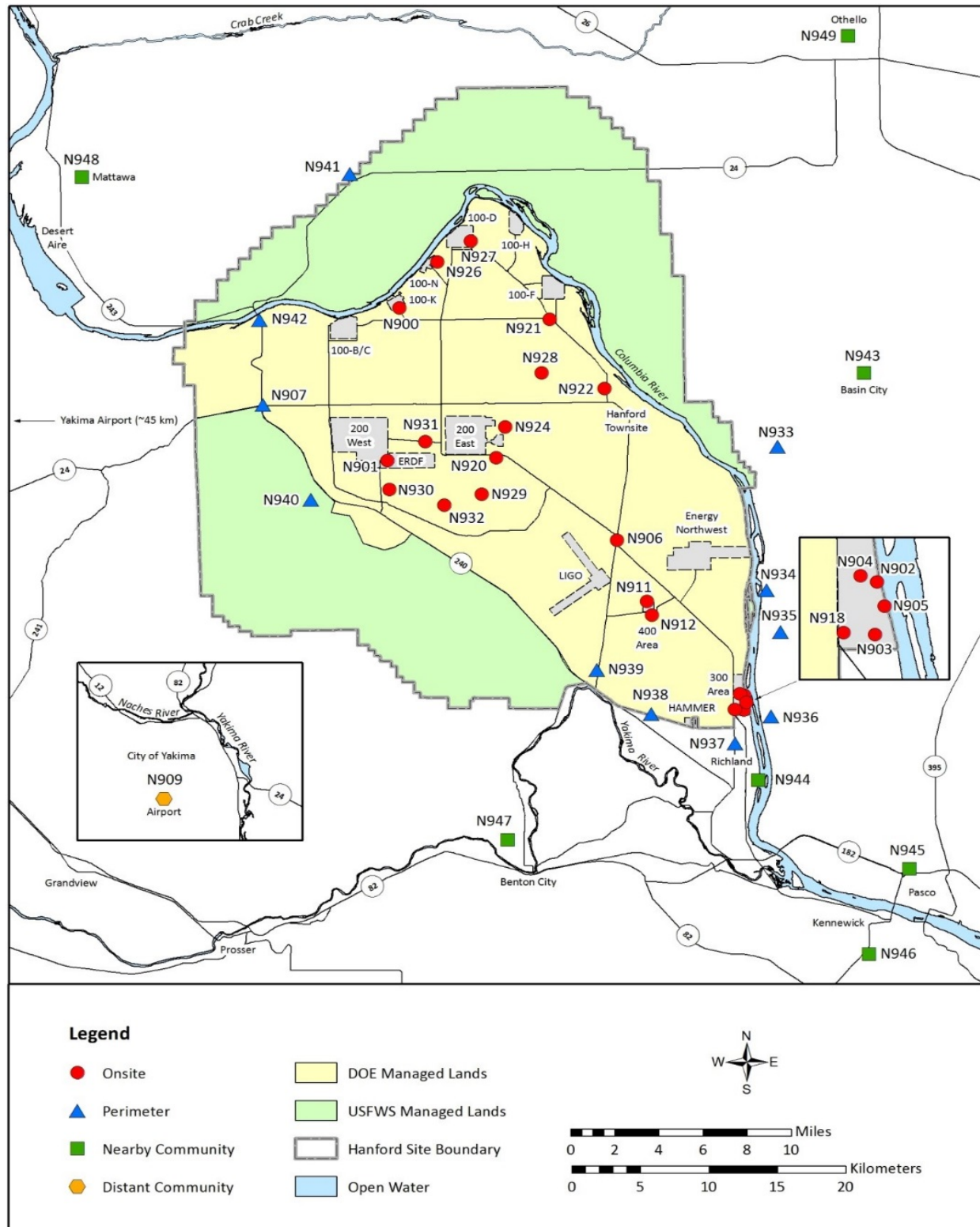


Figure 6-3. Ambient Air Sampling Locations.

Table 6-4. Hanford Site and Offsite Ambient Air Sampling Locations and Analytes. (2 Pages)

EDP Code ^a	Location	Bi-Weekly	Monthly ^b	Analyses	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-East SE	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238	
N929	S of 200-East	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-West SE	Alpha, Beta		GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238	
N905	300 Water Intake ^{c, d}	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238	
N903	300 South Gate ^{e, f}	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238	
N918	300 South West ^e	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238	
N904	300 Trench ^e	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238	
N902	300-NE ^e	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 ^{c, f}	Alpha, Beta		GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238	
Hanford Site Perimeter					
N933	Ringold Met Tower	Alpha, Beta	Tritium	GEA, plutonium-238, 239/240	
N934	W End of Fir Road ^{c, d}	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 ^{c, d}	Alpha, Beta	Tritium	GEA, uranium-234,235,238	
N938	Horn Rapids Substa.	Alpha, Beta		GEA, strontium-90, plutonium-238, 239/240	
N939	Prosser Barricade ^{c, d}	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240	
N907	Yakima Barricade ^c	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	S 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	

Table 6-4. Hanford Site and Offsite Ambient Air Sampling Locations and Analytes. (2 Pages)

EDP Code ^a	Location	Analyses		
		Bi-Weekly	Monthly ^b	Composite
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
^a EDP code=environmental data point code = sampler location code; refer to Figure 6-2. ^b Atmospheric water vapor samples for tritium analysis are collected every 4 weeks using silica gel columns. ^c WDOH particulate air sampler also at this location. ^d WDOH tritium air sampler also at this location. ^e Two tritium samples are collected from this location, one as a Quality Assurance duplicate sample. ^f Quality assurance duplicate sample collected at this location. GEA = gamma energy analysis				

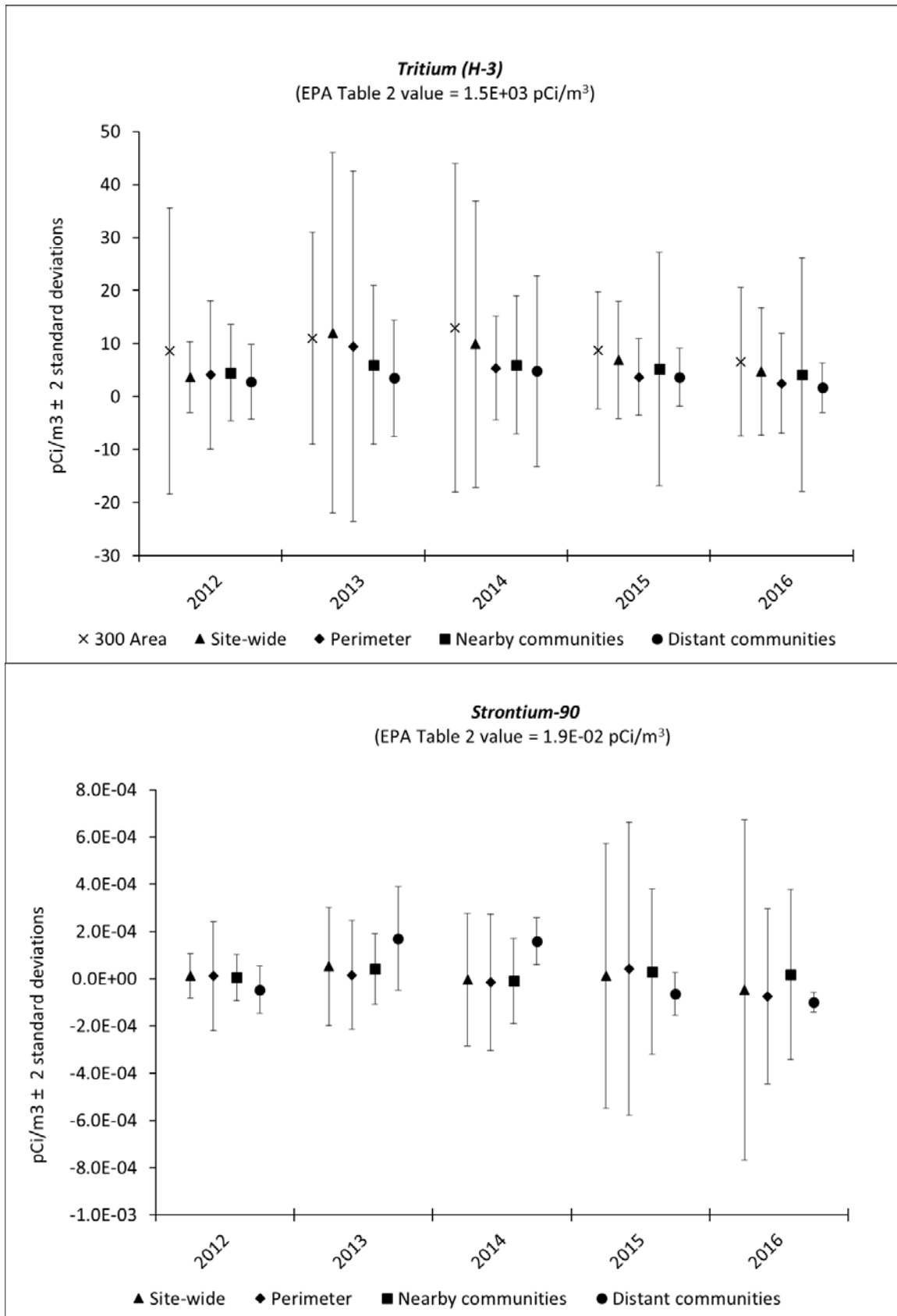
6.2.2.2 Monitoring Results. All sample results in 2016 showed very low radiological concentrations in air. All radionuclide concentrations (Appendix C, Table C-5) were less than their respective EPA Table 2 concentration values. The EPA concentration values (40 CFR 61, Appendix E, Table 2) are concentrations that would result in an annual dose of 10 mrem (100 μ Sv)/yr from airborne radiological material.

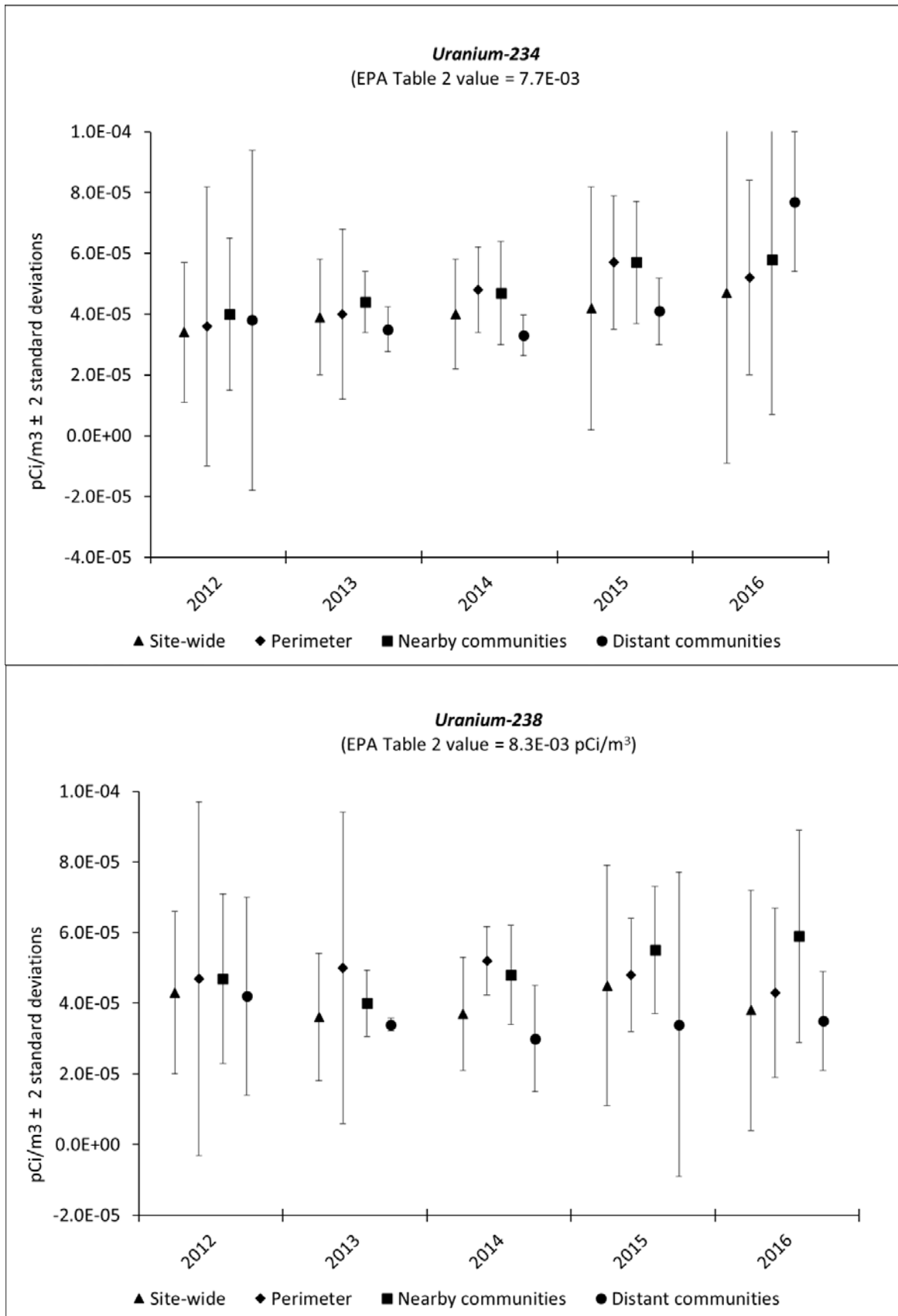
Gross alpha and gross beta concentrations in the air samples collected in 2016 from Hanford Site, perimeter, and nearby Hanford Site communities were comparable to each other and slightly higher than samples from the distant community. Concentrations in 2016 were comparable to concentrations seen in the previous 5 years. Gross beta and gross alpha concentrations in air peak during the fall and winter months, exhibiting a pattern of natural radioactivity fluctuations (Eisenbud 1987). This fluctuation is seen in both Hanford Site and distant location concentrations.

Plutonium-239/240 was not detected in any of the offsite air samples collected in 2016. Figure 6-4 shows plutonium-239/240 concentrations in the air samples collected in 2016 and in previous years.

Uranium-234 and -238 were both detected in approximately 65% of the air samples collected in 2016 from all locations. Figure 6-4 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 10% of the EPA concentration values for both radionuclides.

Tritium was detected in approximately 10% of the samples collected in 2016. Slightly more than half of the samples with detectable tritium concentrations were collected from stations located near the 300 Area. Cesium-137 and strontium-90 was not detected in any of the samples collected during 2016.





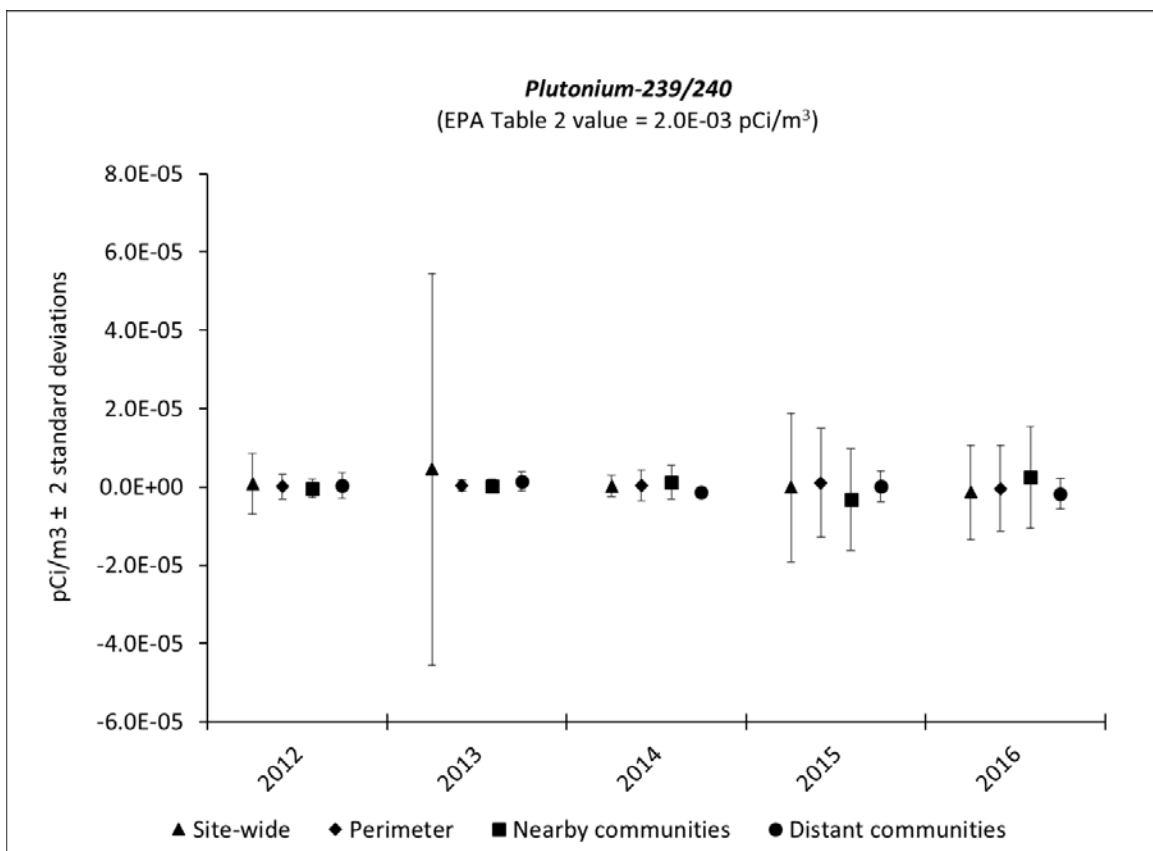


Figure 6-4. Radionuclide Concentrations in Ambient Air Samples (1 pCi = 0.037 Bq).

7.0 Water Monitoring

7.1 Drinking Water Systems

LE Bisping, BR Stenson

Eight U.S. Department of Energy (DOE)-owned, contractor-operated public water systems supply drinking water to DOE facilities on the Hanford Site (Table 7-1). Mission Support Alliance (MSA) operates six of the public water systems and the CH2M Plateau Remediation Contractor (CHPRC) operates two systems. The City of Richland supplies water to the 300 Area, Richland North Area, and Hazardous Materials Management and Emergency Response facility (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)	MSA
400 Area	400 Area Groundwater Wells	CHPRC
609 Fire Station	Trucked Water from Water Treatment Plant 283-W Water Treatment Plant	MSA

CHPRC = CH2M Plateau Remediation Contractor
MSA = Mission Support Alliance

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 Columbia River was the source of supply water for the 100-K Area and 200-West Area facilities. 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) supplied the system for the first 9 months of 2016. Due to an unforeseen equipment malfunction with the primary well, backup well 499-S0-7 499-SO-7 (P-15) was the source of drinking water for the remainder of 2016. Emergency backup well 499-S0-8 (P-14) did not supply water to 400 Area consumers during the reporting period.

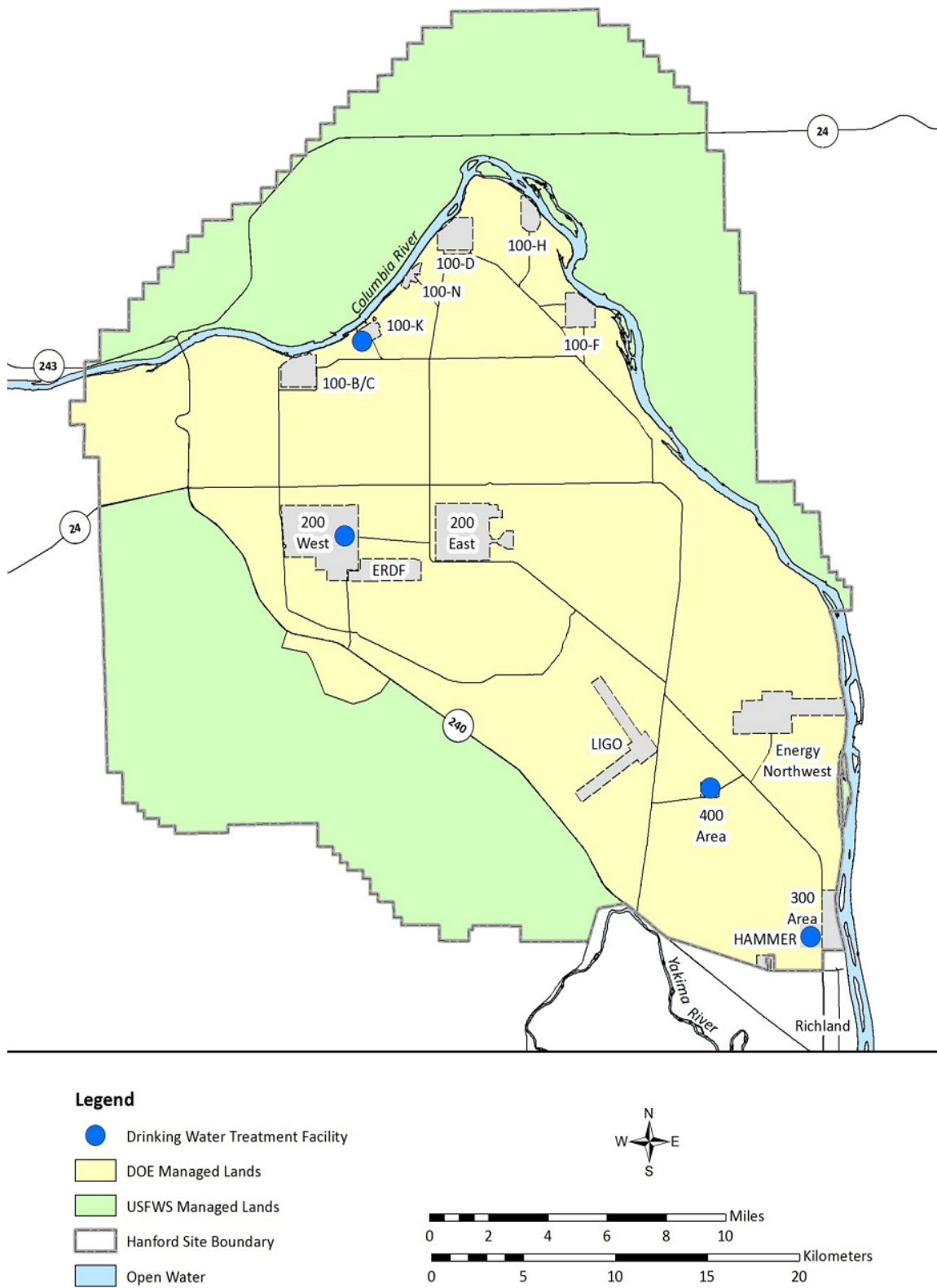


Figure 7-1. Drinking Water Treatment Facilities.

7.1.2 Monitoring

Samples at the 100-K, 200-West, and 400 Areas drinking water treatment facilities were collected monthly and analyzed quarterly or annually for radiological contaminants (Table 7-2). 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 C. 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 report monitoring results annually and characterize 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/Home/ShowDocument?id=2106>.

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 and CHPRC (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, "Group A Public Water Supplies,"](#) requires that all drinking water analytical results be reported routinely to the Washington State Department of Health. 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 to MSA; however, the reports are not published.

All DOE-owned Hanford Site drinking water systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels during 2016. Contaminant concentrations measured during the year were similar to those observed in recent years as described in the annual Hanford Site environmental reports for 2013 (DOE/RL-2013-47) and 2014 (DOE/RL-2014-52).

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 the U.S. Environmental Protection Agency (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 mrem (0.04 millisievert [mSv]). 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 mrem (0.04 mSv) 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 mrem (0.04 mSv).

Annual average concentrations of all monitored radionuclides in Hanford Site drinking water in 2016 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 the first 9 months of 2016 was primary well 499-S1-8J (P-16). The primary well suffered a malfunction in October 2016 and backup well 499-SO-7 (P-15) was the source of drinking water for the last 3 months of 2016. Gross beta and tritium were found in all 400 Area water samples with their annual averages being slightly elevated when compared to historical data where only the 400 Area primary well was sampled, but were still below the maximum allowable contaminant level. Gross alpha and strontium-90 were not detected in 400 Area water samples.

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 (Figure 7-2). In 2016, Environmental Assessment personnel collected raw (untreated) water samples from 400 Area drinking water backup well 499-SO-8 (P-14). Samples were collected quarterly, composited for a single annual tritium analysis ($12,000 \pm 2370$ pCi/L). In addition, a sample was collected from backup well 499-SO-7 (P-15) and analyzed for tritium ($2,320 \pm 641$ pCi/L). Both samples fell below the 20,000-pCi/L (740-Bq/L) federal and state annual average drinking water standards. In previous years, CHPRC Soil and Groundwater Remediation Project personnel annually collected and analyzed raw (untreated) water samples from all three 400 Area drinking water wells (one primary well and two backup wells); however, due to unforeseen equipment malfunction at 499-S1-8J (P-16) and inclement weather during the final quarter of 2016, CHPRC did not collect water samples from the 400 Area drinking water wells. Sampling is next planned for 2017.

Table 7-2. Drinking Water Annual Average Concentrations of Selected Radiological Constituents. (2 Pages)

Constituent	System	Frequency	Sample From	Samples Analyzed at Each Location	Annual Average ^a (pCi/L) ^b			Standard
Gross alpha	100-K Area	Quarterly	Tap	4 ^c	-0.64	±	1.52	15 ^{d,e}
	200-West Area	Quarterly	Tap	4 ^c	0.51	±	0.53	
	400 Area	Quarterly	Tap	4 ^c	-0.54	±	1.44	
	400 Area Well P-14	Quarterly	Well	4	1.92	±	0.62	
	400 Area Well P-15 ^f	1/year	Well	1	2.55	±	1.50	
Gross beta	100-K Area	Q Comp ^g	Tap	4 ^c	1.41	±	3.01	50 ^e
	200-West Area	Q Comp ^g	Tap	4 ^c	1.37	±	2.00	
	400 Area	Q Comp ^g	Tap	4	7.16	±	4.70	
	400 Area Well P-14	Q Comp ^g	Well	4	23.93	±	3.21	
	400 Area Well P-15 ^f	1/year	Well	1	7.36	±	1.33	
Tritium	100-K Area	A Comp ^h	Tap	1 ^c	181	±	389	20,000 ^e
	200-West Area	A Comp ^h	Tap	1 ^c	-167	±	337	
	400 Area	Quarterly	Tap	4	2223	±	5178	

**Table 7-2. Drinking Water Annual Average Concentrations
of Selected Radiological Constituents. (2 Pages)**

Constituent	System	Frequency	Sample From	Samples Analyzed at Each Location	Annual Average ^a (pCi/L) ^b			Standard
Strontium-90	400 Area Well P-14	A Comp ^h	Well	1	12000	±	2370	8 ^{d, e}
	400 Area Well P-15 ^f	1/year	Well	1	2320	±	641	
	100-K Area	A Comp ^h	Tap	1 ^c	0.73	±	0.80	
	200-West Area	A Comp ^h	Tap	1 ^c	0.66	±	0.94	
	400 Area	A Comp ^h	Tap	1 ^c	-0.04	±	0.71	
	400 Area Well P-14	A Comp ^h	Well	4 ^c	-0.69	±	0.68	
	400 Area Well P-15 ^f	1/year	Well	1 ^c	-0.18	±	0.34	

^a Annual average is ± 2 times the standard deviation, unless only one sample analyzed in which case it is the single result \pm total propagated analytical error.

^b Multiply pCi/L by 0.037 to convert to Bq/L.

^c Analytical results are below the minimum detectable concentration.

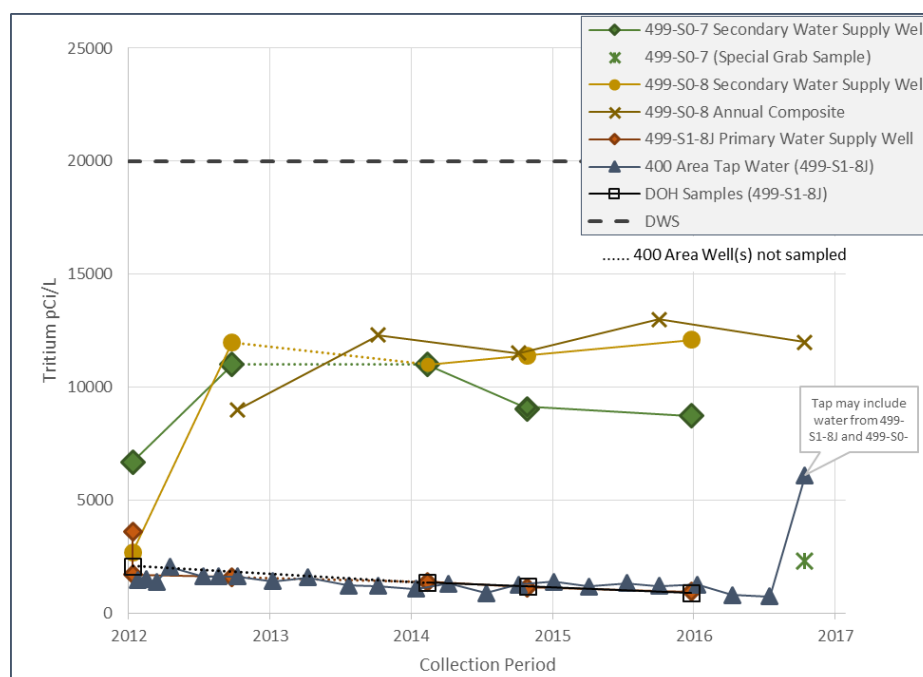
^d WAC 246-290.

^e 40 CFR 141.

^f Special one-time grab sample collected October 2016.

^g Samples were collected monthly and composited quarterly for analyses.

^h Samples were collected quarterly and composited annually for analyses.



**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 Surfacewater

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Samples of surfacewater 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. Surfacewater bodies monitored included the Columbia River, a Hanford Site pond (West Lake), and offsite irrigation sources (Figure 7-3). Aquatic sediment monitoring was conducted for the Columbia River and one Hanford Site pond. Tables 7-3 and 7-4 summarize the sampling locations, types, frequencies, and sample analyses included in surfacewater and sediment monitoring. This section describes the monitoring efforts and summarizes the results for these aquatic environments.

The Columbia River is one of the largest rivers in the continental U.S. in terms of total flow and is the dominant surfacewater 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. River water is also used for irrigation purposes downstream of the Hanford Site as well as a variety of recreational activities. Water removed from the river immediately downstream of the Hanford Site is used to irrigate a small portion of agricultural crops in Benton and Franklin counties. The majority of irrigation water utilized by Franklin County residents originates at Grand Coulee Dam and is provided through its extensive water delivery systems (i.e., canals). Likewise, Benton County relies heavily on the Yakima River for irrigation purposes. Originating in the Rocky Mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of approximately 260,000 mi² (670,000 km²) before discharging to the Pacific Ocean. Three dams in Canada and 11 dams in the United States regulate the flow of the river; four dams are downstream of the Hanford Site. Priest Rapids Dam is the nearest upstream dam, and McNary Dam is the nearest downstream dam in relation 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 Richland, Washington. 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 cause 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 2016. The annual average flow of the Columbia River downstream of Priest Rapids Dam was approximately 113,302 ft³/sec (3,209 m³/sec), slightly below the most recent 10-year average annual flow rate of 115,831 ft³/sec (3,280 m³/sec) (USGS 2013). The highest monthly average flow rate occurred during April (166,076 ft³/sec [4,703 m³/sec]; Figure 7-4). The lowest monthly average flow rate occurred during September (68,507 ft³/sec [1,940 m³/sec]) based on mean daily flows. Daily average flow rates varied from 39,700 to 231,115 ft³/sec (1,124 to 6,545 m³/sec) in 2016. 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 ft (3 m) 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 Area 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 ft (300 to 1,000 m) as it passes through the Hanford Site.

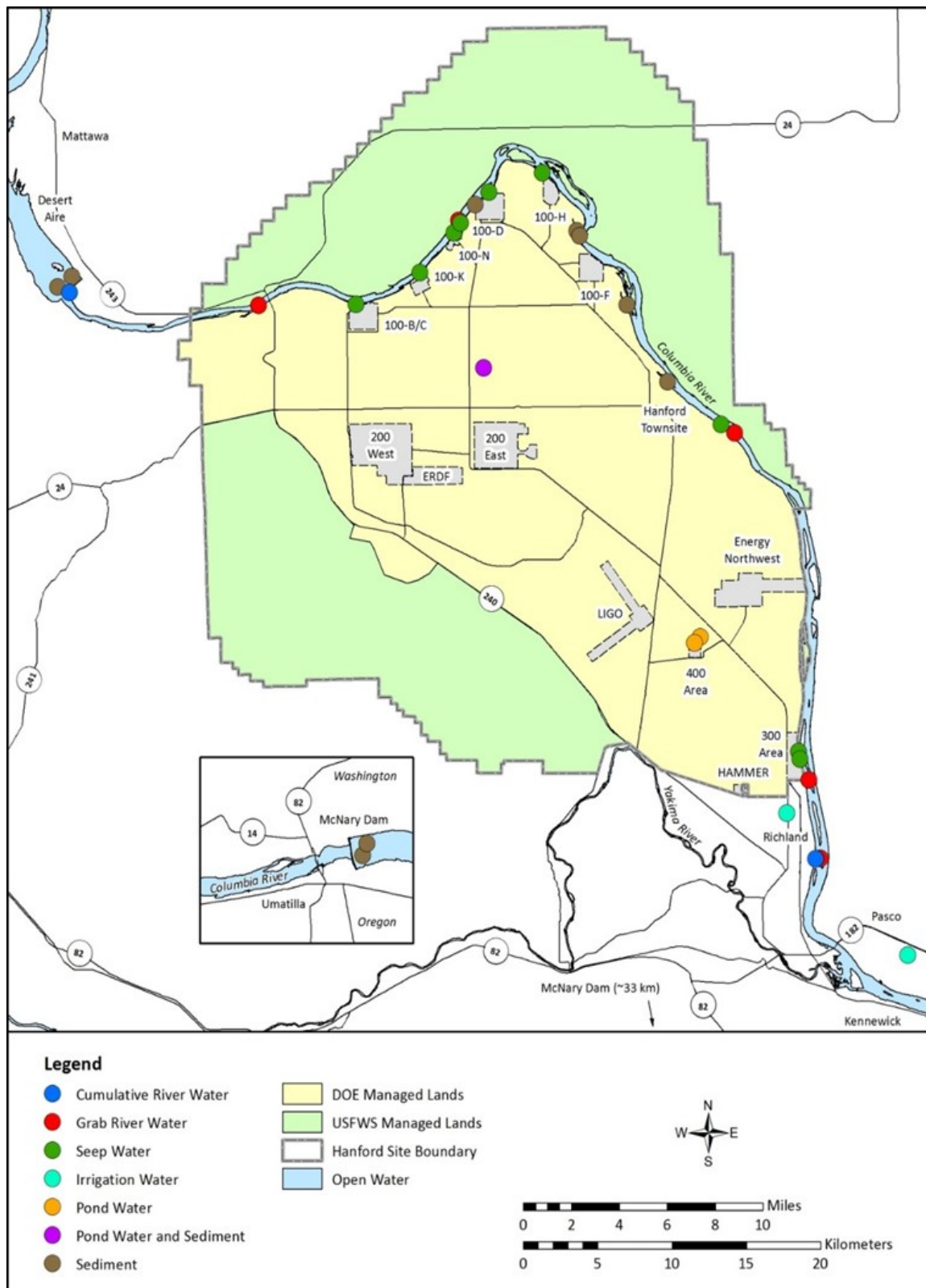


Figure 7-3. Surfacewater and Sediment Sampling Locations.

Table 7-3. Table Water Surveillance.

Location	Sample Type	Frequency	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland Pump House	Cumulative	M Comp ^a	Low tritium ^b , strontium-90, technetium-99, isotopic uranium ^c
	Particulate (filter)	M Cont ^d	Gamma energy analyses, isotopic plutonium ^e
	Soluble (resin)	M Cont ^d	Gamma energy analyses, isotopic plutonium ^e
Vernita Bridge	Grab (transects)	Semi-annual	Gamma energy analyses, low tritium ^b , strontium-90, isotopic uranium ^c , isotopic plutonium ^e , technetium-99
Richland	Grab (transects)	Semi-annual	Gamma energy analyses, low tritium ^b , strontium-90, isotopic uranium ^c , isotopic plutonium ^e , technetium-99
100-N, 300 Areas and Hanford Townsite	Grab (transects)	Annually	Gamma energy analyses, low tritium ^b , strontium-90, isotopic uranium ^c
Columbia River - Inorganics and Organics			
Vernita Bridge	Grab (transects)	Semi-annual	Anions, mercury, metals (filtered and unfiltered), hexavalent chromium
	Grab (transects)	Semi-annual	Volatile organic compounds
Richland	Grab (transects)	Semi-annual	Anions, mercury, metals (filtered and unfiltered), hexavalent chromium
	Grab (transects)	Semi-annual	Volatile organic compounds
100-N, 300 Areas and Hanford Townsite	Grab (transects)	Annually	Anions, metals (filtered and unfiltered), hexavalent chromium
Onsite Ponds			
West Lake Seep	Grab	Annually	Tritium, isotopic uranium ^c
West Lake Water	Grab	3/year	Tritium, isotopic uranium ^c
Offsite Irrigation Water			
Riverview Irrigation Canal	Grab	3/year	Alpha, beta, low tritium ^b , strontium-90, gamma energy analyses
Horn Rapids	Grab	3/year	Alpha, beta, low tritium ^b , strontium-90, gamma energy analyses
^a Indicates river water was collected at set intervals and composited monthly for analyses. ^b Low-level tritium analysis (10-pCi/L detection limit). ^c Includes uranium-234, uranium-235, and uranium-238. ^d River water was sampled for 2 weeks by continuous flow through a filter and resin column. Samples were composited monthly for analyses. ^e Includes plutonium-238 and plutonium-239/240. Comp = Composite Cont = Continuous M = Monthly			

Table 7-4. Columbia River Sediment.

Location ^a	Frequency	Analyses
McNary Dam (Two locations near the dam)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
Hanford Reach ^d	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
Priest Rapids Dam (Two locations near the dam)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
Contiguous Hanford Reach Islands (Locke and Savage)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium ^(b) , isotopic plutonium ^(c) , metals, mercury, and strontium-90

^a Refer to Figure 7-3.

^b Uranium-234, uranium-235, and uranium-238.

^c Plutonium-238 and plutonium-239/240.

^d Hanford Reach consists of sediment collected in the 100-D Spring 102-1 Area, 100-K 63-1 Shoreline Seep Area, 100-H Spring 145-1, 100-F Slough, Hanford Slough, White Bluffs Slough, and 300 Area DR 42-2.

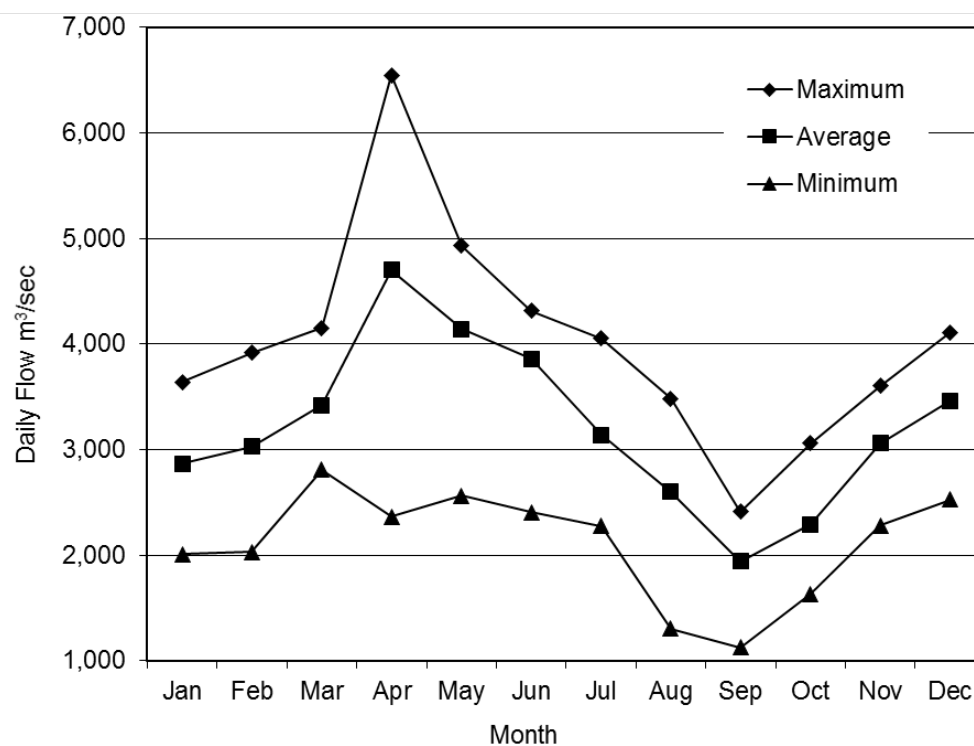


Figure 7-4. Columbia River Flow Rates at Priest Rapids Dam
(multiply m³/sec by 35.31 to obtain ft³/sec).

7.2.1 Monitoring

In 2016, Columbia River water samples were collected and analyzed for radionuclides from fixed-location monitoring stations at Priest Rapids Dam and at the City of Richland raw water intake facility. 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. Irrigation water systems sampling is discussed in Section 7.6.

The fixed-location monitoring stations at Priest Rapids Dam and the City of Richland raw water intake facility 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 hr) and set incremental volumes (e.g., 55 mL). These bi-weekly samples were combined into monthly composite samples for radiological analyses (Table 7-3). 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 monthly composite samples for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in the latest revision of [DOE/RL-91-50, Hanford Site Environmental Monitoring Plan](#).

Radionuclides of interest were selected for analyses based on the following criteria:

- Presence in historical effluent discharges from Hanford Site facilities or in groundwater underlying the Hanford Site near the Columbia River
- Importance in determining water quality and compliance with applicable water quality standards
- 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/yr (EPA 2011, Table ES-1).

Constituents of interest in Columbia River water samples collected at Priest Rapids Dam and the City of Richland raw water intake facility 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% 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% significance level.

National primary and secondary drinking water guideline standards were used to compare concentrations of contaminants of concern at upstream (Vernita) and downstream (Richland Pumphouse) locations for 2016. At both locations, concentrations were similar and lower than the guideline standards. Drinking water supplied by the City of Richland travels through their water treatment plant before it is available for public use.

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 were 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 2016, the Richland Pump house and Vernita Bridge transects were collected semi-annually (spring/late summer). The 100-N Area, Hanford Townsite, and 300 Area locations were all sampled annually during late summer when river flows were low. Low river flows provide the highest probability of detecting Hanford Site contaminants carried by groundwater to the Columbia River. Transect stations at the Richland Pump house, 300 Area, Hanford Townsite, and 100-N Areas were comprised of five locations. The Vernita Bridge station is made up of four locations due to an inability to anchor at the midstream location due to a smooth riverbed and high flow rates.

Columbia River transect water samples collected during 2016 were analyzed for radiological, inorganic, and organic contaminants (Table 7-3). The “contaminants of concern”, specifically metals and anions that were selected for analyses, were based upon previous studies of groundwater plume migration, reviews of existing surfacewater and groundwater upwelling/discharge data, various remedial investigation/feasibility study 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 (recoverable) and filtered (dissolved) samples.

7.2.2 Radiological Results

7.2.2.1 Fixed-location Samples. Results of radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the City of Richland raw water intake facility in 2016, and for the previous 5 years, are summarized in Appendix C, Table C-7. Individual radiological contaminant concentrations measured in Columbia River water during 2016 were well below the DOE-derived concentration standards. The DOE-derived concentrations are based on a 100 mrem (1 mSv) per year standard; dividing by 25 allows for more direct comparison to the 4 mrem (0.04 mSv) per year drinking water standards and Washington State ambient surfacewater quality criteria (40 CFR 141; WAC 173-201A;).

Radionuclide concentrations monitored in Columbia River water were low throughout 2016. Tritium, uranium-234, and uranium-238 were consistently measured in river water at levels greater than their reported minimum detectable concentrations. Uranium-234 and uranium-238 results were less than 1/15th of DOE-derived concentration standards. Uranium-235 was occasionally detected, but all values were near minimum detectable values. One up-gradient sample from Priest Rapids had detectable plutonium-238 and plutonium-239/240 results. All other radionuclides were typically less than the minimum detectable concentrations.

The 2016 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 raw water intake facility were slightly higher than concentrations in samples from Priest Rapids Dam. The maximum concentration detected at the Richland Pumphouse was 49.2 pCi/L (1.8 Bq/L) while Priest Rapids Dam had a maximum concentration of 26.8 pCi/L (1 Bq/L). Average tritium concentrations in Columbia River water collected at the City of Richland were 0.15% of the Washington State ambient surfacewater quality criterion of 20,000 Ci/L (740 Bq/L).

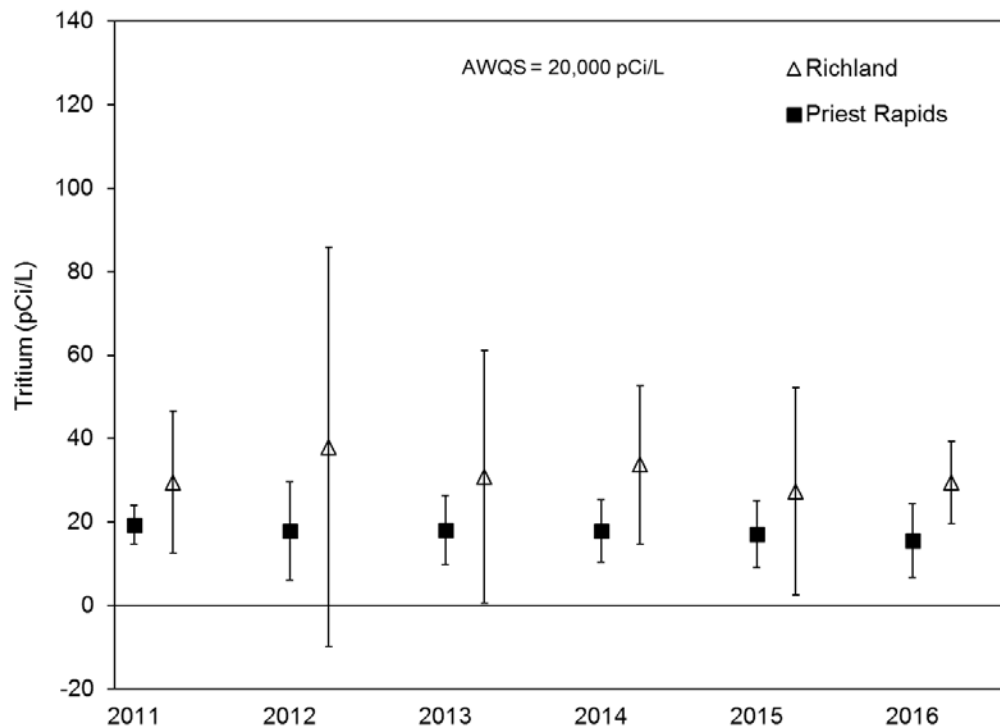


Figure 7-5. Tritium Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (\pm X standard deviations, AWQS=ambient water quality standard; Washington State AWQS for tritium is 20,000 pCi/L [740 Bq/L]).

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 historical 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 shoreline extending from the Hanford Townsite downstream to the 300 Area. The plume is not completely mixed within the Columbia River because of the close proximity to the City of Richland's water intake structure. Sampling along cross-river transects at the City of Richland during 2016 confirmed the existence of a concentration gradient in the river under certain flow conditions 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 2016, 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. Strontium-90 concentrations at Priest Rapids Dam and the City of Richland were below minimum detection limits (0.06 pCi/L). Priest Rapids Dam had a maximum concentration of 0.036 pCi/L (0.0013 Bq/L), and the City of Richland intake had a maximum concentration of 0.030 pCi/L (0.0011 Bq/L). Low concentrations are likely attributable to a permeable reactive barrier within the groundwater that was put into place by DOE that locks up most of the groundwater strontium entering the Columbia River.

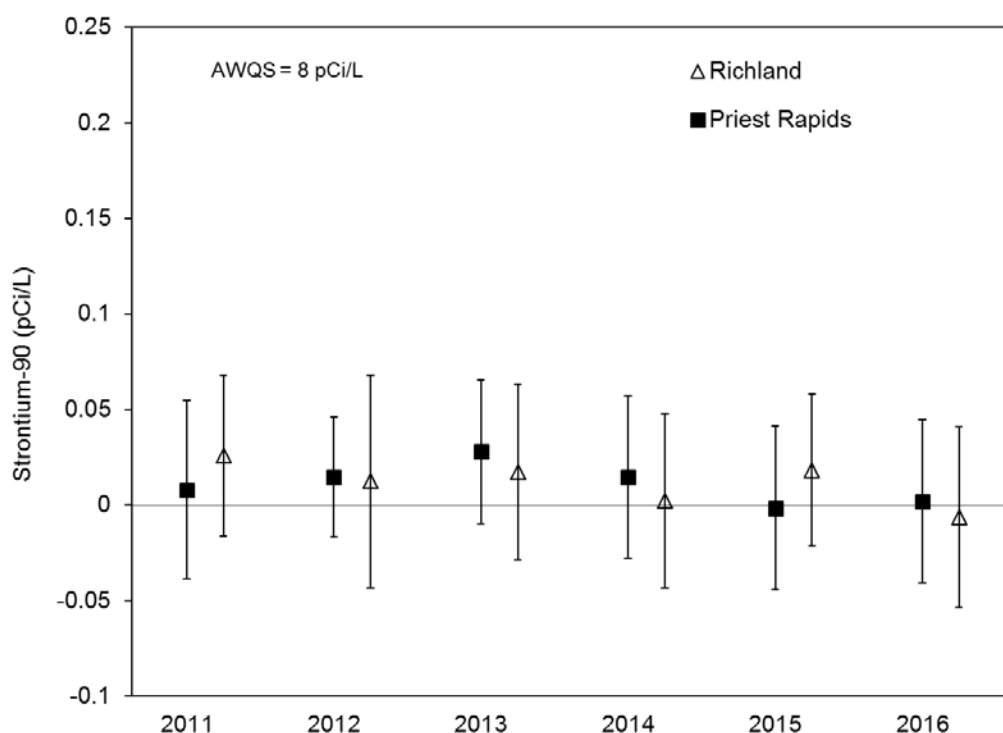


Figure 7-6. Strontium-90 Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (± 2 standard deviations, AWQS = ambient water quality standard).

Annual average uranium-234 and uranium-238 concentrations measured in water samples collected upstream and downstream of the Hanford Site in 2016 were similar to those observed during recent years (Figure 7-7). Average monthly uranium concentrations measured at Priest Rapids Dam (0.57 pCi/L total uranium) in 2016 were slightly lower than those averages measured at the City of Richland (0.61 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 previously been detected at elevated levels in shoreline springs at the 300 Area (Section 7.4; PNNL-13692 and PNNL-16805). There is no Washington State

ambient surfacewater quality criterion directly applicable to uranium; however, total uranium levels in the river during 2016 were well below the EPA drinking water standard of 30 $\mu\text{g/L}$ (approximately 20 pCi/L [0.74 Bq/L]).

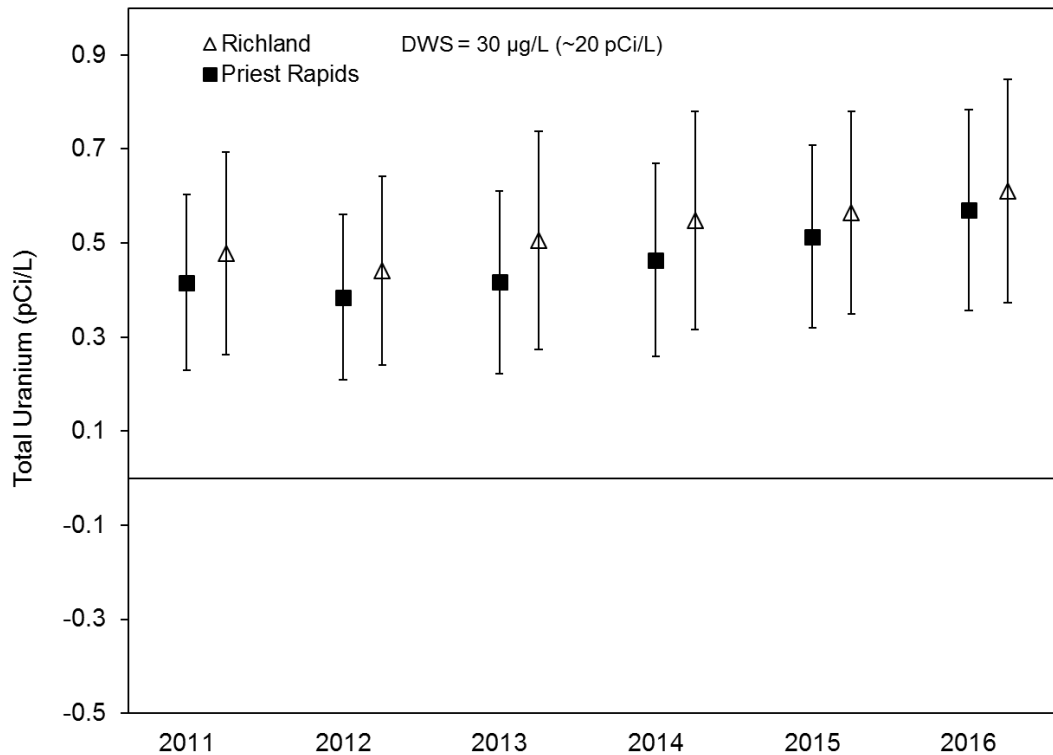


Figure 7-7. Uranium Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (\pm standard deviations; DWS = drinking water standard).

Most plutonium-238 and plutonium-239/-240 concentrations for river water samples at the City of Richland in 2016 were reported as non-detects by the analytical laboratory. However, two samples did show plutonium-238 detections, but all concentrations and detection limits were well below the DOE-derived concentration standards of 1.1 pCi/L (0.04 Bq/L). No Washington State ambient surfacewater quality criterion exists for plutonium-239/-240. Plutonium concentrations at Priest Rapids Dam were not statistically compared with the City of Richland because most upstream and downstream reportable concentrations were less than the required minimum detectable concentrations. Priest Rapids Dam data did have a single plutonium-238 detection of 0.0005 pCi/L (0.000019 Bq/L).

7.2.2.2 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, Table C-8. Sampling locations were documented using a hand-held or vessel-mounted 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 minimum detectable activity included tritium, uranium-234, and uranium-238. Uranium-235 was detected occasionally, and most levels were near minimum detectable concentrations. All measured concentrations of these

radionuclides were less than applicable Washington State ambient surfacewater quality criteria and 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 2016 are depicted in Figure 7-8. The Vernita Bridge transect is the most upstream location. The 100-N Area, Hanford Townsite, 300 Area, and 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. Incomplete mixing of river water and groundwater is likely a result of differing water temperatures as well. All of these factors affect the tritium concentration in this area.

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. However, 2016 showed similar concentrations of tritium when comparing the City of Richland fixed station to the Benton County shoreline transect sample (Richland Pumphouse Hanford River Mile [HRM] 46.4 station-1). Richland Pumphouse HRM 46.4 station -1 transect results had a maximum of 49.6 ± 12.6 pCi/L (1.84 ± 0.47 Bq/L) and the fixed monitoring station had a maximum result of 49.2 ± 11.5 pCi/L (1.82 ± 0.43 Bq/L). The highest tritium concentration measured in cross-river transect water was 108 ± 37.2 pCi/L (4.0 ± 1.38 Bq/L) at the Hanford Townsite which is about 1/200th of the Washington State Drinking Water Quality Standard of 20,000 pCi/L.

Strontium-90 concentrations in Hanford Reach transect samples collected in 2016 were similar to upstream reference concentrations for most locations. The maximum strontium-90 concentration was 0.052 ± 0.036 pCi/L (0.0019 ± 0.0013 Bq/L) from a sample collected along the 100-N transect. The average strontium-90 concentrations found during sampling at the Priest Rapids Dam fixed-location monitoring station were slightly higher than those measured in monthly composite samples at the Richland Pumphouse and Richland Pumphouse HRM 46.4 transect sample collections. All concentrations associated with Priest Rapids Dam, Richland Pumphouse, and Richland Pumphouse HRM 46.4 station-1 were reported as non-detects.

Uranium concentrations in all transect samples collected during 2016 were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]). The uranium-234 concentration was highest in the water sample collected near the Benton County shoreline (300 Area–1 HRM 43.1), which measured 0.88 µg/L (0.59 pCi/L). The maximum uranium-238 concentration was also reported along the Benton County shoreline (300 Area-1 HRM 43.1), which measured 0.67 µg/L (0.45 pCi/L).

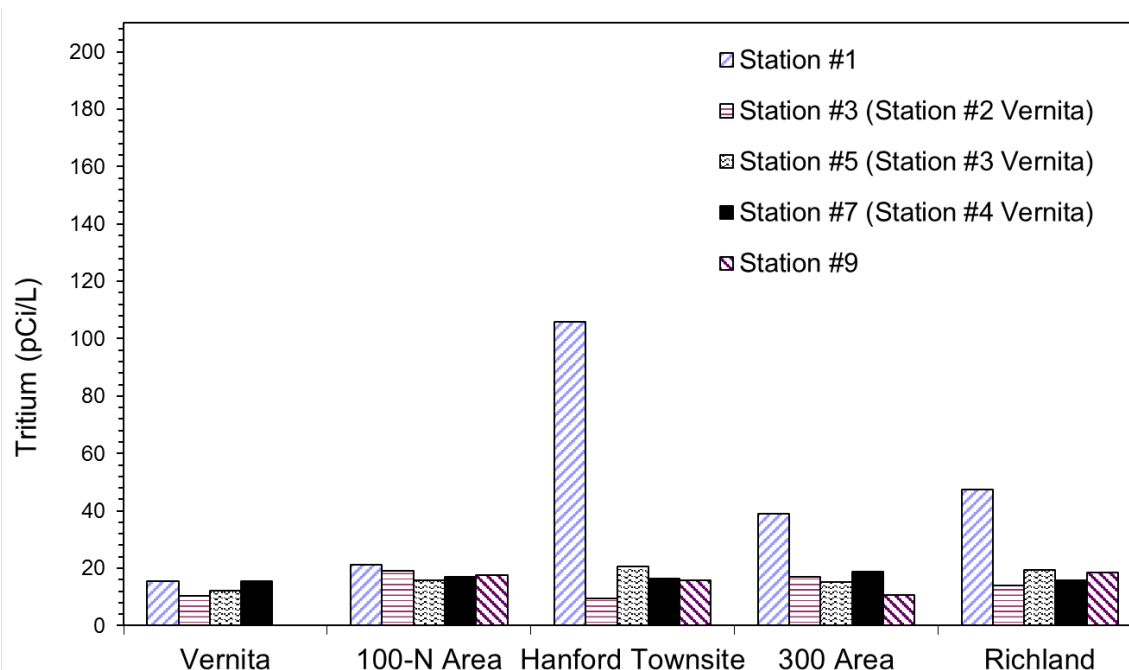


Figure 7-8. Tritium Concentrations in Cross-River Transect Water Samples (Hanford Reach, Columbia River).

Uranium isotopes measured in the 300 Area riverbank seep water samples were higher than those reported at the 300 Area-9 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 2016 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 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 0.036 pCi/L (0.0013 Bq/L) and the City of Richland intake had a maximum concentration of 0.030 pCi/L (0.0014 Bq/L). Average strontium-90 concentrations in Columbia River water at the City of Richland and Priest Rapids were less than the Washington State ambient surfacewater quality criterion (8 pCi/L [0.30 Bq/L]).

7.2.3 Inorganic and Organic Chemical Results

Inorganic and organic water quality data were compiled in 2016 for the Columbia River. A number of the parameters measured have no regulatory limits but are useful 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.

Metal and anion concentrations observed in river water were similar to those previously observed and remain below regulatory limits. Metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Copper and uranium were detected in most samples while detections of arsenic, lead, nickel, and zinc were detected in a few samples. All dissolved metal concentrations in river water were less than the Washington State ambient surfacewater quality criteria for the protection of aquatic life (Appendix C, Table C-10). All dissolved metal concentrations in river water were less than the Washington State ambient surfacewater quality criteria for the protection of aquatic life (Appendix C, Table C-9).

Washington State ambient surfacewater 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 2007) and the City of Richland in recent years.

For samples collected on the cross-river transects, there were no reportable detections of nitrites. The 300 Area HRM 43.1 station-1 (Benton County shoreline) had nitrate concentrations approximately three times the concentration of all other transect results throughout the Hanford Reach, Richland, and Vernita Bridge. Concentrations of chloride and sulfate were slightly elevated at Richland Pumphouse HRM 46.4 station-1 when compared to other transect locations (Figure 7-9). In some 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 10 mg/L, the EPA maximum contaminant level measured as nitrate nitrogen (40 CFR 141;USGS 1998).

Average annual concentrations of chloride 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 HRM 43.1 transect; however, the 100-N, 300 Area, Hanford Townsite, and Vernita Bridge transects also had detections of nitrate in 2016. 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 2010, the overall average has dropped from $109 \mu\text{g/L}$ to $82 \mu\text{g/L}$ in 2016 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 filtered river water samples for 2016 had chromium concentrations below the minimum detectable concentration.

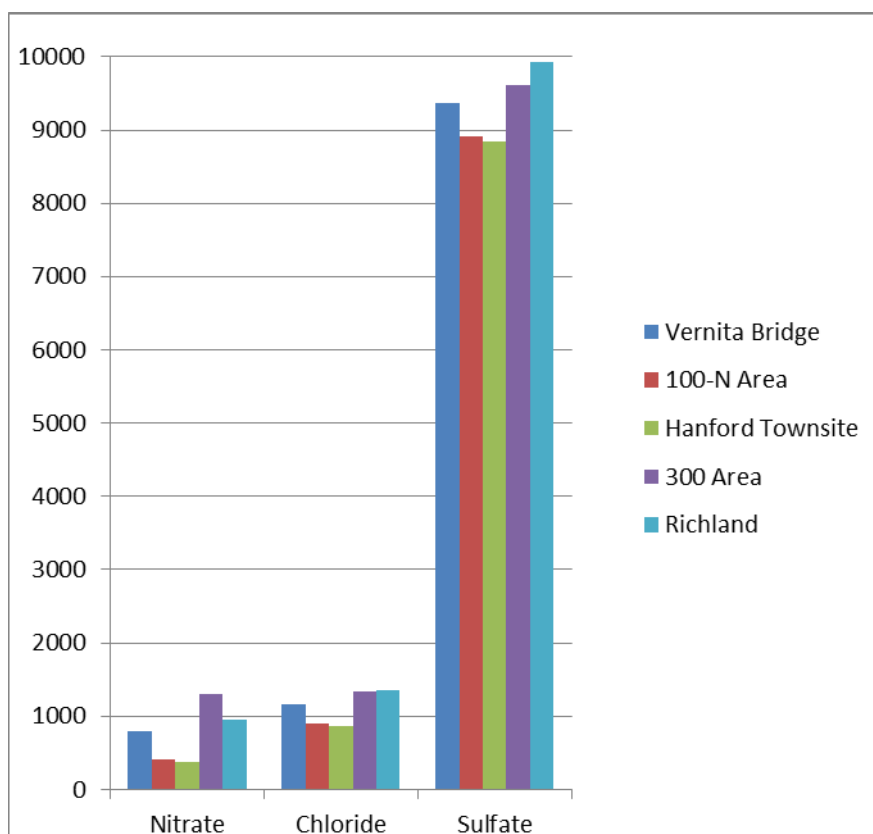


Figure 7-9. Selected Anion Concentrations in Columbia River Transect Samples (micrograms/liter).

7.3 Columbia River Sediment

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 reservoirs behind the dams located downstream of the Hanford Site. The majority of short-lived radioactive constituents have decayed, but some longer-lived radionuclides such as isotopes of cesium, plutonium, strontium, and uranium are still detectable. Fluctuations in the river flow from upriver hydroelectric dam operations, 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 ([PNNL-13417, 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](#), and [PNNL-16990, Summary of Radiological Monitoring of Columbia and Snake River Sediment, 1988 Through 2004](#)). 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 sediment or re-suspension into drinking water supplies. Sediment with accumulated radioactive materials can be an external radiation source; irradiating people fishing,

wading, swimming, sunbathing, or participating in other recreational activities associated with the river or shoreline (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 in. (0 to 16 cm) from 13 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 vessel or 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 in. (0.723 cm)/yr for Priest Rapids Dam and 0.89 in. (2.25 cm)/yr for McNary Dam (Gibbons 2000). Assuming a maximum sediment sampling depth of 6.3 in. (16 cm) with the Ponar dredge, 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 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 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 may also contribute to the contaminant load found in McNary Dam sediment. Sediment samples were also collected at 100-D Spring 102-1, 100-F Slough, 100-H Spring 145-1, Hanford Slough, 100-K Spring 63-1, 300 Area DR 42-2, White Bluffs Slough, and locations adjacent to Locke and Savage Islands. These sites are located along the Hanford Reach of the Columbia River in 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.

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. 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 2016 included cesium-137, hexavalent chromium, 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 required 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, are present in many agricultural fertilizers, and have been present in past releases of Hanford Site effluent. Analytical results for 2016 showed similar concentrations of cesium-137 at 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). Note: both Figures 7-10 and 7-11 have upper and lower bars that represent maximum and minimum values, which may be similar to the average and may not be visible.

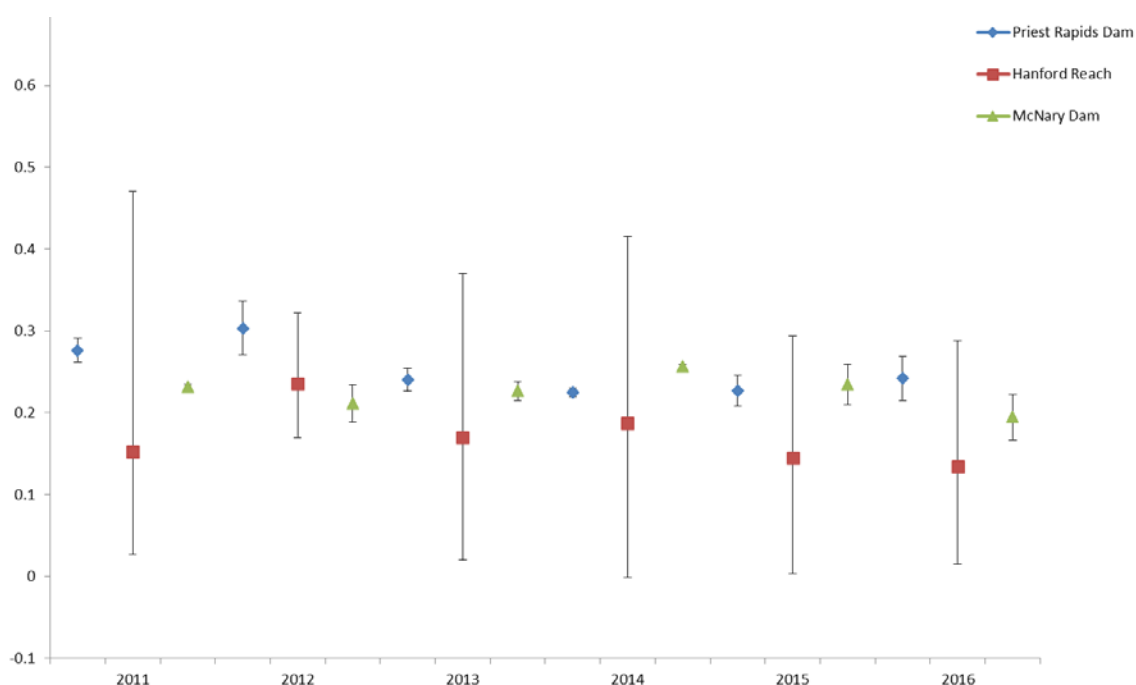


Figure 7-10. Cesium-137 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment.

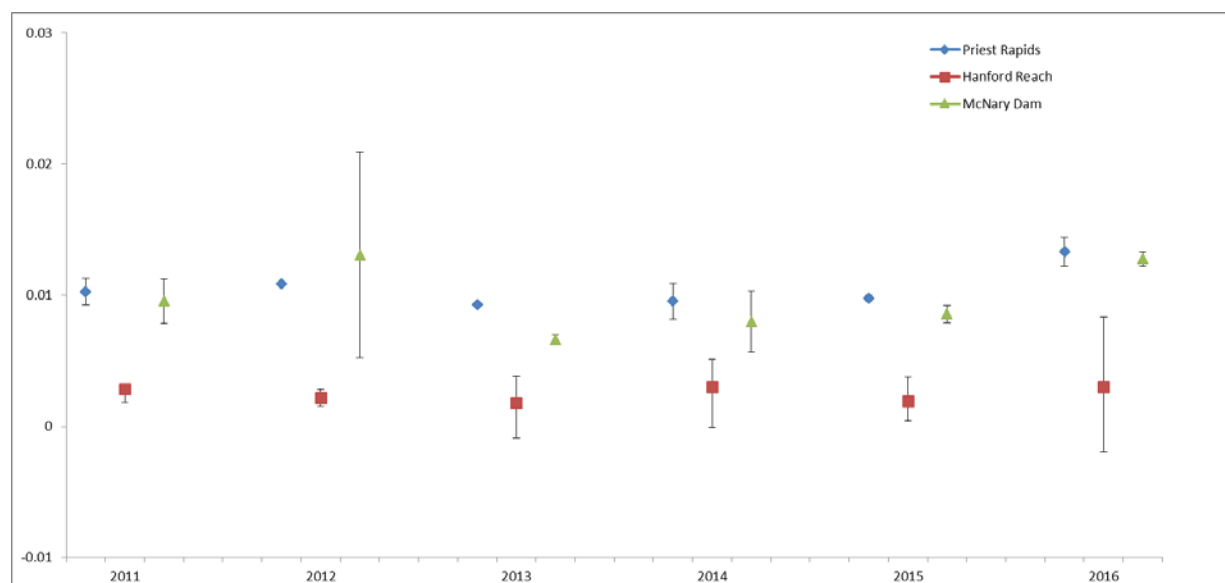


Figure 7-11. Plutonium-239/-240 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment.

Uranium-234 concentrations were slightly elevated in the 300 Area DR-42-2 location when compared to other sediment collected from the Hanford Reach, McNary Dam, and Priest Rapids Dam samples in 2016. Other radionuclide concentrations in river sediment were similar to those reported for previous years, and there were no obvious differences between locations.

Hanford Reach averaged 2.1 pCi/g, while Priest Rapids and McNary Dam concentrations averaged 2.5 pCi/g and 2.7 pCi/g, respectively (Figure 7-12). Note: upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible.

The values for cesium-137 in the White Bluffs Slough location of the Hanford Reach were slightly elevated (0.29 pCi/g maximum concentration) compared to other Hanford Reach sample locations (0.13 pCi/g average concentration) and McNary Dam (0.20 pCi/g average concentration). Priest Rapids did have a maximum value reported of 0.30 pCi/g, which was slightly above the White Bluffs Slough result and all other sediment collection locations. 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 (2011 to 2016) are presented in Figures 7-10, 7-11, and 7-12.

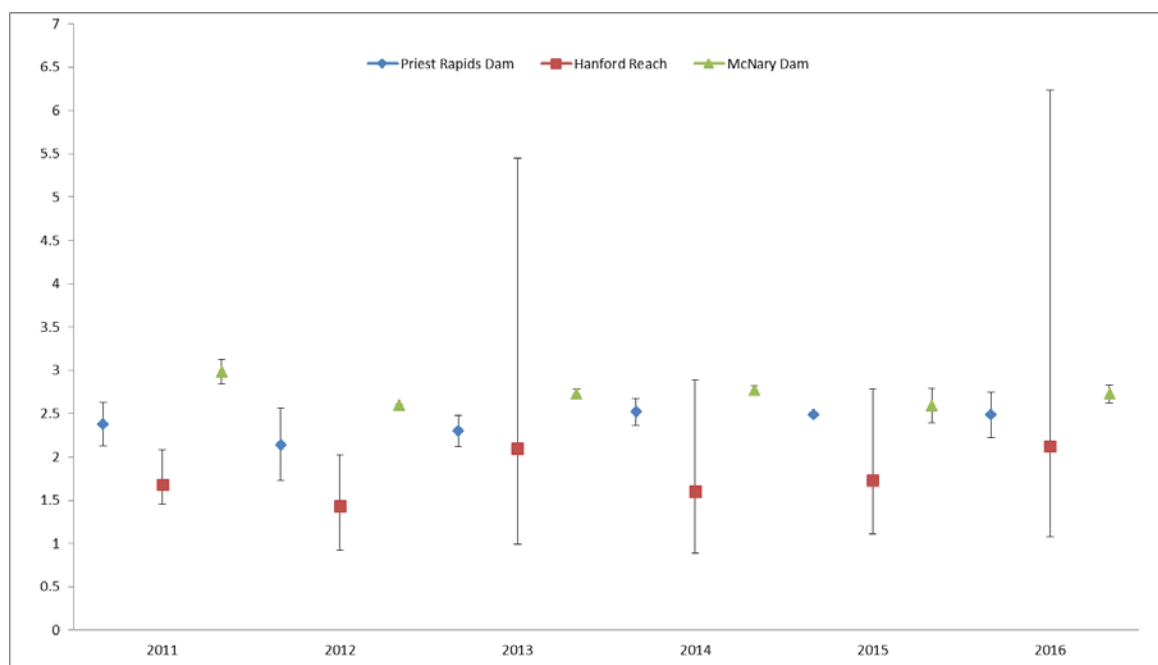


Figure 7-12. Uranium Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment.

7.3.3 Chemical Results

Detectable amounts of most metals were found in all river sediment samples (Figure 7-13). Note: upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible. Maximum and average concentrations of cadmium, chromium, copper, lead, mercury, nickel, thallium, and zinc were higher for sediment collected in the reservoir upstream of Priest Rapids Dam than in sediment from either the Hanford Reach or McNary Dam. Maximum concentrations of antimony, arsenic, beryllium, chromium, lead, and thallium were higher for sediment collected in the Hanford Reach than in sediment collected at Priest Rapids and McNary Dam. Lead concentrations were detected at higher rates in the 100-H Spring 145-1 shoreline sediment in comparison to all other sediment collection locations. Variations in stream hydraulics and associated sediment depositional zones for differing locations were likely attributable to increased concentrations in areas such as 100-H.

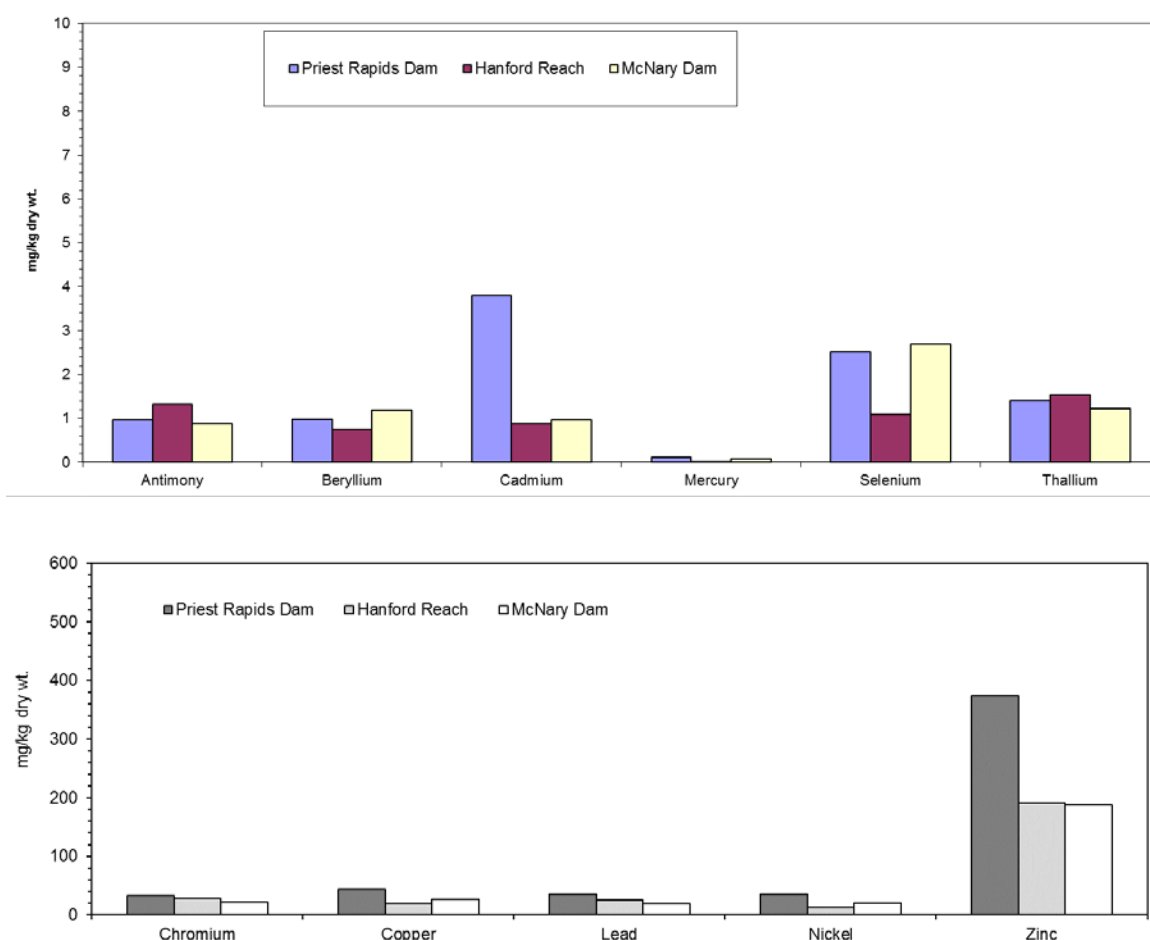


Figure 7-13. Selected Metals Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (Washington and Oregon).

7.4 Columbia River Seep Water

In 2016, samples of Columbia River seep water and three associated shoreline sediment samples 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, aquatic, and riparian environment. Various radiological analyses were performed on selected seeps following reviews of existing surfacewater and groundwater data, multiple remedial investigation/feasibility study 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 Table 7-5 and Appendix C.

Table 7-5. Columbia River Seep Monitoring.

Location ^a	Sample Type	Sampling Frequency	Analyses
100-B Area	Grab	Annually	Anions, metals (filtered and unfiltered), strontium-90, tritium, hexavalent chromium
100-D Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, technitium-99, tritium, isotopic uranium ^b , hexavalent chromium
100-F Area	Grab	Annually	Anions, metals (filtered and unfiltered), strontium-90, tritium, hexavalent chromium
100-K Area	Grab	Annually	Alpha, anions, beta, carbon-14, metals (filtered and unfiltered), strontium-90, technitium-99, tritium, VOA, hexavalent chromium
100-N Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, TPH, tritium, hexavalent chromium
300 Area	Grab	Annually	Alpha, anions, beta, tritium, isotopic uranium ^b , VOA, hexavalent chromium
Hanford Townsite	Grab	Annually	Alpha, anions, beta, iodine-129, metals (filtered and unfiltered), strontium-90, technitium-99, tritium, VOA ^(c) , hexavalent chromium

^a Refer to Figure 7-3; Locations may contain multiple shoreline seeps with differing analyses.

^b Uranium-234, uranium-235, and uranium-238

VOA = Volatile organic analyses

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 (Jenkins 1922). The Columbia River is the discharge area for the unconfined aquifer underlying the Hanford Site. It is also a regional groundwater discharge zone that includes discharge from confined basalt aquifers. 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; PNL-5289; PNL-7500; WHC-SD-EN-TI-006). 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; PNNL-14444; PNNL-16805; PNNL-16894; SGW-41497).

During the early 1980s, researchers walked a 41-mi (66-km) 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 along the Hanford Reach. Water table elevations are declining as a result of decreased artificial groundwater “mounding” from the discharge of millions of gallons of effluent from the 1950s through the early 1980s. As the groundwater mound declines, the water levels will reach “pre-Hanford” water level equilibrium which result in the gradual disappearance of groundwater seeps.

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 (μS)/cm.

The effect of bank storage on groundwater discharges and contaminant concentration variations in aquifer thickness, porosity, and plume concentrations make it difficult to accurately estimate 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) and results of near-shore studies in 1997 (PNNL-11933) 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. It is suspected that some seep samples collected may be a blend of groundwater and Columbia River 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, dose calculations, and contaminant trends (DOE/RL-91-50). Table 7-5 summarizes the sampling locations and frequencies as well as sample types and analyses included in Columbia River seep monitoring during 2016. This section describes the monitoring efforts and summarizes results for these aquatic and riparian 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, contaminant plume locations and movements throughout the Hanford Site, 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.

In 2016, 12 of 15 seeps were successfully sampled. All samples collected were analyzed for tritium. Some samples from selected seeps were analyzed for alpha, anions, beta, carbon-14, hexavalent chromium, 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 7-5).

7.4.2.1 Radiological Results. Contaminants of Hanford Site origin continued to be detected in 2016 in water from riverbank seeps entering the Columbia River along the Hanford Site. Table 7.5.1 provides a summary of the 2016 sampling results and a complete listing is provided in Appendix C, Table C.14. Carbon-14 levels measured in a 100-K Area riverbank seep decreased (maximum 2016 concentration measured 302 pCi/L) in comparison to those previously measured. In fall 2014, carbon-14 results exceeded DOE biota concentrations with approximately 2,200 pCi/L (609 pCi/L established RESidual RADioactivity riparian guideline). As a result, conditions were monitored throughout calendar year 2015 and 2016. Seep collections and surfacewater collections were collected quarterly as a result, and carbon-14 levels have shown an exponential decrease since fall 2014. A shoreline sediment sample was also collected in the 100-K Area in 2016 as a result of those concentrations seen in fall 2014.

Tritium concentrations varied widely with location. The highest tritium concentration measured in riverbank seeps was at the Hanford Townsite 28-2 riverbank seep ($21,200 \text{ pCi/L} \pm 4,130 \text{ pCi/L}$ [$785 \pm 153 \text{ Bq/L}$]), which was just above the Washington State ambient surfacewater quality criterion of 20,000 pCi/L (740 Bq/L) (WAC 173-201A; 40 CFR 141). No 2016 tritium results exceeded DOE-derived standards for riparian life (265,000,000 pCi/L). Tritium concentrations in riverbank seep water samples were higher when compared to maximum concentrations in 2016 Columbia River fixed-station locations at Priest Rapids Dam and the City of Richland, and Columbia River transect station locations. Overall, results in 2016 were comparable to the previous 5 years of concentrations reported in riverbank seeps.

A water sample from a riverbank seep in the Hanford Townsite area was collected in 2016 and submitted to a laboratory for iodine-129 analysis using an ultra-trace method. The water sampled during 2016 from the Hanford Townsite riverbank seep was a non-detect (0.02 pCi/L) for iodine-129. The Washington State surfacewater quality criterion for iodine-129 is 1 pCi/L (0.037 Bq/L), and the DOE-biota concentration guide standards for aquatic and riparian life are 1,000,000 pCi/L and 38,400 pCi/L. From 2013 to 2015, iodine-129 in the Hanford Townsite had a maximum concentration of 0.26 pCi/L, but all samples analyzed for iodine-129 were below the detection limit of 1 pCi/L (0.037 Bq/L).

All water samples from riverbank seeps were analyzed for strontium-90, the highest concentration that was detected in shoreline spring water was in the 100-N Area ($52 \text{ pCi/L} \pm 8.7 \text{ pCi/L}$ [$1.9 \pm 0.32 \text{ Bq/L}$]), approximately 5% of the DOE-derived concentration standards (DOE O 458.1) of 1,100 pCi/L (41 Bq/L). Historically, groundwater in the 100-N Area has had the highest strontium-90 levels measured at Hanford. The 2016 seep water result at 100-N was approximately 3 times higher than the 2015 reported concentration, and was within the typical historical range for this area.

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 lower ($24 \text{ pCi/L} \pm 2.8 \text{ pCi/L}$ uranium-234) than the EPA drinking water standard limit of $30 \text{ } \mu\text{g/L}$ (approximately 20 pCi/L [0.74 Bq/L]). Although maximum concentrations were lower than those found from 2011 to 2015, average concentrations of uranium-234, uranium-235, and uranium-238 were slightly higher in 2016 than they were during 2011 to 2015. Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area near former uranium fuel fabrication facilities and inactive waste sites.

During 2016 riverbank seep collections, three detections of gross alpha were recorded. The 300 Area DR 42-2 riverbank seep had two of the three detections ($31 \text{ pCi/L} \pm 5.6 \text{ pCi/L}$ and $19 \text{ pCi/L} \pm 5.8$), but only one of the two 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-D, 100-K, 100-N, Hanford Spring 28-2, and 300 Area seeps during 2016. 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 ($1.7 \text{ pCi/L} \pm 1.6 \text{ pCi/L}$) and Riverview ($2.0 \text{ pCi/L} \pm 1.7 \text{ pCi/L}$) collection locations. The highest gross beta concentration was measured in the Hanford Townsite 28-2 riverbank seep ($41 \text{ pCi/L} \pm 5.1 \text{ pCi/L}$ [$1.5 \pm 0.19 \text{ Bq/L}$]), which was 82% of the Washington State ambient surfacewater quality criterion of 50 pCi/L (1.85 Bq/L ; WAC 173-201A and 40 CFR 141). 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.

Appendix C, Table C-14 presents concentration ranges of selected metals and anions measured in riverbank seep water during 2011 through 2016. For most locations, the 2016 sample results were similar to those previously reported (PNNL-19455). Nitrate concentrations for 2016 were highest in seep water samples from the 100-F Area. Dissolved chromium concentrations in riverbank seeps for 2016 were also highest in the 100-F Area; while hexavalent chromium concentrations were highest in the 100-D Spring 102-1 Area.

The Washington State ambient surfacewater quality criteria for copper, lead, nickel, and zinc are total-hardness dependent (WAC 173-201A). For comparison purposes, the minimum value of 66-mg/L calcium carbonate for 2006 and 2007 U.S. Geological Survey-collected water samples near the Vernita Bridge were used. Concentrations of most metals measured in water collected from seeps along the Hanford Site shoreline during 2011 through 2016 were below the Washington State ambient surfacewater chronic toxicity levels (WAC 173-201A). All 2016 riverbank seep nitrate concentrations exceeded the Washington State drinking water standard of $10 \text{ } \mu\text{g/L}$ (WAC 246-290). However, the likelihood of public consumption of riverbank seep water is slim to none.

7.4.3 Sediment Monitoring

Beginning in the 1990s, periodic studies were conducted to collect and analyze sediment from riverbank seeps in the 100 and 300 Areas (DOE/RL-92-12; WHC-EP-0609; WHC-SD-EN-TI-125; WHC-SD-EN-TI-198). 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; the 100-H Area was added in 2004.

As a result of changing contaminant plumes and concentrations, sediment collection locations have been moved, added, and deleted from the sampling schedule. However, Hanford Site releases in these areas are best monitored using seep water samples when compared to sediment samples. As such, sediment samples were collected from riverbank seep locations in the 100-D, 100-H, 100-K, and 300 Areas (100-D Spring 102-1, 100-H Spring 145-1, 100-K 63-1, and 300 Area DR 42-2 seep) in 2016. (Table 7-6).

Table 7-6. Sediment Samples from Riverbank Seep Locations.

Location ^a	Sampling Frequency	Analyses
100-D Area	Annually	Anions, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
100-H Area	Annually	Anions, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
100-K Area	Annually	Anions, carbon-14, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
300 Area	Annually	Anions, carbon-14, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon

^a Refer to Figure 7-8

^b Uranium-234, uranium-235, and uranium-238
Plutonium-289, and plutonium 239/240

7.4.3.1 Radiological Results. Results for the 2016 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. Tables C-11 and C-16 in Appendix C compare radionuclide and total organic carbon concentrations in Columbia River sediment near the Hanford Site collected from 2011 through 2016.

7.4.3.2 Metals Results. Concentrations of metals in shoreline seep sediment samples collected in 2016 were similar to concentrations in Columbia River sediment samples with the exception of cadmium, chromium, and thallium. Shoreline sediment collected from 100-D Spring 102-1 had higher levels than those measured in Columbia River sediment samples. Appendix C, Table C-12 compares metal concentrations in sediment samples collected in 2016. 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 had the highest levels of hexavalent chromium, as concentrations were more than twice as much as 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).

7.5 Pond Water and Sediment

West Lake Pond (Figure 7-14) sampling was attempted quarterly during 2016. The Fast Flux Test Facility trends showed continual decreases in potential contaminants, therefore, sampling was discontinued in 2015 as the area had not received radioactive discharges for some time. Only West Lake was sampled in 2016. West Lake is accessible to migratory waterfowl, deer, and other wildlife, creating a potential biological pathway for the dispersion of contaminants that may be associated with upwelling from contaminated groundwater plumes. The Fast Flux Test Facility Pond is a retired disposal site that collected process water, primarily cooling water drawn from 400 Area groundwater wells.

The only naturally occurring pond on the Hanford Site, West Lake is located north of the 200-East Area (ARH-CD-775). 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.

Future sampling efforts will include heavy metal analyses, and data will be discussed in detail in the affected site annual report.

7.5.1 West Lake Pond Water

Grab sample collections were attempted quarterly from West Lake in 2016. All water samples collected from the West Lake were analyzed for tritium and uranium.

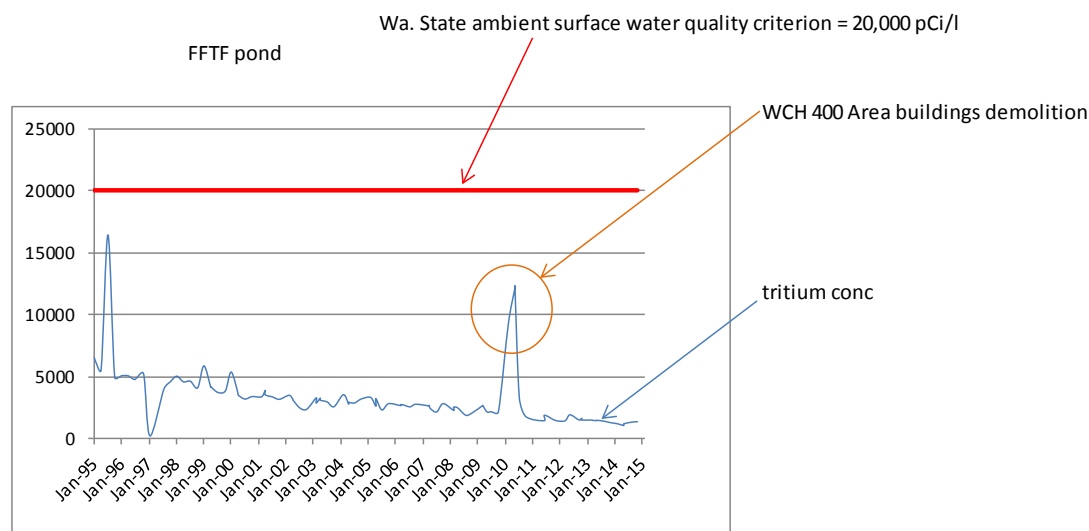


Figure 7-14. Fast Flux Test Facility Pond Water Tritium Concentration.

7.5.2 West Lake Water

Water monitoring continued at West Lake in 2016 with sampling conducted quarterly (though no sample was collected in the third quarter as the pond had no available standing water) as 2014 concentrations showed natural uranium results that exceeded the established riparian guideline levels. The groundwater table in the 200-East Area dropped in recent years (Section 8.0), decreasing the size of West Lake and causing the suspended sediment load to increase. West Lake seep and surfacewater 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 year 2000 study (PNNL-13487) indicated that uranium was present in a soluble form in West Lake water; as a result, analyses of West Lake water for uranium-234, uranium-235, and uranium-238 were resumed in 2011.

The surfacewater collected within the footprint of West Lake was analyzed for tritium, uranium-234, uranium-235, and uranium-238. Tritium concentrations in surfacewater collected from West Lake in 2016 were below the laboratory-reported required detection limit. Figure 7-15 shows the annual average concentrations of uranium-234 in West Lake surfacewater and West Lake seep water from 2013 to 2015. Radionuclide concentrations in the West Lake seep and surfacewater samples collected during 2015 and in the previous 2 years are shown in Appendix C (Tables C-3 and C-4).

A grab sample of surfacewater was attempted for analysis during the second quarter of 2016 when the lake was almost dry. A third quarter collection was attempted in late summer but the lake was dry. West Lake surfacewater was collected again in the fourth quarter to monitor uranium levels more closely.

Two uranium-234 and two uranium-238 results were above applicable DOE-derived concentration standards (DOE/EH-0676) for riparian and aquatic receptors. One sample showed the highest concentrations of uranium-234 and uranium-238 compared to concentrations seen over the last few years. This is likely a result of a higher suspended sediment load in sample collections completed at differing times of the year.

7.5.3 West Lake Sediment

Quarterly sediment samples were collected from West Lake during 2016. The sediment sample was collected from upper-layer material near the pond shoreline.

The West Lake sediment samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, 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 2016 were similar to previous concentrations.

Uranium concentrations are most likely from naturally occurring uranium in the surrounding soil (BNWL-1979). Radionuclide levels from samples collected during 2016 and a summary of those collected during the previous 5 years are shown in Appendix C, Table C-2.

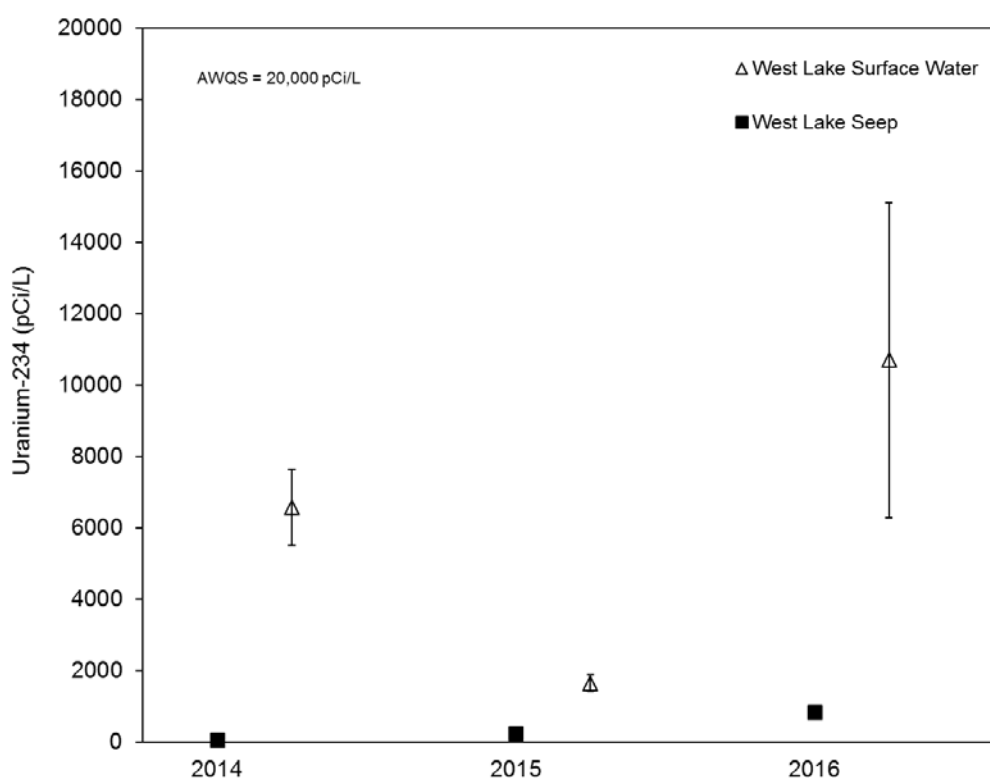


Figure 7-15. Uranium in West Lake Water Samples.

7.6 Offsite Irrigation Water

Water removed from the river immediately downstream of the Hanford Site is used to irrigate a small portion of agricultural crops in Benton and Franklin counties. The majority of irrigation water utilized by Franklin County residents originates at Grand Coulee Dam and is provided through its extensive water delivery systems (i.e., canals). Likewise, Benton County relies heavily on the Yakima River for irrigation purposes.

As a result of public concern about the potential for Hanford Site-associated contaminants in offsite water, sampling was conducted in 2016 to document the levels of radionuclides in water used by the public. The consumption of food products (Section 10.1, Agricultural Monitoring) 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 maximally exposed individual and any other member of the public (Section 4.2.1).

7.6.1 Offsite Irrigation Water Monitoring.

Water samples were collected in 2016 from an irrigation canal located on the east side of the Columbia River downstream of the Hanford Site at Riverview (Road 68, Pasco), and another irrigation supply located on the west side of the Columbia River just downstream of the 300 Area (Horn Rapids, Richland). 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 2016 irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, strontium-90, and tritium.

7.6.2 Sample Results.

Most radionuclide concentrations measured in irrigation water in 2016 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 historic Horn Rapids and Riverview irrigation samples. All radionuclide results were within the historical range and were less than their respective DOE-derived concentration standards and Washington State ambient surface-water quality criteria (DOE O 458.1, WAC 173-201A, 40 CFR 141).

7.7 Liquid Effluent

SJ Johnson

Liquid effluents are disposed of in a variety of ways at the Hanford Site, with each type of disposal governed by applicable regulations and permits. Primary disposal media for liquid effluents include the soil column, the Columbia River, and the City of Richland's sewer system. However, only one of those waste streams is permitted for radioactive constituents. Nonetheless, when discharges occur, 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 Ecology as regulated by [WAC 173-216, "State Waste Discharge Permit Program."](#)

7.7.1 Radionuclide Results

The only permitted discharge point for radioactive liquid effluent to the ground in 2016 was the 200 Area State-Approved Land Disposal Site (SALDS) permitted by the Washington State Department of Ecology through State Waste Discharge Permit ST0004502 (see also section 2.4.1).

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 four 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 the [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#). 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.

8.0 Groundwater Monitoring

MJ Hartman

This section summarizes results of Hanford Site groundwater monitoring for 2016. The [Hanford Site Groundwater Monitoring Report for 2016](#) (DOE/RL-2016-67) contains detailed information and is accessible through the Internet at <http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports>. DOE provides groundwater data to the public via the Internet at <https://ehs.hanford.gov/eda>.

During World War II and the Cold War period (1945–1991), the U.S. government built a total of nine reactors for the production of plutonium and other nuclear materials on the Hanford Site. During reactor 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, 200-West, 300, and 100 Reactor Areas along the river (e.g., 100-BC, 100-K). Since 1989, using its authority under the [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (CERCLA), U.S. Department of Energy (DOE) has worked to remediate this contamination. Key elements associated with managing the Hanford Site's groundwater and vadose zone contamination are to protect the Columbia River and groundwater from further contamination, develop a cleanup decision process, and restore 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 8-1).

DOE has taken the following actions to protect the Columbia River from contaminated groundwater:

- Ceased discharge of unpermitted liquids
- Remediated waste sites in the 100 and 300 Areas
- Operated remedial actions such as pump and treat (P&T) to contain groundwater plumes and reduce the mass of contaminants.

DOE operates an extensive groundwater monitoring program on the Hanford Site. In addition to groundwater wells, DOE monitors hundreds of sampling points near the Columbia River, known as aquifer sampling tubes, for general information about groundwater approaching the river. In 2016, DOE sampled 1,053 wells and 227 aquifer tubes. Many of them were sampled multiple times, for a total of 4,300 sampling events. The samples were analyzed for a variety of radionuclides and chemicals.

Some regions of Hanford Site groundwater are contaminated with chemicals and radionuclides (Figure 8-2). Tritium and iodine-129 form the largest groundwater plumes on the Hanford Site. The size of the largest plumes have gradually declined with time (Figure 8-3). The graph shows changes in plume areas at concentrations above drinking water standards (DWS), primarily based on data from wells screened near the top of the unconfined aquifer. In addition to the five major plumes shown in Figure 8-3, the area of the combined plume footprint also includes carbon-14, cyanide, strontium-90, technetium-99, trichloroethene (TCE), total petroleum hydrocarbon-diesel, and uranium.

The maximum concentrations of contaminants in Hanford Site groundwater have generally declined since the 1980s (Figure 8-4). The apparent increases in maxima for some contaminants between 2000 and 2010 are a result of new monitoring wells being installed to characterize and remediate contamination. Declining concentrations since 2010 are often a result of groundwater and waste site remediation.

The remainder of this section is organized by geographic regions known as “groundwater interest areas” (Figure 8-2). Seven interest areas are adjacent to the Columbia River, a region known as the River Corridor. Four interest areas in the inland region of the Hanford Site comprise the Central Plateau.

8.1 River Corridor

The River Corridor includes former operational areas along the Columbia River: the 100, 300, and 1100 Areas. Table 8-1 summarizes the River Corridor groundwater interest areas and associated contaminant 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 (COCs) in the 100 Area are hexavalent chromium, strontium-90, nitrate, TCE, and tritium (Figure 8-2). 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, TCE, carbon-14, and cis-1,2-dichloroethene (cis-1,2-DCE).

Since the 1990s, DOE has remediated waste sites and groundwater in the River Corridor under interim action and final action records of decision (RODs). Removal of contaminated soil has reduced the potential for exposure to contaminants, including future groundwater impacts. By the end of 2016, 92% of the potential waste sites in the River Corridor had been remediated or were classified as not needing remediation.

Under interim action RODs, groundwater remediation systems in the 100-HR-3 and 100-KR-4 Operable Units (OUs) are limiting the amount of contamination reaching the Columbia River and reducing the mass of contaminants. The primary contaminant addressed is hexavalent chromium and the remedial action target is 20 µg/L in groundwater, with the remedial action goal for groundwater discharging to the Columbia River to not exceed 10 µg/L.

Final action RODs have been signed for the 100-FR source and groundwater OUs, 300-FF-5 OU, and 1100-EM-1 OU. 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 of potential concern (COPCs) in 100-BC include hexavalent chromium, strontium-90, TCE, and tritium. Hexavalent chromium concentrations and the size of the plume declined between 2015 and 2016. The strontium-90 plume remained stable and tritium concentrations remained below the DWS in 2016. TCE exceeds the DWS in a single well screened at the base of the unconfined aquifer.

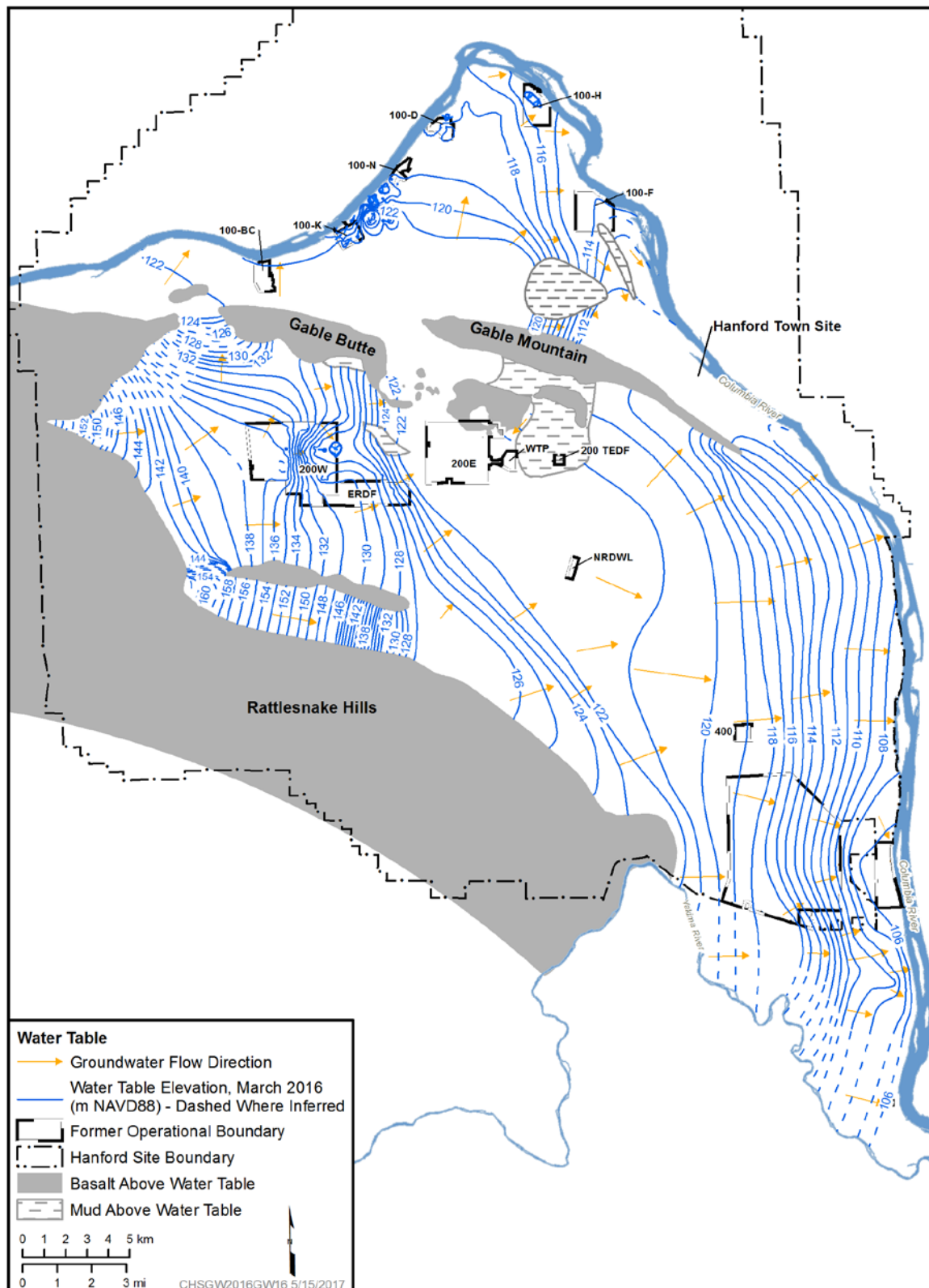


Figure 8-1. Hanford Site Water Table and Directions of Groundwater Flow, 2016.

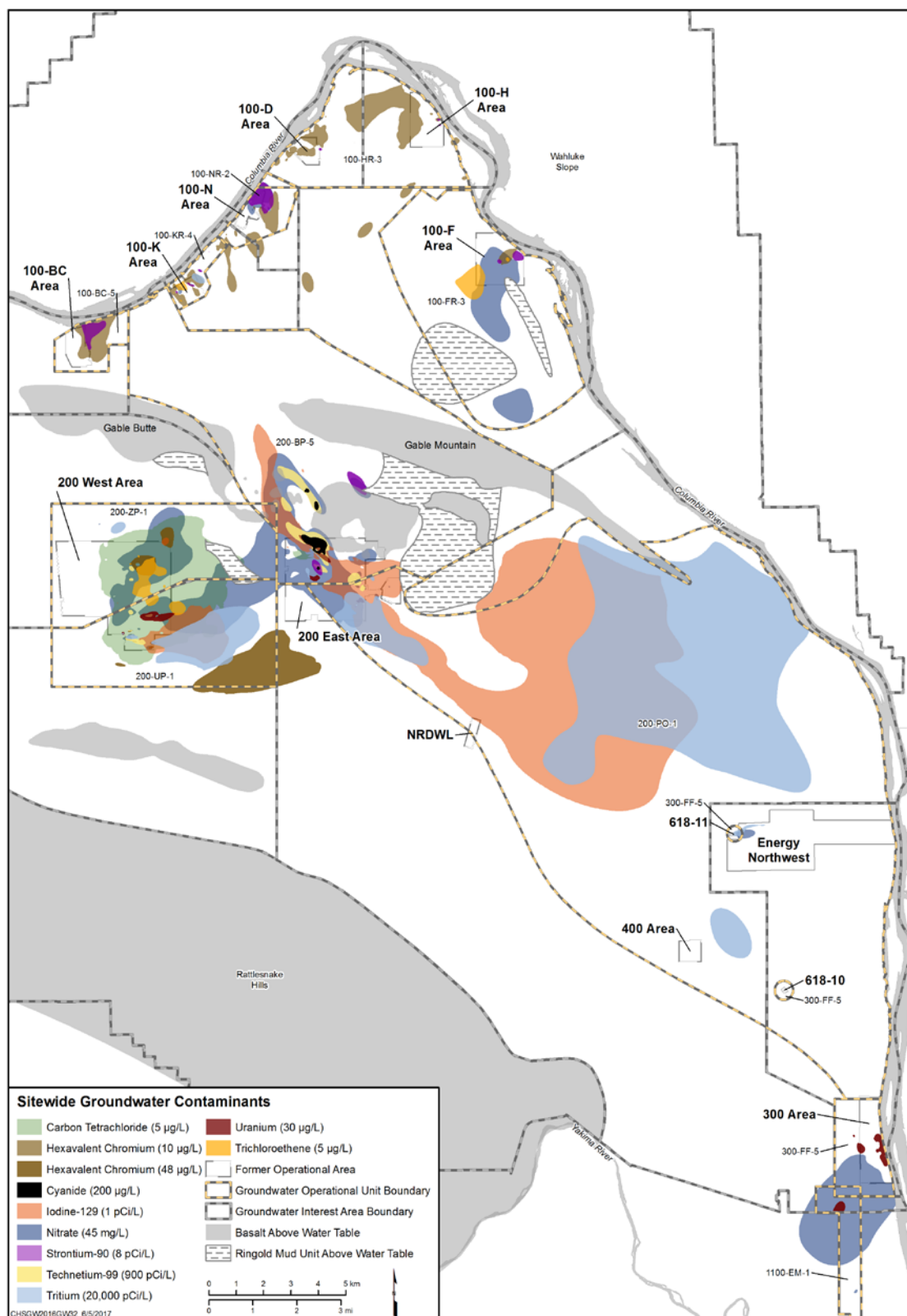


Figure 8-2. Groundwater Contaminant Plumes, 2016.

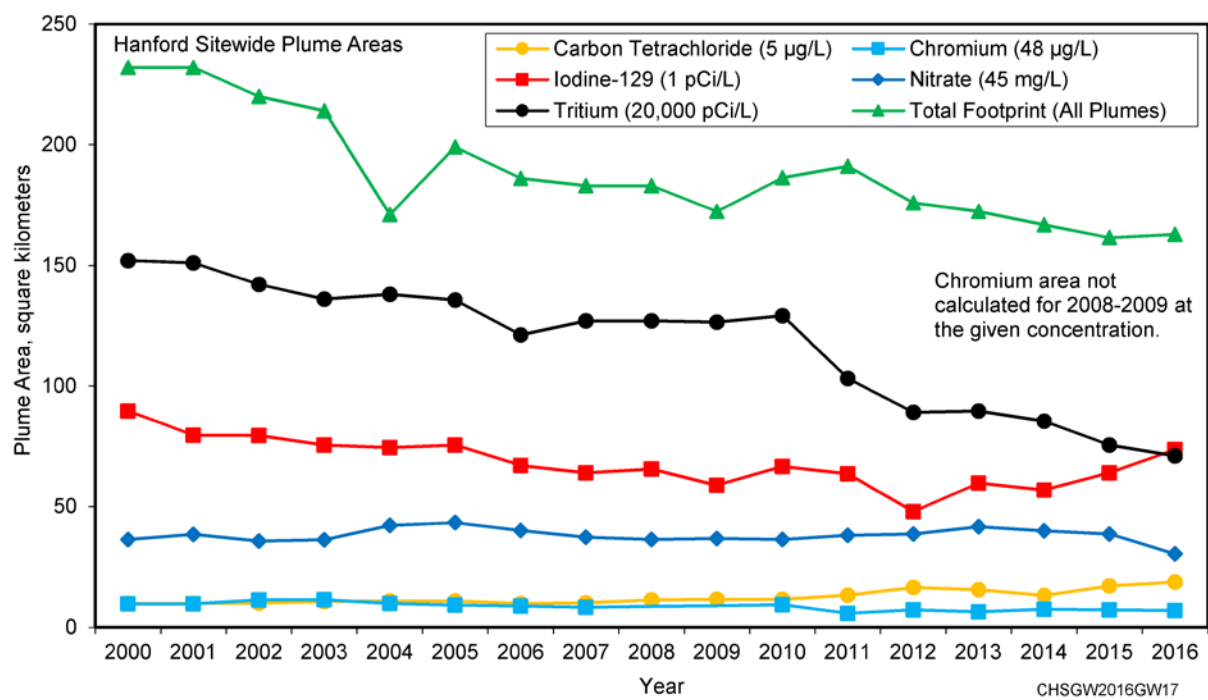


Figure 8-3. Hanford Site Plume Areas.

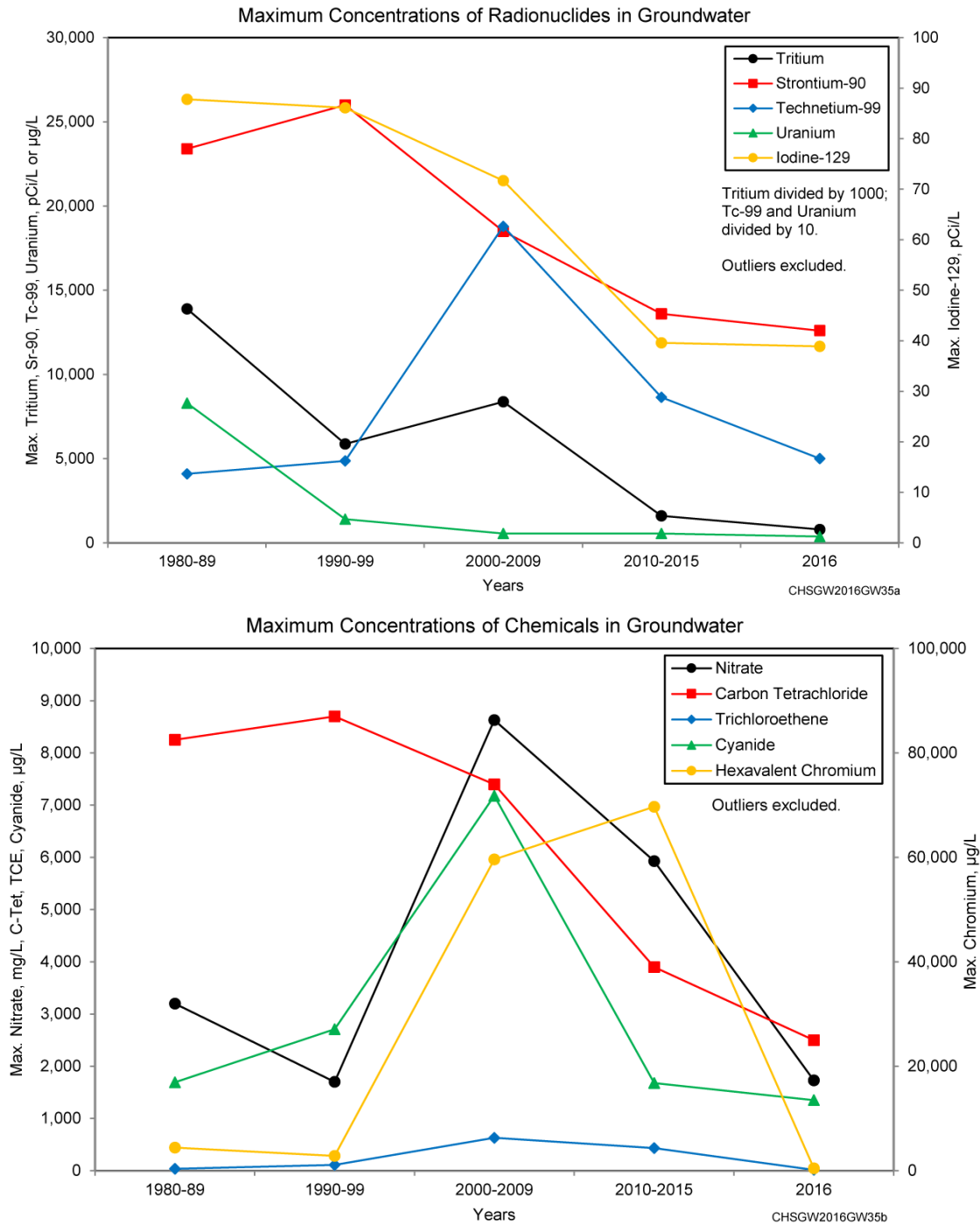

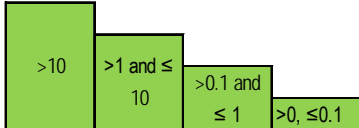





Figure 8-4. Maximum Concentrations of Radioactive and Chemical Contaminants in Hanford Site Groundwater over Time.

Table 8-1. Overview of River Corridor Groundwater Interest Areas.

River Corridor Overview										
Ground-water Interest Area	Primary Operations	Status of Waste Site Remediation ^a	Status of Groundwater ROD	Groundwater Contamination: Maximum Concentration and Plume Area						
				Carbon-14 (pCi/L)	Hexavalent Chromium (µg/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloro-ethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
100-BC	Reactor operations -- B Reactor 1944-69; C Reactor 1952-69	93% complete	None to date	N	55	19.9	49.7	6.69	15,600	5.5
100-FR	Reactor operations -- F Reactor 1945-65; Biological experiments until 1976	100% complete	Final action MNA	N	70	124	126	15	3,330	12.5
100-HR	Reactor operations -- D Reactor 1944-67; DR Reactor 1950-64; H Reactor 1949-65	98% complete	Interim action pump and treat	N	640	66.4	30.1	N	10,600	50
100-KR	Reactor operations -- KE Reactor 1955-71; KW Reactor 1955-70	56% complete	Interim action pump and treat	40,100	380	75.3	164	9.48	730,000	27
100-NR	Reactor operations -- N Reactor 1963-87	92% complete	Interim action permeable reactive barrier	357	110	443	12,600	0.18	303,000	9.45
300-FF	Nuclear fuel fabrication and research -- 1940s-1960s	95% complete	Final action enhanced attenuation, MNA	N	47	(b)	N	2.09	799,000	1,180
1100-EM and Offsite	Vehicle maintenance, 1954-85; solid waste landfill --1950s-1970	100% complete	Final action MNA; goals met	N	N	(b)	N	0.47	N	(b)
Standards ^c				2,000	10	45	8	5	20,000	30
Half-life				5730 yr	N/A	N/A	28.8 yr	N/A	12 yr	>159,000 yr
Mobility in subsurface				High	High to Moderate	High	Slight	Moderate	High	Moderate
Legend										
Colors and listed values indicate maximum concentration in 2016										
 ≥1000 x standard										
 ≥100 x standard and <1000 x standard										
 ≥10 x standard and <100 x standard										
 ≥Standard and <10 x standard										
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 (December 31, 2016).										
(b) Nitrate in 300-FF, and nitrate and uranium in 1100-EM, originate 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				

DOE has remediated most 100-BC waste sites, and vadose zone sampling indicated that no substantive quantities of contamination remain in the vadose zone. However, at a few sites, data from deep vadose soils and the rewetted zone, and the presence of persistent groundwater contamination, suggest that minor quantities of residual contamination may remain.

Remedial investigation (RI) studies concluded in 100-BC in January 2016. DOE submitted an RI report (DOE/RL-2010-96) and proposed plan (DOE/RL-2016-43) to support remedy decisions for groundwater cleanup to EPA in 2016.

8.1.2 100-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, hexavalent chromium, strontium-90, and TCE are the groundwater COCs. Contaminant concentrations are declining overall and are below cleanup levels near the Columbia River in aquifer tubes.

DOE has completed remediation of 100-FR waste sites. Sampling indicated no substantive quantities of contamination remain in the vadose zone.

In 2016 six new wells were installed to support the groundwater remedy, monitored natural attenuation (MNA) of groundwater COCs under a 2014 ROD (EPA and DOE 2014). Data from the new wells showed that a low-permeability mud unit extends above the water table and the unconfined aquifer is absent beneath portions of the groundwater OU. This new interpretation, along with sampling data from the new wells, changed the interpretation of the nitrate plume.

8.1.3 100-HR

The 100-HR-3 Groundwater OU in the northern part of the Hanford Site includes the 100-HR-D and 100-HR-H groundwater interest areas, referred to collectively as 100-HR. About 98% of the potential waste sites have been remediated or were determined not to require remediation under an interim action ROD. Groundwater is contaminated with hexavalent chromium, strontium-90, and nitrate.

Two P&T systems continued to operate under an interim action ROD (EPA/ROD/R10-96/134) to remove hexavalent chromium from groundwater. In 2016, 2.6 billion L (688 million gal) of groundwater was pumped from 86 extraction wells, removing over 85 kg of hexavalent chromium. Since 1997, the P&T systems have removed 2,474 kg of hexavalent chromium.

The overall areal extent of the hexavalent chromium plumes and the length of affected shoreline have declined between 1999 and 2016 (Figure 8-5). The changes are a result of groundwater contaminant removal, remediation of sources, hydraulic control, and natural processes. Fifteen new wells were installed in 100-HR in 2016.

In 2016 the proposed plan (DOE/RL-2011-111) for remediation of waste sites and groundwater was made available for public comment. DOE has proposed ongoing P&T as the preferred alternative for remediating hexavalent chromium in groundwater.

The former 183-H Solar Evaporation Basins constitute the only [*Resource Conservation and Recovery Act of 1976*](#) (RCRA) unit in 100-HR. The unit is monitored in accordance with RCRA corrective action

requirements during the post-closure period to track contaminant trends during operation of the CERCLA P&T interim action.

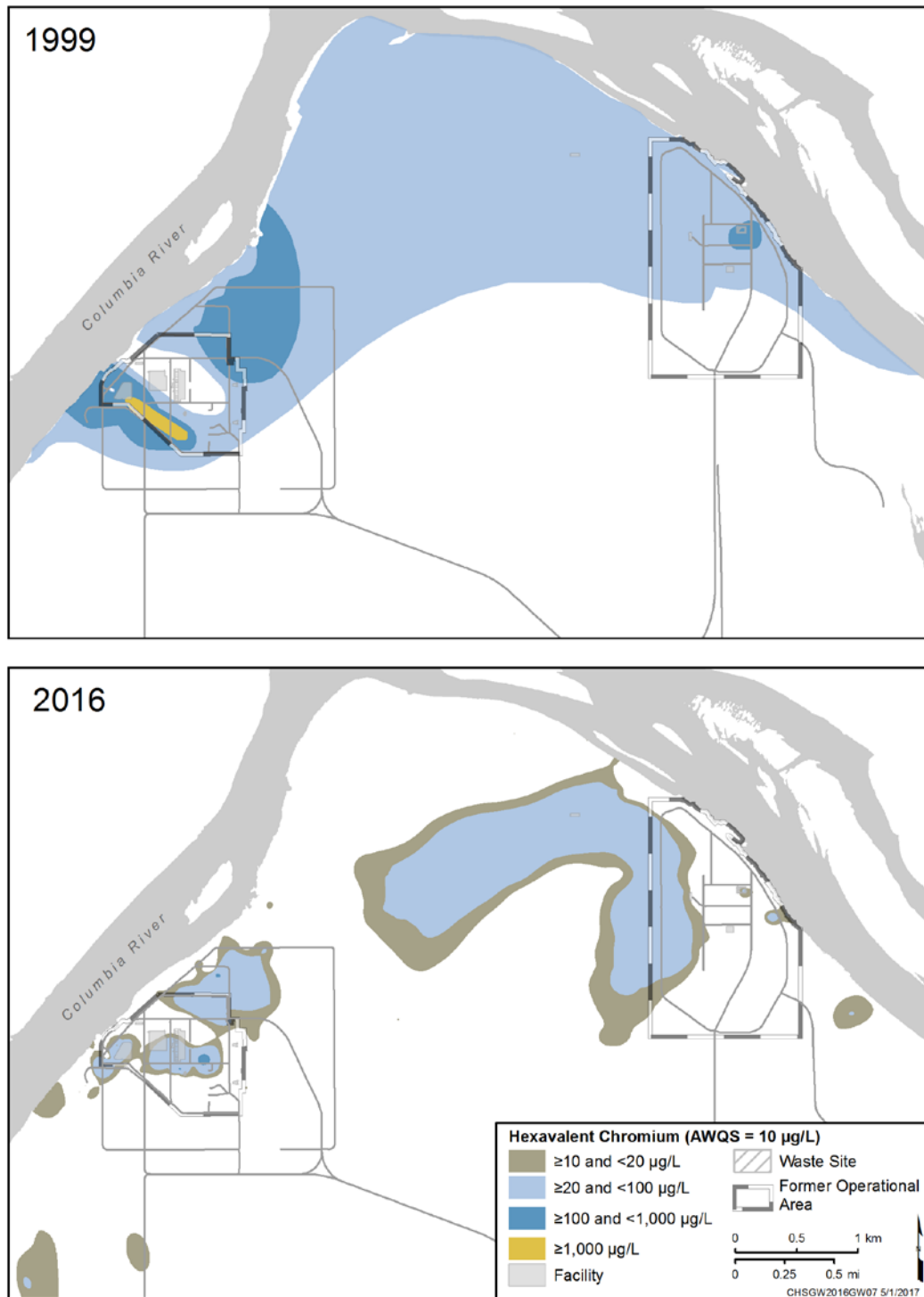


Figure 8-5. 100-HR Hexavalent Chromium Plume in 1999 (early in interim action period) and 2016 (during interim action).

8.1.4 100-KR

Hexavalent chromium is the primary COC in 100-KR groundwater. Smaller plumes of carbon 14, tritium, strontium 90, nitrate, and TCE also are present. About 56% of the potential waste sites have been remediated or were determined not to require remediation under an interim action ROD (EPA/ROD/R10-96/134).

Three P&T systems continued to operate in 100-KR in 2016, extracting over 2.5 billion L (650 million gal) of groundwater from 43 extraction wells. A total of 867 kg of hexavalent chromium has been removed from 100-KR groundwater to date, and the size and concentrations of the plumes have decreased over time (Figure 8-6). Four new extraction wells were installed in 2016.

Because hexavalent chromium concentrations were below the cleanup goal in the western plume, the extraction wells in that region were shut off in May 2016 to begin a rebound test. Hexavalent chromium concentrations subsequently increased in monitoring wells, suggesting the presence of ongoing contaminant sources in the vadose zone.

Groundwater monitoring in 2016 did not show new groundwater impacts from the KW and former KE fuel storage basins. The KW Basin has been emptied of fuel rods but remains a depository for contaminated sludge from the KE and KW Basins.



Figure 8-6. 100-KR Hexavalent Chromium Plume in 1996 (before interim action) and 2016 (during interim action).

8.1.5 100-NR

About 92% of the potential waste sites in 100-NR have been remediated or classified as not requiring remediation. The groundwater COPCs are strontium-90, total petroleum hydrocarbons, nitrate, total chromium, hexavalent chromium, and tritium. Six new monitoring wells were installed in 2016. To reduce the amount of strontium-90 migrating to the Columbia River, DOE is applying an in situ technology called strontium-90 sequestration, using an apatite chemical solution.

DOE submitted a draft RI/ feasibility study (FS) report (DOE/RL-2012-15) and proposed plan (DOE/RL-2012-68) to Ecology for review in 2013. In 2016 DOE continued to respond to Ecology comments on these documents. When finalized, they will be used to develop a ROD for remediation of 100-NR waste sites and groundwater.

In 2016, RCRA monitoring continued under final status detection programs at the 1301-N, 1324-N/NA, and 1325-N facilities. Results indicated no releases of dangerous waste constituents from the RCRA units.

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. About 95% of the potential waste sites have been remediated or classified as not requiring remediation. Remediation is continuing at the remaining sites.

A final action ROD (EPA et al. 2013) calls for enhanced attenuation of uranium and MNA of TCE, cis-1,2-DCE, tritium, and nitrate. The enhanced attenuation component of the groundwater remedy involves infiltrating and injecting phosphate solutions to the ground to bind with uranium and form insoluble minerals. The first stage of enhanced attenuation was completed in 2015, and monitoring data were collected and evaluated in 2016. Initial amorphous phosphate minerals appear to be sequestering uranium, as expected. Figure 8-7 shows how the uranium plume has attenuated between 1996 and 2016.

In 2016 three characterization boreholes were drilled and decommissioned and one monitoring well was decommissioned.

RCRA groundwater monitoring continued at the 300 Area Process Trenches. The unit is monitored in accordance with post-closure corrective action requirements. Uranium and cis-1,2-DCE continued to exceed Permit limits in 2016. Remediation will be coordinated under the 300-FF-5 Groundwater OU.

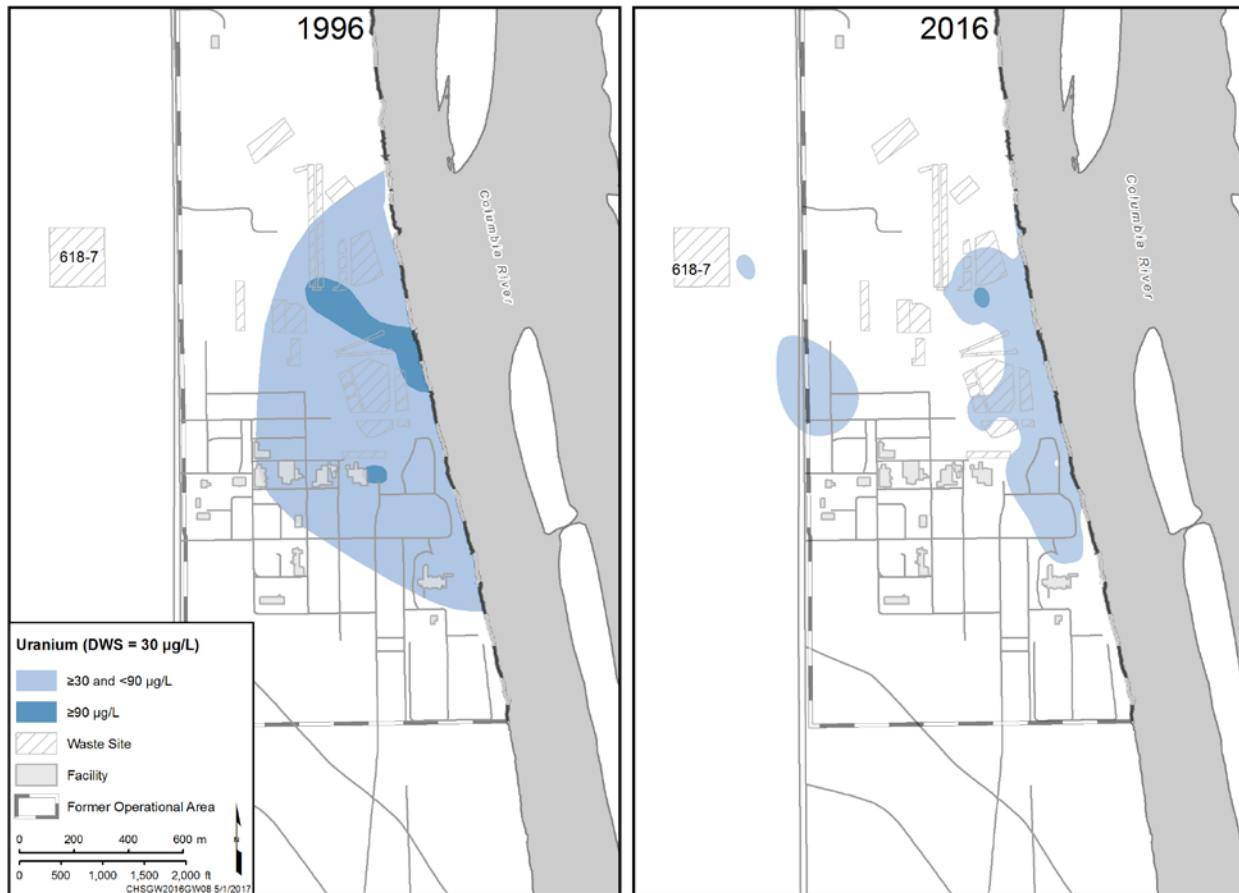


Figure 8-7. 300-FF Uranium Plume in 1996 and 2016.

8.1.7 1100-EM and Richland North

The 1100-EM-1 Groundwater OU was removed from the National Priorities List (40 CFR 300, Appendix B5) in 1996. The selected remedy was MNA for volatile organic compounds, with institutional controls preventing drilling of new water supply wells. Cleanup goals were met, and no further remedial action or groundwater monitoring is required.

DOE monitors wells in and near the North Richland well field, which is part of the municipal water supply system. Groundwater in this region has not been impacted by Hanford Site contamination.

Uranium concentrations in two wells near the southern border of the Hanford Site have increased gradually since 1996, continuing to exceed the DWS in 2016. The presence of uranium at these locations is attributed to a plume moving northeast from a former surface impoundment at AREVA NP, Inc., an offsite nuclear fuel production facility, which has been remediated.

8.2 Central Plateau

The Central Plateau, located in the middle of the Hanford Site, includes the 200-West and 200-East Areas. 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 Areas. Ponds, cribs, and ditches used for liquid waste disposal were primary sources of groundwater contamination. There are also seven single shell tank waste management areas (WMAs) in the 200 Areas. Some of these tanks have leaked, contaminating the vadose zone and groundwater.

Contamination is still present in many parts of the thick Central Plateau vadose zone and may continue to migrate into the groundwater, and DOE is beginning to characterize and remediate these sites. In 2016 DOE drilled characterization boreholes to study deep vadose zone contamination in the 200-East and 200-West Areas. Groundwater and deep vadose zone remediation on the Central Plateau include the 200-West P&T, U Plant and S-SX extraction systems, a deep vadose zone treatability test in B Complex, and a removal action for the 200-BP-5 groundwater OU at the B Complex.

Large groundwater contaminant plumes of tritium, nitrate, and iodine-129 formed when the waste discharged to ponds and cribs in the Central Plateau reached the aquifer (Figure 8-2). Plume sizes have decreased over the years because of dispersion and, in the case of tritium, radioactive decay. A large carbon tetrachloride plume originated in the Plutonium Finishing Plant area of the 200-West Area. Other groundwater contaminants in the Central Plateau include technetium-99, uranium, strontium-90, TCE, hexavalent chromium, cyanide, and other dangerous waste constituents (Table 8-2).

8.2.1 200-BP

Most of the groundwater contamination in the 200-BP groundwater interest area is associated with waste sites in the northwestern portion of the 200-East Area. Nitrate, iodine-129, and technetium-99 exceed DWS and form the largest contaminant plumes. Smaller plumes of uranium, cyanide, strontium-90, and tritium also exceed their DWS. Cesium-137 and plutonium-239/240 contamination is limited to only one or two wells.

An action memorandum (DOE/RL-2016-41) was released in December 2016 to implement a non-time-critical removal action for the B Complex high-concentration technetium-99 and uranium plumes. This action will target groundwater extraction from plume areas that exceed 10 times the 900 pCi/L DWS for technetium-99 and the 30 µg/L DWS for uranium. Extracted groundwater will be treated at the 200 West P&T and reinjected into the aquifer in the 200-West Area. A groundwater treatability test was conducted in this vicinity during 2015 and 2016, demonstrating successful extraction of groundwater and removal of 14 kg of uranium. Since initiation of this extraction system in September 2015, 13.9 kg of uranium, 70,160 kg of nitrate, and 1.3 Ci of technetium-99 have been removed (Figure 8-8).

Extraction of perched water, contaminated with uranium and nitrate, resumed in December 2016. The system was expanded from one to three extraction wells. Since startup the system has removed 84.5 kg of uranium and 778 kg of nitrate from the ground.

In 2016 RCRA groundwater monitoring continued at WMA B-BX-BY, WMA C, the 216-B-63 Trench, Low-Level Waste Management Area (LLWMA)-1, LLWMA-2, and the Liquid Effluent Retention Facility. A replacement monitoring well was installed in 2016 for WMA C. New monitoring plans for LLWMA-1 and WMA C are expected to be implemented in 2017.

Table 8-2. Overview of Central Plateau Groundwater Interest Areas.

Central Plateau Overview													
Ground-water Interest Area	Primary Operations	Status of Ground-water ROD	Groundwater Remedial Action	Groundwater Contamination: Maximum Concentration and Plume Area									
				Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Cyanide (µg/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloroethene (µg/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)
200-BP	B Plant Pu separation: 1945-1952; B Plant Sr and Cs recovery: 1967-1985	FS Drafted in 2015 (with 200-PO-1)	B Complex groundwater extraction treatability test 2015; Perched water P&T 2011-2015	N	160	1,350	5.27	1,510	4,470	5.07 ^a	32,700	61,400	3,790
200-PO	PUREX Plant Pu separation: 1956-1972 and 1983-1989	FS Drafted in 2015 (with 200-BP-5)	Vadose zone desiccation test: 2011	0.17	350	7	8.91	146	13.7	1.3	1,950	418,000	23.9
200-UP	REDOX Plant (Pu separation) 1952-1967; U Plant (U recovery) 1952-1957	Signed 2012 (interim action)	Uranium plume P&T began 2015; I-129 containment began 2015; S-SX P&T 2012-present; U Plant P&T 1994-2011	See 200-ZP	460	4.7	20.2	531	15.3	See 200-ZP	39,000	250,000	2,400
200-ZP	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	2,320	420	N	1.2	708	N	14	10,700	58,800	6.5
Standards ^b				5	48	200	1	45	8	5	900	20,000	30
Half-life (years)				N/A	N/A	N/A	1.60E+07	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 and listed values indicate maximum concentration in groundwater in 2016													
Height of bar indicates plume area above standard (km ²)													
<div><div><div>>100 x standard and <1000 x standard</div><div>>10 x standard and <100 x standard</div><div>≥Standard and <10 x standard</div><div>N Not detected or not analyzed</div></div><div><div>>10</div><div>>1 and ≤10</div><div>>0.1 and ≤1</div><div>>0, ≤0.1</div></div></div>													
a. TCE in a 100-K well within footprint of 200-BP.													
b. Drinking water standards for all but (MTCA standard for hexavalent chromium)													
ABBREVIATIONS													
N/A = Not applicable P&T = pump and treat ROD = record of decision MTCA = Model Toxics Control Act													

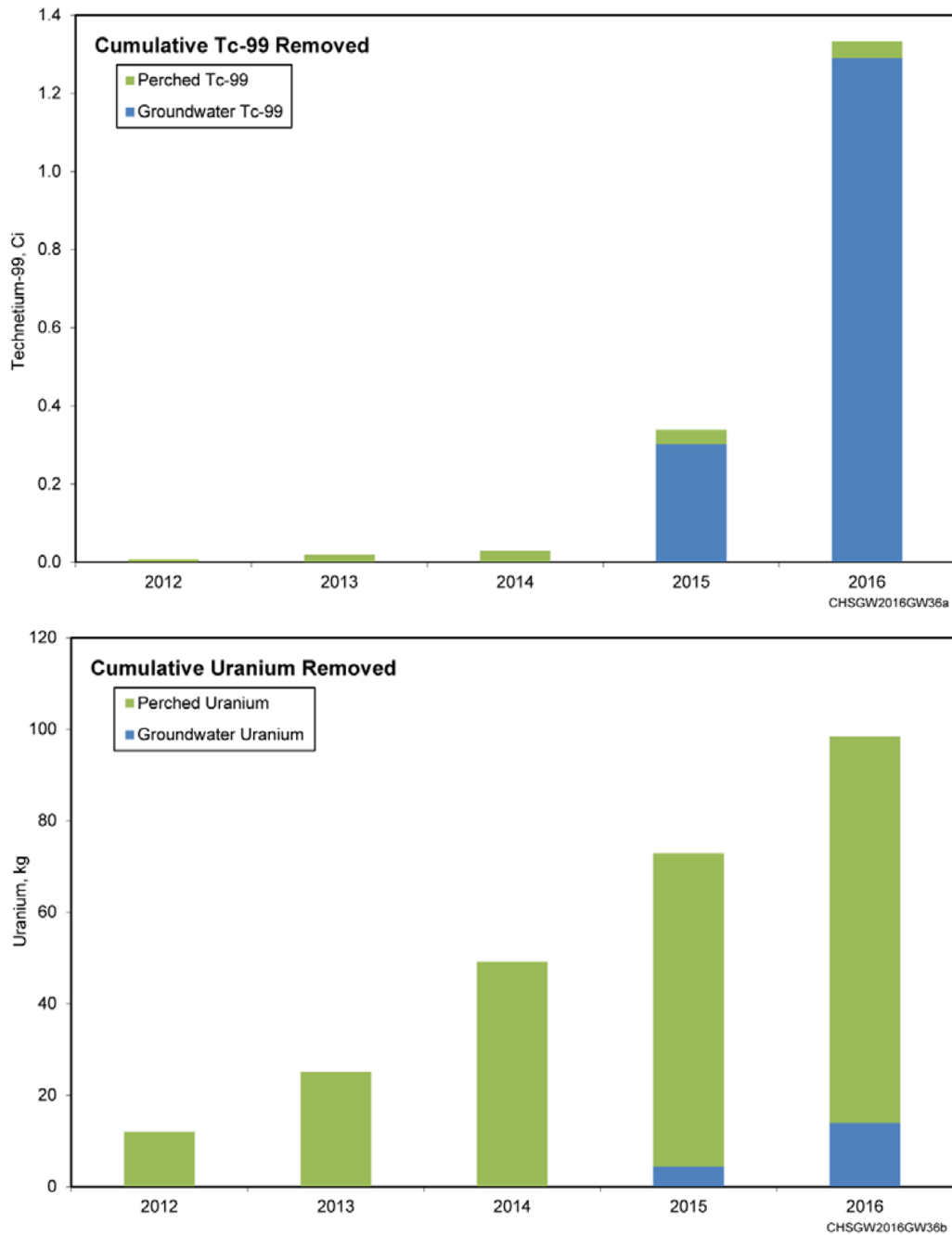


Figure 8-8. 200-BP Contamination Removed from Perched Water and Groundwater in the B Complex Area.

8.2.2 200-PO

The southern portion of the 200-East Area and a large region 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. Other 200-PO contaminants include strontium-90, technetium-99, and uranium in smaller areas near their discharge sources (Figure 8-2).

The size of the regional tritium plume (Figure 8-9) from 200-PO has decreased by 65% since 1980 (from 185 to 65 km² [71.4 to 25 mi²]). The maximum concentration has declined from over 6 million pCi/L in the 1980s to 418,000 pCi/L in 2016.

In 2016, RCRA monitoring was conducted at WMA A-AX, the 216-A-29 Ditch, 216-A-36B Crib, 216-A-37-1 Crib, 216-B-3 Pond, Nonradioactive Dangerous Waste Landfill (NRDWL), and the Integrated Disposal Facility. New RCRA monitoring plans were implemented at the 216-A-29 Ditch, NRDWL, and WMA A-AX in 2016. New monitoring plans for the 216-A-36B Crib, 216-A-37-1 Crib, and 216-B-3 Pond are expected to be implemented in 2017.

The Solid Waste Landfill is regulated under Washington State solid waste handling regulations. A new monitoring plan was implemented in 2016.

8.2.3 200-UP

The southern portion of the 200-West Area and adjacent areas to the east and south comprise 200-UP. Carbon tetrachloride, technetium-99, uranium, tritium, iodine-129, nitrate, and hexavalent chromium plumes are present. Carbon tetrachloride in this region originated from sources in 200-ZP. An interim action ROD (EPA et al. 2012) includes P&T, hydraulic control, and MNA. Eight new monitoring wells were installed for the 200-UP-1 OU in 2016. Data from these wells will help characterize and monitor groundwater contaminants.

The U Plant uranium/technetium-99 groundwater extraction system continued to operate in 2016, and contaminant concentrations have declined (Figure 8-10). In 2016, 9.9 kg of uranium, 0.47 Ci of technetium-99, 71,100 kg of nitrate, and 29.7 kg of carbon tetrachloride were removed from the aquifer.

A P&T system at WMA S-SX continued to operate in 2016, and contaminant concentrations are declining (Figure 8-10). In 2016, the system removed 0.38 Ci of technetium-99, 4,190 kg of nitrate, 5.4 kg of hexavalent chromium, and 11.4 kg of carbon tetrachloride from groundwater.

An iodine-129 hydraulic containment system, composed of three injection wells east of 200-West Area, continued to operate in 2016.

RCRA groundwater monitoring continued at WMA S-SX, WMA U, and the 216-S-10 Pond and Ditch. DOE submitted a new RCRA monitoring plan for 216-S-10 to Ecology in 2016.

The Environmental Restoration Disposal Facility is a CERCLA disposal facility used for disposal of low level radioactive mixed waste generated by remedial actions. The results of 2016 groundwater monitoring continued to indicate that the facility has not impacted groundwater.

8.2.4 200-ZP

Contaminant sources in 200-ZP, located in the 200-West Area, included cribs, ponds, and single shell storage tanks. A final action ROD (EPA et al. 2008) for the 200-ZP-1 OU groundwater identified carbon tetrachloride as the primary COC (Figure 8-11). Other COCs are TCE, iodine-129, technetium-99, nitrate, hexavalent chromium, and tritium.

In 2016, 26 extraction wells and 27 injection wells were in use to remediate groundwater in the 200-ZP-1 groundwater OU. The system processed 3.0 billion L (800 million gal) of groundwater, removing 1,721 kg of carbon tetrachloride, 330,900 kg of nitrate, and other contaminants from groundwater. Combined, the final action system, the interim action system, and the former soil vapor extraction system have removed 104,913 kg of carbon tetrachloride from the subsurface (Figure 8-12). The soil vapor extraction system successfully removed contamination from the vadose zone. Continued operation of the system was no longer beneficial so it was permanently shut down in 2015.

RCRA groundwater monitoring continued at WMA T, WMA TX-TY, LLWMA-3, and LLWMA-4 in 2016. Groundwater monitoring continued at the State-Approved Land Disposal Site, which receives treated water from the Hanford Site Effluent Treatment Facility. It is regulated under a State Waste Discharge Permit and has created a local tritium plume.

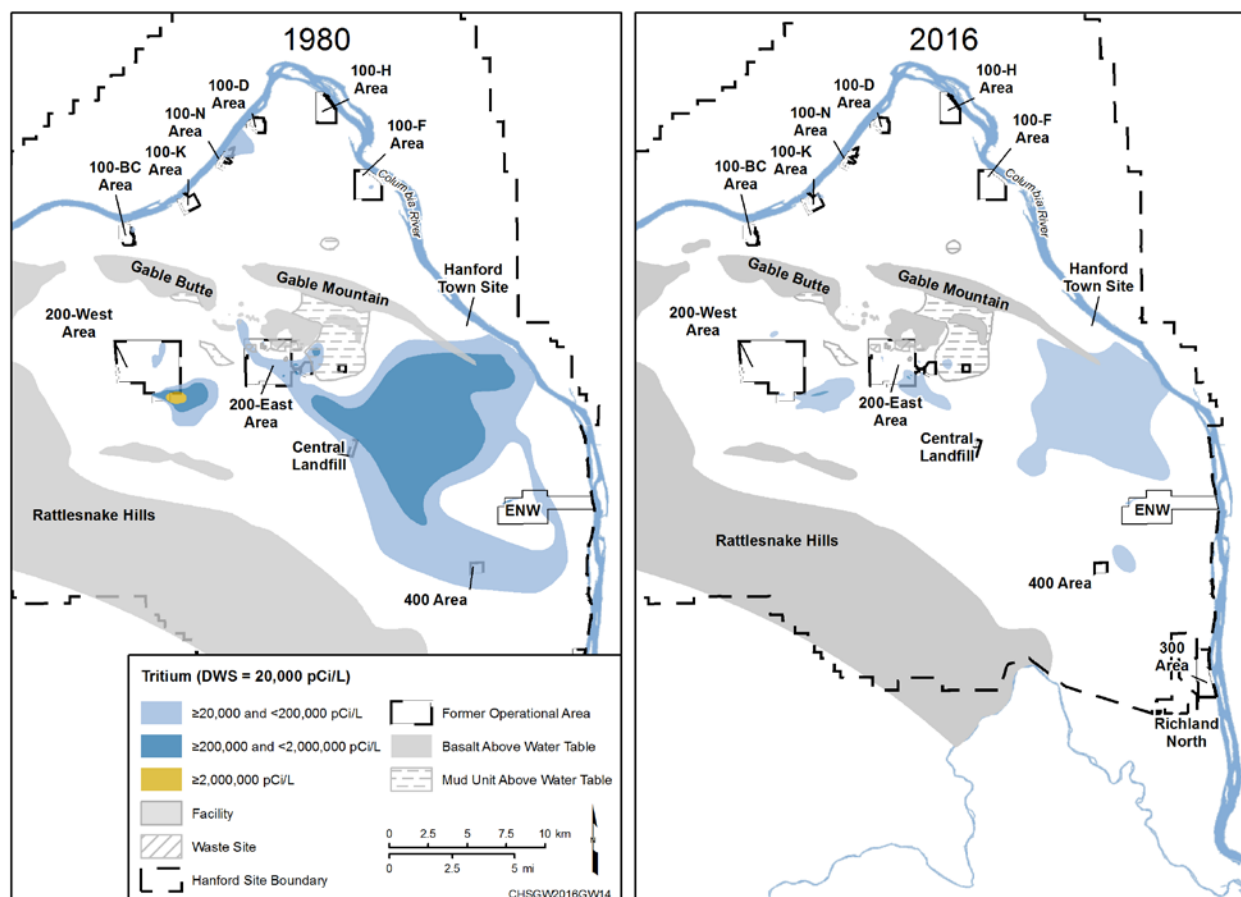


Figure 8-9. Hanford Site Tritium Plumes in 1980 and 2016.

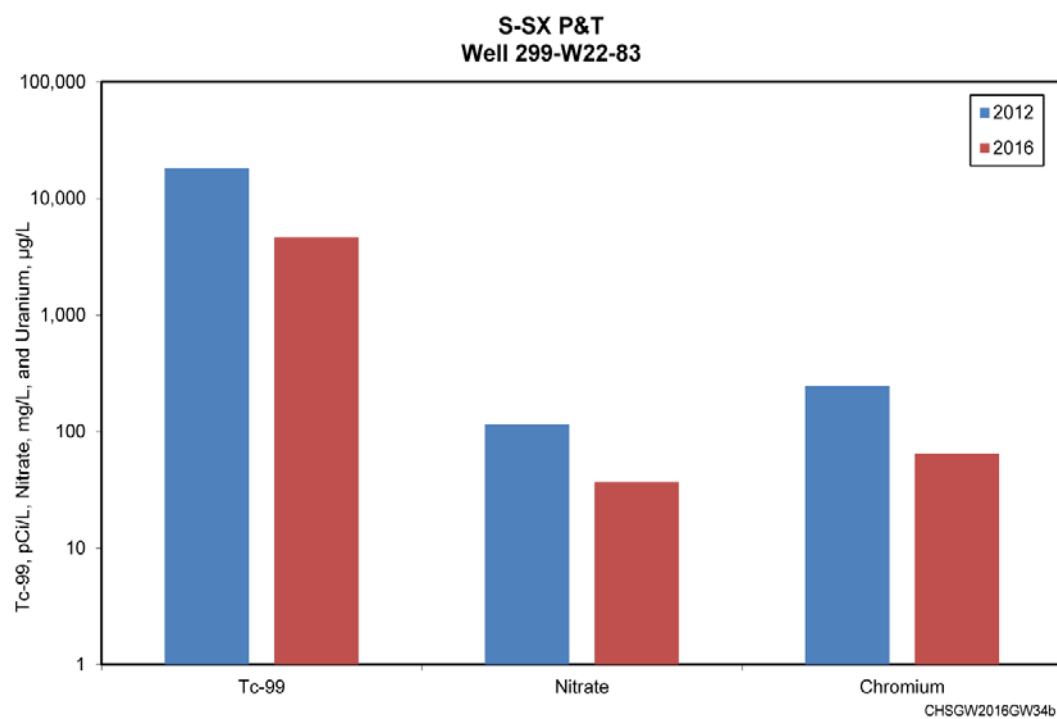
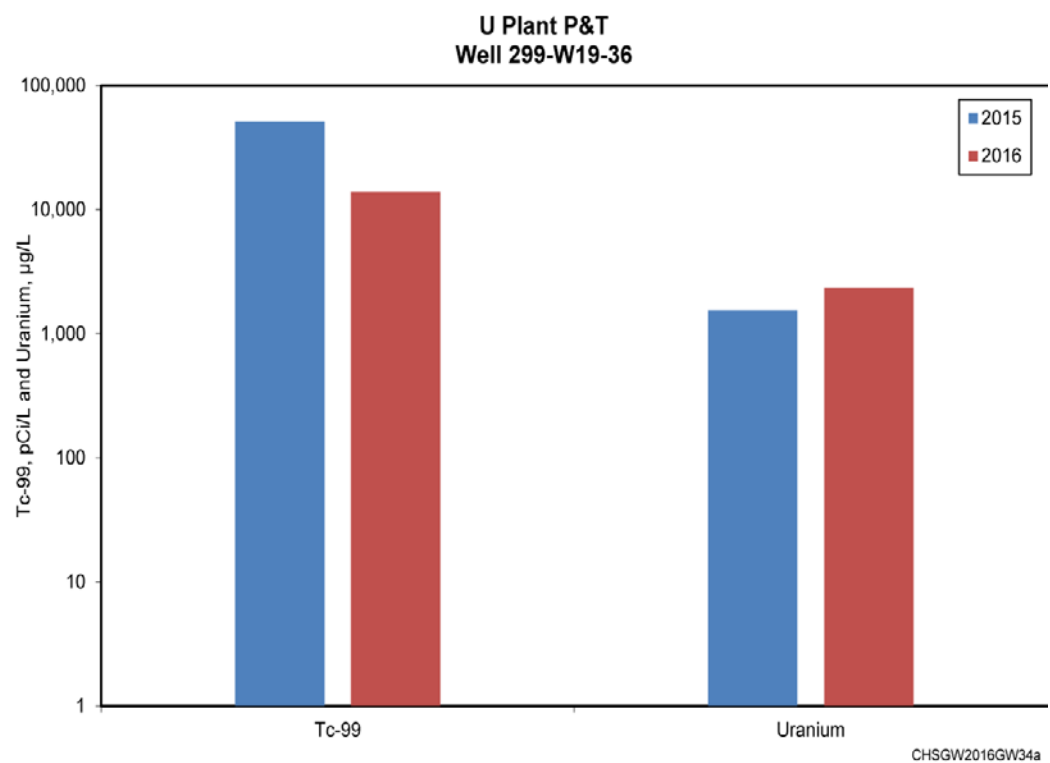


Figure 8-10. Changes in 200-UP Contaminant Concentrations Before and During Pump and Treat.

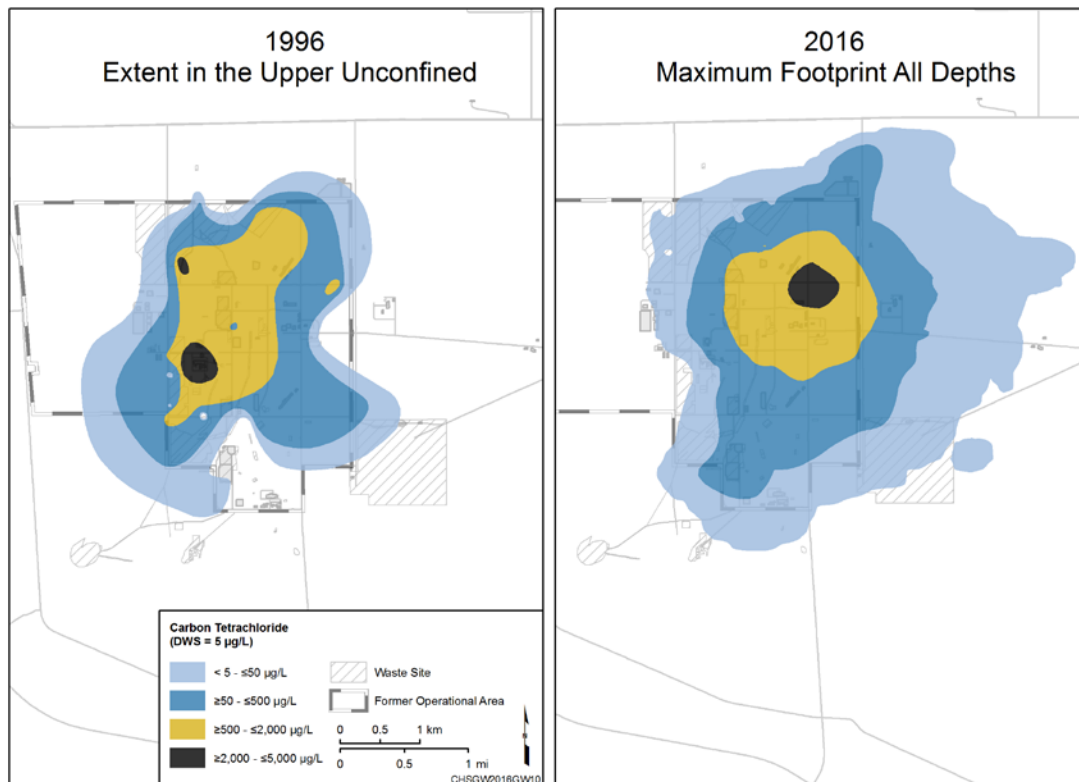


Figure 8-11. 200-West Carbon Tetrachloride Plume in 1996 and 2016.

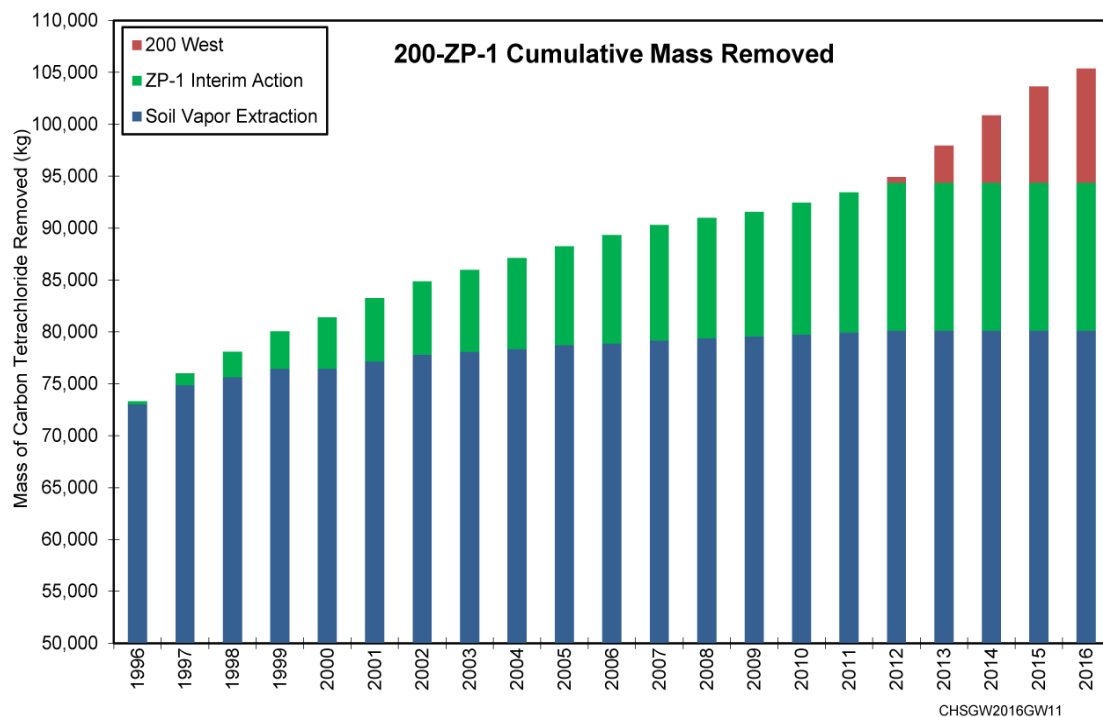


Figure 8-12. 200-ZP Carbon Tetrachloride Mass Removed by Final P&T, Interim P&T, and Soil Vapor Extraction.

8.3 Confined Aquifers

Most Hanford Site groundwater contamination is found in the unconfined aquifer, but 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, hexavalent chromium, and nitrate have entered this unit in a portion of the 200-West Area (200-ZP) 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 local region east of the 200-East Area (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 and/or southeast.

In the northern Hanford Site, fine-grained sedimentary units, informally called the Ringold upper mud unit, 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. The vertical hydraulic gradient between the basalt confined aquifer and the unconfined aquifer is upward beneath most of the Hanford Site. Groundwater monitoring data do not indicate that contamination has migrated into the upper basalt confined aquifer.

9.0 Soil Monitoring

JW Wilde

Radiological monitoring of soil is conducted at a variety of locations: 1) onsite near Hanford Site facilities, waste sites, contamination areas and operations, 2) onsite away from facilities and operations, 3) and offsite at perimeter and distant locations and in nearby communities. Contaminant concentration data are used for the following:

- Determine the effectiveness of effluent monitoring and radioactive material controls
- Assess the adequacy of containment at waste disposal sites, waste site remediation and contamination areas
- Detect and monitor unusual conditions in which there was a potential release or spread of radioactive material
- Provide information on long-term radionuclide contamination trends in soil at undisturbed sample locations.

Data obtained from onsite soil samples is used as a qualitative indicator and subordinate data of ambient air sampling results per the Washington State Department of Health (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 for calendar years 2016 (DOE/RL-2013-53, Rev. 2) and 2017 (DOE/RL-2013-53, Rev. 3).

9.1 Monitoring Results

According to the latest version of the [Hanford Site Environmental Monitoring Plan](#) (DOE/RL-91-50), soil monitoring provides information about long-term contamination trends and baseline environmental radionuclide activities at undisturbed sample locations both on and off the Hanford Site.

9.2 Sampling Results

Soil samples are collected near facilities, waste sites, contamination areas and operations on the Hanford Site to detect potential migration and deposition of radioactive materials 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 2016 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 are collected every 3 to 5 years and were last collected in 2015.

Table 9-1. Soil Sample Locations.

Number of Samples Analyzed	Operational Area (discrete samples analyzed)								
	ETF	Trench 94	100-N	200-West ^a	200-East ^a	300 ^a	400	600 ^a	ERDF
73	3	3	3	27	11	8	1	16	1

^a Number of samples includes one or more duplicate samples.

Individual soil samples are 2.2 lb (1.0 kg), which consist of five plugs of soil. Each sample is approximately 1 in. (2.5 cm) deep and 4 in. (10 cm) in diameter. Soil samples were 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.

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 with concentrations of radionuclides measured in samples collected offsite at various locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin counties in 2015 (Section 9.3). 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 (e.g., 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 hrs/yr 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^a.

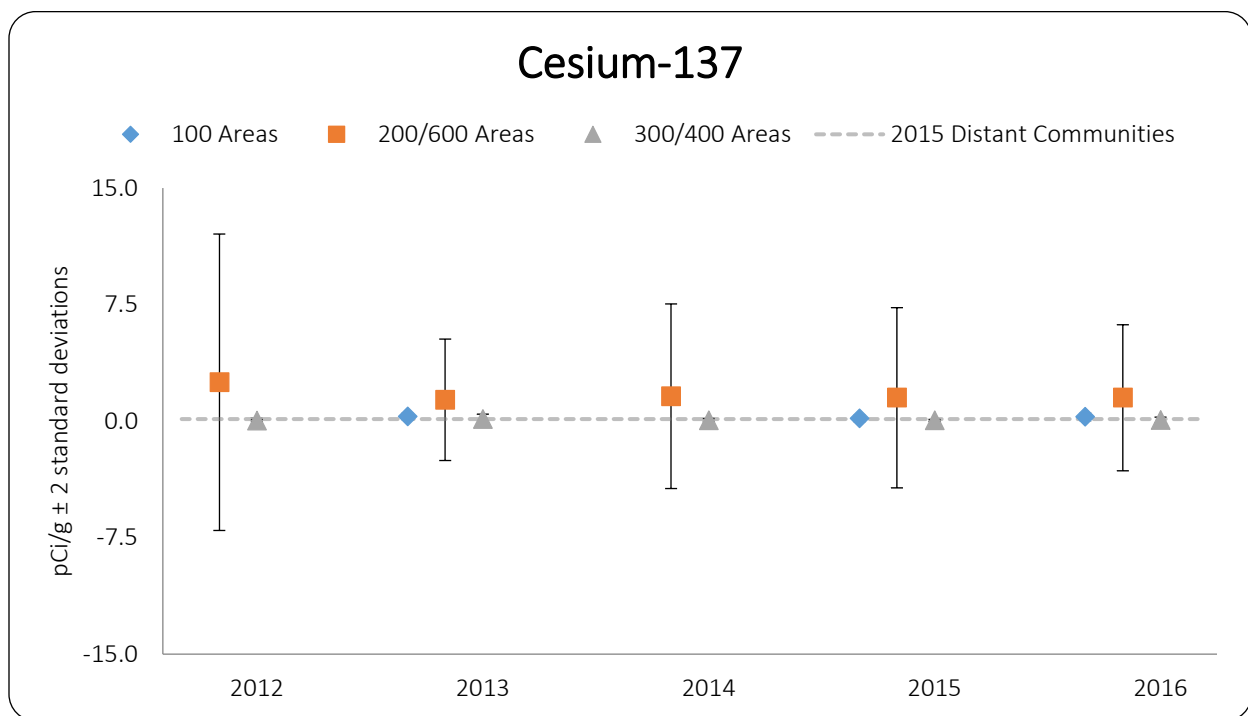
Category	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-235	Uranium-238	Plutonium-239/-240
Accessible soil concentration limits ^b	7.1	2,800	30	630	170	370	190

^a pCi/g dry weight. To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

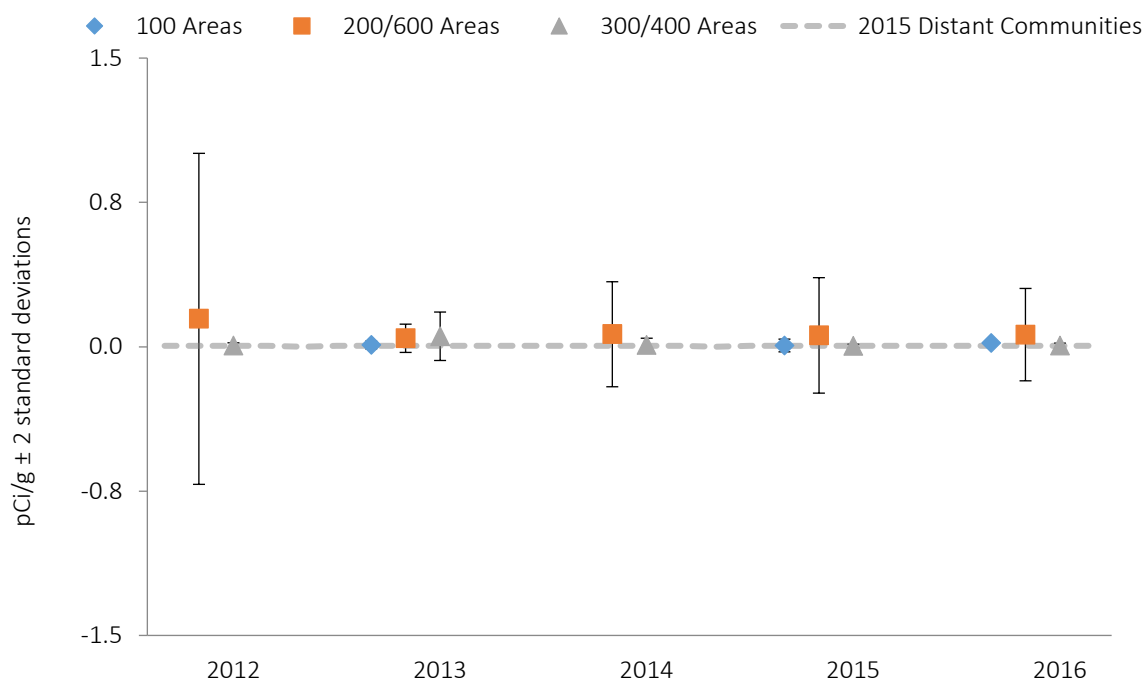
^b Hanford Site soil that is not behind security fences; refer to WHC-SD-EN-TI-070.

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 2016 were higher than the concentrations in samples collected farther away. As expected, data also showed that concentrations of certain radionuclides in 2016 were similar or 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.

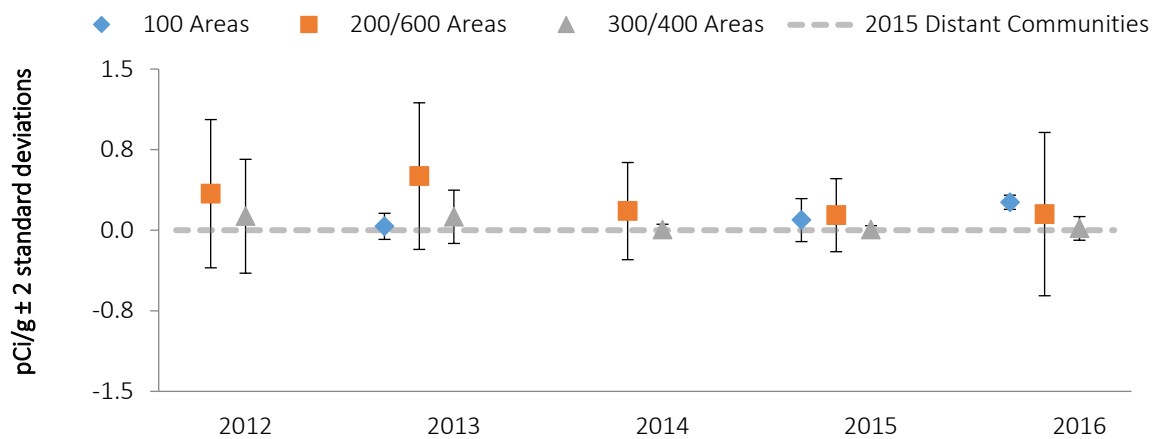
Cesium-137, strontium-90, plutonium-239/-240, and uranium were detected consistently in 2016 soil samples. Concentrations of these radionuclides were similar or slightly elevated near and within facility boundaries when compared to concentrations measured offsite at distant communities. Figure 9-1 shows the average concentrations of selected radionuclides in soil samples collected during 2016 and the preceding 4 years. Some individual levels demonstrate a high degree of variability, although overall trends are stable.



Plutonium-239/240



Strontium-90



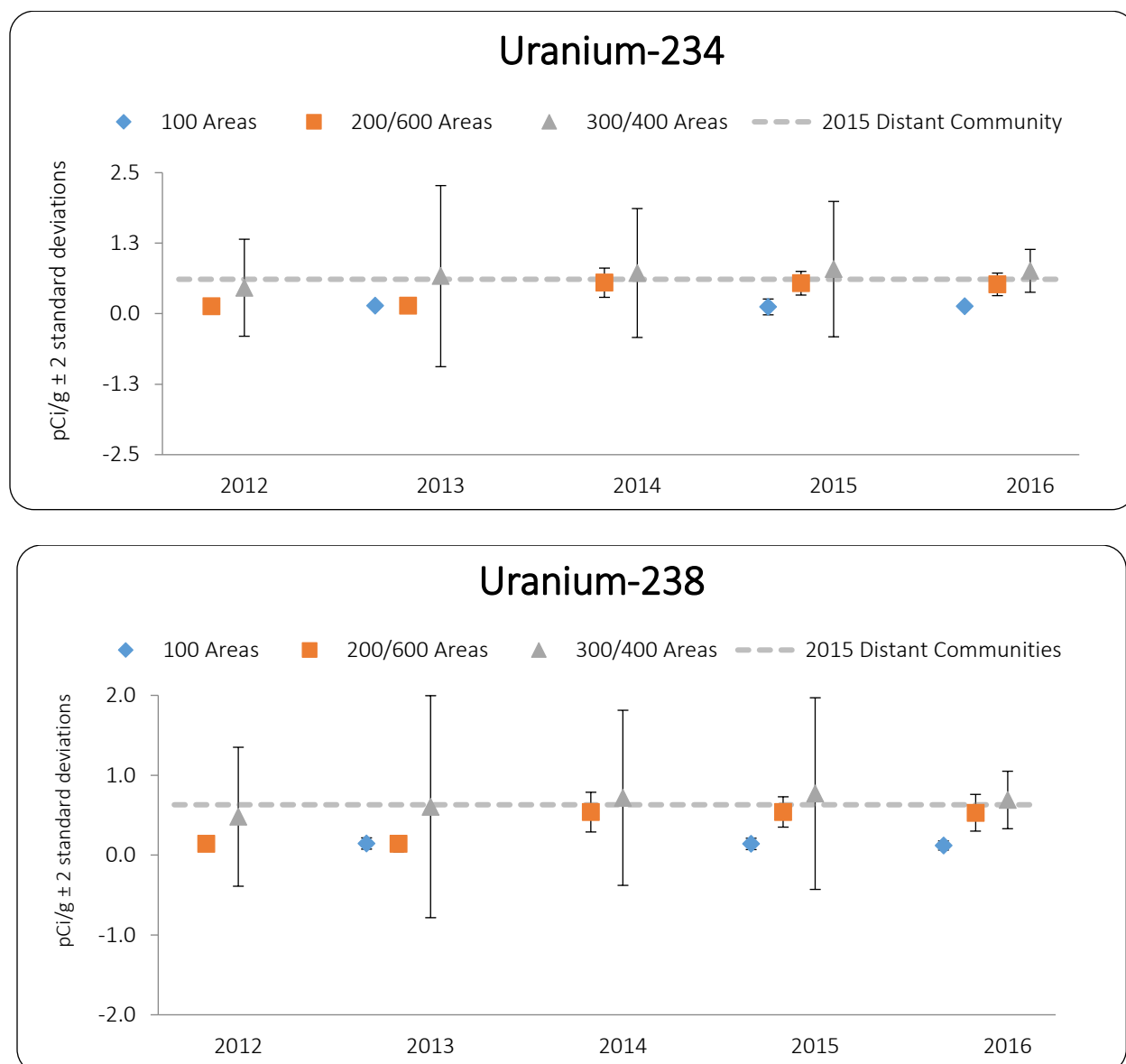


Figure 9.1. Hanford Site Soil Samples Average Concentrations of Selected Radionuclides, 2011–2016 (As a result of figure scale, some uncertainties [error bars] are concealed by the point symbol).

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 2016, as well as sampling location maps, are available upon request.

Results for soil samples collected in 2016 at locations in the 100, 200-East, 200-West, 300, and 600 Areas 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 and recent remediation activities. 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.

To comply with WDOH Notice of Construction requirements, special soil deposition sampling was collected during 2016 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 the Environmental Restoration Disposal Facility from a predominantly downwind sampling location. The 2016 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.

Soil monitoring provides information on long-term contamination trends and baseline environmental radionuclide activities at undisturbed sampling locations both on and off the Hanford Site (DOE/RL-91-50). Soil samples collected on and around the Hanford Site for more than 50 years have been added to a large database documenting onsite and offsite levels of manmade radionuclides in soil at specific locations. This database contains baseline data against which analysis results from unplanned contaminant releases from the Hanford Site can be compared. Soil at sitewide (onsite away from facilities and operations) and offsite locations was last routinely monitored for radiation in 2015.

Table 9-3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples^a. (2 Pages)

Isotope	Hanford Area	2016		2011 to 2015	
		Number of Samples	Detectors	Average ^b (pCi/gm)	Maximum ^c (pCi/gm)
Cobalt -60	100	3	0	1.7E-02 ± 4.0E-02	4.5E-02 ± 2.0E-02 ⁽⁴⁾
	200-East	16	0	1.5E-03 ± 2.2E-02	1.8E-02 ± 4.6E-02 ⁽⁴⁾
	200-West	28	0	-1.2E-04 ± 2.1E-02	2.0E-02 ± 2.6E-02 ⁽⁴⁾
	300	8	0	4.4E-04 ± 1.7E-02	1.4E-02 ± 1.9E-02 ⁽⁴⁾
	400	1	0	1.5E-02 ^e	1.5E-02 ± 1.5E-02 ⁽⁴⁾
	600	16	0	-6.6E-04 ± 3.2E-02	2.8E-02 ± 4.1E-02 ⁽⁴⁾
Cesium -137	100	3	3	2.7E-01 ± 3.0E-01	4.8E-01 ± 6.7E-02
	200-East	16	16	2.8E+00 ± 7.4E+00	1.1E+01 ± 5.4E-01
	200-West	28	27	1.4E+00 ± 3.3E+00	6.2E+00 ± 3.3E-01
	300	8	5	7.1E-02 ± 1.8E-01	2.9E-01 ± 3.1E-02
	400	1	1	5.3E-02 ^e	5.3E-02 ± 1.5E-02
	600	16	16	5.1E-01 ± 9.2E-01	1.8E+00 ± 1.8E-01
Plutonium-238	100	3	0	3.5E-02 ± 3.7E-02	5.0E-02 ± 5.8E-02 ⁽⁴⁾
	200-East	16	5	4.4E-04 ± 1.1E-03	1.2E-03 ± 6.1E-04
	200-West	28	18	1.8E-03 ± 4.1E-03	9.9E-03 ± 3.3E-03
	300	8	4	7.5E-04 ± 9.9E-04	1.4E-03 ± 7.2E-04
	400	1	1	4.7E-04 ^e	4.7E-04 ± 3.8E-04
	600	15	5	7.7E-04 ± 2.3E-03	3.6E-03 ± 8.3E-04
Plutonium-239/-240	100	3	0	1.9E-02 ± 1.2E-02	2.6E-02 ± 4.1E-02 ⁽⁴⁾
	200-East	16	13	1.2E-02 ± 2.2E-02	4.1E-02 ± 4.2E-03
	200-West	28	27	1.1E-01 ± 3.2E-01	6.9E-01 ± 1.0E-01
	300	8	6	5.4E-03 ± 1.3E-02	2.1E-02 ± 3.2E-03
	400	1	1	2.1E-03 ^e	2.1E-03 ± 7.9E-04
	600	16	16	3.7E-02 ± 1.2E-01	2.3E-01 ± 1.8E-02
Strontium-90	100	3	0	2.6E-01 ± 6.6E-02	2.8E-01 ± 3.5E-01 ⁽⁴⁾
	200-East	16	9	3.9E-01 ± 1.3E+00	2.2E+00 ± 4.1E-01
	200-West	28	11	7.9E-02 ± 2.5E-01	4.2E-01 ± 9.6E-02

Table 9-3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples^a. (2 Pages)

Isotope	Hanford Area	2016				2011 to 2015			
		Number of Samples	Detects	Average ^b (pCi/gm)	Maximum ^c (pCi/gm)	Number of Samples	Detects	Average ^b (pCi/gm)	Maximum ^c (pCi/gm)
Uranium -234	300	8	1	2.3E-02 ± 1.0E-01	1.4E-01 ± 4.8E-02	52	1	7.4E-02 ± 4.4E-01	8.9E-01 ± 5.3E-01 ^d
	400	1	0	-2.2E-02 ^e	-2.2E-02 ± 2.0E-02 ⁽⁴⁾	5	0	-1.2E-04 ± 7.8E-01	6.5E-01 ± 4.6E-01 ^d
	600	16	2	3.7E-02 ± 1.1E-01	2.0E-01 ± 5.4E-02	54	25	2.0E-01 ± 6.1E-01	1.2E+00 ± 4.6E-01
	100	3	3	1.3E-01 ± 7.5E-03	1.3E-01 ± 7.7E-02	3	3	1.6E-01 ± 5.7E-02	1.9E-01 ± 6.2E-02
	200-East	16	16	5.2E-01 ± 1.5E-01	6.5E-01 ± 1.1E-01	52	51	3.4E-01 ± 4.9E-01	1.1E+00 ± 1.9E-01
	200-West	28	28	4.9E-01 ± 1.8E-01	6.0E-01 ± 1.0E-01	85	80	3.0E-01 ± 3.9E-01	7.5E-01 ± 1.2E-01
	300	8	8	7.5E-01 ± 4.2E-01	1.1E+00 ± 1.7E-01	52	52	6.6E-01 ± 1.3E+00	2.5E+00 ± 6.5E-01
	400	1	1	5.8E-01 ^e	5.8E-01 ± 1.1E-01	5	5	3.7E-01 ± 4.6E-01	7.4E-01 ± 2.1E-01
Uranium -235	600	16	16	5.7E-01 ± 2.2E-01	9.0E-01 ± 1.4E-01	54	53	3.2E-01 ± 4.0E-01	7.5E-01 ± 1.1E-01
	100	3	0	6.8E-03 ± 2.3E-02	2.3E-02 ± 3.8E-02 ⁽⁴⁾	3	1	1.2E-02 ± 5.4E-03	1.5E-02 ± 1.2E-02
	200-East	15	12	5.6E-02 ± 5.7E-02	1.1E-01 ± 4.3E-02	52	35	3.3E-02 ± 6.5E-02	1.1E-01 ± 5.1E-02
	200-West	28	23	5.4E-02 ± 4.7E-02	1.1E-01 ± 5.0E-02	78	50	2.8E-02 ± 4.5E-02	9.7E-02 ± 4.1E-02
	300	8	8	9.7E-02 ± 6.4E-02	1.4E-01 ± 5.4E-02	52	44	4.6E-02 ± 9.4E-02	1.9E-01 ± 5.7E-02
	400	1	1	7.7E-02 ^e	7.7E-02 ± 4.0E-02	5	4	2.8E-02 ± 3.5E-02	5.8E-02 ± 2.7E-02
	600	16	13	6.2E-02 ± 5.5E-02	1.1E-01 ± 5.0E-02	44	27	3.4E-02 ± 5.4E-02	9.9E-02 ± 4.3E-02
	100	3	3	1.2E-01 ± 5.7E-02	1.5E-01 ± 9.5E-02	3	3	1.4E-01 ± 4.2E-02	1.7E-01 ± 5.5E-02
Uranium -238	200-East	16	16	5.2E-01 ± 1.2E-01	6.1E-01 ± 1.1E-01	52	51	3.3E-01 ± 4.7E-01	1.1E+00 ± 1.9E-01
	200-West	28	28	5.0E-01 ± 2.0E-01	6.3E-01 ± 9.8E-02	85	80	3.0E-01 ± 3.7E-01	6.6E-01 ± 1.0E-01
	300	8	8	7.0E-01 ± 3.4E-01	1.1E+00 ± 1.6E-01	52	51	6.5E-01 ± 1.2E+00	2.5E+00 ± 6.8E-01
	400	1	1	4.4E-01 ^e	4.4E-01 ± 9.3E-02	5	5	3.9E-01 ± 6.0E-01	9.3E-01 ± 2.5E-01
	600	16	16	6.0E-01 ± 2.9E-01	9.7E-01 ± 1.4E-01	54	53	3.4E-01 ± 4.1E-01	8.0E-01 ± 1.2E-01

^a pCi/g dry weight.^b Average ± two standard deviations.^c Maximum ± analytical uncertainty.^d Maximum value reported is a non-detect.^e Standard deviation cannot be calculated for one sample.

Table 9-4. Radionuclide Concentrations in Other Contractor Project Soil Samples^a.

Project/ Facility	Location ^b	Date	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-238	Plutonium-239/- 240
Trench 94	D458	6/20/2016	-1.6E-02±3.2E-02	7.70E-02±3.50E-02	2.10E-01±5.80E-02	6.00E-01±1.00E-01	5.80E-01±1.10E-01	1.90E-03±1.60E-03
	D460	6/20/2016	9.9E-03±2.00E-02	1.10E-02±2.70E-02	2.00E-01±5.30E-02	4.40E-01±8.70E-02	4.90E-01±9.10E-02	2.00E-03±1.00E-03
	D461	6/20/2016	1.20E-02±2.9E-02	3.0E-01±7.5E-02	6.5E+00±5.8E-01	6.50E-01±1.10E-01	6.10E-01±1.10E-01	5.70E-03±1.5E-03
Effluent Treatment Facility	D457	6/20/2016	4.10E-03±2.60E-02	2.20E+00±4.10E-01	1.10E+01±5.40E-01	6.00E-01±1.00E-01	5.80E-01±9.9E-02	2.90E-04±1.20E-03
	D458	6/20/2016	-1.6E-02±3.2E-02	7.70E-02±3.50E-02	2.10E-01±5.80E-02	6.00E-01±1.00E-01	5.80E-01±1.10E-01	1.90E-03±1.60E-03
	D459	6/20/2016	-2.10E-02±2.70E-02	2.10E-01±5.60E-02	1.10E+00±1.30E-01	6.40E-01±1.10E-01	5.70E-01±8.70E-02	7.70E-03±1.60E-03
ERDF	D146	4/27/2016	-6.60E-03±1.30E-02	-2.00E-01±1.60E-01	8.10E-03±1.10E-02	1.10E-01±9.00E-02	1.00E-01±9.00E-02	1.40E-02±3.10E-02
100N	D156	8/2/2016	-1.8E-03±1.20E-02	2.80E-01±3.50E-01	1.40E-01±3.00E-02	1.20E-01±7.50E-02	1.20E-01±7.50E-02	2.00E-02±4.40E-02
	D158	8/2/2016	4.50E-02±2.00E-02	2.80E-01±3.10E-01	4.90E-01±4.30E-02	1.30E-01±8.60E-02	1.50E-01±9.50E-02	2.60E-02±4.10E-02
	D183	8/2/2016	8.00E-03±1.50E-02	2.10E-01±2.80E-01	4.80E-01±6.70E-02	1.30E-01±7.70E-02	8.20E-02±5.90E-02	1.20E-02±2.60E-02
Accessible soil concentration ^c			7.1	2,800	30	630	370	190

^a pCi/g dry weight: 1 pCi = 0.037 Bq. Dry weight ± total analytical uncertainty.^b Sampling location code.^c 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.

There were 17 instances of radiological contamination in soil discovered during 2016 site investigations. Of the 17, five were posted as contamination areas, the other 12 were cleaned up and disposed of onsite in licensed burial grounds. None of the soil samples were submitted for radioisotopic analysis. The number of soil investigation contamination incidents in 2016 were generally within historical values. Table 9-5 summarizes the number and general locations of soil contamination incidents investigated during 2016, and provides the number of contamination incidents investigated from 2000 through 2016.

Table 9-5. Soil Contamination Incidents Investigated.

Location	2016 Incidents	Year	Incidents
100 Area	2	2000	25
200-East Area		2001	20
Tank farms	1	2002	22
Burial grounds	2	2003	30
Cribs, ponds, and ditches	6	2004	19
Fence lines	0	2005	20
Roads and railroads	0	2006	25
Unplanned release sites	0	2007	17
Underground pipelines	0	2008	16
LERF/ETF	1	2009	28
Miscellaneous	0	2010	22
200-West Area		2011	10
Tank farms	1	2012	10
Burial grounds	1	2013	21
Cribs, ponds, and ditches	0	2014	22
Fence lines	0	2015	20
Roads and railroads	0	2016	17
Unplanned release sites	0		
Underground pipelines	0		
Miscellaneous	0		
Cross-site transfer line	1		
200-BC cribs and trenches	0		
200-North Area	0		
300 Area	0		
400 Area	0		
600 Area	2		
Total	17		

10.0 Biota Monitoring

JR Draper

The U.S. Department of Energy's (DOE) subcontractor Mission Support Alliance (MSA) monitors the biota, including state and federally listed species, to assess the abundance, vigor or condition, and distribution on the Hanford Site. The associated data is used by DOE and Hanford Site contractors to support environmental cleanup and restoration activities, mitigation actions, and land use planning and to maintain compliance with ecological resource laws. MSA's Ecological Compliance staff conducts ecological compliance reviews for most projects on the Hanford Site to determine if the proposed scope of work will adversely impact biological resources and to provide recommendations to reduce environmental impacts.

10.1 Agricultural Monitoring

ME Hoefer

Food and farm products (apricots, corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in 2016 at locations near the Hanford Site (Figure 10-1; note not all agricultural monitoring locations shown are sampled each year due to program efficiencies, budgetary restrictions, and historical trending purposes). These products are used to determine pathway-specific exposure assumptions by way of annual dose calculations based on a 1 mrem/yr (10 microsievert [μSv]/yr) threshold and ingestion pathways for annual intake, assuming 100% of each food originated in the affected area.

Water removed from the river immediately downstream of the Hanford Site is used to irrigate a small portion of agricultural crops in Benton and Franklin counties. The majority of irrigation water utilized by Franklin County residents originates at Grand Coulee Dam and is provided through its extensive water delivery systems (i.e. canals). Likewise, Benton County relies heavily on the Yakima River for irrigation purposes.

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
- From farms irrigated with water taken from the Columbia River downstream of the Hanford Site.

Sample analyses are used to assess the amounts of Hanford Site-origin contaminants in food and farm products by comparing the following:

- Analytical results obtained from similar samples collected from the same regions over long periods of time

- Samples collected at downwind locations to results from samples obtained from generally upwind or distant locations
- 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 2016 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. Data for potassium-40 and beryllium-7 are 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 dose of 1 mrem/yr (10 μ Sv/yr) (DOE/RL-91-50). Agricultural products sampled in 2016 are listed in Table 10-1 and described in the following sections.

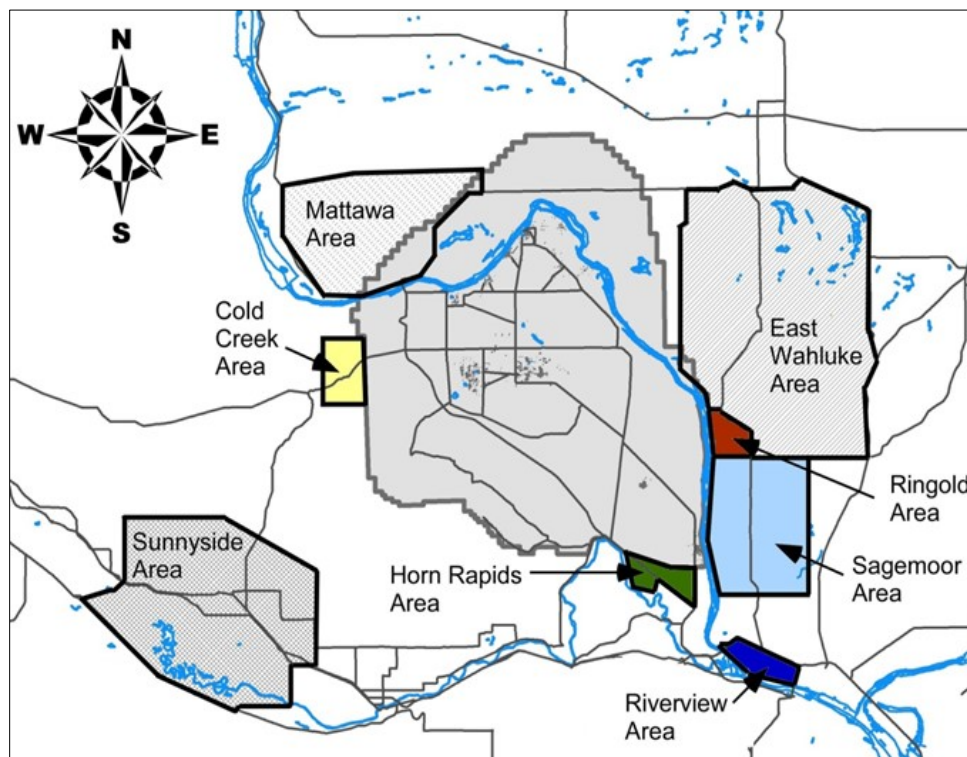


Figure 10-1. Agricultural Monitoring Locations.

NOTE: Duplicate information may or may not be included in this data.

Table 10-1. Agricultural Monitoring Location.

Product	Sampling Locations	Analytes
Apricots	East Wahluke, Riverview, Sagemoor, and Sunnyside	¹⁴ C, Gamma, Sr-90
Corn	East Wahluke, Riverview, Sagemoor, and Sunnyside	¹⁴ C, Gamma, Sr-90
Leafy vegetables	Riverview, Sagemoor, and Sunnyside	Gamma, Sr-90
Melons	East Wahluke, Riverview, Sagemoor, and Sunnyside	¹⁴ C, Gamma, Sr-90
Milk	East Wahluke, Sagemoor, and Sunnyside	Gamma, Sr-90, Tritium
Potatoes	East Wahluke, Riverview, and Sunnyside	Gamma, Sr-90
Tomatoes	Riverview and Sunnyside	Gamma, Sr-90, Tritium
Wine must	Columbia Basin, Mattawa, and Yakima Valley	Low-level Tritium, Gamma

10.1.1 Milk

Milk samples were obtained quarterly in 2016 from several dairies in the East Wahluke and Sagemoor sampling areas, and one dairy in Sunnyside.

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 dairy generally upwind of the Hanford Site.

10.1.1.1 Tritium. Tritium was detected in all milk samples collected in 2016. Overall concentrations ranged from a maximum of 59 pCi/L (2.2 Bq/L) in a Sagemoor area sample to a minimum of 14 pCi/L (0.52 Bq/L) in an East Wahluke area sample. Annual average concentrations for the three sampling areas were 34 pCi/L (1.3 Bq/L). Specific location average was 38 pCi/L (1.4 Bq/L) for Sagemoor (n = 5); 30 pCi/L (1.1 Bq/L) for East Wahluke (n = 4); and 32 pCi/L (1.2 Bq/L) for Sunnyside (n = 2). The maximum concentration for Sagemoor was greater than those measured at this location in the last few years, and overall averages for all areas were slightly higher than historically measured.

10.1.1.2 Strontium-90. No detectable concentrations were found in 2016 milk samples.

10.1.1.3 Cesium-137. No synthetic gamma emitters were detected in milk samples collected and analyzed in 2016.

10.1.1.4 Potassium-40. Naturally occurring potassium-40 was detected in all milk samples collected in 2016. Concentrations ranged from a maximum of 1,600 pCi/L (59 Bq/L) in a Sagemoor area sample to a minimum of 1,250 pCi/L (46 Bq/L) in a Sunnyside sample. The East Wahluke area had a maximum of 1,470 pCi/L (54 Bq/L) and the overall average was 1,451 pCi/L (54 Bq/L) for all results.

10.1.2 Fruit, Vegetables, and Farm Products

Apricot, corn, leafy vegetable (e.g., lettuce), melon, potato, tomato, and wine must samples were collected from upwind and downwind sampling areas during the 2016 growing season (Figure 10-1; Table 10-1). All fruit and vegetable samples were analyzed for gamma-emitting radionuclides and strontium-90. Corn, leafy vegetables, and melons were also analyzed for carbon-14 for additional monitoring due to increased concentrations in the 100-K-Area and to further support Waste Treatment Plant-monitoring. Wine must was analyzed for gamma-emitting radionuclides and tritium. Tomato samples were also monitored for tritium (Table 10-1) and showed no detectable concentrations during 2016.

A single leafy vegetable sample (Sunnyside area) had slightly elevated concentrations of beryllium-7; however, these concentrations were within historical range and follow typical result patterns. Two additional samples had detections of strontium-90 (East Wahluke and Riverview areas) but values reported were well below DOE project dose-based reporting limits and were within historical limits measured at these locations. All fruit and vegetable concentrations of cesium-137, cobalt-60, and tritium were reported as non-detects and were well within historical range.

All wine must samples had detectable concentrations of tritium; were well within the historical range; and mirrored tritium concentrations found in Columbia River fixed-station water collection areas, as well as irrigation water results for 2016.

All apricot, corn, leafy vegetable, melon, potato, tomato, and wine must samples had detectable concentration levels of naturally occurring potassium-40.

10.2 Fish and Wildlife Monitoring

JW Wilde

Fishing is a popular activity along the Hanford Reach of the Columbia River. The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during the 2016 calendar year were smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), 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 locations on and around the Hanford Site where fish and wildlife were collected in 2016. Samples of fish and wildlife were analyzed for selected (suspected or known to be present) 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 and reference samples obtained at locations determined not to be affected by Hanford Site effluents and emissions at least every 5 years.

Table 10-2. Animal Monitoring Analysis.

Biota	Offsite Locations	Onsite Locations	Gamma	Strontium-90	Trace Metals
Fish (smallmouth bass)	1	2	14	14	3
Fish (common carp)	1	2	11	22	11
Mammals (deer/elk)	0	4	7	4	4
Waterfowl (California quail)	0	2	8	8	0

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. Chemically similar to calcium, strontium-90 consequently accumulates in hard tissues rich in calcium such as bones, antlers, and eggshells. In addition, 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, because strontium-90 does not accumulate in edible portions of fish and wildlife, it generally does not contribute much to the human dose (NCRP 2009).

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 the isotope 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 it 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 (e.g., 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.

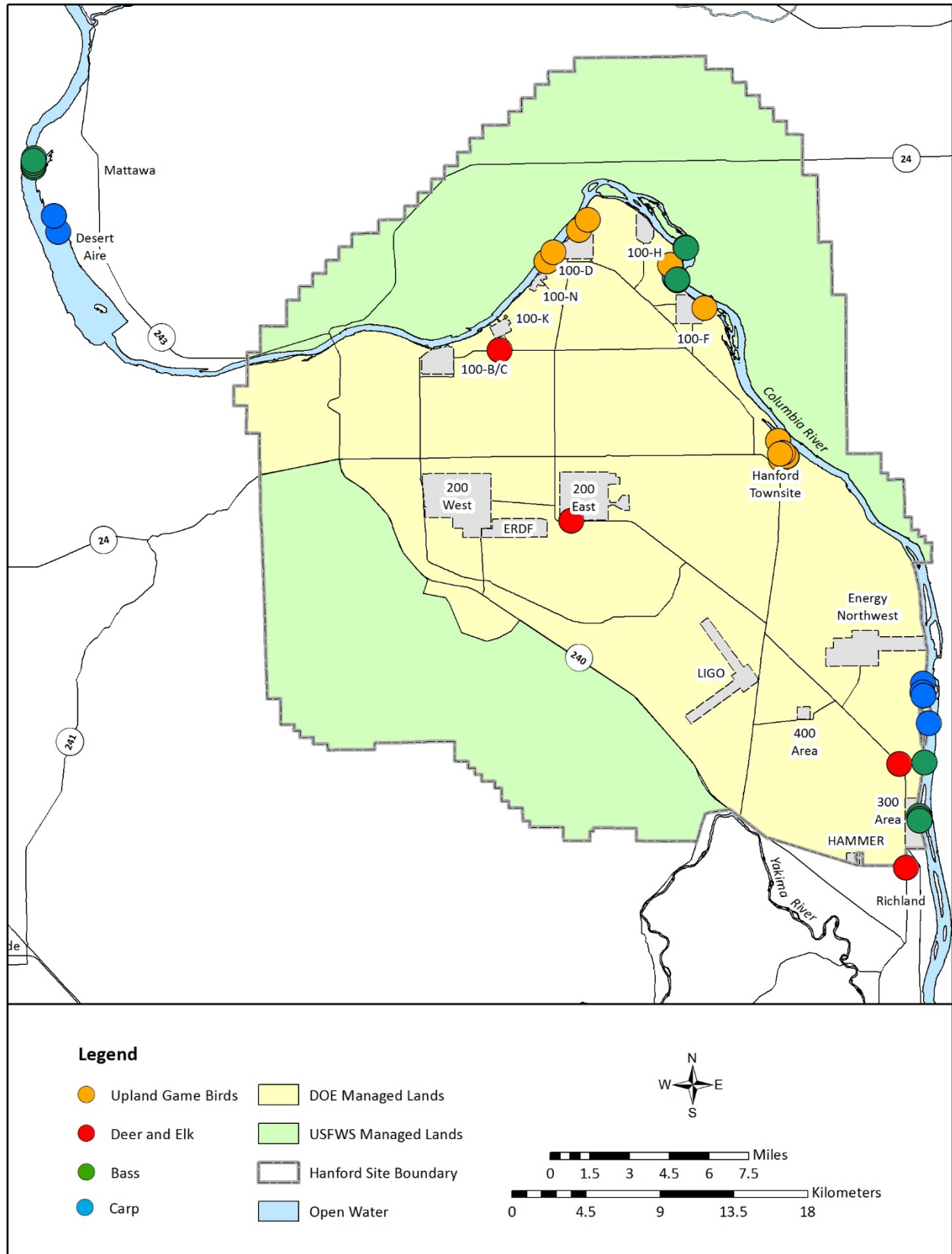


Figure 10-2. Animal Monitoring Locations.

10.2.1 Smallmouth Bass

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-one smallmouth bass were collected in 2016 from three locations in the Hanford Reach and a reference location: Nine fish were collected from the Hanford Townsite to the 300 Area; six fish from the 100 Area and six reference samples were obtained in 2016 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; three samples had metals, isotopic uranium, and isotopic plutonium analyses added to the suite.

10.2.1.1 Cesium-137. Manmade gamma-emitting radionuclides, including cesium-137, were not detected in 2016 in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

10.2.1.2 Strontium-90. Strontium-90 was not detected in smallmouth bass samples collected in 2016 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.

10.2.1.3 Trace Metals. Three bass samples were analyzed for 17 different trace metal concentrations. Barium, copper, manganese, mercury, selenium, silver, 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	3	0	Manganese	3	2
Antimony	3	0	Mercury	3	1
Arsenic	3	0	Nickel	3	1
Barium	3	2	Selenium	3	1
Beryllium	3	0	Silver	3	1
Cadmium	3	0	Thallium	3	0
Chromium	3	1	Thorium	3	0
Copper	3	3	Uranium	3	0
Lead	3	0	Zinc	3	3

10.2.2 Common Carp

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 a 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 in many cultures; therefore, it is included in the sampling rotation.

Fourteen common carp were collected in 2016 from two locations in the Hanford Reach and a reference location (five fish were sent to Washington State Department of Health [WDOH] for oversight analysis). Eleven samples were submitted to laboratory for analyses (nine standard samples, one duplicate, and one lab split): There were four fish collected from the region known as the White Bluffs Slough for the 100 Area and five fish from the waters around the wooded island section of the river above the 300 Area. Five reference samples were obtained in 2016 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.

10.2.2.1 Cesium-137. Manmade gamma-emitting radionuclides, including cesium-137, was not found in 2016 in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

10.2.2.2 Strontium-90. Strontium-90 was not detected in common carp filet or carcass samples in 2016. These results are consistent with those reported historically near the Hanford Site.

10.2.2.3 Uranium. Uranium isotopic analysis was performed on 11 carp samples in 2016. Uranium-234 was detected in 7 of the 11 samples. Uranium-235 was detected in 4 of the 11 samples. Uranium-238 was detected in 6 of the 11 samples for 2016. This was slightly less detects than in 2014 in a similar number of samples (10).

10.2.2.4 Trace Metals. Eleven (including a duplicate and lab split) carp samples were analyzed for 17 different trace metal concentrations. Barium, copper, lead, manganese, mercury, selenium, thorium, 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 2016 the mercury levels in carp were higher in the Hanford Townsite area of the Hanford Site when compared to the carp of the 100 Area and reference area.

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 10-4. Common Carp Metals Analyses.

Isotope	Samples	Detects	Isotope	Samples	Detects
Aluminum	11	0	Manganese	11	1
Antimony	11	0	Mercury	11	6
Arsenic	11	0	Nickel	11	0
Barium	11	1	Selenium	11	11
Beryllium	11	0	Silver	11	0
Cadmium	11	0	Thallium	11	0
Chromium	11	1	Thorium	11	2
Copper	11	10	Uranium	11	10
Lead	11	1	Zinc	11	11

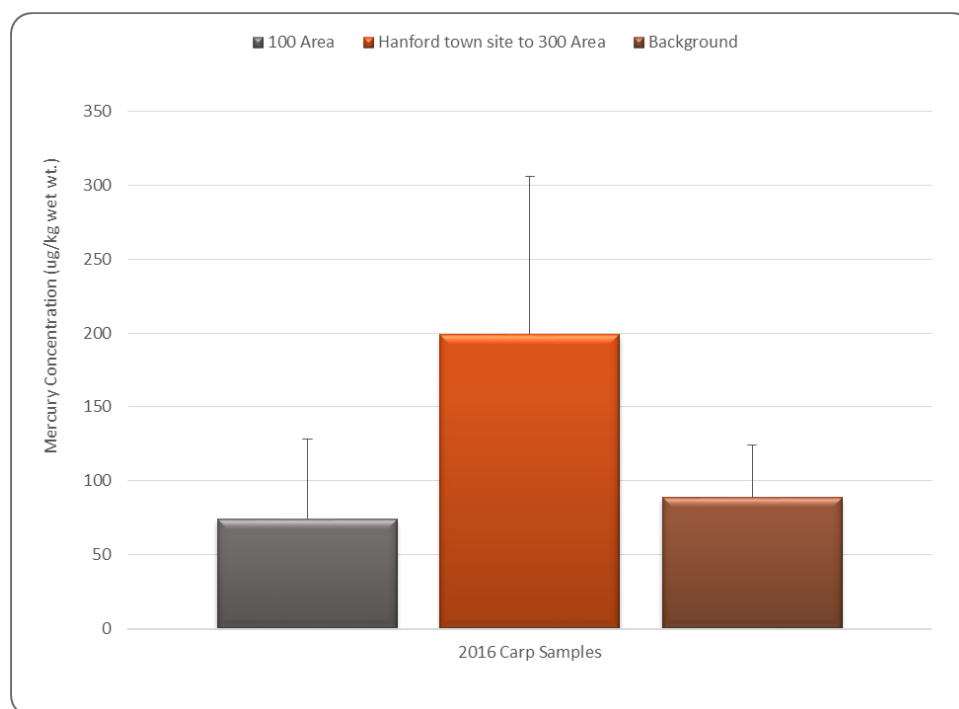


Figure 10-3. Carp Mercury Concentrations Compared in the 100, 300, and Reference Areas.

10.2.3 Mule 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 2016, the Hanford Site Environmental Surveillance Program collected deer and elk killed due to road strikes rather than hunting animals onsite. 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 three 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 four animals collected on the Hanford Site in 2016 were compared to levels from a reference elk collected in 2014 by the WDFW in western Washington. The results from deer collected in 2016 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.

10.2.3.1 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.

10.2.3.2 Strontium-90. Strontium-90 was detected in all four bone samples analyzed during 2016. Concentrations of strontium-90 detected in deer bone samples collected ranged from 0.0891 pCi/g (0.0033 Bq/g) wet weight to 0.163 pCi/g (0.006 Bq/g) wet weight. Strontium-90 concentrations measured in bone samples from 2014 at the reference location were 229 pCi/g (0.0085 Bq/g) wet weight (Figure 10-4).

10.2.3.3 Trace Metals. Trace metals were analyzed in mule deer and elk liver samples collected from Hanford Site samples and the reference location. Ten metals (aluminum, barium, cadmium, chromium, copper, manganese, selenium, silver, thorium, and zinc) were found above analytical detection limits in 2016.

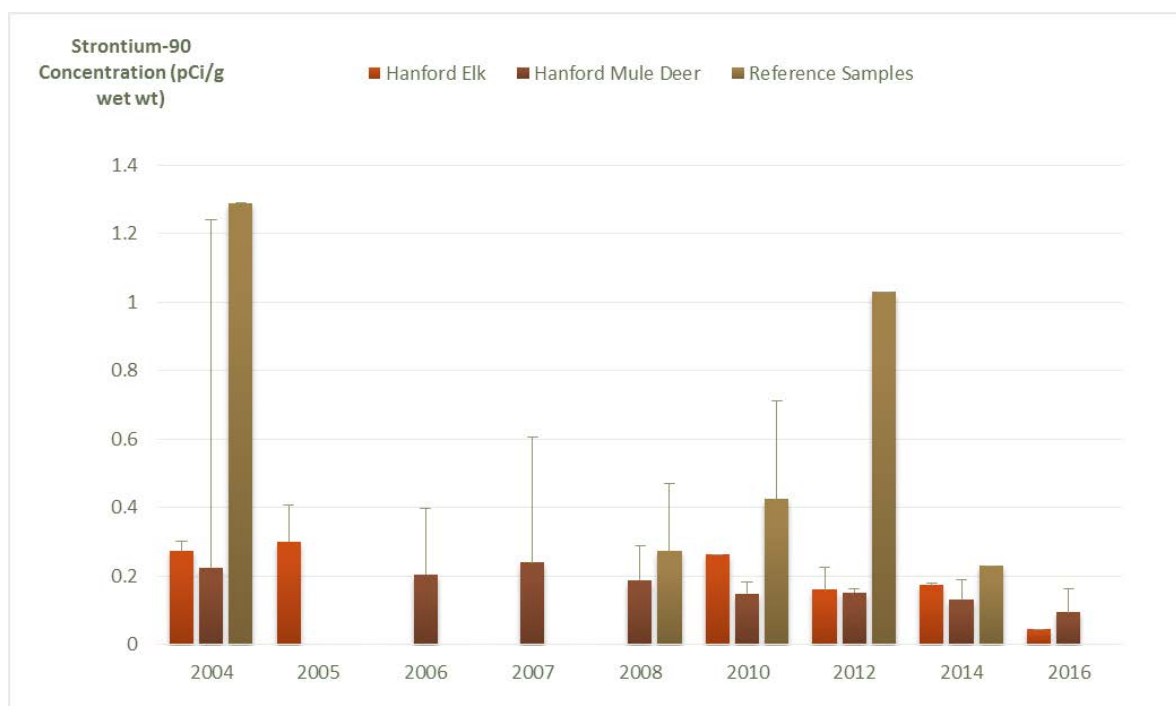


Figure 10-4. Mule Deer and Elk Bone Strontium-90 Concentrations.
(Maximum concentrations are represented by the upper bar)

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 onsite 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 area they are collected. 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. In 2016, 8 California quail were collected on the Hanford Site from the 100 Area and 10 were collected in the Hanford Townsite region. No quail were collected from a reference location in 2016 and all results will be compared to reference from 2014 and earlier. These quail were processed into eight samples, four from each region (including one duplicate sample and one lab split sample). Two quail from the Hanford Townsite 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 2016 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.

10.2.4.1 Cesium-137. Manmade gamma-emitting radionuclide, cesium-137, was not detected above the detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) for any upland game bird muscle samples analyzed in 2016. 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).

10.2.4.2 Strontium-90. Strontium-90 concentrations were detected in two quail bone samples collected in 2016. Comparisons of the maximum and median strontium-90 concentrations reported for game bird bone samples collected at the Hanford Site since 2002 and reference locations are consistent with these results, which do not indicate elevated levels of strontium-90 (Figure 10-5).

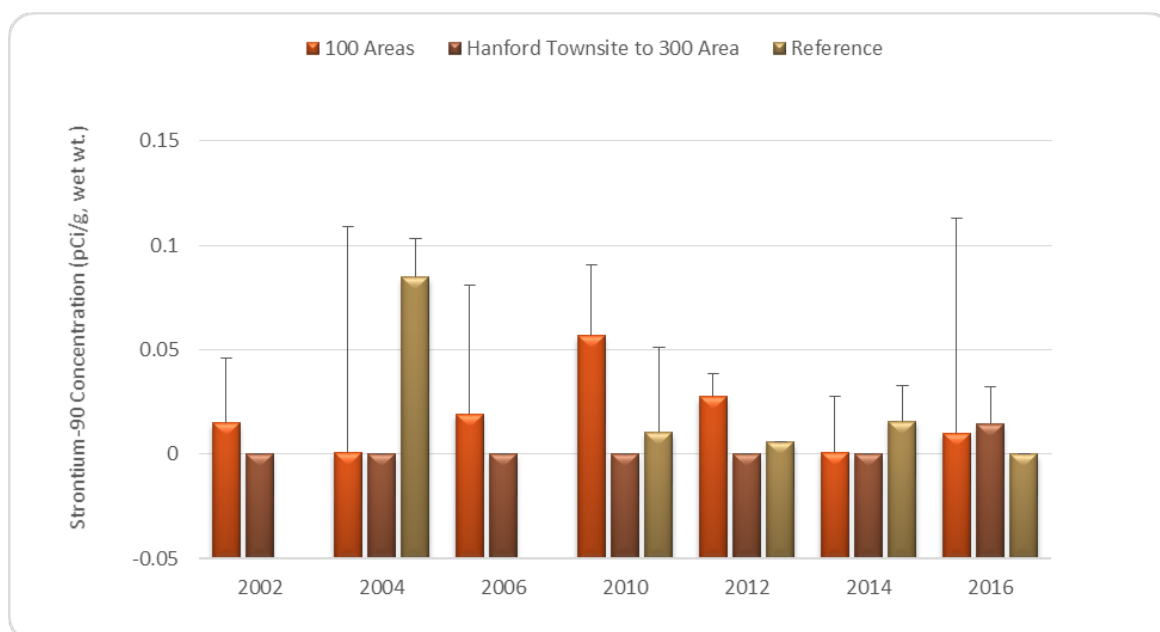


Figure 10-5. California Quail Bone Strontium-90 Concentrations.
(Upper bar represents maximum concentrations)

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, waste sites, contamination areas and operations is monitored for radiation to determine the effectiveness of effluent monitoring and radioactive material controls, 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 areas onsite and in uncultivated areas offsite. 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 monitoring and control efforts, purpose, and programs that support them, refer to Section 10.3.3 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. Collected on and around the Hanford Site for over 50 years, vegetation 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 statistics 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 are used as a qualitative indicator and verification of ambient air sampling results per FF-01. Vegetation samples from offsite locations were collected in 2015, these samples are collected every 3 to 5 years.

Table 10-5. Vegetation Monitoring Locations.

Samples Analyzed	Operational Area (discrete samples analyzed)					
	100-N	200-East Area	200-West Area ^a	300 Area ^a	400 Area	600 Area ^a
49	2	9	21	2	1	14

^a Sample numbers include one or more duplicates.

Individual vegetation samples (approximately 17.6 oz [500 g]) 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.

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 2015 at offsite sampling locations in Yakima, Grant, and Franklin Counties. Comparisons can be used to

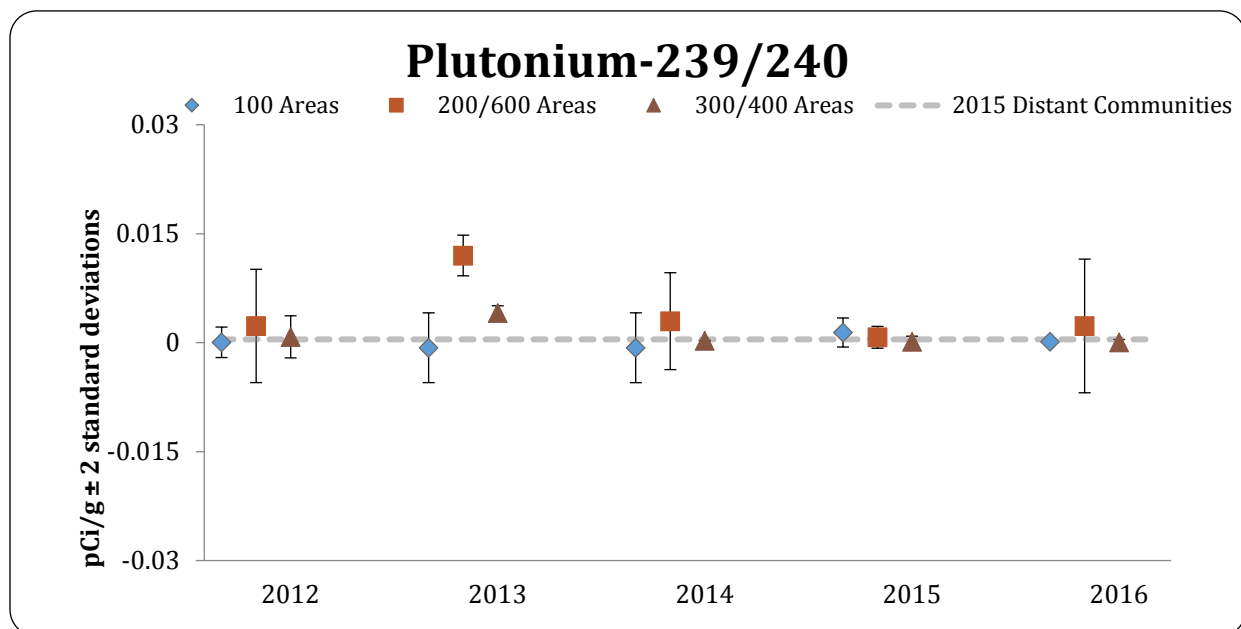
determine the differences between contributions from site operations and remedial action sites, and contributions from natural sources and worldwide fallout.

10.3.1 Vegetation Monitoring Results.

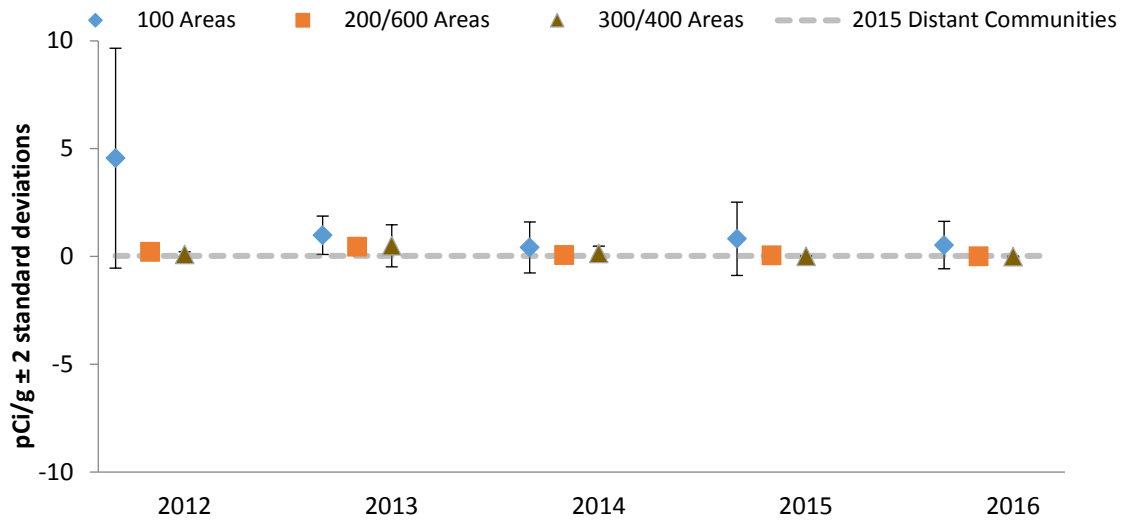
Some degree of variability is always associated with collecting and analyzing environmental samples; therefore, variations in sample concentrations are expected annually. In general, radionuclide concentrations in vegetation samples collected from or adjacent to waste disposal facilities in 2016 were similar to or slightly higher than concentrations in samples collected farther away, including concentrations measured offsite in 2015. Generally, the predominant radionuclides were activation and fission products in the 100 Area, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas.

Uranium-234, uranium-235, and/or uranium-238 were regularly detected in the 2016 samples. Three samples showed detectable concentrations of cesium-137 and three samples showed detectable strontium-90 levels. 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.

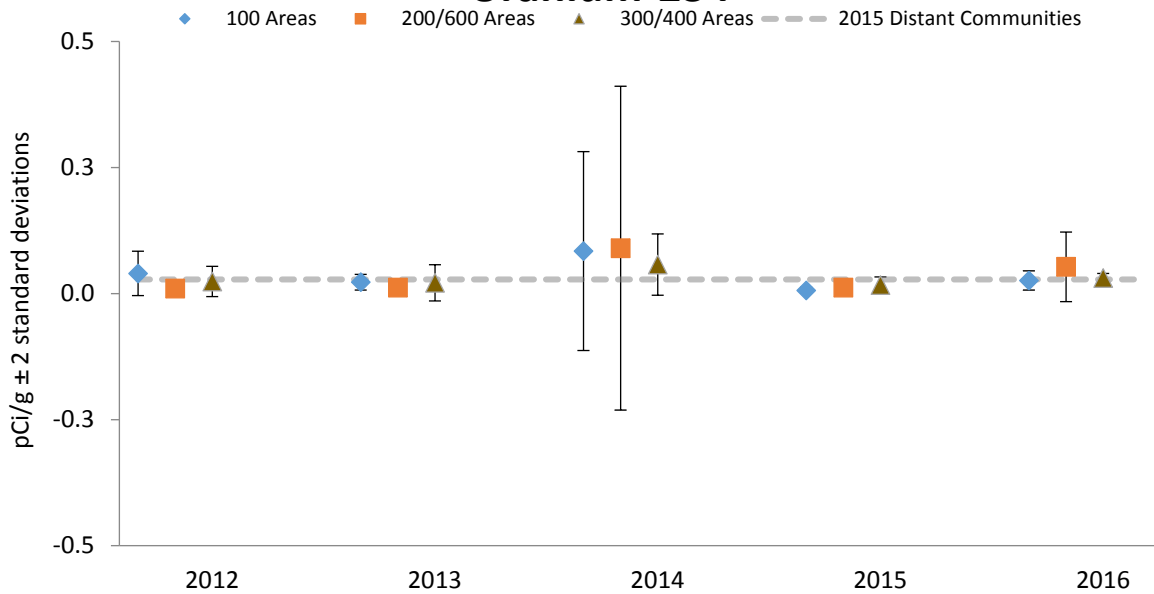
Table 10-6 provides a summary of selected radionuclides detected in vegetation samples collected and analyzed in 2016 and previous years. The average and maximum results are reported for the six primary waste facility/operational areas of interest, including comparative data for the preceding 5 years.



Strontium-90



Uranium-234



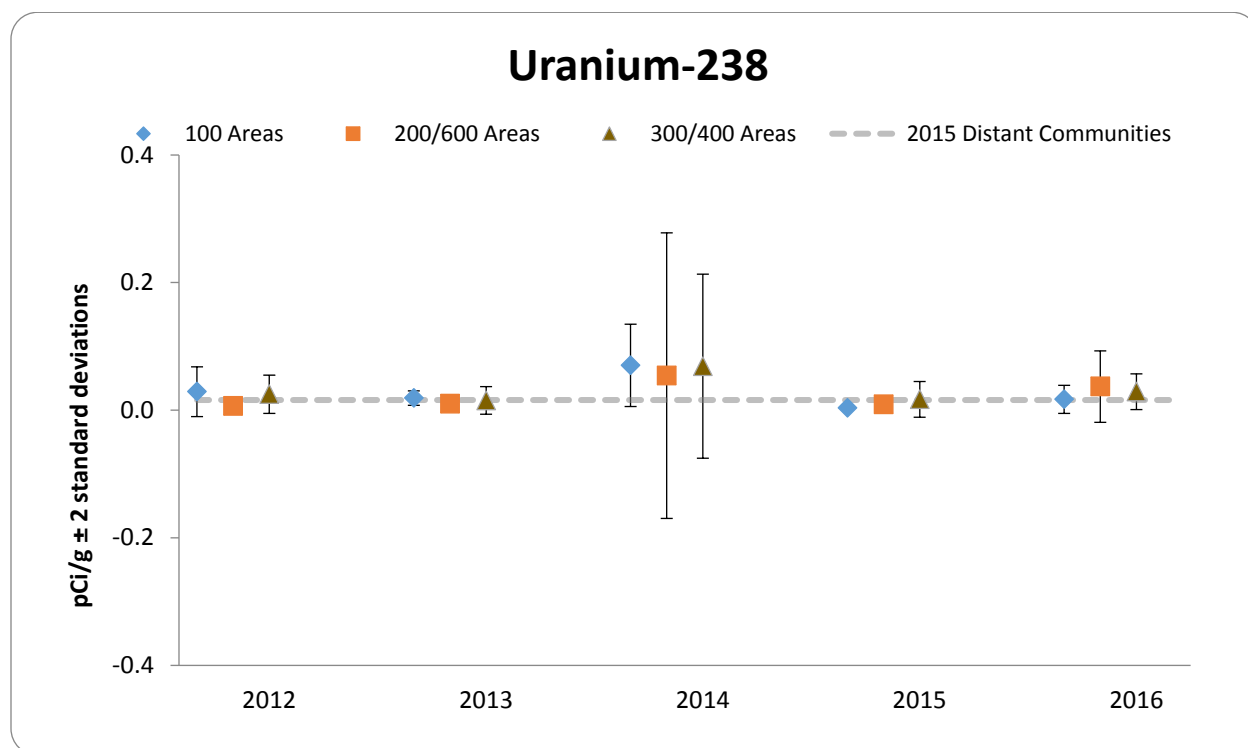


Figure 10-6. Hanford Site Vegetation Average Concentrations of Select Radionuclides.

Table 10-6. Hanford Site Vegetation Concentrations of Select Radionuclides. (3 Pages)

Isotope	Hanford Area	Number of Samples	Number of Detects	2016 Average ^a (pCi/gm)	Maximum ^b (pCi/gm)	Number of Samples	Number of Detects	2011–2015 Average ^a (pCi/gm)	Maximum ^b (pCi/gm)
Cobalt-60	100	3	0	3.1E-02 ± 6.9E-02	7.7E-02 ± 6.7E-02	12	0	-7.5E-05 ± 2.7E-02	1.9E-02 ± 4.4E-02
	200-East	9	0	5.3E-03 ± 2.7E-02	2.7E-02 ± 3.4E-02	38	0	1.7E-03 ± 4.1E-02	5.4E-02 ± 1.1E-01
	200-West	21	0	2.0E-03 ± 2.8E-02	3.5E-02 ± 3.4E-02	65	0	-3.8E-03 ± 4.3E-02	6.4E-02 ± 4.7E-02
	300	2	0	1.5E-02 ± 3.0E-04	1.5E-02 ± 2.8E-02	27	0	-8.3E-03 ± 5.8E-02	3.9E-02 ± 3.5E-02
	400	1	0	2.40E-02	2.4E-02 ± 2.4E-02	4	0	-5.7E-03 ± 3.4E-02	2.1E-02 ± 5.2E-02
	600	14	0	6.0E-03 ± 3.0E-02	3.0E-02 ± 2.2E-02	46	0	9.8E-03 ± 4.1E-02	6.7E-02 ± 6.5E-02
Cesium-137	100	3	0	5.3E-03 ± 4.0E-02	2.2E-02 ± 5.9E-02	12	1	1.4E-02 ± 4.7E-02	5.7E-02 ± 5.0E-02
	200-East	9	1	2.4E-02 ± 5.6E-02	9.1E-02 ± 3.3E-02	38	16	6.2E-02 ± 1.1E-01	2.4E-01 ± 2.6E-02
	200-West	21	1	1.9E-02 ± 4.4E-02	8.6E-02 ± 2.9E-02	65	17	4.8E-02 ± 1.2E-01	3.2E-01 ± 1.2E-01
	300	2	0	3.3E-02 ± 2.0E-02	4.3E-02 ± 4.8E-02	27	9	7.4E-02 ± 1.9E-01	3.6E-01 ± 9.7E-02
	400	1	0	-2.50E-03	-2.5E-03 ± 1.9E-02	4	0	2.5E-02 ± 6.5E-02	7.7E-02 ± 5.9E-02
	600	14	1	2.2E-02 ± 6.9E-02	1.3E-01 ± 3.5E-02	46	10	4.2E-02 ± 1.1E-01	2.0E-01 ± 8.6E-02
Plutonium-238	100	3	0	-1.8E-04 ± 7.1E-04	9.3E-05 ± 3.3E-04	11	0	-4.9E-04 ± 4.3E-03	2.7E-03 ± 6.5E-03
	200-East	6	0	4.3E-05 ± 1.2E-04	1.4E-04 ± 1.9E-04	38	2	7.5E-04 ± 1.0E-02	1.6E-02 ± 1.9E-02
	200-West	20	2	4.6E-05 ± 3.3E-04	4.6E-04 ± 3.4E-04	65	3	5.3E-04 ± 1.1E-02	2.7E-02 ± 1.2E-02
	300	2	0	-7.3E-05 ± 1.1E-04	-2.0E-05 ± 1.6E-04	27	1	1.9E-03 ± 1.1E-02	1.9E-02 ± 2.1E-02
	400	1	0	4.60E-05	4.6E-05 ± 2.0E-04	4	0	3.4E-05 ± 1.3E-03	8.1E-04 ± 5.4E-03
	600	13	0	2.0E-05 ± 2.6E-04	2.1E-04 ± 2.4E-04	45	0	1.1E-03 ± 1.4E-02	3.2E-02 ± 2.3E-02
Plutonium-239/-240	100	1	0	1.40E-04	1.4E-04 ± 4.1E-04	12	1	2.6E-04 ± 2.3E-03	2.1E-03 ± 1.0E-03
	200-East	8	3	7.9E-04 ± 2.4E-03	3.7E-03 ± 6.8E-04	38	4	1.3E-03 ± 3.3E-03	5.7E-03 ± 5.6E-03
	200-West	21	15	4.2E-03 ± 1.2E-02	2.1E-02 ± 2.0E-03	65	31	2.4E-02 ± 3.2E-01	1.3E+00 ± 2.8E-01
	300	2	0	-9.3E-05 ± 6.6E-05	-6.0E-05 ± 2.4E-04	27	0	9.9E-04 ± 2.9E-03	4.4E-03 ± 5.5E-03
	400	1	0	3.20E-04	3.2E-04 ± 2.8E-04	4	0	7.7E-04 ± 3.5E-03	3.7E-03 ± 4.3E-03

Table 10-6. Hanford Site Vegetation Concentrations of Select Radionuclides. (3 Pages)

Isotope	Hanford Area	Number of Samples	Number of Detects	2016 Average ^a (pCi/gm)	Maximum ^b (pCi/gm)	Number of Samples	Number of Detects	2011–2015 Average ^a (pCi/gm)	Maximum ^b (pCi/gm)
	600	14	3	2.4E-04 ± 8.6E-04	1.3E-03 ± 5.5E-04	46	7	6.6E-04 ± 4.5E-03	7.3E-03 ± 9.7E-03
Strontium-90	100	3	3	5.3E-01 ± 1.1E+00	1.3E+00 ± 2.6E-01	12	11	2.3E+00 ± 7.6E+00	1.3E+01 ± 1.7E+00
	200-East	9	0	-1.8E-03 ± 3.6E-02	2.5E-02 ± 2.9E-02	38	23	2.8E-01 ± 5.1E-01	1.0E+00 ± 2.8E-01
	200-West	21	0	8.5E-03 ± 4.0E-02	4.2E-02 ± 3.3E-02	65	18	1.3E-01 ± 3.7E-01	7.4E-01 ± 2.0E-01
	300	2	0	-2.6E-02 ± 1.7E-02	-1.7E-02 ± 2.3E-02	27	10	1.6E-01 ± 4.1E-01	8.4E-01 ± 1.9E-01
	400	1	0	7.50E-03	7.5E-03 ± 2.4E-02	4	0	4.0E-02 ± 1.3E-01	1.5E-01 ± 1.7E-01
	600	14	0	5.2E-03 ± 4.3E-02	3.5E-02 ± 2.7E-02	46	9	1.0E-01 ± 4.3E-01	1.3E+00 ± 3.4E-01
Uranium-234	100	3	2	2.6E-02 ± 1.9E-02	3.9E-02 ± 1.3E-02	12	9	3.6E-02 ± 1.0E-01	1.8E-01 ± 1.4E-01
	200-East	9	9	7.9E-02 ± 5.3E-02	1.2E-01 ± 4.0E-02	38	25	4.1E-02 ± 1.8E-01	3.6E-01 ± 1.8E-01
	200-West	21	19	3.1E-02 ± 4.5E-02	9.4E-02 ± 4.5E-02	65	48	2.8E-02 ± 1.3E-01	3.4E-01 ± 1.7E-01
	300	2	2	3.4E-02 ± 3.8E-03	3.5E-02 ± 1.4E-02	27	23	2.9E-02 ± 5.2E-02	1.1E-01 ± 3.8E-02
	400	1	1	2.50E-02	2.5E-02 ± 1.3E-02	4	3	1.9E-02 ± 2.1E-02	3.6E-02 ± 1.2E-01
	600	14	13	6.9E-02 ± 6.7E-02	1.4E-01 ± 4.7E-02	46	30	1.1E-02 ± 7.5E-02	1.3E-01 ± 1.3E-01
Uranium-235	100	3	2	1.7E-02 ± 2.5E-03	1.8E-02 ± 1.1E-02	12	3	1.0E-02 ± 2.4E-02	4.4E-02 ± 1.1E-01
	200-East	9	9	5.0E-02 ± 3.3E-02	8.1E-02 ± 3.8E-02	38	9	4.3E-02 ± 3.3E-01	1.0E+00 ± 0.0E+00
	200-West	20	8	1.7E-02 ± 4.0E-02	6.8E-02 ± 3.6E-02	65	19	7.9E-03 ± 9.6E-02	1.6E-01 ± 1.2E-01
	300	2	2	2.30E-02	2.3E-02 ± 1.2E-02	27	4	2.9E-03 ± 1.2E-02	8.8E-03 ± 7.3E-03
	400	1	1	1.30E-02	1.3E-02 ± 1.1E-02	4	0	2.5E-02 ± 7.4E-02	8.9E-02 ± 1.1E-01
	600	14	8	3.6E-02 ± 5.0E-02	7.7E-02 ± 3.9E-02	45	9	-3.8E-04 ± 5.8E-02	5.8E-02 ± 1.0E-01
Uranium-238	100	3	2	1.7E-02 ± 2.2E-02	2.7E-02 ± 1.2E-02	12	8	2.8E-02 ± 6.1E-02	1.0E-01 ± 1.2E-01
	200-East	9	8	5.2E-02 ± 3.3E-02	8.7E-02 ± 3.6E-02	38	19	2.5E-02 ± 7.7E-02	1.4E-01 ± 1.3E-01
	200-West	21	13	2.6E-02 ± 5.7E-02	1.2E-01 ± 3.8E-02	65	41	1.5E-02 ± 6.7E-02	1.4E-01 ± 1.1E-01
	300	2	2	3.8E-02 ± 6.0E-03	4.1E-02 ± 1.5E-02	27	26	3.1E-02 ± 5.6E-02	1.2E-01 ± 1.1E-01

Table 10-6. Hanford Site Vegetation Concentrations of Select Radionuclides. (3 Pages)

Isotope	Hanford Area	Number of Samples	Number of Detects	2016 Average ^a (pCi/gm)	Maximum ^b (pCi/gm)	Number of Samples	Number of Detects	2011–2015 Average ^a (pCi/gm)	Maximum ^b (pCi/gm)
	400	1	0	9.40E-03	9.4E-03 ± 9.1E-03	4	3	1.1E-02 ± 8.8E-03	1.8E-02 ± 7.9E-02
	600	14	10	4.4E-02 ± 5.2E-02	9.4E-02 ± 4.3E-02	46	32	9.8E-03 ± 9.7E-02	1.6E-01 ± 2.5E-01
^a Average ± two standard deviations ^b Maximum ± analytical uncertainty									

Vegetation samples collected in 2016 at locations in the 100-N, 200-East, 200-West, 400, and 600 Areas were comparable to those collected in previous years. Vegetation samples collected in the 200 and 600 Areas showed concentrations of uranium-234, uranium-235, and uranium-238 that were comparable to historical data. The uranium levels are a result of uranium releases to the environment during past fuel-fabrication operations in that area. The range of strontium-90 concentrations was comparable to historical levels.

10.3.2 Radiological Contamination

JW Wilde, RC Roos

Investigations of radioactive contamination 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 surveys performed during investigations were field-surveyed for alpha- and beta-gamma radiation.

Radiological contamination was found in vegetation during 45 incidents during the 2016 investigations; 44 were Russian thistle (*Salsola tragus*) plants or fragments and 1 plant material was unidentified. No samples were analyzed for specific radionuclides. Surveys resulted in 3 locations posted as contamination areas; 42 contaminated vegetation discoveries were disposed at a licensed facility.

Section 10.3.3 provides a discussion of the vegetation control on the Hanford Site. Table 10-7 summarizes the number and general locations of vegetation contamination incidents discovered from 2000 to 2016.

Table 10-7. Hanford Site Vegetation Contamination Incidents Investigated. (2 Pages)

Location	2016 Incidents	Year	Incidents
100 Area	0	2000	66
200-East Area		2001	20
Tank farms	5	2002	16
Burial grounds	11	2003	32
Cribs, ponds, and ditches	3	2004	60
Fence lines	6	2005	66
Roads and railroads	0	2006	75
Unplanned release sites	0	2007	62
Underground pipelines	1	2008	127
LERF/ETF	10	2009	109
Miscellaneous	0	2010	36
200-West Area		2011	10
Tank farms	3	2012	18
Burial grounds	1	2013	35
Cribs, ponds, and ditches	4	2014	50
Fence lines	1	2015	48
Roads and railroads	0	2016	45
Unplanned release sites	0		
Underground pipelines	0		
Miscellaneous	0		
Cross-site transfer line	0		

Table 10-7. Hanford Site Vegetation Contamination Incidents Investigated. (2 Pages)

Location	2016 Incidents	Year	Incidents
600 Area burial grounds	0		
200-North Area	0		
300 Area	0		
400 Area	0		
600 Area	0		
1100 Area	0		
Total	45		

10.3.3 Vegetation Control

JM Rodriguez, 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 5,444 ac (2,203 ha) were treated with herbicides in 2016 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.

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. Approximately 85 ac (34 ha) of noxious weeds on the Hanford Site were treated with herbicides in 2016 along roadways and abandoned rail lines. The [*Environmental Assessment: Integrated Vegetation Management on the Hanford Site, Richland, Washington*](#) (DOE/EA-1728-F) was completed in 2012.

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 2016 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 yellow starthistle in 2016

consisted of hand pulling individual plants as they were identified and spot treatment with herbicides on roadways and in areas of the Hanford Townsite.

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. If diligent control efforts are continued over the next few years, the yellow starthistle population at Hanford can change 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 populations 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 south of the Wye Barricade. 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. Rush skeletonweed has become the most challenging noxious weed to control on the Hanford Site due to the large aerial extent of infestation, density of infestation, and sustained effort required to eliminate individual plants and populations.

Biological control agents commonly applied to rush skeletonweed at the Hanford Site have not significantly reduced plant populations or seed production.

Babysbreath (Gypsophila paniculata). Babysbreath is generally resistant to control by herbicides; however, the above-ground portion of the plant can be destroyed by some herbicides that can prevent flowering and seed production. The plants should be eradicated by continually removing the top portions through herbicide use. By removing the green portions of the plants, the energy reserves in the roots will eventually be depleted, killing the plant. Mainly found in the Hanford Townsite, babysbreath was not controlled in 2016 due to limited resources for the effort.

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). In 2016, control of diffuse knapweed was limited to herbicide application on roadways and railroad right-of-ways, and hand pulling in critical areas. The population of this species near the Columbia River high watermark has not been actively controlled by herbicides because of the biological sensitivity of the area. Several biological control agents are established at Hanford.

Tackweed (Tribulus terrestris). Tackweed has become increasingly common on the Hanford Site over the past several years. In 2016, a large population found at the Hanford Townsite was controlled using a combination of herbicide application and hand pulling. Other tackweed found across the Hanford Site as individual plants or small populations were also controlled.

Purple Loosestrife (Lythrum salicaria). The banks of the Columbia River and islands along the Hanford Site are monitored for purple loosestrife, as these locations in these areas are appropriate for this weed. Individual plants and small populations are found along the south and west bank of the river. Under good ecological conditions, biological measures for controlling purple loosestrife are effective; however, widely fluctuating water levels along the Columbia River destroy the biological control organisms as they attempt to over-winter soil at the base of the plants. Winter mortality prevents effective population control agents from developing. No control measures were applied in 2016 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 in years past. 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 2014 began to show new green growth in 2016. Effective control of weeds often depends on the plant having sufficient green-leaf area for herbicide to enter the plant. The small amount of green growth found in 2016 was not sufficient for effective herbicide application. It is expected that these trees will be sprayed with herbicide in 2017.

Spotted Knapweed (Centaurea maculosa). Spotted knapweed at the Hanford Site has been controlled so that sprouts or seedlings are rare. In 2016, no sprouts or seedlings were found. The Hanford Site will continue to be monitored for several years to ensure that viable seeds and roots have been eliminated from the soil. Cooperative efforts with neighboring landowners continue to eliminate spotted knapweed

near the Hanford Site. The root-feeding weevil *Cyphocleonus achates* has been released specifically to help eradicate spotted knapweed at Hanford; however, it is expected that the population is too small and scattered to sustain a biological control population. *Cyphocleonus* is known to use diffuse knapweed; it is hoped that this weevil 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, JM Rodriguez

In 2016, only 2 ac (0.8 ha) across the Hanford Site were planted with grass seed to stabilize areas where traffic and erosion had damaged the grass cover on waste sites. Waste sites in the 200-East and 200-West Areas were designed and constructed with a cap of perennial grass 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:

- **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.
- **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 become mobile, transporting radioactive contamination 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.

- **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-in. (15- to 18-cm) average precipitation received at the Hanford Site typically percolates 2 to 4 ft (0.6–1.2 m) 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, which inhibits 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.

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11.0 Resource Protection

11.1 Ecological Protection

JW Wilde, KJ Cranna, JE Grzyb, JJ Nugent, JA Pottmeyer

Ecological monitoring is performed on the Hanford Site to collect and track data needed to ensure compliance with various environmental laws, regulations, and policies governing U.S. Department of Energy (DOE) activities. Ecological monitoring data provide baseline information about the plants, animals, and habitat under DOE stewardship at Hanford required for decision making under the [National Environmental Policy Act of 1969](#) (NEPA) and [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (CERCLA).

The [Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement](#) (CLUP; DOE/EIS-0222-F) evaluated future land-use planning at the Hanford Site to facilitate decision making about the site's uses and facilities for a 50-year period. DOE adopted the CLUP to balance land-use with the preservation of important ecological and cultural values of the Site.

The [Hanford Site Biological Resources Management Plan](#) (BRMP; DOE/RL-96-32) is identified by the CLUP as the primary plan 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]² provides a comprehensive direction that specifies DOE biological resource policies, goals, and objectives.

DOE 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 through 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); [Migratory Bird Treaty Act of 1918](#) (MBTA) (16 USC 703); as well as compliance with executive orders, DOE orders, and DOE resource management guidance

²The CLUP document uses a different acronym (BRMaP, in place of BRMP used here) for abbreviating the *Hanford Site Biological Resource Management Plan* document.

- 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 Rare Plants

JA Pottmeyer

Plant populations monitored at the Hanford Site include taxa designated by the Washington State Natural Heritage Program as endangered, threatened, or sensitive species and those listed as Review Group 1 (see Section 11.2). In 2016, the known rare plant sites located in the central portion of the Hanford Site were visited to assess and document habitat characteristics and species' trends with the goal of developing effective strategies for future rare plant management. Prior to surveys, rare plant records from the Hanford Site were reconciled with records on file with the Washington State Natural Heritage Program. Surveys were timed to prioritize known occurrences of rare species and their habitats. Other rare species with the potential to occur on the site were searched for in conjunction with those surveys but were not targeted. Resurveys for high priority species included searches for additional subpopulations in the surrounding area as time allowed.

Table 11-1 summarizes the results of the 2016 rare plant surveys. Additional details from these surveys are included in the fiscal year (FY) 2016 monitoring report available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

Table 11-1. Summary of 2016 Rare Plant Surveys. (2 Pages)

Common Name	Scientific Name	State Status ^a	2016 Status on Central Hanford Site
Hoover's desert parsley	<i>Lomatium tuberosum</i>	S	Plants abundant and vigorous; wide range of size classes
Columbia milkvetch	<i>Astragalus columbianus</i>	S	Species appears to be relatively stable
Piper's Daisy	<i>Erigeron piperianus</i>	S	Population stable; seedlings were abundant or copious
Suksdorf's monkeyflower	<i>Eryanthre suksdorfii</i>	S	Present at several sites, where it was spotted for the first time since the mid-1990's
Spreading pygmyleaf	<i>Loeflingia squarrosa</i>	T	Found at three sites; one site was found to be extirpated, probably due to road hardening
Rosy pussytoes	<i>Calyptidium rosea</i>	T	A few small plants found at one site; the species was not found at other known sites

Table 11-1. Summary of 2016 Rare Plant Surveys. (2 Pages)

Common Name	Scientific Name	State Status ^a	2016 Status on Central Hanford Site
Great Basin gilia	<i>Aliciella leptomeria</i>	T	Found at two small known sites; not found at other known sites
Small-flowered evening-primrose	<i>Eremothera minor</i>	S	Species abundant and vigorous at new location identified in 2015; found in three locations, but missing from some previously known sites
Pygmy evening-primrose	<i>Eremothera pygmaea</i>	S	Species abundant and vigorous at an inactive quarry site
Gray cryptantha	<i>Cryptantha leucophaea</i>	S	An extensive survey of this species was done in 2015, so it was not a focus in 2016. This population was found to be relatively stable on the Hanford Site in 2015. One site revisited had been impacted by a rebuild of an access road, but seedlings were observed in the area. In addition, one new site was documented.
Thompson's sandwort	<i>Eremogone franklinii</i> var <i>thompsonii</i>	S	This species was found at the same new documented site as <i>C. leucophaea</i> . Found in many of the same locations as <i>C. leucophaea</i> .
Tufted evening-primrose	<i>Oenothera cespitosa</i> var <i>cespitosa</i>	S	A site first noted during 2015 fieldwork was documented. Seedlings were present. One previously documented occurrence was not found.
Coyote tobacco	<i>Nicotiana attenuata</i>	S	Known sites around an active waste burial ground were visited; one area has been chained off to protect plants. The chained area contains several hundred plants, and peripheral sites had a few plants.
Columbia yellowcress	<i>Rorippa columbiae</i>	T	Limited time was spent in the riparian area along the Hanford Reach. All three species were found in the three locations revisited.
Lowland toothcup	<i>Rotala ramosior</i>	T	
Awned halfchaff sedge	<i>Lipocarpa aristula</i>	T	

^a Washington State Status of plant species is determined by the Washington Natural Heritage Program.

E = Endangered. In danger of becoming extinct or extirpated from Washington.

S = Sensitive. Vulnerable or declining and could become Threatened or Endangered in the state.

T = Threatened. Likely to become Endangered in Washington.

11.1.2 Fish and Wildlife Monitoring

JW Wilde

This section provides inventory, monitoring, and survey information for fish and wildlife evaluated at the Hanford Site during 2016. This information is provided in context with historical data and trend information. Historically, three fish and wildlife species (fall Chinook salmon [*Oncorhynchus tshawytscha*], steelhead [*Oncorhynchus mykiss*], and bald eagles [*Haliaeetus leucocephalus*]) have been monitored annually on the Hanford Site. These species are either protected by federal or state laws and regulations or are of special interest to the public and stakeholders. 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 annual monitoring efforts included nesting raptors and migratory birds. Each calendar year, additional species-specific monitoring are performed based on stakeholder interest, legal requirements, resource status, BRMP resource level, and data needs. In addition to the aforementioned annual projects, calendar year (CY) 2016 monitoring also included raptor nest monitoring, roadside and sagebrush bird surveys, mule deer, snake hibernacula, and long-billed curlews. The sections below provide summaries of the monitoring results; the detailed monitoring reports are currently or shortly available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.2.1 Fall Chinook Salmon

JJ Nugent

Commonly referred to as king salmon, Chinook (*Oncorhynchus tshawytscha*) 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 in the fall. Females fan out nests or redds in suitable gravel substrate and deposit eggs in a pocket while males simultaneously extrude milt to fertilize the eggs. Redds are readily identifiable during this time and appear as clean swept gravel patches amidst darker undisturbed substrate 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, and economic importance that reaches areas downstream on the Columbia River and along 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, Nugent and Wilde 2015, Nugent 2016, MSA 2017). 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 aerial surveys, which 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 that were maintained in the current monitoring campaign. In 2011, eight additional sub-sections (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, Dunes, and 300 Area) were defined to better monitor the abundance and distribution of fall Chinook salmon 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 2016, four surveys were completed along the Hanford Reach (October 23, November 6, November 13, and November 20). Table 11-2 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 11-3. The peak annual redd count for 2016 (13,268) was the fifth highest count since 1948 and exceeds the previous 10-year average (10,092). The historical trend in redd counts since 1948 is shown in Figure 11-1. Fall Chinook salmon redd counts on the Hanford Reach in 2016 decreased by 35.8% from the highest count, which was recorded in 2015 (20,678). Although the redd count decreased in 2016, the recent annual redd counts generally far surpass counts for past decades.

Table 11-2. Summary of Fall Chinook Salmon Redd Counts by Areas for the 2016 Aerial Surveys in the Hanford of the Columbia River.

Area	Description	10/23/2016	11/6/2016	11/13/2016	11/20/2016	Maximum Count
0	Islands 17-21 (Richland)	0	0	0	0	0
1	Islands 11-16	0	380	830	861	861
1a	Savage Island/Hanford Slough	0	0	0	0	0
2	Islands 8-10	35	1020	1685	1735	1735
3	Near Island 7	0	650	660	670	670
4	Island 6 (lower half)	54	1135	1805	1807	1807
5	Island 4, 5, and upper 6	68	2140	2262	2270	2270
6	Near Island 3	30	380	550	600	600
7	Near Island 2	40	810	1120	1140	1140
8	Near Island 1	10	253	300	340	340
8a	Upstream of Island 1 to Coyote Rapids	0	0	0	0	0
9	Near Coyote Rapids	13	165	232	235	235
9a	Upstream of Coyote Rapids to China Bar	0	20	20	20	20
China Bar	China Bar/Midway	4	60	60	80	80
10	Near Vernita Bar	220	3140	3400	3500	3500
11	Upstream of Vernita Bar to Priest Rapids Dam	0	7	10	10	10

Table 11-3. Summary of Fall Chinook Salmon Redd Counts by Sub-areas Adjacent to Hanford Site Operations for the 2016 Aerial Surveys in the Hanford Reach of the Columbia River.

Sub-area	10/23/2016	11/6/2016	11/13/2016	11/20/2016	Maximum Count
300 Area	0	0	0	0	0
Dunes	0	0	0	0	0
100-F	0	640	660	670	670
100-H	68	2140	2262	2270	2270
100-D	10	53	300	340	340
100-N	0	0	0	0	0
100-K	0	0	0	0	0
100-BC	13	165	232	235	235

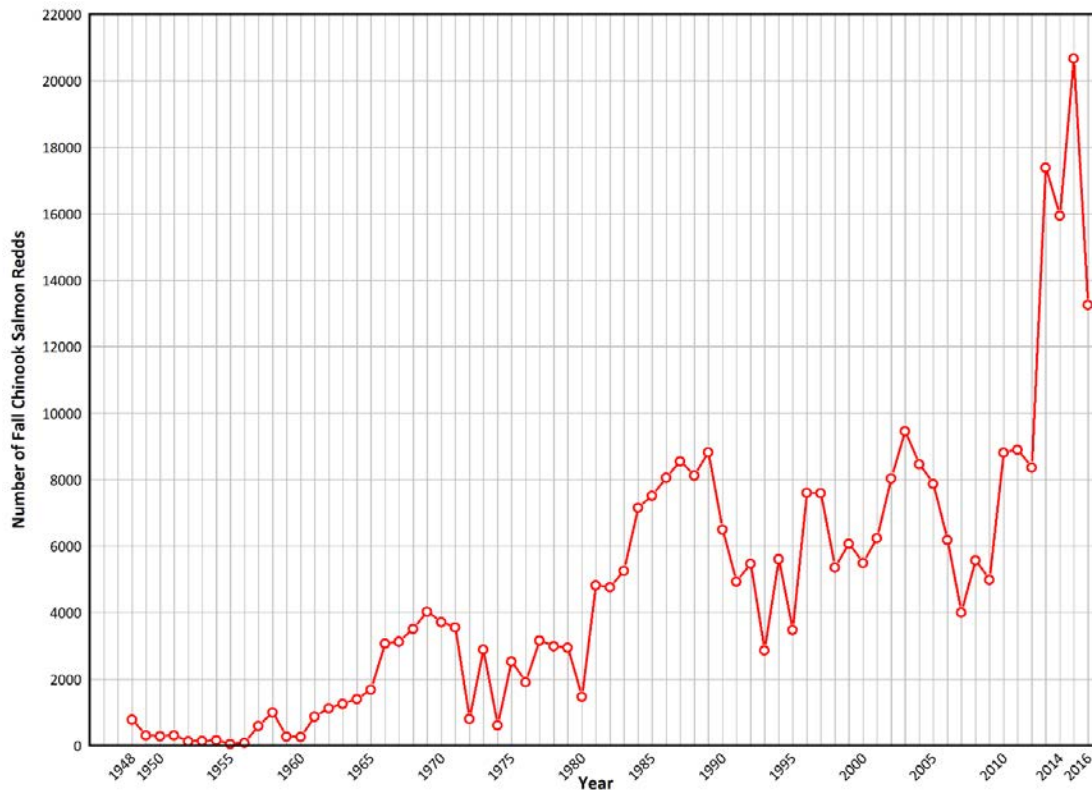


Figure 11-1. Visual Hanford Reach Fall Chinook Salmon Redd Counts 1948 to 2016.

11.1.2.2 Bald Eagle

JE Grzyb

[DOE/RL-94-150, Bald Eagle Management Plan for the Hanford Site, South-Central Washington](#), 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-mi (400-m) 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 2016/2017 season (as of March 21, 2017), 64 night roost surveys and 2 boat surveys were conducted. The Washington Department of Fish and Wildlife (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 15 minutes prior to sunset until dark. Night roost surveys were conducted biweekly at eight locations between November 21, 2016, and March 6, 2017. With the revised version of DOE/RL-94-150 scheduled to be released in 2017, the 2016/2017 eagle monitoring efforts also focused on testing shorter buffer distances for night roosts. This was achieved by creating artificial disturbances that imitate Hanford Site activities at various distances from the roosts inside the current buffer zone.

The entire Hanford Reach was surveyed by boat two times during the 2016/2017 season (December 7, 2016, and March 21, 2017). 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. During the first night roost survey on November 21, 2016, the maximum count of 56 bald eagles on the Hanford Reach was observed for the 2016/2017 season, which was far less than the record maximum count of 141 documented during the 2014/2015 season but remains higher than the historic average maximum count of 25 eagles (1961 to 2013). This was most likely a result of the high number of adult fall Chinook salmon spawning in the Hanford Reach in recent years. Spawning-out salmon carcasses that accumulate along the Hanford Reach provide bald eagles their primary food source. During 2016/2017 boat surveys, adult eagles were observed sitting on a nest at the Bonneville Power Administration's (BPA) sub-station tower location (near the Upstream of Wooded Island nest that was occupied during the 2012/2013 to 2014/2015 seasons).

Nest site surveys were conducted in three locations (White Bluffs Peninsula, Hanford Townsite sub-station, and BPA sub-station tower). Nest sites were monitored for nesting activities (e.g., a pair defending the nest from other eagles, nest tending, and pair bonding behaviors) (Figure 11-2). As of March 21, 2017, eagles appeared to be using the White Bluffs Peninsula nest, as well as a newly discovered nest located across the river from the B and C Reactors. The three previously identified nesting areas are posted with nest protection signs to ensure that no vehicular traffic approaches the nests within 436 yd (400 m), as required by DOE/RL-94-150. Mission Support Alliance (MSA) staff will continue to monitor the nests to determine the outcome of the nesting attempts. Later in 2017, a complete bald eagle monitoring report will be included in the comprehensive PSRP annual report, and available online at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>. Bald eagles were removed from the federal endangered and threatened species list in July 2007 and were down-listed from sensitive to no concern by the WDFW in January 2017. Federal laws including the *Bald and Golden Eagle Protection Act of 1940* and the MBTA still provide protection for eagles, their nest trees, and communal night roosts.

11.1.2.3 Raptor Nest Monitoring

JJ Nugent

The Hanford Site supports a large and diverse community of raptorial birds (Fitzner et al. 1981) 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 (7). The Ferruginous Hawk (*Buteo regalis*) is a Washington State-listed threatened species, and the Bald Eagle (*Haliaeetus leucocephalus*) is a federal species of concern. The Burrowing Owl (*Athene cunicularia*) is a Washington State candidate species and the Swainson's Hawk (*Buteo swainsoni*), Prairie Falcon (*Falco mexicanus*), and Osprey (*Pandion haliaetus*) are Washington State monitored species. Raptor species on the Hanford Site are also afforded protection under the MBTA. Because of the status of these species and their protection under the MBTA, U.S. Department of Energy, Richland Operations Office (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. Common Ravens (*Corvus corax*) also nest on the Hanford Site and, although they are not considered raptors, they perform a similar ecological role.

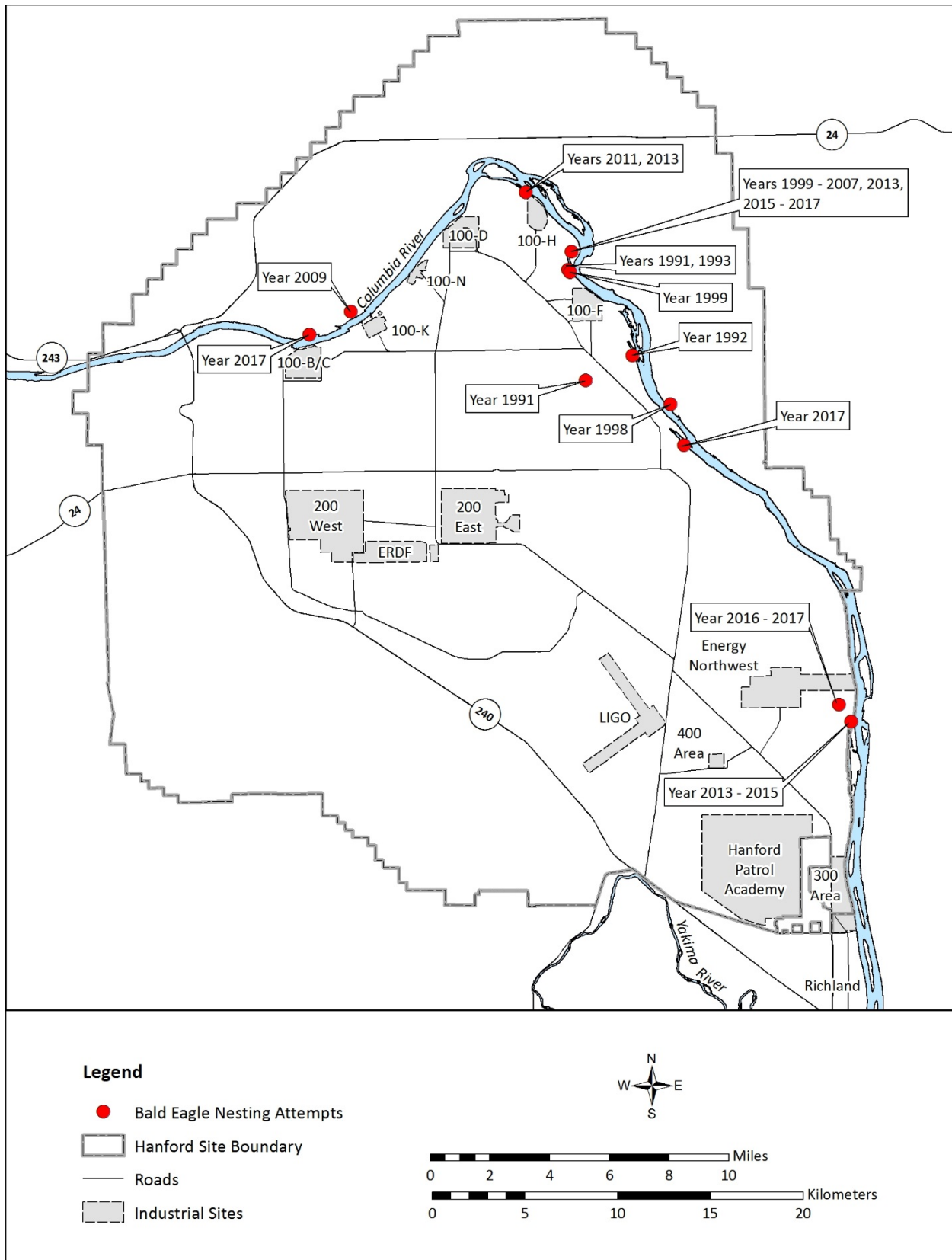


Figure 11-2. Location of Known Bald Eagle Nesting Attempts on the Hanford Site.

Nest surveys for raptors and ravens were conducted on DOE-managed lands including the central Hanford, McGee Ranch, Riverland, dunes areas, and the southern shoreline of the Columbia River. Nest surveys were not performed in an area south of 200-East Area including the BC Controlled Area and the Central Landfill due to access controls. Nest searches occurred in late May and early June, during which time all species occupy their respective nesting territories. Survey methods used in 2016 were consistent with the methods used in 2012 through 2015 (Nugent et al. 2013; HNF-58717; Nugent et al. 2015; Nugent et al. 2016) with the exception of a portion of the Central Plateau (containing the 200 Areas) was surveyed for the first time in 2016. This area was avoided in previous years (2012 to 2015) due to the high number of elevated structures and restricted areas. In 2016, it was decided that due to more focused cleanup efforts in the 200 Areas this area should be thoroughly surveyed.

In addition to the annual survey of nesting raptors and ravens on the Hanford Site, DOE-RL coordinated with WDFW to determine occupancy and productivity of all traditional Ferruginous Hawk nesting territories on the DOE-RL-managed lands of the Hanford Site. WDFW is required to report on the status of Ferruginous Hawks every 5 years to verify whether the species' current listing of threatened is justified or whether a reclassification is needed (WAC 220-610-110). Seventeen traditional Ferruginous Hawk nesting territories have been identified on the DOE-RL managed lands of the Hanford Site. Three surveys were conducted in 2016, two occupancy surveys (March and April) and one productivity survey (June).

A total of 111 nest sites were recorded in 2016. Nest substrates used by raptors and ravens on DOE-RL-managed lands in 2016 are shown in Table 11-4. All raptor and raven nest sites located in 2016 are displayed in Figure 11-3. A comparison of the number of raptor and raven nest sites located in 2012 to 2016 is presented in Figure 11-4. Two Common Raven nests and a Red-tailed Hawk (*Buteo jamaicensis*) nest were observed in 2016 in the portion of the Central Plateau that was not surveyed in previous years. There have been incidental sightings of Common Raven nests in this area from 2012 through 2015. Thus, systematic survey data from 2016 have provided similar data as incidentally recorded data from previous years.

Nests of 10 raptor species (i.e., Ferruginous, Swainson's, Red-tailed Hawks, Prairie Falcons, American Kestrels [*Falco sparverius*], Bald Eagles, Ospreys, Great Horned [*Bubo virginianus*], Long-eared [*Asio otus*], and Burrowing Owls) as well as Common Ravens were located in 2016. Two Bald Eagle nests were documented in 2016. A pair of Bald Eagles built a nest on a transmission tower near the BPA Benton substation approximately 0.6 mi (1,100 m) northwest of the upstream Wooded Island nest site that was occupied in 2013 to 2015. It appeared that the pair used nesting materials from the upstream Wooded Island nest. This pair successfully fledged two young. The second Bald Eagle nest was constructed on the White Bluffs peninsula in the same location as in 2015 (Cranna et al. 2015). Like the nest built on the peninsula in 2015, the success of the nest in 2016 could not be determined due to increased foliage on the trees that obscured the view of the nest. However, an adult Bald Eagle was observed in the nest on May 12, past the date of the recorded latest first-egg date (May 10) for Washington State, and a pair of adult Bald Eagles were seen at the nest on July 6 by field personnel conducting an electrofishing project in White Bluffs Slough.

Table 11-4. Nest Substrates Used by Raptors and Ravens on DOE-RL-Managed Lands of the Hanford Site in 2016.

Species	Tree	Cliff	Transmission Tower	Utility Pole	Meteorological Tower	Nest Platform	Traffic Sign	Building (Chimney)	Irrigation Pipe	Total
Ferruginous Hawk			3							3
Swainson's Hawk	18		1	1						20
Red-tailed Hawk	3	2	4							9
Prairie Falcon		2								2
American Kestrel*	2	1						1		4
Bald Eagle	1		1							2
Osprey						5				5
Great Horned Owl	4									4
Long-eared Owl	2									2
Burrowing Owl ^a									1	1
Common Raven ^b	4	1	48	4	1		1			59
Total	34	6	57	5	1	5	1	1	1	111

^a Nests of American Kestrels and Burrowing Owls are difficult to find; therefore, nest numbers likely represent minimums.

^b Common Ravens are technically not raptors but occupy a similar ecological niche and are protected under the *Migratory Bird Treaty Act of 1918*.

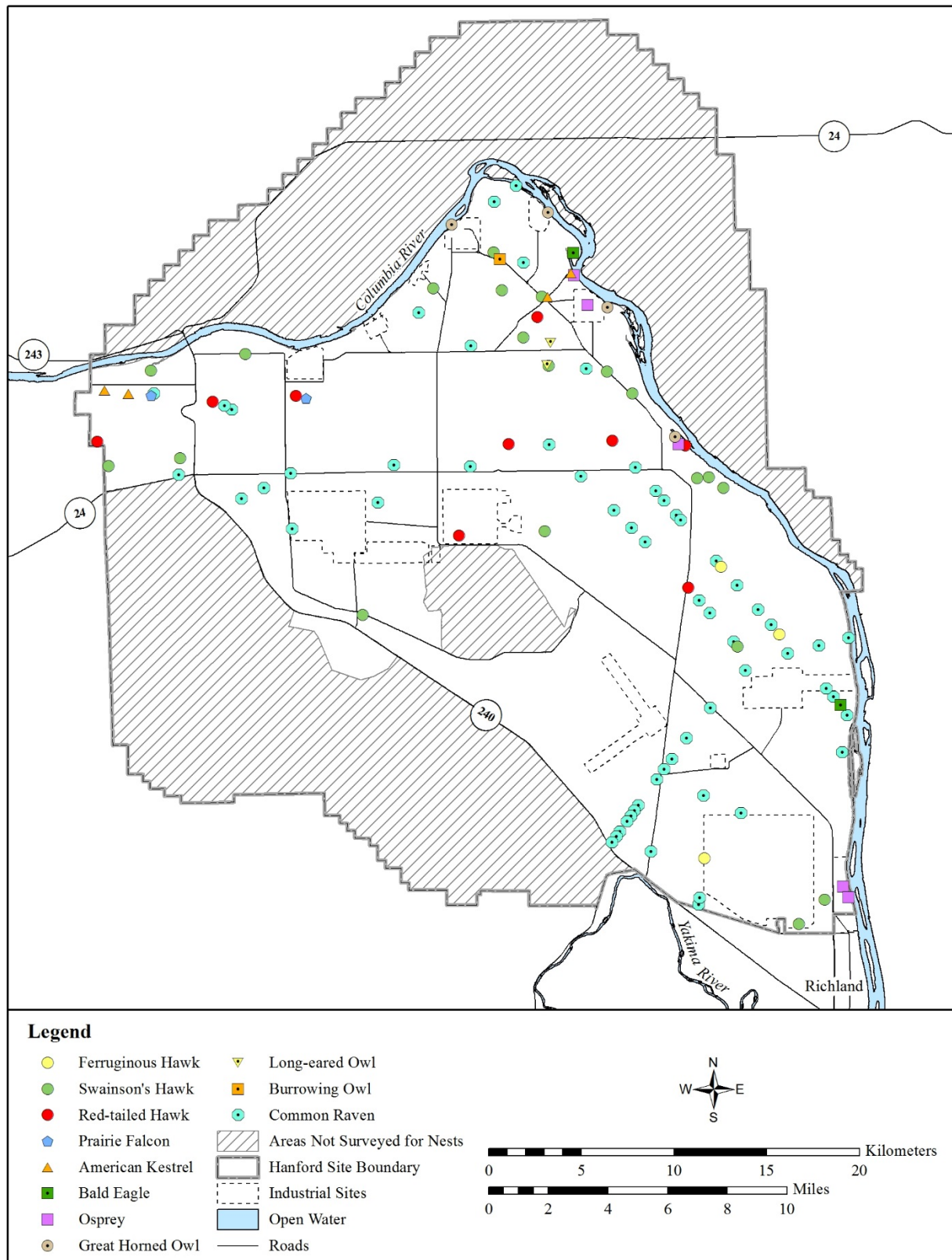


Figure 11-3. Raptor and Common Raven Nests Located on DOE-RL Managed Lands of the Hanford Site in 2016.

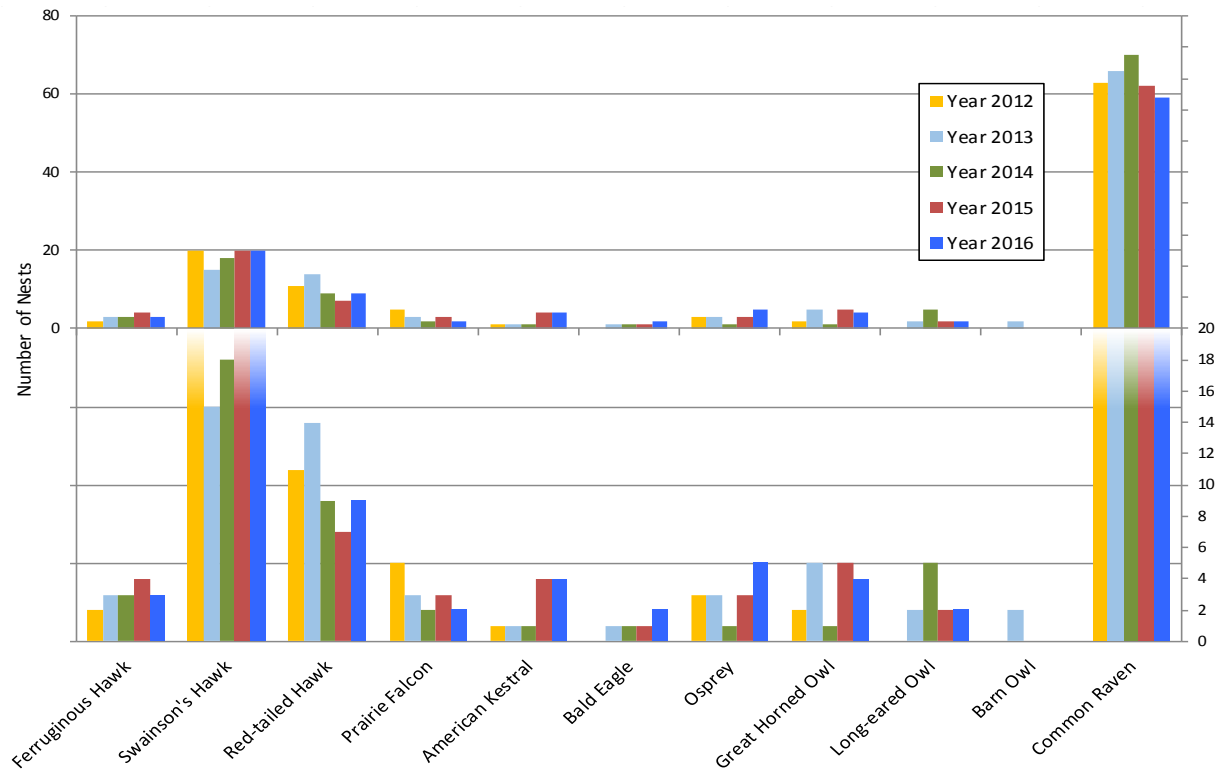


Figure 11-4. Number of Raptor and Raven Nest Sites Located on DOE-RL Managed Lands of the Hanford Site in 2012 through 2016.

Note: The lower graph is a zoomed in look on the small numbered animals.

Ferruginous Hawks occupied three nest sites on the Hanford Site in 2016 that was comparable to the previous 4 years (2 to 4 nests per year). The three nest sites were located on 230-kV transmission towers and were all previously known WDFW nesting territories. A total of six young were produced on the Hanford Site, two at each nest. Preliminary results (final results are expected out in early 2017) from WDFW state-wide Ferruginous Hawk nesting territory surveys indicate that the Hanford Site is an important refuge for the survival of the species in the region.

Twenty Swainson's Hawk nests were observed in 2016, which is within the range of nests found in the past 4 years (15 to 20 nests per year) and on the higher end of the range of nests found in the past 43 years (9 to 23 nests per year). Nine Red-tailed Hawk nests were observed in 2016, which is within the range of nests found in the past 4 years (9 to 14 nests per year) and on the lower end of the range of nests found in the past 43 years (7 to 19 nests per year).

Two Prairie Falcon nests were found in 2016, which was similar to the past 4 years (two to five nests per year). Nests were found on the basalt cliffs on Gable Butte and Umtanum Ridge. The number and location of Prairie Falcon nests documented on the Hanford Site has remained relatively constant over the years.

Four American Kestrel nests were located in 2016; this is likely an underrepresentation of the actual number of nests on the Hanford Site. American Kestrels nest in holes and crevices on trees, cliffs, buildings, and other structures. The Hanford Site provides nesting habitat for the kestrels but their cavity nests are difficult to detect using the methods of this survey. Similarly, Northern Harriers (*Circus*

cyaneus) are ground nesters, and although they likely nest on the Hanford Site their nests are difficult to detect using these methods. No Northern Harrier nests were detected in 2016; however, an adult female harrier was observed showing nest defensive behaviors on May 17 in White Bluffs Slough just south of the 100-H Area.

Osprey nests on the Hanford Site have increased since the building of nest platforms. The highest number of Osprey nests (five) were recorded on the Hanford Site in 2016. This was a marked increase from the one to three nests observed in the past 4 years.

With the exception of Burrowing Owl nests, owl nest numbers have remained relatively constant in the last 43 years. The number of Great Horned Owl and Long-eared Owl nests were within historical ranges. Four Great Horned Owl nests were found in 2016, which is within the range of one to seven nests per year. Two Long-eared Owl nests were located in 2016, which is within the range of one to six nests per year. No Barn Owl (*Tyto alba*) or Short-eared Owl (*Asio flammeus*) nests were detected in the survey area in 2016. Barn Owls are not frequently observed nesting on the Hanford Site and Short-eared Owls rarely nest on the Hanford Site. Only one Burrowing Owl nest was incidentally observed in 2016, but it is assumed that more nests exist on the site. The Burrowing Owl is a Washington State candidate species and a more extensive survey of Burrowing Owl nests will be completed in 2017.

Common Raven nest site numbers decreased on the Hanford Site in 2016. The amount of Common Raven nests observed during nest surveys had been increasing since the 1970s, reaching a peak number of 70 nests in 2014. The 2015 and 2016 surveys showed a drop in the number of raven nests with 62 and 59 nests, respectively. Ravens often flourish in areas where humans have altered the natural environment. The majority of raven nests found on the Hanford Site are on transmission towers or utility poles. Increased numbers of nesting ravens can have detrimental impacts to sensitive species in the area, in particular, ravens prey on eggs and nestlings of other birds nesting on the Hanford Site. A decrease in Common Raven nests may benefit the health and survival of other birds nesting on the Hanford Site. Additional information detailing the 2016 monitoring effort is available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.2.4 Hanford Bird Surveys

JW Wilde

The Hanford Site contains a wide expanse of bird habitat such as basalt outcrops, riparian streams and springs, shrub-steppe on slopes and plains, sand dunes and blowouts, and abandoned fields or disturbed areas. The large size of 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. 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, these actions have caused a decrease in a number of shrub-steppe bird populations; 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 federally listed as threatened or endangered. In addition, the Hanford Site and surrounding area provide refuge for 17 state-listed species, including numerous birds (e.g., ferruginous hawks, state threatened; American white pelican (*Pelecanus erythrorhynchos*), state threatened; and bald eagle, a federal species of concern).

Ecological monitoring staff conduct roadside 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 2016, roadside surveys were performed during breeding season, the months of May and June. Four Hanford routes (Figure 11.5) were surveyed one time each in 2016. The surveys performed during breeding season documented 1,219 individuals similar to the 1,332 and 1,227 individuals counted during the similar period in 2014 and 2015, respectively. A total of 50 unique bird species were documented during the breeding season surveys, similar to the 51 species recorded in 2014 and 52 species recorded in 2015 breeding season surveys.

The Old Fields survey route had the highest species diversity with 42 identified. The Gable Mountain and Horn Rapids to Hanford Townsite survey routes had the lowest species diversity of 13 (Table 11-5). The western meadowlark (*Sturnella neglecta*) was the most abundant species documented along all routes. Surveys documented 218 western meadowlarks, 17.88% of all individuals counted.

The second most abundant species counted, the horned lark (*Eremophila alpestris*), had 210 individuals (17.22%) of birds surveyed. Western meadowlarks were counted on 82 survey points (82%) and the horned lark was documented on 77 survey points (77%). These two species were counted over three times as many survey points as any other species documented in 2016, with the third most survey points being 25 of the common raven.

The Hanford Site participated in performing survey sites as part of the Sagebrush Songbird Survey program led by the Washington Audubon and WDFW. A total of eight sites were surveyed looking for target birds that included Brewer's sparrow (*Spizella breweri*), sagebrush sparrow (*Artemisiospiza nevadensis*), sage thrasher (*Oreoscoptes montanus*), and vesper sparrows (*Pooecetes gramineus*). Each site is surveyed once per month during April, May, and June. Following arrival and a brief quiet period, a 10-minute point count survey was performed. As with the roadside surveys the horned lark and western meadowlark were the most prevalent species identified. Sagebrush sparrow was the most frequent target species with 68 individuals over 24 surveys. The number of sagebrush sparrows identified in surveys on the Hanford Site was above average when compared to surveys across Washington State. All data for these surveys were submitted to the Washington Audubon and WDFW for inclusion into the eBird online database for later evaluation.

The Hanford bird monitoring program documents the presence, abundance, and distribution of species of concern on the Hanford Site. Both the U.S. Fish and Wildlife Service (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 not considered species of concern but for which status and distribution data are documented. 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. Additional information detailing migratory bird monitoring efforts is available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

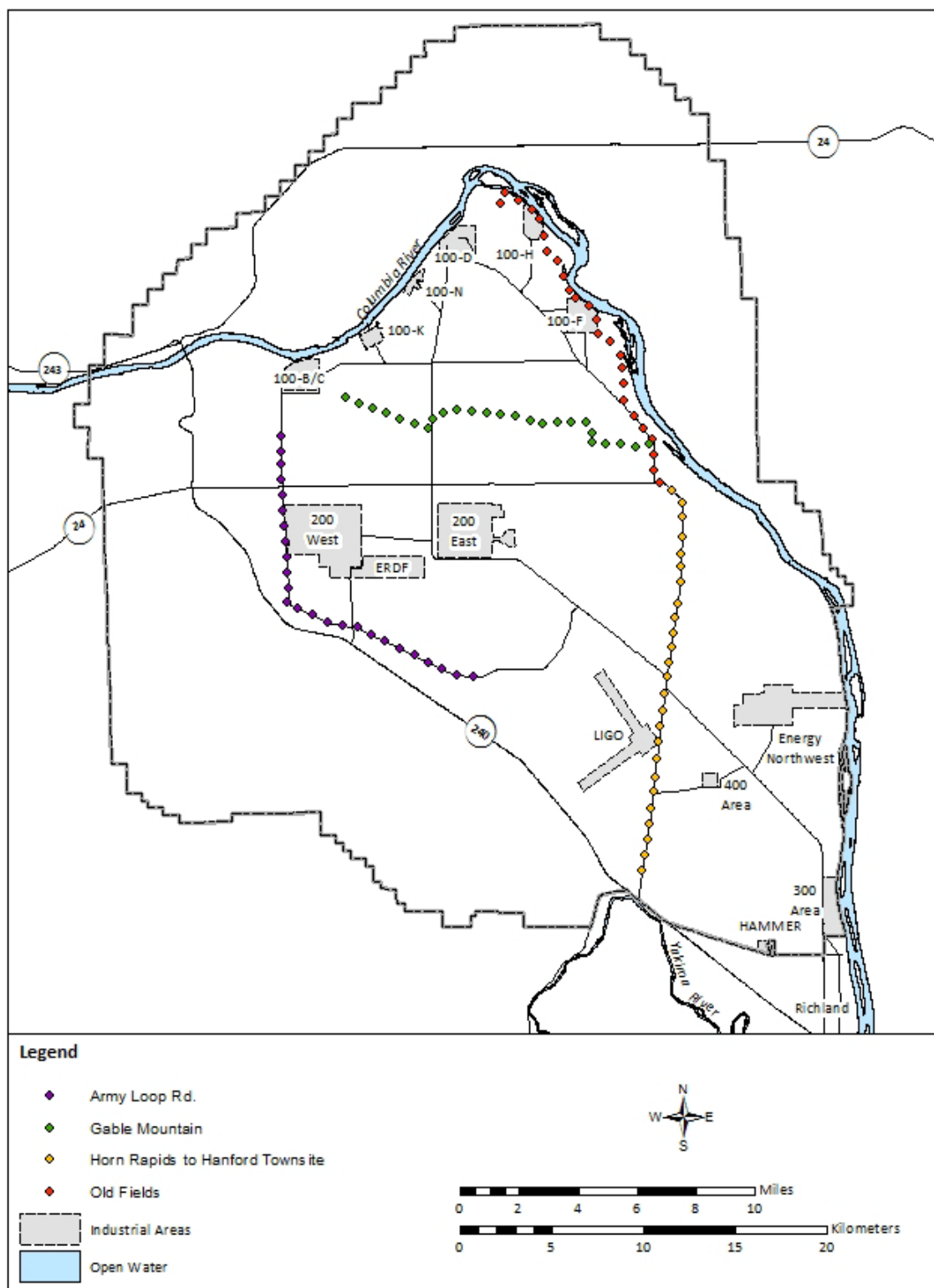


Figure 11-5. Roadside Bird Survey Routes.

Table 11-5. Species Richness and Abundance During 2016 Roadside Bird Surveys.

Route Name	Number of Surveys Performed	Number of Species	Abundance
Army Loop Road	1	16	103
Gable Mountain	1	13	207
Horn Rapids to Townsite	1	13	223
Old Fields	1	42	686
Total	4	50^a	1219
^a Unique species identified			

11.1.2.5 Snake Hibernacula

JE Grzyb

In 2016, a total of 14 previously known snake hibernacula were surveyed between March 29 and 31. The 2016 surveys were a follow-up to the 2012 and 2013 surveys performed. The 2012 and 2013 surveys focused on the identification of potential hibernacula and confirmatory visits to determine if hibernacula were being utilized. The combined 2012 and 2013 surveys increased the known snake hibernacula on the Hanford Site from 3 to 23 (HNF-56087). Surveys relied primarily on the auditory presence of rattlesnakes, which were in or near the hibernacula during emergence. In 2016 total of 29 western rattlesnakes (*C. viridis*) were observed at 6 of these locations. Two additional hibernacula were discovered while surveying on March 30. The McGee Pipe hibernaculum is inside what appears to be an old military installation septic tank. This was discovered by extending a video camera down a pipe that was flush with the ground. At the bottom, five western rattlesnakes were observed. Due to the abrupt contour change of the pipe and the concentration of snakes, the camera could not be pushed further into the hibernaculum, but field staff were confident that more snakes were likely to occupy the structure. On multiple occasions, field staff attempted to use a portable video camera to look into hibernacula that appeared to be unobstructed and accessible. This camera, known as the SeeSnake micro CA-300 by Ridged™, has a small lens with light-emitting diode lights and is secured to a 60-ft (20-m) retractable optic cord. The camera successfully captured both video and still-frame pictures in hibernacula located inside old infrastructures, such as McGee Pipe and North of Asphalt Tanks. The second hibernaculum was discovered while surveying the Vernita Cliffs. While walking a talus slope en route from the Utility Pole Base hibernaculum to Vernita Cliff 3, field staff discovered that the talus slope was itself a den; it was given the name Vernita Cliff 4. As of this 2016 report, there are 27 hibernaculum known on the Hanford Site. As for the distribution of snake hibernacula on the Hanford Site, there appears to be a very prominent cluster of dens along the Vernita Cliffs and Gable Mountain. Figure 11-6 illustrates this distribution.

In all, 50 western rattlesnakes and no other species were observed during the 2016 hibernacula surveys. With the exclusion of the new hibernacula surveyed, the overall total is nearly identical when comparing the 2012 and 2013 surveys to the same hibernacula surveyed in 2016, although 8 of the 14 hibernacula known to be historically active were found vacant. Because snakes typically return to the same hibernaculum annually, this vacancy can possibly be explained by emergence prior to monitoring. Comparing the average temperatures taken at the Hanford weather station # 24 at noon, it was 21.2 °C (70.2 °F) during the 2013 surveys and 19 °C (66.2 °F) in 2016. Western rattlesnakes are generally only active from April through September. The pivotal body temperature for both arousal and dormancy is 10 °C (50 °F), but a body temperature closer to 16 °C (60.8 °F) may be required to stimulate them enough to exit the den (Lueneburger). Both survey years were completed in warmer temperatures, further backing the evidence that emergence had already begun. The snakes detected at hibernacula

entrances during these surveys likely represent only a portion of the total number of western rattlesnakes using each den. In addition, snakes of other species, potentially including sensitive species, often share dens with rattlesnakes; however, due to the lack of rattles, confirmation is much more difficult without the acoustic clues.

By knowing where hibernacula are located on the Hanford Site and by having a better knowledge of when they are occupied, decisions can be made during site cleanup activities to reduce disturbance to both den sites and snakes. If known sites are to be disturbed, corrective actions will include waiting until after full emergence and engaging mitigation efforts.

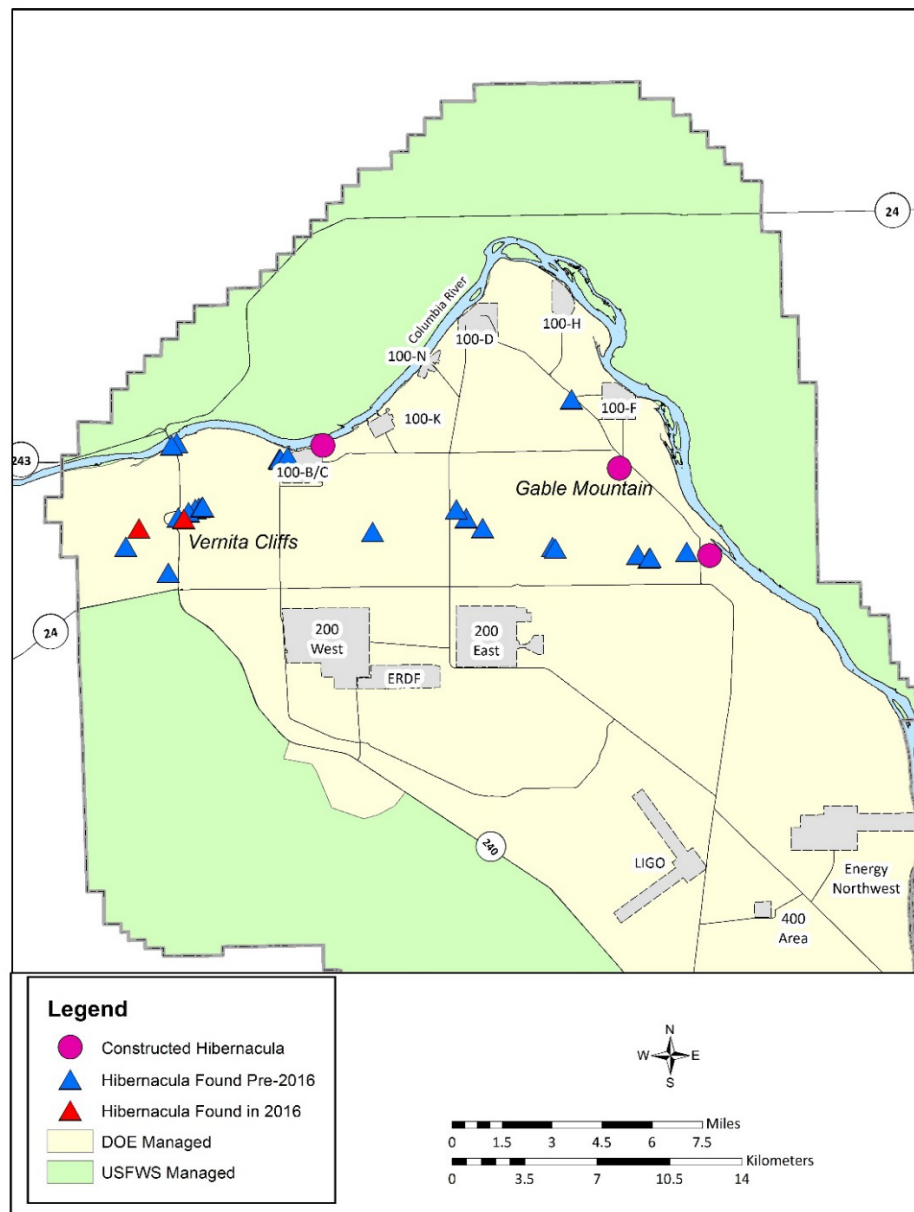


Figure 11-6. All known snake hibernacula on the Hanford Site.

11.1.2.6 Mule Deer. Population characteristics of mule deer on the Hanford Site are monitored using roadside surveys to assess relative population size, and the age and sex ratios of the population. Additional data are collected to assess the frequency of testicular atrophy in males. Surveys were conducted from a vehicle along a specified route. Surveys began within an hour (+ or -) of dawn, and were driven alternatively from north to south and south to north. The route is approximately 37 mi (60 km) long; the northern end of the route is near 100-B/C Area, the southern end is just north of the 300 Area. The survey route is divided into a northern half and a southern half, with the break occurring at the north end of the Hanford Townsite. Tiller and Poston found little overlap in the home ranges of deer occupying these two regions (Tiller and Poston 2000). Each route was travelled in both directions equally. For example, when the northern route was surveyed with the starting point of the Hanford Townsite and stopped at the routes 100-B/C Area endpoint, the paired southern route survey started at the 300 Area and stopped at the Hanford Townsite. To the extent possible, this should have reduced bias that may occur due to time of day and movement from one day to the next.

Two people conducted each survey - the driver and a second observer. Survey speed was 5 to 35 mi/hr (8 to 56 km/hr), with higher speeds on the Hanford primary roads and slower speeds on the secondary and dirt roads. When deer were spotted, the driver stopped and/or pulled off the road. The odometer reading was recorded, a global positioning system position was collected, and the distance and direction from the observation point were collected with a laser range finder and compass.

Four surveys were conducted during the post-hunting period, between December 16, 2015, and January 26, 2016. There were 330 combined deer observations over four repeated surveys. It is likely that the surveys included multiple observations of some of the same animals. Individual animals were identified according to sex and age class (fawn or adult). For male deer, the presence of misshapen, velvet-covered antlers was used as an indicator of testicular atrophy.

Changes in mule deer population size and health can be monitored by examining trends in the ratios of fawns to does over time. In 2016, the fawn-to-doe mean estimate was 44.4 fawns per 100 does for the northern region and 37.2 for the southern region. The ratio in the northern region was slightly higher and the southern slightly lower than the last measurement in 2013. The 10-year average has remained relatively steady, ranging between 31.2 and 36.2 fawns per 100 does in the northern region and between 28.6 and 34.0 in the southern region. This relatively steady trend in fawn-to-doe ratios indicates a stable mule deer population. Hanford Site fawn-to-doe ratios for all survey years (1994 through 2010) are weighted averages, using the total number of fawns and does seen per survey as the weighting factor.

Testicular atrophy and sterility have been observed in some male mule deer on the Hanford Site ([PNNL-11518, Investigation of Anatomical Anomalies in Hanford Site Mule Deer](#)). Extensive investigation during the 1990s found no relationships between the presence of testicular atrophy and numerous factors including contaminant levels, diet, disease, or natural conditions such as aging or genetics (PNNL-11518). Affected males are easily detected in the field because of their abnormal, misshapen, and velvet-covered antlers. The observed frequency of misshapen antlers in mule deer has ranged from a high of 17% in the southern region in 1998 to a low of 0% in both regions in 2003. The 10-year averages in the northern region have been relatively steady at between 2.5% and 4.5%, while the 10-year average in the southern region has been generally declining from around 6% to about 3%. In 2016, observations of affected male deer were higher than last observed in the northern region and lower in the southern;

the observed frequency of antler abnormality was 4.5% in the northern region and 4.7% in the southern region. These frequencies should be interpreted with caution because the small sample sizes may not fully reflect population conditions. In general, the data indicate the health of the male mule deer on the Hanford Site has not changed substantially over the last decade.

11.1.2.7 Long-billed Curlews

JJ Nugent

The Long-billed Curlew (*Numenius americanus*) is the largest North American shorebird and is closely related to the snipe, sandpipers, and yellowlegs. Long-billed Curlews breed in short-grass and mixed-grass habitats of the Great Plains, Great Basin, and intermontane valleys of western United States and southwestern Canada. (Dugger and Dugger 2002). The Long-billed Curlew is a Washington State monitored species (WDFW 2017) and is also provided protection under the MBTA. In the late 1970s, Allen (1980) found that the Hanford Site, including the portions now managed by USFWS, supported a Long-billed Curlew population of approximately 300 birds during the breeding season. She found approximately 100 birds on the Hanford Site west of the Columbia River with roughly 60 paired, 20 unpaired but territorial males, and 20 unattached individuals. In 2016, monitoring was conducted to determine if the historic areas designated as Long-billed Curlew nesting areas on the Hanford Site (Allen 1980) are still in use and to investigate other areas more recently identified by monitoring staff as potential nesting areas. This survey will provide land managers with specific nesting areas so that these areas can be avoided and disturbances minimized during the nesting season. Information collected during this survey will initiate the development of a more current understanding of nesting Long-billed Curlews on the DOE-RL managed lands of the Hanford Site.

Survey methods were loosely based on techniques used by Allen (1980). A total of 100 roadside point counts along 4 routes and 9 standalone point counts were established. Designated routes and standalone point counts were placed in previously known (Allen 1980) and potentially suitable Long-billed Curlew nesting areas. Areas of Sandberg's bluegrass and cheatgrass greater than 123.6 ac (50 ha) in size were considered potentially suitable Long-billed Curlew nesting areas. Roadside point counts were spaced every ~0.5 mi (800 m) along the four routes. Standalone point counts were placed in areas not covered by the four survey routes. All point counts were performed in the exact same manner. Surveyors navigated to each survey point using a global positioning system, 32.8 to 164 ft (walked 10 to 50 m) off the road, and began the survey. The survey at each point began with a 3-minute passive observation interval followed by a 2 ½-minute call-broadcast interval then followed with a 4-minute passive observation interval. During each interval of the survey, the observer listened and scanned (with and without the aid of binoculars) the surrounding area for Long-billed Curlews. The call-broadcast section of the survey was conducted with a cellular phone speaker and included 30 seconds of Long-billed Curlew vocalization, 30 seconds of silence, 30 seconds of Long-billed Curlew vocalization, 30 seconds silence, and 30 seconds of Long-billed Curlew vocalization.

A total of 36 Long-billed Curlews were detected including 35 at point counts and 1 between point counts (Figure 11-7). Ten point counts along Route 1 could not be surveyed due to access restrictions. Eight of the 10 point counts not surveyed were in the Hanford Patrol Academy firing range, which was in use during our survey window. The other two point counts not surveyed were situated in an active Bald Eagle (*Haliaeetus leucocephalus*) nest buffer protection zone near Energy Northwest.

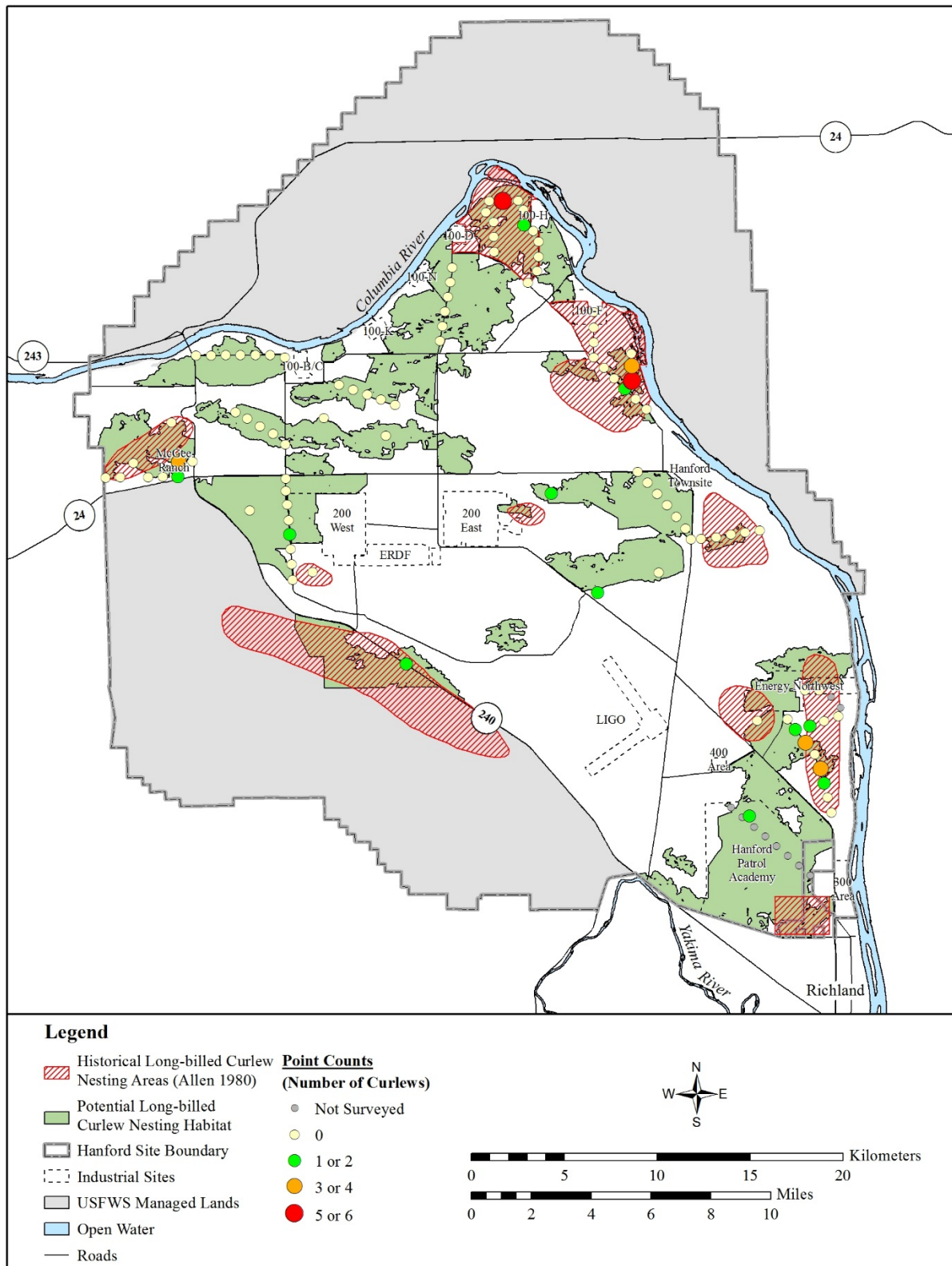


Figure 11-7. Long-billed Curlew Point Count Surveys Conducted on DOE Managed Lands of the Hanford Site in 2016.

Long-billed Curlews were detected mainly in four areas (near Energy Northwest, 100-F Area, 100-H/100-D Area, and McGee Ranch [Figure 11-7]). In addition, small numbers of Curlews were observed at scattered locations throughout the Hanford Site, including one at the Highway 240 Area, two northeast of 200-East, one southeast of 200-East, and one located along Army Loop Road. One Curlew was incidentally observed during an unrelated ecological review within the firing range of the Hanford Patrol Academy on June 7, 2016. Long-billed Curlews were observed in many of the same areas that were documented as Curlew habitat by Allen (1980) in the late 1970s. It is important to note that the 300 Area site (this site is west of Route 4 South and is not technically part of the 300 Area) – the highest density Curlew area previously described on the Hanford Site (Allen 1980) – was not surveyed in this study because it is currently being transferred out of DOE’s ownership. Additional information detailing the 2016 monitoring effort is available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

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 2017](#)) and WDFW ([WDFW 2017](#)) maintain state lists.

The purpose of the *Endangered Species Act of 1973* is 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 of 1973*. The National Oceanic and Atmospheric Administration’s National Marine Fisheries Service (NOAA 2015) 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 11-6 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.

Table 11-6. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (3 Pages)

Species	Status ^a	
	Federal	State
Plants		
Annual sandwort (<i>Minuartia pusilla</i>)		Sensitive
Awed halfchaff sedge (<i>Lipocarpa aristulata</i>)		Threatened
Beaked spike-rush (<i>Eleocharis rostellata</i>)		Sensitive

Table 11-6. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (3 Pages)

Species	Status ^a	
	Federal	State
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 dodder (<i>Cuscuta denticulata</i>)		Threatened
Dwarf evening primrose (<i>Eremothera pygmaea</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 leptomeria</i>)		Threatened
Hairy bugseed (<i>Corispermum villosum</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
Miner's candle (<i>Cryptantha scoparia</i>)		Sensitive
Piper's daisy (<i>Erigeron piperianus</i>)		Sensitive
Rosy pussypaws (<i>Calyptridium rosea</i>)		Threatened
Small-flower evening-primrose (<i>Eremothera minor</i>)		Sensitive
Snake River cryptantha (<i>Cryptantha spiculifera</i>)		Sensitive
Snowball cactus (<i>Pediocactus nigrispinus</i>)		Sensitive
Suksdorf's monkey flower (<i>Erythranthe suksdorfii</i>)		Sensitive
Thompson's sandwort (<i>Eremogone franklinii</i> var. <i>thompsonii</i>)		Sensitive
Tufted evening-primrose (<i>Oenothera cespitosa</i> ssp. <i>cespitosa</i>)		Sensitive
Umtanum desert buckwheat (<i>Eriogonum codium</i>)	Threatened	Endangered
White Bluffs bladderpod (<i>Physaria douglasii</i> ssp. <i>tuplashensis</i>)	Threatened	Threatened
White eatonella (<i>Eatonella nivea</i>)		Threatened
Mollusks		
California floater (<i>Anodonta californiensis</i>)		Candidate
Columbia pebblesnail (<i>Fluminicola fuscus</i>)		Candidate
Shortface lanx (<i>Fisherola nuttalli</i>)		Candidate
Insects		
Columbia clubtail (dragonfly; <i>Gomphus lynnae</i>)		Candidate
Columbia River tiger beetle (<i>Cicindela columbica</i>) ^b		Candidate
Silver-bordered fritillary (<i>Boloria selene</i>)		Candidate
Fish		
Bull trout (mid-Columbia River; <i>Salvelinus confluentus</i>) ^c	Threatened	Candidate
Chinook salmon (upper Columbia spring-run; <i>Oncorhynchus tshawytscha</i>)	Endangered	Candidate
Leopard dace (<i>Rhinichthys falcatus</i>) ^c		Candidate
Mountain sucker (<i>Catostomus platyrhynchus</i>) ^c		Candidate
River lamprey (<i>Lampetra ayresii</i>) ^c	Species of concern	Candidate
Steelhead (upper Columbia River; <i>Oncorhynchus mykiss</i>)	Threatened	Candidate
Birds		
American white pelican (<i>Pelecanus erythrorhynchos</i>)		Threatened
Bald eagle (<i>Haliaeetus leucocephalus</i>)	Species of concern	None
Burrowing owl (<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
Flammulated owl (<i>Otus flammeolus</i>) ^c		Candidate
Golden eagle (<i>Aquila chrysaetos</i>)		Candidate
Greater sage grouse (<i>Centrocercus urophasianus</i>)		Threatened
Lewis's woodpecker (<i>Melanerpes lewis</i>) ^c		Candidate
Loggerhead shrike (<i>Lanius ludovicianus</i>)		Candidate

Table 11-6. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (3 Pages)

Species	Status ^a	
	Federal	State
Northern goshawk (<i>Accipiter gentilis</i>) ^c		Candidate
Peregrine falcon (<i>Falco peregrinus</i>)	Species of concern	None
Sagebrush sparrow (<i>Artemisiospiza nevadensis</i>)		Candidate
Sage thrasher (<i>Oreoscoptes montanus</i>)		Candidate
Sandhill crane (<i>Grus canadensis</i>)		Endangered
Western grebe (<i>Aechmophorus occidentalis</i>)		Candidate
Amphibians and Reptiles		
Sagebrush lizard (<i>Sceloporus graciosus</i>)		Candidate
Striped whipsnake (<i>Masticophis taeniatus</i>)		Candidate
Western toad (<i>Bufo boreas</i>)		Candidate
Mammals		
Black-tailed jackrabbit (<i>Lepus californicus</i>)		Candidate
Merriam's shrew (<i>Sorex merriami</i>)		Candidate
Townsend's ground squirrel (<i>Spermophilus townsendii</i>)		Candidate
Washington ground squirrel (<i>Urocitellus washingtoni</i>) ^c	Candidate	Candidate
White-tailed jackrabbit (<i>Lepus townsendii</i>)		Candidate

^a 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 believed to qualify for threatened or endangered species status but for which listing proposals have not been prepared; Sensitive=Taxa vulnerable or declining that could become endangered or threatened without active management or removal of threats; Species of concern=Not currently listed or candidates under the *Endangered Species Act of 1973* but of conservation concern within specific U.S. Fish and Wildlife Service regions.

^b Probable but not observed on the Hanford Site.

^c Reported but seldom observed on the Hanford Site.

Two federally listed fish species, spring-run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*), are known to occur regularly in the Hanford Reach of the Columbia River. 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 under the federal *Endangered Species Act of 1973* in April 2013; the rule was reaffirmed and made effective later that year (78 FR 23984). No other plants or animals known to occur on the Hanford Site are currently on the federal list of endangered and threatened species (50 CFR 17); however, one mammal species (Washington ground squirrel) is currently a candidate for federal listing. 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 31 state-level sensitive and candidate species of animals and 17 sensitive plant species occurring or potentially occurring on the Hanford Site.

Washington State officials maintain additional lower level lists of species, including a monitor list for animals (WDFW 2017) and review and watch lists for plants (WNHP 2017). Species on the state monitor and review lists are not considered species of concern but are monitored for status and distribution (Table 11-7). These species are managed, as needed, by the state to prevent them from becoming endangered, threatened, or sensitive, and 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 11-7), along with 10 watch or review list plant species (Table 11-8).

Table 11-7. Washington State Monitored Animal Species.

Species	Species
Birds	Insects
Arctic tern (<i>Sterna paradisaea</i>) ^a	Juba skipper (<i>Hesperia juba</i>)
Ash-throated flycatcher (<i>Myiarchus cinerascens</i>) ^a	Nevada skipper (<i>Hesperia nevada</i>)
Black tern (<i>Chlidonias niger</i>) ^a	Pasco pearl crescent (<i>Phyciodes tharos pascoensis</i>)
Black-crowned night-heron (<i>Nycticorax nycticorax</i>)	Persius' duskywing (<i>Erynnis persius</i>)
Black-necked stilt (<i>Himantopus mexicanus</i>)	Purplish copper (<i>Lycaena helloides</i>)
Bobolink (<i>Dolichonyx oryzivorus</i>) ^a	Ruddy copper (<i>Lycaena rubidus perkinsorum</i>)
Caspian tern (<i>Sterna caspia</i>)	Viceroy (<i>Limenitis archippus lahontani</i>)
Forster's tern (<i>Sterna forsteri</i>)	Amphibians and Reptiles
Grasshopper sparrow (<i>Ammodramus savannarum</i>)	Night snake (<i>Hypsiglena chlorophaea</i>)
Gray flycatcher (<i>Empidonax wrightii</i>)	Racer (<i>Coluber constrictor</i>)
Great blue heron (<i>Ardea herodias</i>)	Short-horned lizard (<i>Phrynosoma douglasii</i>)
Great egret (<i>Ardea alba</i>)	Tiger salamander (<i>Ambystoma tigrinum</i>)
Gyr Falcon (<i>Falco rusticolus</i>) ^a	Woodhouse's toad (<i>Anaxyrus woodhousii</i>)
Horned grebe (<i>Podiceps auritus</i>)	Mollusks
Lesser goldfinch (<i>Spinus psaltria</i>)	Oregon floater (<i>Anodonta oregonensis</i>)
Long-billed curlew (<i>Numenius americanus</i>)	Western floater (<i>Anodonta kennerlyi</i>)
Osprey (<i>Pandion haliaetus</i>)	Western pearlshell (<i>Margaritifera falcata</i>)
Prairie falcon (<i>Falco mexicanus</i>)	Winged floater (<i>Anodonta nuttalliana</i>)
Red-necked grebe (<i>Podiceps grisegena</i>) ^a	Mammals
Snowy owl (<i>Nyctea scandiaca</i>)	American badger (<i>Taxidea taxus</i>)
Swainson's hawk (<i>Buteo swainsoni</i>)	Canyon bat (<i>Parastrellus hesperus</i>)
Turkey vulture (<i>Cathartes aura</i>) ^a	Long-legged myotis (<i>Myotis volans</i>) ^b
Western bluebird (<i>Sialia mexicana</i>)	Northern grasshopper mouse (<i>Onychomys leucogaster</i>)
Fish	Pallid bat (<i>Antrozous pallidus</i>)
Pacific lamprey (<i>Entosphenus tridentatus</i>) ^b	Sagebrush vole (<i>Lemmys curtatus</i>)
Paiute sculpin (<i>Cottus beldingi</i>)	Western small-footed myotis (<i>Myotis ciliolabrum</i>) [†]
Reticulate sculpin (<i>Cottus perplexus</i>)	
Sand roller (<i>Percopsis transmontana</i>)	
^a Reported but seldom observed on the Hanford Site.	
^b Federal species of concern.	

Table 11-8. Hanford Site Washington State Review List Plant Species.

Species	State Listing ^a
Beardless wildrye (<i>Leymus triticoides</i>)	Review Group 1
Dryspike Sedge (<i>Carex siccata</i>)	Review Group 1
Flat-top broomrape (<i>Orobancha corymbosa</i>)	Review Group 1
Rosette crinklemat (<i>Tiquilia nuttallii</i>)	Review Group 1
Shy gilly-flower (<i>Gilia inconspicua</i>)	Review Group 1
Smooth cliffbrake (<i>Pellaea glabella</i> var. <i>simplex</i>)	Review Group 1t
Smooth willowherb (<i>Epilobium campestre</i>)	Review Group 1
Vanilla grass (<i>Anthoxanthum hirtum</i>)	Review Group 1
Western false dragonhead (<i>Physostegia parviflora</i>)	Review Group 1
Yellow wildrye (<i>Leymus flavescens</i>)	Review Group 1

^a 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

CD Currie, AP Fergusson, KM Mendez

Cultural and historic resources protection on the Hanford Site is conducted under the direction of the DOE-RL Cultural and Historic Resources Program to ensure site compliance with federal cultural resources laws and regulations (Section 2.5). Program activities in 2016 included the following:

- Performed cultural resources reviews for federal undertakings conducted at the Hanford Site in accordance with [National Historic Preservation Act of 1966](#) (NHPA) Section 106 (54 USC 300101) and CERCLA with NHPA as an ARAR.
- 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.

DOE-RL's Cultural and Historic Resources Program personnel oversee all cultural resource activities at the Hanford Site. Project-specific NHPA Section 106 compliance workscope in 2016 was performed by staff archaeologists from MSA and Washington Closure Hanford (WCH).

The DOE-RL Cultural and Historic Resources Program also schedules monthly meetings with archaeological staff from Hanford Site contractors (MSA and WCH) to discuss and resolve issues relating to Cultural Resources Management (e.g., survey procedures, site testing, site evaluation, consultations with external parties) with the objective of establishing and maintaining consistency among contractors.

11.3.1 Cultural Resources Reviews

Pursuant to the NHPA Section 106, DOE-RL conducts cultural resources reviews of federal undertakings at the Hanford Site. The Section 106 regulations are also addressed as applicable or relevant and appropriate requirements under the CERCLA Section 121(d), requiring remedial actions to identify and take into account the effects of activities on historic properties included on or eligible for inclusion in the National Register of Historic Places (NRHP). NHPA Section 106 cultural resources 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.

In 2016, Hanford Site archaeologists completed 97 NHPA Section 106 cultural resources reviews that included the following:

- Twenty-seven undertakings 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 necessary³
 - Twelve were identified as No Historic Properties Affected.
 - Nine were determined to have No Adverse Effects to historic properties.
 - Six were identified as having Adverse Effects requiring 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.
- Thirty-five projects affected historic buildings and were determined exempt by Hanford Site archaeologists after meeting the DOE-approved historic buildings programmatic agreement (DOE/RL-96-77) exemption criteria following an initial review.
- Twenty-five projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews (Previously Reviewed Project Analyses Reviewed Project Analysis).
- Ten projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration (Post Reviews) in accordance with Section 5.1.1 of the [Hanford Cultural Resources Management Plan](#) (DOE/RL-98-10).

A total of 5,950.29 ac (2,407.99 ha) of new ground was surveyed for cultural resources from NHPA Section 106 project-specific surveys. In addition, some undertakings required NRHP (36 CFR 60) eligibility evaluations. Most projects cleared under these expedited reviews occurred in the 200 Areas of the Hanford Site (Figure 11-8).

³This number does not reflect all full cultural resources reviews initiated in 2016. Additional reviews were initiated in 2016 but completed in 2017 and are not included in this report.

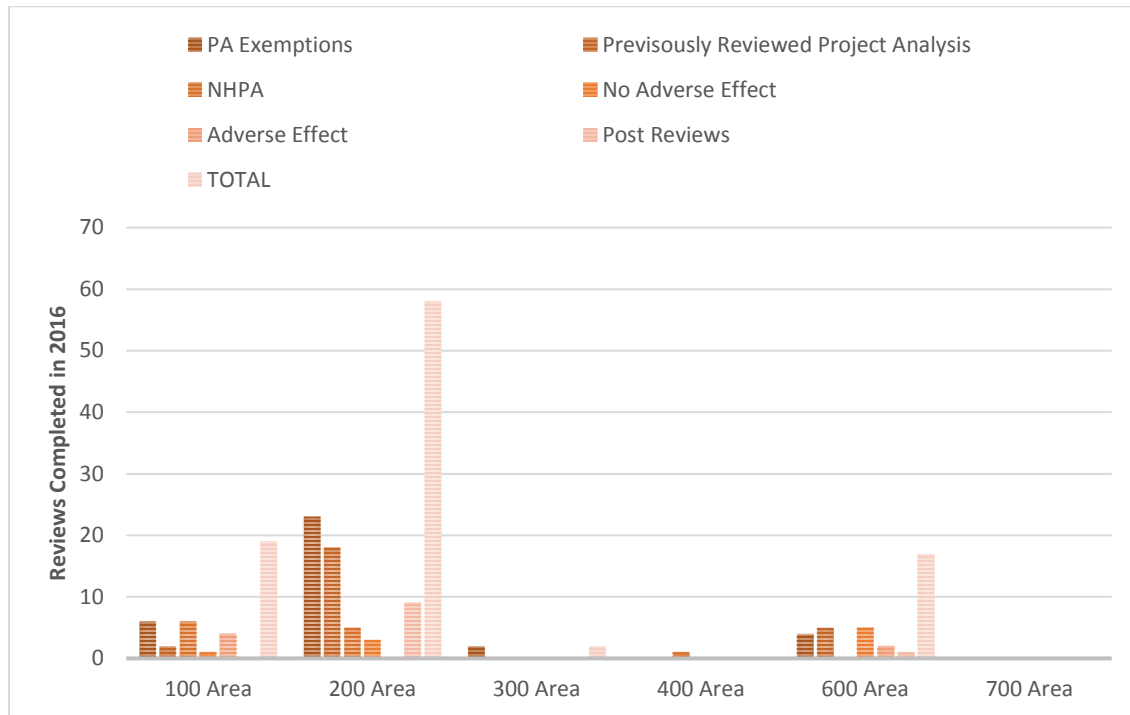


Figure 11-8. Hanford Site National Historic Preservation Act Section 106 Reviews by Area.

11.3.2 Cultural Resources Protections and Section 110 Activities

To ensure protection of cultural and historic resources located on the Hanford Site, monitoring activities are conducted to comply with NHPA Section 110 (54 USC 300101) and the [Archaeological Resources Protection Act](#) (16 USC 470aa-mm):

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 weathering and erosion effects 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 2016, 11 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 5-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 2016, approximately 125 ac (51 ha) of new ground was surveyed for cultural resources under the Section 110 program. No archaeological sites or isolates were recorded during this survey effort. Also in 2016, 221 new archaeological sites were recorded and 107 new isolated finds were located (Table 11-9). National Register evaluations have not been completed on the newly discovered sites. Archaeological site forms for three previously recorded archaeological sites were updated, of which one was determined ineligible in 2016, one was previously determined ineligible, and one was previously determined eligible for the National Register. Eleven archaeological sites recorded in previous years were determined not eligible. No Historic Property Inventory Forms (HPIF) were completed during the reporting period for components of Hanford's built environment.

Table 11-9. Sites and Isolates Recorded or Updated.

2016	Eligible	Not Eligible	Unevaluated	Total
Site updates	1	2	0	3
New sites	0	0	221	221
New isolates	0	0	107	107
Historic Property Inventory Form	0	0	0	0
Total	1	2	328	331

11.3.2.2 Data and Artifact Collections Management. In 2014, the Cultural Resources Program transitioned to a paperless record keeping system, a process that continued in 2016. 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 2016, 169 new projects were opened, with pertinent information entered as acquired into the Section 106 database, and 158⁴ 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 DOE-approved users. As part of ongoing database management in 2016, a total of 27 polygons delineating completed

⁴This number is larger than the number of projects opened because projects from previous years were closed during 2016.

archaeological surveys were added to the Hanford Site Survey Master shapefiles (map file) and 93 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 93 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 (WSU-TC) 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 2016.

11.3.3 Cultural Resources Consultations

DOE conducts formal consultations with the Washington State Historic Preservation Officer within the DAHP, Native American Tribes, and other interested parties for cultural resources reviews to comply with NHPA Section 106 and NEPA (Section 2.1.4). DOE-RL consulted with the Washington State Historic Preservation Officer and Native American Tribes on all 27 projects that required a full review because of their potential to affect cultural resources within the project area.

DOE Cultural Resources Program staff members held 11 meetings in 2016 with Tribal Cultural Resources staff members from the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of Yakama Nation, and Wanapum. Discussions focused on the cultural resources reviews completed and initiated in 2016, proposed undertakings within traditional cultural property boundaries and view sheds, and approaches to protecting threatened archaeological sites and places containing Native American human remains.

11.4 Collection Management and Curation

MC Petrich-Guy and J Gardener-Andrews

DOE's National Park Program is responsible for management of the artifacts from Hanford's Manhattan Project and Cold War eras collected in compliance with DOE/RL-96-77. This programmatic agreement directs DOE-RL to identify and preserve any artifacts that may have value as interpretive or educational exhibits within national, state, or local museums. To further public access and education goals, DOE and MSA have formed a unique partnership with Washington State University's Hanford History Project (HHP) for management and curation of this collection. The partnership has provided public access to the collection for the first time since 2014 as well as research opportunities and use in academic programs for undergraduates. During 2016, five artifacts were evaluated for inclusion and picked up from Hanford Site facilities and delivered to the Hanford History Project (HHP) repository at WSU-TC, leaving 26 (3.5%) of the 743 tagged artifacts scheduled for collection between 2016 and 2048.

The HHP provides professional curatorial and archival services for the management, conservation, and public access of the Hanford Collection, which consists of artifacts and multimedia relating to the

Manhattan Project and Cold War Eras (Figure 11-9). In addition to public outreach and education, WSU-TC provides a repository for the collection that allows DOE to meet the requirements of [36 CFR 79, "Curation of Federally-Owned and Administered Archaeological Collections,"](#) including protecting these resources from theft, fire, breakage, or deterioration.

The transition of the Hanford Collection to the WSU-TC facility began in July 2015 and continued through September 2016. During 2016, the remaining 60% of the Collection was moved from the artifact staging facility on the Hanford Site to either the WSU-TC curation facility in the Innovation Center Building or to a staging room for screening prior to transition. Prior to being moved offsite, Collection items were screened for residual radioactivity above allowable limits (DOE O 458.1) and controlled or classified materials to determine whether items could be released to the public. The remaining multimedia to be transitioned offsite has been screened for residual radioactivity and is scheduled for screening for controlled or classified materials during 2017.



Figure 11-9. Archives Storage Area at WSU-TC.

During 2016, the HHP processed and housed artifacts, multimedia were moved offsite, and public access was facilitated to the Hanford Collection. Artifacts collected since 2011 were indexed and added to the collections management database, Re:Discovery Proficio; of these, 246 (55%) have been fully catalogued. Of the 126 linear feet of multimedia within the Collection, 88 linear feet (70%) was rehoused and catalogued. In coordination with DOE's National Park Program, the HHP worked with the public as well as regional and national institutions to implement access to the collection for education and research. As part of public education and outreach efforts, the HHP received and worked with 18 student interns, volunteers, and research/usage requestors; as well as participated in 6 outreach events that reached hundreds of members of the public in the Tri-Cities. When the Collection was moved offsite, the HHP held a month long exhibit, *Preserving the Past*, on the WSU-TC campus. Additional artifacts, multimedia, and information to several museums (e.g., Bainbridge Island Museum; High Desert Museum in Bend, Oregon; Wanapum Heritage Center; Moses Lake Museum; Washington State Historical Society; The Art Center at Washington State University, Tri-Cities) as well as used for interpretation at the Manhattan Project National Historical Park's B Reactor (Figure 11-10). Cataloguing and rehousing of Hanford Collection artifacts and multimedia will also continue during 2017, as will public education and outreach.



Figure 11-10. Preserving the Past Exhibit at the Washington State University, Tri Cities Campus.

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12.0 Quality Assurance

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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 U.S. Department of Energy (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 (PSRP) managed by Mission Support Alliance. The Environmental Surveillance program includes environmental surveillance and monitoring across multiple media types both on and off the Hanford Site. The program conducts multimedia 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 2016 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 by CH2M Hill Plateau Remediation Company in the [Hanford Site Groundwater Monitoring Report for 2016](#) (DOE/RL-2016-67) and are not discussed in this section. However, details of the groundwater monitoring program can be found in Section 8.

Quality assurances and QCs 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 contracted laboratories, which are also required to meet these plan specifications. To ensure the highest quality data are obtained, the 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 that satisfies 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

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

-
- EPA Requirements for Quality Assurance Project Plans (EPA 2001b)
 - 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.

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 sitewide 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 their tasks 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
- Ensure that employee training records are current and complete.

12.2 Quality Control Samples

Several types of QC samples are collected during Environmental Surveillance sampling events. The QC procedures and associated QC samples ensure the highest quality data possible. These procedures are followed in the field and laboratories.

Several types of field QC samples are collected to ensure the validity of the sampling procedures and the resulting sample data. The potential cross-contamination between samples during the sampling process is evaluated using trip blanks and equipment blanks. Additionally, field duplicates are collected to evaluate sample matrix heterogeneity and sample collection reproducibility.

Laboratory QC samples are also used to ensure the validity of the resulting data. The potential for cross-contamination of samples in the laboratory is evaluated using method blanks. In order to evaluate the precision and accuracy of laboratory data several types of QC samples are used including laboratory duplicates, 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% (1 in 20 samples) is used for environmental surveillance activities when feasible.

Table 12-1. Field and Laboratory Quality Control Sample Types, Characteristics, and Frequency.

Sample Type	Primary Characteristics Evaluated	Frequency
Field QC Samples		
Trip blank (TB)	Volatile organic compound (VOC) cross-contamination during transportation	1 per field trip, if VOCs are collected
Equipment blank (EB)	Cross-contamination from non-dedicated equipment	1 per sampling method type per year for selected analytes
Field Duplicate	Sample matrix heterogeneity and sample collection reproducibility	1 per 20 samples, where feasible
Laboratory QC Samples		
Method blank	Laboratory contamination	As defined in the laboratory contract or QA plan, and/or analysis procedures
Laboratory duplicates	Laboratory reproducibility	
Matrix spike	Matrix effect and laboratory accuracy	
Matrix spike duplicate	Laboratory reproducibility/accuracy	

Blanks. A sample of the carrying agent (gas, liquid, or solid) analyzed using the same analytical process and associated procedures as the samples they are associated with.

Field Duplicate Samples. Two samples collected at the same location at roughly the same time. The parent and duplicate samples are each uniquely labeled and used to evaluate the homogeneity of the sample matrix and the reproducibility of the collection procedures.

Laboratory Duplicate Sample. A single field sample aliquoted into two laboratory samples for individual extraction and analysis. Laboratory duplicates are a measure of variation within a field sample and the reproducibility of the laboratory procedures.

Matrix Spikes/Matrix Spike Duplicates. Prepared using field samples to which a calibrated amount of the analyte(s) of interest is added. Matrix spikes are used to evaluate the accuracy, reproducibility, and recovery efficiency of an analytical method.

12.3 Sample Collection Quality Assurance and Quality Control

Trained personnel collected environmental samples for air, surfacewater, biota (wildlife and food/farm products), soil, vegetation, and sediment in accordance with PSRP-approved schedules, desk instructions, and procedures. Established sampling locations were accurately identified with visible postings or plotted global positioning system readings and documented to ensure data continuity. In 2016, collected environmental samples were submitted to General Engineering Laboratories, LLC (GEL) and Test America Richland Laboratories (TARL; 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
TestAmerica Richland Laboratory	X	X		X
General Engineering Laboratories, LLC	X	X	X	X

Assessments of field sampling activities are routinely performed and documented by media task leads. In 2016, field duplicate samples were collected and analyzed for air, soil, Columbia River water, natural vegetation, milk, wine, wildlife, irrigation water, sediment, and seep samples. The accepted method of evaluating the precision or reproducibility of duplicate samples is the calculation of the relative percent difference (RPD). RPDs are calculated for individual analytes. The generalized formula for calculating RPDs is as follows:

$$RPD = \left(\frac{|S - D|}{\frac{(S + D)}{2}} \right) \times 100$$

Where a measure of precision of the measurement of a sample (S) and its duplicate (D).

For the 2016 Environmental Surveillance effort, field duplicate samples were collected at the locations indicated in Table 12-3.

Table 12-3. 2016 Field Duplicate Samples.

Media	Location	Number of Duplicate Sample Pairs
Air	Various	54
Soil	Various	5
Natural Vegetation	Various	3
Columbia River Water	Richland Pump house/Priest Rapids Dam	9
Columbia River Water Transects	Various	14
Columbia River Sediment	100-D-Spring	1
Seeps	100-F Springs	7
Wildlife – Bass/Carp	Various	4
Wildlife – Upland Game	100 Area	2
Leafy vegetables	East Wahluke Area	1
Potatoes	Riverview	1
Milk	Sagemoor Composite	1
Wine	Columbia Basin	2

To be considered acceptable (within the control limits), results for sample duplicate pairs must be non-detected. For detected results, the RPD of the duplicate sample pair must be less than 30%. Duplicate results for 2016 are shown in Table 12-4.

Table 12-4. 2016 Field Duplicate Sample Results. (6 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
Air	Alpha (gross)	43 of 54	79
	Beta (gross)	49 of 54	90
	Americium-241	4 of 4	100
	Antimony-125	4 of 4	100
	Colbalt-60	4 of 4	100
	Cesium-134	4 of 4	100
	Cesium-137	4 of 4	100
	Europium-152	4 of 4	100
	Europium-154	4 of 4	100
	Europium-155	4 of 4	100
	Hydrogen-3 (tritium)	14 of 14	100
	Plutonium-238	4 of 4	100
	Plutonium-239/-240	4 of 4	100
	Potassium-40	4 of 4	100
	Ruthenium-106	4 of 4	100
	Strontium-90	4 of 4	100
	Uranium-234	4 of 4	100
	Uranium-235	4 of 4	100
	Uranium-238	4 of 4	100
Soil	Antimony-125	5 of 5	100
	Cesium-134	5 of 5	100
	Cesium-137	5 of 5	100
	Cobalt-60	5 of 5	100
	Europium-152	5 of 5	100
	Europium-154	5 of 5	100
	Europium-155	5 of 5	100
	Plutonium-238	5 of 5	100
	Plutonium-239/-240	5 of 5	100
	Potassium-40	5 of 5	100
	Ruthenium-106	5 of 5	100
	Strontium-90	5 of 5	100
	Uranium-234	5 of 5	100
	Uranium-235	5 of 5	100
	Uranium-238	5 of 5	100
Natural Vegetation	Antimony-125	3 of 3	100
	Cesium-134	3 of 3	100
	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	3 of 3	100
	Plutonium-238	3 of 3	100
	Plutonium-239/-240	2 of 3	67
	Potassium-40	3 of 3	100
	Ruthenium-106	3 of 3	100
	Strontium-90	3 of 3	100
	Uranium-234	3 of 3	100
	Uranium-235	3 of 3	100

Table 12-4. 2016 Field Duplicate Sample Results. (6 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
Columbia River Water	Uranium-238	3 of 3	100
	Strontium-90	4 of 4	100%
	Uranium-234	3 of 4	75%
	Uranium-235	4 of 4	100%
	Uranium-238	3 of 4	75%
	Tecnetium-99	4 of 4	100%
	Tritium	3 of 4	75%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Potassium-40	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Cesium-134	1 of 1	100%
	Plutonium-238	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Plutonium-239/-240	1 of 1	100%
Columbia River Water Transects	Aluminum	3 of 4	75%
	Iron	4 of 4	100%
	Lead	4 of 4	100%
	copper	4 of 4	100%
	Magnesium	4 of 4	100%
	Manganese	4 of 4	100%
	Mercury	4 of 4	100%
	Molybdenum	4 of 4	100%
	Nickel	4 of 4	100%
	Potassium	4 of 4	100%
	Silver	4 of 4	100%
	Strontium	4 of 4	100%
	Thallium	4 of 4	100%
	Thorium	4 of 4	100%
	Tin	4 of 4	100%
	Titanium	4 of 4	100%
	Antimony	4 of 4	100%
	Arsenic	4 of 4	100%
	Barium	4 of 4	100%
	Beryllium	4 of 4	100%
	Boron	3 of 4	100%
	Cadmium	4 of 4	100%
	Cesium	4 of 4	100%
	Chromium	4 of 4	100%
	Cobalt	4 of 4	100%
	Uranium	4 of 4	100%
	Bismuth	4 of 4	100%
	Calcium	4 of 4	100%
	Phosphorus	4 of 4	100%

Table 12-4. 2016 Field Duplicate Sample Results. (6 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Selenium	4 of 4	100%
	Phosphate	2 of 2	100%
	Sulfate	2 of 2	100%
	Chloride	2 of 2	100%
	Fluoride	2 of 2	100%
	Bromide	2 of 2	100%
	Nitrogen in Nitrate	2 of 2	100%
	Nitrogen in Nitrite	2 of 2	100%
	Hexavalent chromium	4 of 4	100%
	tritium	2 of 2	100%
	Cesium-137	2 of 2	100%
	Cesium-134	2 of 2	100%
	Cobalt-60	2 of 2	100%
	Potassium-40	2 of 2	100%
	Berillium-7	2 of 2	100%
	Ruthenium-106	2 of 2	100%
	Antimony-125	2 of 2	100%
	Europium-152	2 of 2	100%
	Europium-154	2 of 2	100%
	Europium-155	2 of 2	100%
	Strontium-90	2 of 2	100%
	Uranium-234	2 of 2	100%
	Uranium-235	1 of 2	50%
	Uranium-238	2 of 2	100%
Seep	Aluminum	1 of 2	50
	Iron	2 of 2	100%
	Lead	2 of 2	100%
	copper	2 of 2	100%
	Magnesium	2 of 2	100%
	Manganese	2 of 2	100%
	Mercury	2 of 2	100%
	Molybdenum	2 of 2	100%
	Nickel	2 of 2	100%
	Potassium	1 of 2	50%
	Silver	2 of 2	100%
	Strontium	2 of 2	100%
	Thallium	2 of 2	100%
	Thorium	2 of 2	100%
	Tin	2 of 2	100%
	Titanium	2 of 2	100%
	Antimony	2 of 2	100%
	Arsenic	2 of 2	100%
	Barium	2 of 2	100%
	Beryllium	2 of 2	100%
	Boron	2 of 2	100%
	Cadmium	2 of 2	100%
	Cesium	2 of 2	100%
	Chromium	2 of 2	100%

Table 12-4. 2016 Field Duplicate Sample Results. (6 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Cobalt	2 of 2	100%
	Uranium	2 of 2	100%
	Vanadium	2 of 2	100%
	Zinc	2 of 2	100%
	Zirconium	2 of 2	100%
	Bismuth	2 of 2	100%
	Calcium	2 of 2	100%
	Phosphorus	2 of 2	100%
	Selenium	2 of 2	100%
	Hexavalent chromium	2 of 2	100%
	Tritium	0 of 1	0%
	Phosphate	1 of 1	100%
	Sulfate	1 of 1	100%
	Chloride	1 of 1	100%
	Fluoride	1 of 1	100%
	Bromide	1 of 1	100%
	Bicarbonate	1 of 1	100%
	Hydroxylion	1 of 1	100%
	Alkalinity	1 of 1	100%
	Carbonate Alakalinity	1 of 1	100%
	Nitrogen in Nitrate	1 of 1	100%
	Nitrogen in Nitrite	1 of 1	100%
Wildlife Bass/Carp	Aluminum	1 of 1	100%
	Iron	1 of 1	100%
	Lead	1 of 1	100%
	Copper	0 of 1	0%
	Magnesium	1 of 1	100%
	Manganese	1 of 1	100%
	Mercury	1 of 1	100%
	Molybdenum	1 of 1	100%
	Nickel	1 of 1	100%
	Potassium	1 of 1	100%
	Silver	1 of 1	100%
	Strontium	1 of 1	100%
	Thallium	1 of 1	100%
	Thorium	1 of 1	100%
	Tin	1 of 1	100%
	Titanium	1 of 1	100%
	Antimony	1 of 1	100%
	Arsenic	1 of 1	100%
	Barium	1 of 1	100%
	Beryllium	1 of 1	100%
	Boron	1 of 1	100%
	Cadmium	1 of 1	100%
	Cesium	1 of 1	100%
	Chromium	1 of 1	100%
	Cobalt	1 of 1	100%
	Uranium	0 of 1	0%

Table 12-4. 2016 Field Duplicate Sample Results. (6 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Vanadium	1 of 1	100%
	Zinc	1 of 1	100%
	Zirconium	1 of 1	100%
	Bismuth	1 of 1	100%
	Calcium	1 of 1	100%
	Phosphorus	1 of 1	100%
	Selenium	0 of 1	0%
	Cesium-137	2 of 2	100%
	Cesium-134	2 of 2	100%
	Cobalt-60	2 of 2	100%
	Potassium-40	2 of 2	100%
	Berillium-7	2 of 2	100%
	Plutonium-238	1 of 1	100%
	Ruthenium-106	2 of 2	100%
	Antimony-125	2 of 2	100%
	Europium-152	2 of 2	100%
	Europium-154	2 of 2	100%
	Europium-155	2 of 2	100%
	Strontium-90	2 of 2	100%
	Uranium-234	1 of 1	100%
	Uranium-238	1 of 1	100%
	Tritium	2 of 2	100%
Wildlife Upland Game	Cesium-137	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Potassium-40	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Strontium-90	1 of 1	100%
	Uranium-234	1 of 1	100%
	Uranium-238	1 of 1	100%
Leafy Vegetables	Cesium-137	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Potassium-40	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Strontium-90	1 of 1	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%

Table 12-4. 2016 Field Duplicate Sample Results. (6 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
Potatoes	Uranium-238	1 of 1	100%
	Tritium	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Potassium-40	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	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%
	Tritium	1 of 1	100%
Milk	Cesium-137	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Potassium-40	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	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%
	Tritium	0 of 1	0%
Wine	Cesium-137	2 of 2	100%
	Cesium-134	2 of 2	100%
	Cobalt-60	2 of 2	100%
	Potassium-40	2 of 2	100%
	Berillium-7	2 of 2	100%
	Ruthenium-106	2 of 2	100%
	Antimony-125	2 of 2	100%
	Europium-152	2 of 2	100%
	Europium-154	2 of 2	100%
	Europium-155	2 of 2	100%
	Strontium-90	2 of 2	100%
	Uranium-234	2 of 2	100%
	Uranium-238	2 of 2	100%
	Tritium	2 of 2	100%

^a Number of reported results within control limits are those with the Relative Percent Difference value less than 30%, and the result is greater than the minimum detectable activity or method detection limit.

12.4 Media Audits and Comparisons

Selected sediment, surfacewater, food and farm products, wildlife, soil, and vegetation samples are provided to the Washington State Department of Health (WDOH) for comparative analysis as part of the PSRP 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 ([DOH 320-115, Hanford Environmental Radiation Oversight Program: 2015 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 provides 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 Environmental Sciences website at <http://www.doh.wa.gov/CommunityandEnvironment/Radiation/EnvironmentalSciences.aspx>.

Media types analyzed by the WDOH in 2016 included the following:

- Air Filters from 14 locations
- Columbia River continuous water from one location
- Columbia River transects from four locations
- Columbia River shoreline springs (seeps) from six locations.
- Offsite irrigation water from two locations
- Columbia River Sediment from eight locations
- Apricots from three locations
- Melons from three locations
- Leafy Vegetables from three locations
- Potatoes from two locations
- Corn from four locations
- Upland Game Birds from two locations
- Carp from two locations
- Deer/Elk from one background location
- Soil from six locations
- Vegetation from five locations.

No comparison data for 2016 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 at

<http://www.doh.wa.gov/communityandenvironment/radiation/publications/environmentalsciences.aspx>.

12.5 Laboratory Quality Assurance Programs

Contracted analytical laboratories are required to participate in internal and independent QC programs to evaluate analytical precision and accuracy. These laboratories employ chemists and 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), which is conducted twice a year, and the DOE Consolidated Audit Program (DOECAP), which is conducted annually.

12.5.1 Analytical Quality Assurance and Quality Control

In 2016, Hanford Site Environmental Surveillance samples were sent to two laboratories (GEL and TARL). These laboratories participated in various independent QA and QC programs including MAPEP and DOECAP. These managed programs use standardized audit methods, processes, and procedures to ensure the validity, reliability, and defensibility of data annually from the contract laboratories. MAPEP results for GEL and TARL are presented in Tables 12-5 and 12-6, respectively.

Table 12-5. 2016 DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC.

Environmental Sample Media and Analytes		MAPEP 34 Series June 2016 ^a	MAPEP 35 Series December 2016 ^a
Radionuclides			
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-235, uranium-238	Strontium-90 ^b	Strontium-90 ^b
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	100% Acceptable	100% Acceptable
Vegetation	Americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/-240, strontium-90, uranium-234/233, uranium-238	100% Acceptable	Strontium-90 ^b
Soil	Americium-241, cesium-134, cesium-137, cobalt-60, potassium-40, plutonium-238, plutonium-239/-240, strontium-90, technetium-99	100% Acceptable	100% Acceptable
Inorganic Compounds			
Water	Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, thallium, vanadium, zinc	100% Acceptable	Mercury ^b
^a Performance results 100% acceptable for all analytes reported to Public Safety and Resource Protection Program unless otherwise noted. ^b Result is acceptable but was issued a warning for having a bias between 20% and 30%.			
MAPEP = Mixed Analyte Performance Evaluation Program			

**Table 12-6. DOE Mixed Analyte Performance Evaluation Program Results
for TestAmerica Richland Laboratory.**

Environmental Sample Media and Analytes		MAPEP 34 Series June 2016 ^a	MAPEP 35 Series December 2016 ^a
Radionuclides			
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	Plutonium-238 ^b	Cesium-134 ^c Cesium-137 ^c Cobalt-60 ^c Plutonium-238 ^c Plutonium-239/-240 ^c Strontium-90 ^c Uranium-234/233 ^c Uranium-238 ^c
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	Americium-241 ^d Technetium-99 ^d	Technetium-99 ^b Uranium-238 ^c Strontium-90 ^d
Vegetation	Americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/-240, strontium-90, uranium-234/-233, uranium-238	100% Acceptable	NA
Soil	Americium-241, cesium-134, cesium-137, cobalt-60, potassium-40, plutonium-238, plutonium-239/-240, strontium-90, technetium-99	Plutonium-239/240 ^c Technetium-99 ^d	Cesium-137 ^b

^a Performance results 100% acceptable for all analytes reported to Public Safety and Resource Protection Program unless otherwise noted.

^b Result is acceptable but was issued a warning for having a bias between 20% and 30%.

^c Result not acceptable; bias >30%.

^d Result not acceptable; false positive.

MAPEP = Mixed Analyte Performance Evaluation Program

12.5.2 Laboratory Performance Evaluation and Proficiency Testing

Participation of Hanford Site analytical laboratories in DOE and U.S. Environmental Protection Agency (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 radiological results were issued warnings for biased strontium-90 results in the 20 to 30% range. However, these results are considered acceptable. Therefore, GEL's radiological MAPEP results are 100% acceptable for studies 34 and 35 in 2016 for air, water, soil, and vegetation.

GEL's MAPEP results for inorganic compounds in water were issued a warning for mercury in MAPEP study 35. However, this is considered an acceptable result. Therefore, GEL's inorganic MAPEP results are 100% acceptable. Results of MAPEP studies 34 and 35 for GEL are provided in Table 12-5 or at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

TARL's MAPEP program radiological results for studies 34 and 35 in 2016 received warnings for plutonium-238 in air and technetium-99 in water. However, these results are considered acceptable. TARL had unacceptable results for technetium-99, strontium-90, and americium-241 due to false positive results. Additionally, TARL had numerous unacceptable results due to bias greater than 30%. Most of these high bias results were from the air filter sample in study 35 and could be due to an anomaly associated with that specific sample. For additional details of the TARL MAPEP results for studies 34 and 35 please see Table 12-6 or the full reports at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

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.

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Appendix A. Glossary

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

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*, 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 *radionuclide*. 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, earth, and 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 = 3.7×10^{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 – 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.

biota concentration guide (BCG) – is the limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose limits for protection of populations of aquatic and terrestrial biota to be exceeded

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 *-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 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 (3.7×10^{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) and 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., U.S. Environmental Protection Agency, U.S. Nuclear Regulatory Commission, and U.S. 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

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

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

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 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

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 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 a 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 or extremely or acutely hazardous waste that contains both a nonradioactive hazardous component and a radioactive component.

monitoring – As defined in DOE O 458.1, Chg 3, 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 these measurement results 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 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 – All actions that provide confidence that an item or process meets or exceeds user requirements and expectations.

quality control – All 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), neutrons (A), and 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 (PCB) 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 PCB *remediation* waste, the requirements for a risk-based disposal approval are specified in 40 CFR 761.61(c). 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 deviation – A measure of the dispersion of sample values from a population. If the data are from a normal or bell-shaped statistical distribution then about 68% of the values are within one standard deviation of the mean and about 95% of the values are within two standard deviations of the mean.

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 O 458.1, Chg 3, 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 determining 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, 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.

References

40 CFR 761. “Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions.” *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/title40/40cfr761_main_02.tpl.

DOE O 458.1, Chg. 3. 2013. *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-admc3>.

Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901, et seq. Online at <https://www.epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act>.

Toxic Substances Control Act. 1976. Public Law 94-469, as amended, 15 U.S.C. 2601 et seq. Online at <http://www.gpo.gov/fdsys/pkg/STATUTE-90/pdf/STATUTE-90-Pg2003.pdf>.

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B.0 Background Information

The following information is provided to assist the reader in understanding this report. Included in this Appendix is information on scientific notation; units of measure, radioactivity, and radiological dose; chemical and elemental nomenclature; understanding data tables and data uncertainty; understanding graphs; and an explanation of select 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 P.O. Box 352900 Seattle, WA 98195-2900 (206) 543-4164 www.catalog.kub.wa.edu	Portland State University Government Information Branford Price Millar Library 1875 SW Park Ave Portland, OR 97207-1151 (503) 725-4542 http://library.pdx.edu/governmentinformationservice.html and http://library.pdx.edu/public_comment.html#hanf
Washington State University, Tri-Cities US DOE Public Reading Room Consolidated Information Center, Rm 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 (through Gonzaga): 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, under using scientific (E notation), 1×10^9 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 a value given is 2.0×10^3 (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 2.0×10^{-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.

Table B-1. Units of Measure.

Symbol	Name	Symbol	Name
Temperature		Concentration	
°C	degree Celsius	ppb	parts per billion
°F	degree Fahrenheit	ppm	parts per million
Time		ppmv	parts per million by volume
d	day	Length	
hr	hour	cm	centimeter (1×10^{-2} m)
min	minute	ft	foot
sec	second	in.	inch
yr	year	km	kilometer (1×10^3 m)
Rate		m	meter
cfs (or ft ³ /sec)	cubic feet per second	mi	mile
cpm	counts per minute	Area	
gpm	gallon per minute	ha	hectare (1×10^4 m ²)
mph	mile per hour	km ²	square kilometer
mR/hr	milliroentgen per hour	mi ²	square mile
mrem/yr	millirem per year	ft ²	square foot
Volume		Mass	
cm ³	cubic centimeter	g	gram
ft ³	cubic foot	kg	kilogram (1×10^3 g)
gal	gallon	mg	milligram (1×10^{-3} g)
L	liter	μg	microgram (1×10^{-6} g)
m ³	cubic meter	lb	pound
mL	milliliter (1×10^{-3} L)		
yd ³	cubic yard		

Table B-2. Conversion Table.

Multiply	By	To Obtain	Multiply	By	To Obtain
cm	0.394	in.	in.	2.54	cm
m	3.28	ft	ft	0.305	m
km	0.621	mi	mi	1.61	km
kg	2.205	lb	lb	0.454	kg
L	0.2642	gal	gal	3.785	L
m ²	10.76	ft ²	ft ²	0.093	m ²
ha	2.47	acre	acre	0.405	ha
km ²	0.386	mi ²	mi ²	2.59	km ²
m ³	35.31	ft ³	ft ³	0.0283	m ³
m ³	1.308	yd ³	yd ³	0.7646	m ³
pCi	1,000	nCi	nCi	0.001	pCi
μCi/mL	109	pCi/L	pCi/L	10-9	μCi/mL
Ci/m ³	1012	pCi/m ³	pCi/m ³	10-12	Ci/m ³
mCi/cm ³	1015	pCi/m ³	pCi/m ³	10-15	mCi/cm ³
nCi/m ²	1.0	mCi/km ²	mCi/km ²	1.0	nCi/m ²
Ci	3.7×10^{10}	Bq	Bq	2.7×10^{-11}	Ci
pCi	0.037	Bq	Bq	27	pCi
rad	0.01	Gy	Gy	100	rad
rem	0.01	Sv	Sv	100	rem
ppm	1,000	ppb	ppb	0.001	ppm

Multiply	By	To Obtain
°C	$(^{\circ}\text{C} \times 9/5) + 32$	°F
oz	28.349	g
ton	0.9078	tonne

Multiply	By	To Obtain
°F	$(^{\circ}\text{F} - 32) \div 9/5$	°C
g	0.035	oz
tonne	1.1	ton

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., pCi/L). 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.3. Radioactivity Unit Conversions.

aCi 27	fCi 1	fCi 27	pCi 1	pCi 27	nCi 1	nCi 27	μCi 1	μCi 27	mCi 1	mCi 27	Ci 1	Ci 27	kCi 1
1 μBq	37 μBq	1 mBq	37 mBq	1 Bq	37 Bq	1 kBq	37 kBq	1 MBq	37 MBq	1 GBq	37 GBq	1 TBq	37 TBq

New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) ($1 \text{ Ci} = 3.7 \times 10^{10} \text{ dps}$).
1 Becquerel = 1 disintegrations/sec (dps).

Table B-4. Radioactivity Units.

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel ($2.7 \times 10^{-11} \text{ Ci}$)
mCi	millicurie ($1 \times 10^{-3} \text{ Ci}$)	mBq	millibecquerel ($1 \times 10^{-3} \text{ Bq}$)
μCi	microcurie ($1 \times 10^{-6} \text{ Ci}$)	kBq	kilobecquerel ($1 \times 10^3 \text{ Bq}$)
nCi	nanocurie ($1 \times 10^{-9} \text{ Ci}$)	MBq	megabecquerel ($1 \times 10^6 \text{ Bq}$)
pCi	picocurie ($1 \times 10^{-12} \text{ Ci}$)	GBq	gigabecquerel ($1 \times 10^9 \text{ Bq}$)
fCi	femtocurie ($1 \times 10^{-15} \text{ Ci}$)	TBq	terabecquerel ($1 \times 10^{12} \text{ Bq}$)
aCi	attocurie ($1 \times 10^{-18} \text{ Ci}$)		

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], U.S. 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 Dose Limits.

Annual Radiation Dose Limits	Agency
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 Limits for Non-human Biota

Regulatory dose limits for non-human biota are set by DOE (Table B-6).

Table B-6. Radioactivity Dose Limits for Non-human Biota.

Daily Radiation Dose Limits	Agency
Aquatic Animal - 1 rad	DOE
Riparian Animal – 0.1 rad	DOE
Terrestrial Plant - 1 rad	DOE
Terrestrial Animal – 0.1 rad.	DOE

B.7 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 (μ 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 mrem (10 μ Sv) 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 mSv) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 mSv) would soon result in death in approximately 50% of those exposed. Exposure to lower amounts of radiation (10 mrem [100 μ 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.

Table B-7. Radiological Dose Units Conversions.

μSv 0.01	μSv 0.1	μSv 1	μSv 10	μSv 100	mSv 1	mSv 10	mSv 100	Sv 1
1 μrem	10 μrem	100 μrem	1 mrem	10 mrem	100 mrem	1 rem	10 rem	100 rem

Unit of absorbed dose – Gray (Gy; formerly rad); unit of dose equivalent – sievert (Sv; formerly rem).
Table also converts Gy to rad.

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. Dose to non-human biota is calculated in rads and compared to the limits in Table B-6.

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-8. Radiation Dose or Exposure Units.

Symbol	Name
rad	rad (10 milligray [mGy])
mrاد	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
μrem	microrem (1×10^{-6} rem)
Sv	sievert (100 rem)
mSv	millisievert (1×10^{-3} Sv)
μSv	microsievert (1×10^{-6} Sv)
nSv	nanosievert (1×10^{-9} Sv)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
μR	microroentgen (1×10^{-6} R)
Gy	gray (100 rad)
mGy	milligray (1×10^{-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-9. Radionuclides and Half-Lives.

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
³ H	tritium	12.35 yr	¹⁰³ Ru	ruthenium-103	39.28 d	U	natural uranium	~4.5 × 10 ⁹ (a)
⁷ Be	beryllium-7	53.3 d	¹⁰⁶ Ru	ruthenium-106	368.2 d	²³³ U	uranium-233	1.585 × 10 ⁵ yr
¹⁴ C	carbon-14	5,730 yr	¹¹³ Sn	tin-113	115.1 d	²³⁴ U	uranium-234	2.445 × 10 ⁵ yr
⁴⁰ K	potassium-40	1.28 × 10 ⁹ yr	¹²⁵ Sb	antimony-125	2.77 yr	²³⁵ U	uranium-235	7.038 × 10 ⁸ yr
⁵¹ Cr	chromium-51	27.704 d	¹²⁹ I	iodine-129	1.57 × 10 ⁷ yr	²³⁷ Np	neptunium-237	2.14 × 10 ⁶ yr
⁵⁴ Mn	manganese-54	312.5 d	¹³¹ I	iodine-131	8.04 d	²³⁸ U	uranium-238	4.468 × 10 ⁹ yr
⁵⁵ Fe	iron-55	2.7 yr	¹³⁴ Cs	cesium-134	2.062 yr	²³⁸ Pu	plutonium-238	87.74 yr
⁵⁹ Fe	iron-59	44.529 d	¹³⁷ Cs	cesium-137	30.0 yr	²³⁹ Pu	plutonium-239	2.4065 × 10 ⁴ yr
⁵⁹ Ni	nickel-59	7.5 × 10 ⁴ yr	^{137m} Ba	barium-137m	2.552 min	²⁴⁰ Pu	plutonium-240	6.537 × 10 ³ yr
⁶⁰ Co	cobalt-60	5.271 yr	¹⁵² Eu	europium-152	13.33 yr	²⁴¹ Pu	plutonium-241	14.4 yr
⁶³ Ni	nickel-63	96 yr	¹⁵⁴ Eu	europium-154	8.8 yr	²⁴² Pu	plutonium-242	3.763 × 10 ⁵ yr
⁶⁵ Zn	zinc-65	243.9 d	¹⁵⁵ Eu	europium-155	4.96 yr	²⁴¹ Am	americium-241	432.2 yr
⁸⁵ Kr	krypton-85	10.72 yr	²¹² Pb	lead-212	10.64 hr	²⁴³ Am	americium-243	7,380 yr
⁹⁰ Sr	strontium-90	29.12 yr	²²⁰ Rn	radon-220	55.6 sec	²⁴³ Cm	curium-243	28.5 yr
⁹⁰ Y	yttrium-90	64.0 hr	²²² Rn	radon-222	3.8235 d	²⁴⁴ Cm	curium-244	18.11 yr
⁹⁵ Zr	zirconium-95	63.98 d	²³² Th	thorium-232	1.405 × 10 ¹⁰ yr	²⁴⁵ Cm	curium-245	8,500 yr
⁹⁹ Tc	technetium-99	2.13 × 10 ⁵ yr						

NOTE: Natural uranium is a mixture dominated by uranium-238; thus, the half-life is approximately 4.5 × 10⁹ years.

B.8 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-10. Elemental and Chemical Constituent Nomenclature.

Symbol	Constituent	Symbol	Constituent
Ag	silver	K	potassium
Al	aluminum	LiF	lithium fluoride
As	arsenic	Mg	magnesium
B	boron	Mn	manganese
Ba	barium	Mo	molybdenum
Be	beryllium	NH ₃	ammonia
Br	bromine	NH ₄ ⁺	ammonium
C	carbon	N	nitrogen

Symbol	Constituent	Symbol	Constituent
Ca	calcium	Na	sodium
CaF ₂	calcium fluoride	Ni	nickel
CCl ₄	carbon tetrachloride	NO ₂ ⁻	nitrite
Cd	cadmium	NO ₃ ⁻	nitrate
CHCl ₃	trichloromethane	Pb	lead
Cl ⁻	chloride	PO ₄ ⁻³	phosphate
CN ⁻	cyanide	P	phosphorus
Cr ⁺⁶	chromium (hexavalent)	Sb	antimony
Cr	chromium (total)	Se	selenium
CO ₃ ⁻²	carbonate	Si	silicon
Co	cobalt	Sr	strontium
Cu	copper	SO ₄ ⁻²	sulfate
F ⁻	fluoride	Ti	titanium
Fe	iron	Tl	thallium
HCO ₃ ⁻	bicarbonate	V	vanadium
Hg	mercury		

B.9 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.10 Standard Deviation

The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual sample results. If analytical results follow a bell-shaped curve (or a normal statistical distribution), then 95% of the time an independent sample would fall within the mean plus or minus two times the standard deviation (or mean \pm 2 SD).

B.11 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.12 Standard Error of the Mean

Just as individual values are accompanied by uncertainty, the mean is accompanied by an associated standard error (SE). The standard error is calculated from the SD and the number of samples. As the number of samples increases the SE decreases, therefore uncertainty in the mean is reduced. The mean plus or minus two times the standard error of the mean would include approximately 95% of the means estimated from that same population.

B.13 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 following 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. 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.

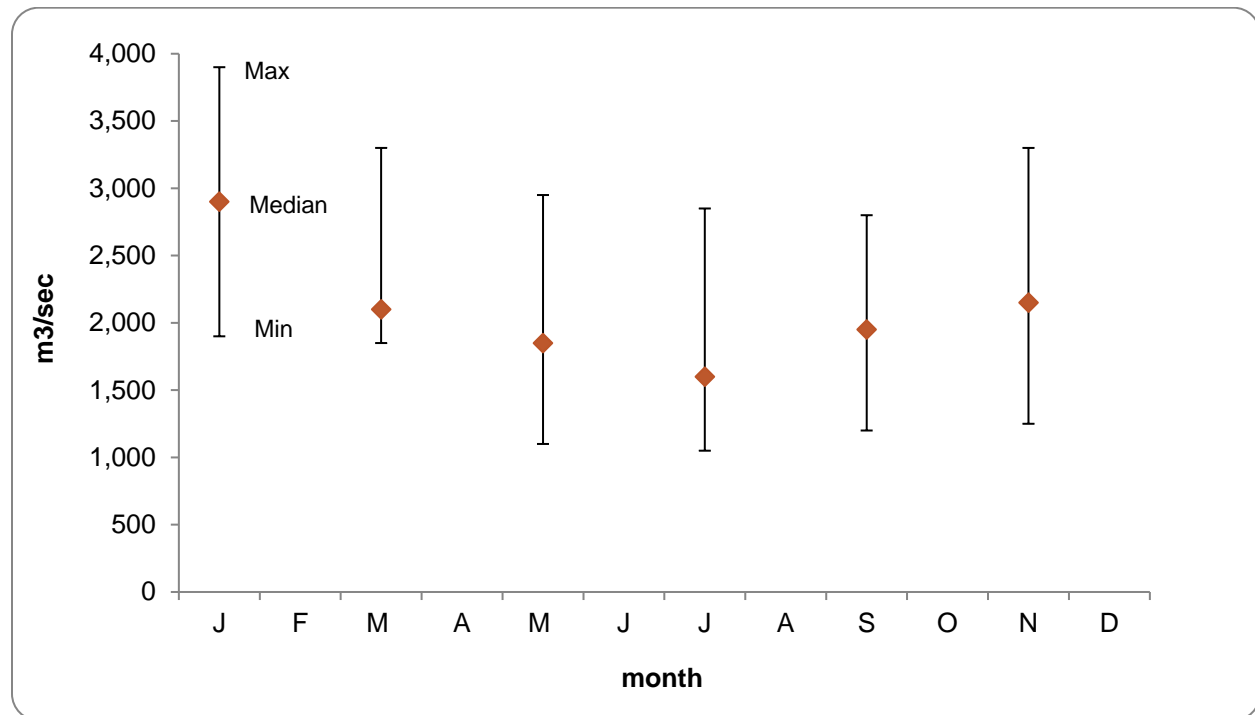


Figure B-1. Maximum, Median, and Minimum Values Graphical Representation.

B.14 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.15 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.

B.16 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 g/L would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 g/L (Figure B-2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure B-3). Each scale has its benefits in presenting information. Note that the linear scale often has a natural minimum value of zero for the y-axis. Zero and negative values cannot be plotted on logarithmic scale plots and the analyst must select an appropriate minimum value for the y-axis.

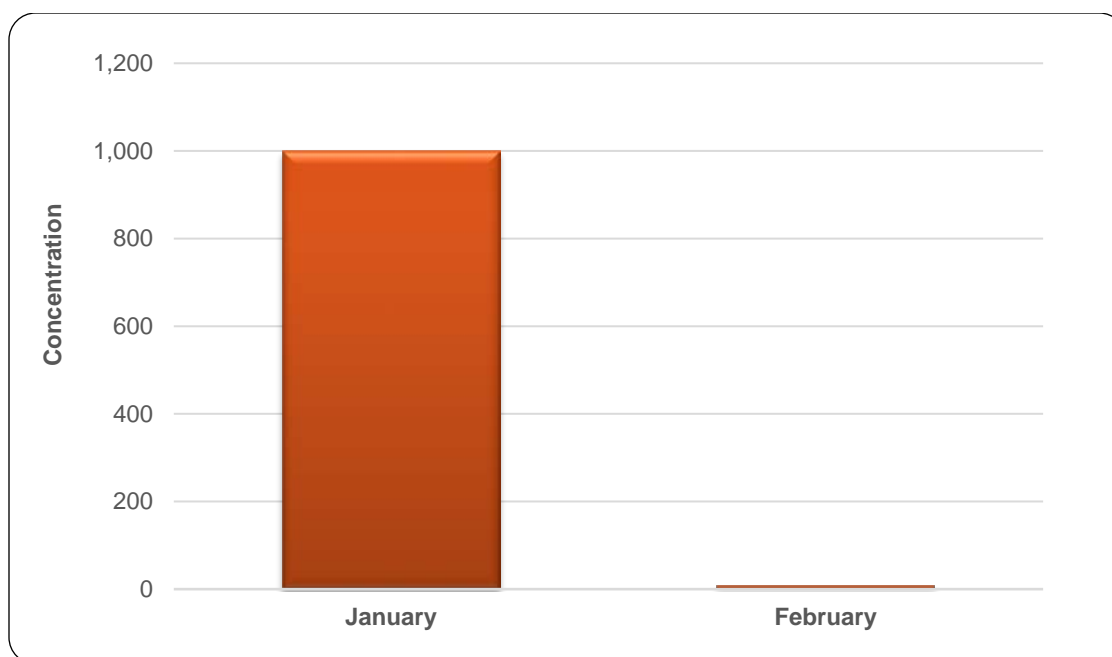


Figure B-2. Data Plotted Using a Linear Scale.

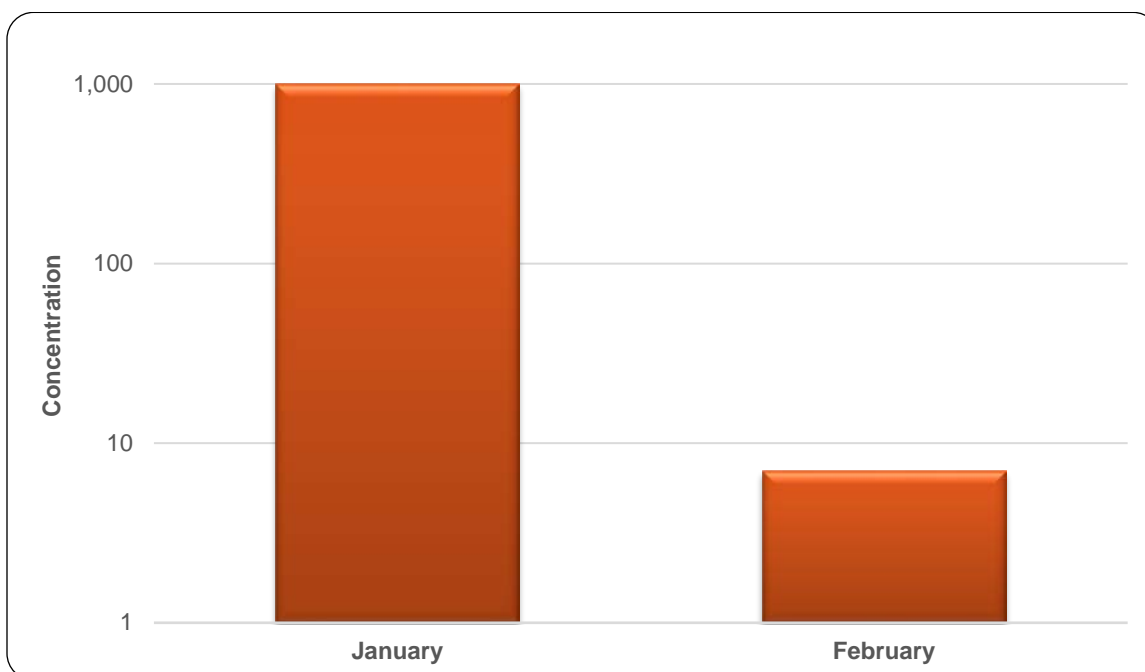


Figure B-3. Data Plotted Using a Logarithmic Scale.

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% chance that the value is between the upper and lower ends of the error bar and a 5% chance that the true value

is either lower or higher than the error bar.¹ For example, in Figure B-4, the first plotted value is 2.0 ± 1.1 , so there is a 95% chance that the true value is between 0.9 and 3.1, a 2.5% chance that it is less than 0.9, and a 2.5% 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 (e.g., 2 and 3) may actually be quite similar when compared statistically.

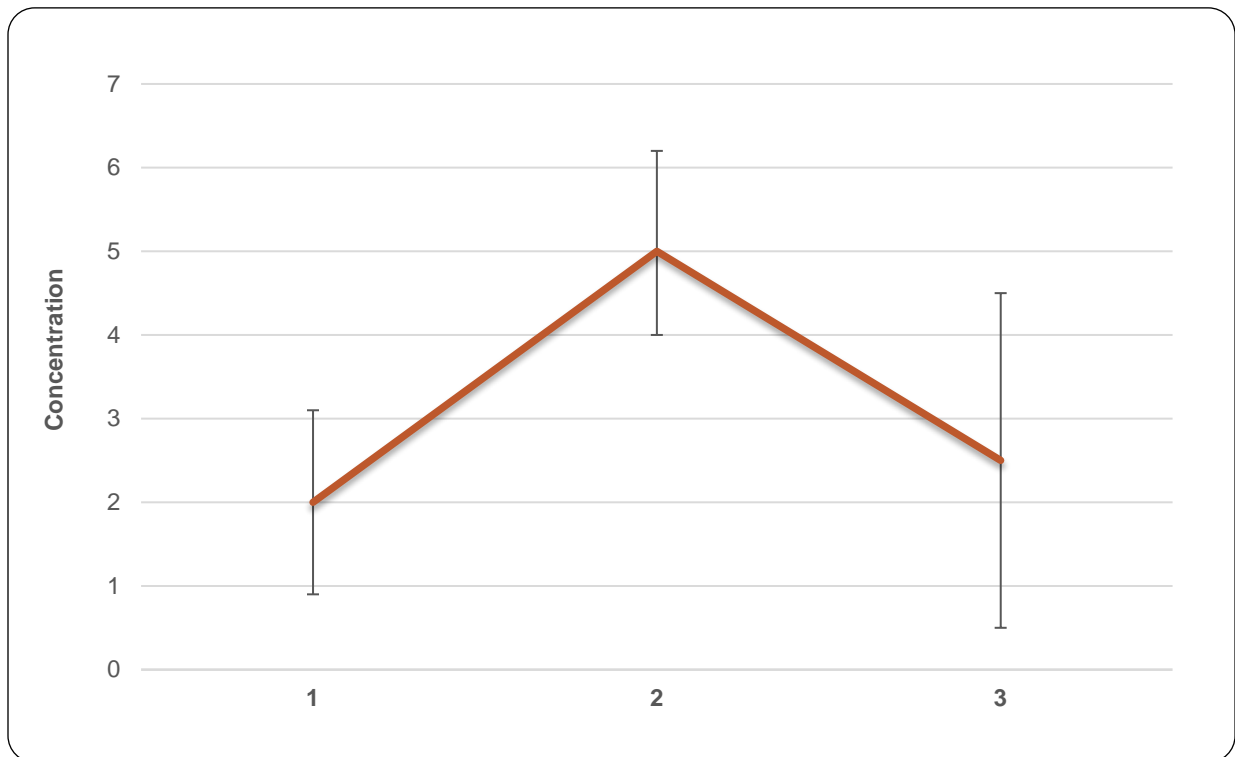


Figure B-4. Data with Error Bars Plotted Using a Linear Scale.

¹Assuming the data are normally distributed.

Appendix C. Additional Monitoring Results

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C.0 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.

C.1 Onsite Pond

Table C-1. Radionuclide Concentrations in West Lake Sediment.

Radionuclide	2016				2011-2015						
	No. of Samples	Concentration Maximum ^a			No. of Samples	Concentration					
		Average ^b				Maximum ^a					
		pCi/g ^c		pCi/g ^c		pCi/g ^c		pCi/g ^c	pCi/g ^c		pCi/g ^c
Antimony-125 ^d	4	3.2E-02	±	5.3E-02	7	-1.1E-02	±	1.8E-02	6.1E-04	±	2.3E-02
Cesium-134 ^{d,e}	4	9.1E-03	±	2.0E-02	7	1.2E-02	±	4.0E-02	1.2E-02	±	4.0E-02
Cesium-137	4	1.4E+00	±	1.3E-01	7	5.2E-01	±	8.6E-01	1.6E+00	±	1.6E-01
Cobalt-60 ^d	4	1.3E-02	±	1.8E-02	7	-9.1E-04	±	1.3E-02	1.1E-02	±	1.8E-02
Europium-152 ^d	4	3.3E-02	±	5.4E-02	7	2.7E-03	±	6.3E-02	5.4E-02	±	8.0E-02
Europium-154 ^d	4	5.9E-02	±	6.3E-02	7	-2.4E-02	±	4.9E-02	2.7E-02	±	5.8E-02
Europium-155 ^{d,e}	4	5.5E-02	±	6.0E-02	7	3.3E-02	±	7.2E-02	8.5E-02	±	8.6E-02
Gross Alpha ^d	4	2.3E+01	±	7.6E+00	7	7.5E+00	±	6.7E+00	1.2E+01	±	3.1E+00
Gross Beta	4	3.0E+01	±	2.4E+00	7	2.3E+01	±	1.4E+01	2.9E+01	±	2.4E+00
Potassium-40	4	1.6E+01	±	1.4E+00	7	1.5E+01	±	8.5E+00	1.9E+01	±	1.7E+00
Ruthenium-106 ^d	4	1.0E-01	±	6.7E-02	7	-4.1E-02	±	1.8E-01	6.3E-02	±	1.6E-01
Strontium-90 ^d	4	4.4E-01	±	9.9E-02	7	9.5E-02	±	3.4E-01	4.9E-01	±	9.7E-02
Technetium-99 ^d	4	6.0E-01	±	2.8E-01	7	1.4E-01	±	3.7E-01	4.8E-01	±	3.2E-01
Uranium-234	4	9.6E+00	±	1.6E+00	7	3.7E+00	±	4.5E+00	7.6E+00	±	1.1E+00
Uranium-235 ^d	4	6.5E-01	±	1.6E-01	7	2.1E-01	±	2.0E-01	3.2E-01	±	8.9E-02
Uranium-238	4	9.3E+00	±	1.5E+00	5	3.4E+00	±	4.0E+00	6.8E+00	±	1.0E+00

^a Result and maximum values are ± total propagated analytical uncertainty.

^b Averages are ±2 standard deviations of the mean. Average values calculated using reporting limit values for all results at or below minimum detectable concentrations.

^c 1 pCi = 0.037 Bq.

^d Results include concentrations below detection limit.

^e Included rejected samples due to laboratory interference, low abundance, and/or no valid peak.

Table C-2. Radionuclide Concentrations in West Lake Seep Water.

Radionuclide	2016					2011-2015							DOE-Derived Concentration Standards	Washington State Ambient Surface Water Quality Standard ^c
	No. of samples	Concentration				No. of samples	Concentration							
		Average ^a	Maximum ^b <i>pCi/L</i>				Average ^a <i>pCi/L</i>			Maximum ^b <i>pCi/L</i>				
Tritium	1	^e	- 5.6E+00	±	1.3E+02	3	3.0E+02	±	5.6E+02	6.9E+02	±	2.1E+02	2,000,000	20,000 ^{c,d}
Uranium-234	1	^e	8.3E+02	±	1.4E+02	4	2.1E+02	±	1.7E+02	2.6E+02	±	3.8E+01	500	—
Uranium-235	1	^e	4.4E+01	±	1.5E+01	4	1.2E+01	±	1.2E+01	1.9E+01	±	1.3E+01	600	—
Uranium-238	1	^e	7.7E+02	±	1.3E+02	4	1.8E+02	±	1.5E+02	2.5E+02	±	6.9E+01	600	—

^a Averages are ±2 standard deviations of the mean.

^b Maximum values are ± total propagated analytical uncertainty.

^c WAC 246-290, 40 CFR 141. Dashes indicate no concentration guides available.

^d WAC 173-201A-250 and EPA-570/9-76-003.

^e Average values are not calculated when only one sample was analyzed; Sample collected in 2012 did not include Tritium analysis.

Table C-3. Radionuclide Concentrations in West Lake Pond Water.

Radionuclide	2016							2011-2015							DOE-Derived Concentration Standards	Washington State Ambient Surface Water Quality Standard ^c
	No. of samples	Concentration						No. of samples	Concentration							
		Average ^a <i>pCi/L</i>			Maximum ^b <i>pCi/L</i>				Average ^a <i>pCi/L</i>			Maximum ^b <i>pCi/L</i>				
Tritium	2	-1.7E+01	±	2.3E+01	-5.1E+00	±	1.1E+02	7	3.3E+01	±	1.2E+02	1.2E+02	±	1.5E+02	2,000,000	20,000 ^{c,d}
Uranium-234	2	5.4E+03	±	1.1E+04	1.1E+04	±	4.4E+03	7	1.7E+03	±	4.8E+03	6.6E+03	±	1.1E+03	500	—
Uranium-235	2	7.1E+02	±	1.4E+03	1.4E+03	±	1.6E+03	7	7.0E+01	±	1.8E+02	2.5E+02	±	9.4E+01	600	—
Uranium-238	2	6.9E+03	±	1.4E+04	1.4E+04	±	5.2E+03	7	1.7E+03	±	4.6E+03	6.4E+03	±	1.0E+03	600	—

^a Averages are ±2 standard deviations of the mean.

^b Maximum values are ± total propagated analytical uncertainty.

^c WAC 246-290, 40 CFR 141. Dashes indicate no concentration guides available.

^d WAC 173-201A-250 and EPA-570/9-76-003.

C.2 Ambient Air

Table C-4. Concentrations of Select Radionuclides (pCi/m³)^a in On-site Air Samples. (4 Pages)

Radionuclide	Site	2016				Sampler	2011–2015				EPA Table 2 ^{e, f}
		Number of Samples	Detections ^b	Average ^c	Maximum ^d		Number of Samples	Detections ^b	Average ^c	Maximum ^d	
gross α	100-K Area	189	181	1.3E-03 ± 1.6E-03	4.9E-03 ± 1.1E-03	N576	907	869	1.3E-03 ± 1.8E-03	7.8E-03 ± 1.3E-03	2.0E-02
gross α	200-East	574	568	1.4E-03 ± 1.5E-03	5.2E-03 ± 1.0E-03	N158	2723	2649	1.4E-03 ± 1.9E-03	7.6E-03 ± 1.1E-03	
gross α	200-West	587	581	1.5E-03 ± 1.6E-03	5.8E-03 ± 1.1E-03	N433	2938	2866	1.4E-03 ± 2.0E-03	1.4E-02 ± 2.0E-03	
gross α	618-10 BG	112	112	1.3E-03 ± 1.5E-03	4.9E-03 ± 2.1E-03	N548	502	479	1.3E-03 ± 2.3E-03	1.6E-02 ± 2.3E-03	
gross α	ERDF	81	81	1.1E-03 ± 9.1E-04	3.2E-03 ± 1.3E-03	N518	390	372	9.6E-04 ± 9.2E-04	4.0E-03 ± 1.3E-03	
gross β	100-K Area	189	189	1.6E-02 ± 1.8E-02	5.1E-02 ± 5.0E-03	N534	909	908	1.7E-02 ± 2.2E-02	8.4E-02 ± 6.5E-03	9.0E+00
gross β	200-East	574	574	1.5E-02 ± 2.2E-02	1.8E-01 ± 1.3E-02	N158	2723	2722	1.7E-02 ± 2.3E-02	1.2E-01 ± 9.0E-03	
gross β	200-West	587	587	1.5E-02 ± 1.5E-02	4.8E-02 ± 4.6E-03	N554	2938	2938	1.6E-02 ± 2.2E-02	7.6E-02 ± 5.8E-03	
gross β	618-10 BG	112	112	1.8E-02 ± 2.2E-02	6.4E-02 ± 1.1E-02	N549	502	501	1.8E-02 ± 2.6E-02	1.1E-01 ± 9.0E-03	
gross β	ERDF	81	81	1.4E-02 ± 1.5E-02	4.3E-02 ± 7.2E-03	N517	390	390	1.4E-02 ± 1.8E-02	4.8E-02 ± 4.5E-03	
⁹⁰ Sr	100-K Area	14	0	-6.1E-05 ± 4.1E-04	2.8E-04 ± 3.8E-04	N578	74	3	1.3E-05 ± 3.4E-04	7.5E-04 ± 6.3E-04	1.9E-02
⁹⁰ Sr	200-East	43	1	1.3E-04 ± 1.6E-03	5.2E-03 ± 2.1E-03	N158	210	35	6.2E-05 ± 4.0E-04	1.7E-03 ± 5.7E-04	
⁹⁰ Sr	200-West	45	0	-4.3E-05 ± 6.2E-04	5.1E-04 ± 4.7E-04	N956	228	24	6.2E-06 ± 3.2E-04	5.5E-04 ± 4.7E-04	

Table C-4. Concentrations of Select Radionuclides (pCi/m³)^a in On-site Air Samples. (4 Pages)

Radionuclide	Site	2016				Sampler	2011–2015				EPA Table 2 ^{e, f}
		Number of Samples	Detections ^b	Average ^c	Maximum ^d		Number of Samples	Detections ^b	Average ^c	Maximum ^d	
⁹⁰ Sr	618-10 BG	8	0	1.0E-04 ± 2.0E-04	2.7E-04 ± 2.5E-04	N579	40	6	9.8E-05 ± 2.2E-04	4.7E-04 ± 2.6E-04	1.9E-02
⁹⁰ Sr	ERDF	6	0	9.4E-06 ± 7.2E-05	3.4E-05 ± 2.0E-04	N482	30	3	7.5E-05 ± 2.3E-04	3.3E-04 ± 3.6E-04	
¹³⁷ Cs	100-K Area	14	0	3.6E-05 ± 3.6E-04	4.3E-04 ± 4.5E-04	N576	74	12	8.3E-05 ± 3.7E-04	4.9E-04 ± 2.0E-04	
¹³⁷ Cs	200- East	43	2	1.6E-04 ± 8.2E-04	2.1E-03 ± 8.7E-04	N158	210	38	2.7E-04 ± 2.7E-03	1.9E-02 ± 6.2E-03	
¹³⁷ Cs	200- West	45	0	7.0E-05 ± 3.6E-04	3.5E-04 ± 4.1E-04	N304	228	23	6.2E-05 ± 3.6E-04	7.6E-04 ± 3.8E-04	
¹³⁷ Cs	618-10 BG	8	0	6.9E-06 ± 8.3E-05	8.5E-05 ± 1.3E-04	N548	40	4	6.3E-05 ± 4.7E-04	1.2E-03 ± 4.0E-04	2.10E-03
¹³⁷ Cs	ERDF	6	0	-3.4E-05 ± 8.0E-05	3.2E-05 ± 1.0E-04	N517	30	3	4.7E-05 ± 1.9E-04	2.9E-04 ± 1.3E-04	
²³⁸ Pu	100-K Area	12	0	1.8E-06 ± 1.1E-05	1.3E-05 ± 1.6E-05	N578	71	0	1.9E-06 ± 1.1E-05	3.9E-05 ± 5.5E-05	
²³⁸ Pu	200- East	41	0	5.2E-07 ± 8.1E-06	1.3E-05 ± 2.0E-05	N968	198	3	5.6E-07 ± 6.0E-06	1.3E-05 ± 8.8E-06	
²³⁸ Pu	200- West	42	0	6.8E-07 ± 6.8E-06	9.9E-06 ± 1.2E-05	N168	210	3	6.1E-07 ± 8.1E-06	3.7E-05 ± 1.9E-05	
²³⁸ Pu	618-10 BG	8	0	5.7E-06 ± 1.3E-05	1.9E-05 ± 2.9E-05	N579	40	2	4.7E-06 ± 1.8E-05	4.6E-05 ± 2.2E-05	2.0E-03
²³⁸ Pu	ERDF	6	0	2.0E-06 ± 9.7E-06	7.5E-06 ± 1.9E-05	N482	30	0	8.3E-07 ± 7.1E-06	8.5E-06 ± 9.1E-06	
^{239/240} Pu	100-K Area	14	0	1.7E-06 ± 9.8E-06	1.5E-05 ± 3.4E-05	N534	70	9	3.2E-06 ± 1.1E-05	1.8E-05 ± 1.2E-05	
^{239/240} Pu	200- East	42	0	-6.8E-08 ± 4.8E-06	5.6E-06 ± 1.4E-05	N158	204	13	1.3E-06 ± 5.4E-06	1.2E-05 ± 6.9E-06	
^{239/240} Pu	200- West	43	3	1.1E-05 ± 6.8E-05	2.1E-04 ± 7.8E-05	N165	224	49	1.3E-05 ± 9.2E-05	4.5E-04 ± 1.6E-04	

Table C-4. Concentrations of Select Radionuclides (pCi/m³)^a in On-site Air Samples. (4 Pages)

Radionuclide	Site	2016				Sampler	2011–2015				EPA Table 2 ^{e, f}
		Number of Samples	Detections ^b	Average ^c	Maximum ^d		Number of Samples	Detections ^b	Average ^c	Maximum ^d	
^{239/240} Pu	618-10 BG	8	1	2.2E-05 ± 4.4E-05	7.3E-05 ± 5.3E-05	N548	40	27	8.0E-05 ± 2.7E-04	6.8E-04 ± 2.6E-04	7.7E-03
^{239/240} Pu	ERDF	5	0	7.1E-06 ± 2.0E-05	2.4E-05 ± 2.9E-05	N482	30	9	5.1E-06 ± 1.8E-05	4.6E-05 ± 2.0E-05	
²³⁴ U	100-K Area	12	1	7.9E-06 ± 1.0E-05	1.9E-05 ± 1.4E-05	N534	60	29	7.6E-06 ± 9.6E-06	2.1E-05 ± 1.1E-05	
²³⁴ U	200- East	43	8	1.2E-05 ± 2.2E-05	4.9E-05 ± 4.7E-05	N973	210	107	8.3E-06 ± 1.0E-05	2.6E-05 ± 1.9E-05	
²³⁴ U	200- West	45	3	1.1E-05 ± 2.2E-05	4.7E-05 ± 3.6E-05	N449	228	112	8.5E-06 ± 1.1E-05	3.4E-05 ± 3.9E-05	
²³⁴ U	618-10 BG	8	0	5.7E-06 ± 1.5E-05	2.2E-05 ± 2.7E-05	N580	40	20	1.4E-05 ± 3.1E-05	9.2E-05 ± 5.2E-05	
²³⁴ U	ERDF	6	0	1.0E-05 ± 2.9E-05	3.3E-05 ± 4.1E-05	N517	29	15	1.6E-05 ± 1.7E-05	4.2E-05 ± 2.1E-05	7.1E-03
²³⁵ U	100-K Area	10	0	2.8E-07 ± 7.3E-06	5.9E-06 ± 1.2E-05	N476	55	4	1.6E-06 ± 4.9E-06	9.7E-06 ± 1.8E-05	
²³⁵ U	200- East	35	0	3.4E-06 ± 1.0E-05	1.9E-05 ± 2.7E-05	N481	198	8	1.7E-06 ± 5.3E-06	1.7E-05 ± 2.1E-05	
²³⁵ U	200- West	38	1	7.1E-06 ± 2.4E-05	6.9E-05 ± 5.0E-05	N161	216	17	2.1E-06 ± 5.4E-06	1.2E-05 ± 1.5E-05	
²³⁵ U	618-10 BG	5	0	7.2E-07 ± 4.5E-06	5.2E-06 ± 1.1E-05	N580	34	2	1.8E-06 ± 7.2E-06	8.4E-06 ± 6.3E-06	
²³⁵ U	ERDF	5	0	8.8E-07 ± 4.8E-06	4.0E-06 ± 9.8E-06	N518	26	2	2.4E-06 ± 6.3E-06	1.3E-05 ± 2.8E-05	
²³⁸ U	100-K Area	12	1	3.5E-06 ± 1.1E-05	1.2E-05 ± 1.2E-05	N575	60	27	6.4E-06 ± 9.3E-06	1.9E-05 ± 1.1E-05	8.3E-03
²³⁸ U	200- East	43	6	7.6E-06 ± 1.7E-05	3.6E-05 ± 3.5E-05	N158	209	104	7.0E-06 ± 9.4E-06	3.0E-05 ± 2.9E-05	
²³⁸ U	200- West	44	3	7.8E-06 ± 1.6E-05	3.9E-05 ± 3.5E-05	N442	228	115	6.5E-06 ± 7.7E-06	2.1E-05 ± 1.0E-05	

Table C-4. Concentrations of Select Radionuclides (pCi/m³)^a in On-site Air Samples. (4 Pages)

Radionuclide	Site	2016				Sampler	2011–2015				EPA Table 2 ^{e, f}
		Number of Samples	Detections ^b	Average ^c	Maximum ^d		Number of Samples	Detections ^b	Average ^c	Maximum ^d	
²³⁸ U	618-10 BG	8	0	6.5E-06 ± 1.4E-05	1.7E-05 ± 2.9E-05	N548	40	25	5.6E-05 ± 3.0E-04	7.6E-04 ± 2.6E-04	1.9E-03
²³⁸ U	ERDF	6	0	8.8E-06 ± 1.8E-05	2.2E-05 ± 3.2E-05	N517	29	19	1.8E-05 ± 2.2E-05	5.3E-05 ± 7.9E-05	
²⁴¹ Am	100-K Area	13	0	9.5E-05 ± 4.9E-04	9.0E-04 ± 2.5E-03	N900	72	10	1.1E-05 ± 4.4E-04	7.3E-04 ± 7.3E-04	
²⁴¹ Am	200- East	43	0	2.9E-05 ± 1.6E-03	1.9E-03 ± 2.2E-03	N582	96	0	-6.0E-05 ± 1.5E-03	1.8E-03 ± 2.5E-03	1.9E-03
²⁴¹ Am	200- West	45	1	9.9E-05 ± 1.6E-03	2.7E-03 ± 4.7E-03	N200	98	6	-2.3E-04 ± 1.7E-03	2.4E-03 ± 2.3E-03	
²⁴¹ Am	618-10 BG	8	0	1.2E-05 ± 2.3E-05	3.7E-05 ± 4.1E-05	N579	40	22	3.5E-05 ± 1.0E-04	2.4E-04 ± 9.4E-05	
²⁴¹ Pu	100-K Area	12	0	1.3E-04 ± 1.7E-03	2.7E-03 ± 3.3E-03	N534	60	1	1.3E-04 ± 9.6E-04	1.6E-03 ± 1.4E-03	1.9E-03
²⁴¹ Pu	200- East	4	0	-2.5E-04 ± 9.8E-04	2.4E-04 ± 4.5E-04	N481	20	0	4.8E-05 ± 6.3E-04	7.7E-04 ± 1.1E-03	
²⁴¹ Pu	200- West	12	0	-1.2E-04 ± 9.5E-04	7.3E-04 ± 1.6E-03	N555	12	1	8.1E-05 ± 1.1E-03	9.8E-04 ± 9.8E-03	

^a 1 pCi = 0.037 Bq^b Number of samples with measurable concentrations of contaminant^c Average ± two standard deviations of all samples analyzed^d Maximum ± analytical uncertainty^e DOE derived concentration guides are shown for gross alpha and gross beta^f EPA values are based on an effective dose equivalent of 10 mrem/yr (40 CFR 61, Appendix E, Table 2)

BG = Burial Ground project

D4 = deactivation, decontamination, decommissioning, and demolition

DOE = U.S. Department of Energy

EPA = U.S. Environmental Protection Agency

ERDF = Environmental Restoration Disposal Facility

Table C-5. Concentrations of Selected Radionuclides (pCi/m³)^a in Ambient Air Samples. (3 Pages)

Radionuclide	Site	2016				Sampler	2011 - 2015				EPA Table 2 ^{e,f}
		Number of Samples	Detections ^b	Average ^c	Maximum ^d		Number of Samples	Detections ^b	Average ^c	Maximum ^d	
gross α	Onsite	539	452	7.8E-04 ± 1.3E-03	5.8E-03 ± 1.4E-03	N932	2634	2371	8.6E-04 ± 1.4E-03	8.1E-03 ± 1.1E-03	2.0E-02
gross α	Perimeter	294	247	7.7E-04 ± 1.3E-03	4.7E-03 ± 8.7E-04	N907	1416	1278	8.7E-04 ± 1.5E-03	7.7E-03 ± 1.2E-03	
gross α	Nearby Communities	189	153	7.3E-04 ± 1.1E-03	3.7E-03 ± 8.0E-04	N948	496	467	9.2E-04 ± 1.5E-03	6.0E-03 ± 9.2E-04	
gross α	Distant Community	27	19	6.6E-04 ± 1.2E-03	3.3E-03 ± 7.4E-04	N909	131	108	7.5E-04 ± 1.4E-03	4.2E-03 ± 8.5E-04	
gross β	Onsite	539	539	1.7E-02 ± 1.9E-02	6.1E-02 ± 5.7E-03	N924	2638	2638	2.0E-02 ± 2.8E-02	1.3E-01 ± 1.0E-02	9.0E+00
gross β	Perimeter	294	294	1.7E-02 ± 2.0E-02	6.4E-02 ± 6.7E-03	N937	1416	1416	2.0E-02 ± 2.6E-02	9.5E-02 ± 8.8E-03	
gross β	Nearby Communities	189	189	1.7E-02 ± 2.1E-02	7.2E-02 ± 6.6E-03	N943	906	906	2.0E-02 ± 2.8E-02	1.6E-01 ± 1.6E-02	
gross β	Distant Community	27	27	1.5E-02 ± 1.9E-02	5.2E-02 ± 4.4E-03	N909	131	131	1.8E-02 ± 2.4E-02	9.5E-02 ± 7.4E-03	
³ H	Onsite	126	22	4.7E+00 ± 1.2E+01	3.4E+01 ± 9.2E+00	N902	560	342	9.0E+00 ± 2.6E+01	1.1E+02 ± 1.1E+01	1.5E+03
³ H	Perimeter	97	5	2.5E+00 ± 9.4E+00	2.7E+01 ± 8.0E+00	N939	448	207	6.0E+00 ± 2.0E+01	9.4E+01 ± 8.9E+00	
³ H	Nearby Communities	28	2	4.1E+00 ± 2.2E+01	5.8E+01 ± 1.3E+01	N944	128	59	5.4E+00 ± 1.4E+01	4.8E+01 ± 1.1E+01	
³ H	Distant Community	13	1	1.7E+00 ± 4.7E+00	5.8E+00 ± 4.7E+00	N909	65	24	5.1E+00 ± 2.0E+01	7.1E+01 ± 1.2E+01	
⁹⁰ Sr	Onsite	34	0	-4.7E-05 ± 7.2E-04	1.4E-03 ± 1.2E-03	N922	149	2	1.4E-05 ± 3.2E-04	9.7E-04 ± 7.9E-04	1.9E-02

Table C-5. Concentrations of Selected Radionuclides (pCi/m³)^a in Ambient Air Samples. (3 Pages)

Radionuclide	Site	2016				Sampler	2011 - 2015				EPA Table 2 ^{e,f}
		Number of Samples	Detections ^b	Average ^c	Maximum ^d		Number of Samples	Detections ^b	Average ^c	Maximum ^d	
⁹⁰ Sr	Perimeter	18	0	-7.5E-05 ± 3.7E-04	3.3E-04 ± 4.3E-04	N935	108	0	1.2E-05 ± 3.2E-04	6.5E-04 ± 6.4E-04	
⁹⁰ Sr	Nearby Communities	6	0	1.7E-05 ± 3.6E-04	2.8E-04 ± 3.0E-04	N945	38	0	7.6E-06 ± 1.9E-04	4.0E-04 ± 5.0E-04	
⁹⁰ Sr	Distant Community	2	0	-1.0E-04 ± 4.2E-05	-8.4E-05 ± 3.6E-04	N909	15	0	2.7E-05 ± 2.1E-04	2.8E-04 ± 2.5E-04	
¹³⁷ Cs	Onsite	40	0	-5.7E-06 ± 3.9E-04	3.2E-04 ± 4.3E-04	N912	207	2	8.3E-05 ± 5.3E-04	1.2E-03 ± 1.0E-03	1.9E-02
¹³⁷ Cs	Perimeter	22	0	9.3E-05 ± 2.8E-04	3.5E-04 ± 2.1E-04	N933	138	2	5.5E-05 ± 7.9E-04	1.9E-03 ± 1.6E-03	
¹³⁷ Cs	Nearby Communities	14	0	-2.8E-06 ± 3.0E-04	3.5E-04 ± 4.6E-04	N948	96	1	1.1E-04 ± 6.8E-04	1.2E-03 ± 7.0E-04	
¹³⁷ Cs	Distant Community	2	0	-6.9E-05 ± 2.7E-04	6.7E-05 ± 2.3E-04	N909	15	0	6.1E-05 ± 6.4E-04	7.7E-04 ± 9.1E-04	
²³⁴ U	Onsite	28	16	4.7E-05 ± 5.6E-05	1.3E-04 ± 7.6E-05	N920	152	133	3.8E-05 ± 3.0E-05	1.2E-04 ± 7.6E-05	7.7E-03
²³⁴ U	Perimeter	8	6	5.2E-05 ± 3.2E-05	9.0E-05 ± 5.3E-05	N936	60	53	4.5E-05 ± 3.8E-05	8.3E-05 ± 1.8E-05	
²³⁴ U	Nearby Communities	10	6	5.8E-05 ± 5.1E-05	1.1E-04 ± 7.0E-05	N945	68	59	4.6E-05 ± 3.1E-05	8.7E-05 ± 1.9E-05	
²³⁴ U	Distant Community	2	2	7.7E-05 ± 2.3E-05	8.8E-05 ± 5.6E-05	N909	15	12	3.7E-05 ± 3.1E-05	7.2E-05 ± 3.5E-05	
²³⁸ U	Onsite	28	18	3.8E-05 ± 3.4E-05	6.8E-05 ± 4.6E-05	N920	152	146	4.1E-05 ± 2.6E-05	9.3E-05 ± 6.5E-05	8.3E-03
²³⁸ U	Perimeter	8	6	4.3E-05 ± 2.4E-05	6.4E-05 ± 5.1E-05	N937	60	56	4.9E-05 ± 3.7E-05	1.2E-04 ± 6.4E-05	
²³⁸ U	Nearby Communities	10	8	5.9E-05 ± 3.0E-05	8.1E-05 ± 5.3E-05	N946	68	66	4.9E-05 ± 2.2E-05	8.0E-05 ± 6.9E-05	
²³⁸ U	Distant Community	2	1	3.5E-05 ± 1.4E-05	4.1E-05 ± 3.7E-05	N909	15	13	3.6E-05 ± 2.5E-05	6.0E-05 ± 2.5E-05	

Table C-5. Concentrations of Selected Radionuclides (pCi/m³)^a in Ambient Air Samples. (3 Pages)

Radionuclide	Site	2016				Sampler	2011 - 2015				EPA Table 2 ^{e,f}
		Number of Samples	Detections ^b	Average ^c	Maximum ^d		Number of Samples	Detections ^b	Average ^c	Maximum ^d	
^{239/240} Pu	Onsite	39	0	-1.4E-06 ± 1.2E-05	1.1E-05 ± 1.9E-05	N931	194	7	1.2E-06 ± 2.5E-05	1.6E-04 ± 5.2E-05	2.0E-03
^{239/240} Pu	Perimeter	18	0	-3.9E-07 ± 1.1E-05	1.0E-05 ± 2.4E-05	N938	103	3	4.1E-07 ± 6.2E-06	1.8E-05 ± 1.9E-05	
^{239/240} Pu	Nearby Communities	8	0	2.5E-06 ± 1.3E-05	1.1E-05 ± 2.6E-05	N946	51	4	-7.8E-08 ± 6.9E-06	1.0E-05 ± 3.7E-06	
^{239/240} Pu	Distant Community	2	0	-1.7E-06 ± 3.9E-06	2.6E-07 ± 2.6E-06	N909	15	0	6.1E-08 ± 2.9E-06	2.7E-06 ± 2.6E-06	
²⁴¹ Am	Onsite	40	0	1.2E-05 ± 2.1E-03	2.2E-03 ± 2.7E-03	N929	207	3	1.0E-05 ± 1.9E-03	4.0E-03 ± 3.2E-03	1.9E-03
²⁴¹ Am	Perimeter	22	0	1.4E-04 ± 1.4E-03	1.7E-03 ± 2.0E-03	N933	138	0	-1.1E-04 ± 2.1E-03	2.1E-03 ± 2.3E-03	
²⁴¹ Am	Nearby Communities	14	0	1.3E-04 ± 1.9E-03	2.8E-03 ± 2.1E-03	N949	96	0	-2.2E-04 ± 3.0E-03	5.1E-03 ± 5.3E-03	
²⁴¹ Am	Distant Community	2	0	5.0E-05 ± 2.1E-04	1.6E-04 ± 1.6E-03	N909	15	0	-5.3E-04 ± 3.1E-03	1.8E-03 ± 2.1E-03	

^a 1 pCi = 0.037 Bq.^b 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.^c Average ± two standard deviations of all samples analyzed.^d Maximum ± analytical uncertainty^e DOE derived concentration guides are shown for gross alpha and gross beta^f EPA values are based on an effective dose equivalent of 10 mrem/year (40 CFR 61, Appendix E, Table 2).

C.3 Columbia River Water

Table C-6. Radionuclide Concentrations in Columbia River Water (Richland, Washington). (2 Pages)

Radionuclide ^b		2016				2011-2015				WA Ambient Surface Water Quality Standard ^d
		Number of		Concentration ^a		Number of		Concentration ^a		
		Samples	Detects	Maximum (pCi/L) ^c	Average (pCi/L) ^c	Samples	Detects	Maximum (pCi/L) ^c	Average (pCi/L) ^c	
Composite System										
Strontium-90		14	0	3.04E-02 ± 2.54E-02	-6.24E-03 ± 4.72E-02	62	0	5.58E-02 ± 3.70E-02	1.51E-02 ± 4.90E-02	8
Tritium		14	14	4.92E+01 ± 1.15E+01	3.00E+01 ± 2.15E+01	62	62	1.08E+02 ± 1.70E+01	3.19E+01 ± 2.97E+01	20000
Technetium-99		14	0	4.01E-01 ± 3.22E-01	3.21E-01 ± 4.88E-01	62	0	6.18E-01 ± 4.48E-01	5.40E-02 ± 4.73E-01	900
Uranium-234		14	14	3.35E-01 ± 6.07E-02	2.90E-01 ± 7.57E-02	62	62	3.40E-01 ± 7.49E-02	2.61E-01 ± 7.11E-02	--
Uranium-235		14	3	3.41E-02 ± 2.36E-02	1.58E-02 ± 2.19E-02	62	16	7.81E-02 ± 3.59E-02	1.57E-02 ± 2.80E-02	--
Uranium-238		14	14	2.53E-01 ± 5.53E-02	2.19E-01 ± 1.89E-02	62	62	2.82E-01 ± 6.34E-02	2.14E-01 ± 6.01E-02	--
Continuous System										
Cesium-137	D ^b	12	0	2.35E-03 ± 2.25E-03	-5.47E-04 ± 3.14E-03	44	0	1.67E-03 ± 3.08E-03	-5.61E-05 ± 1.90E-03	200
	p ^b	12	0	4.4E-03 ± 5.6E-03	3.0E-04 ± 5.0E-03	44	0	6.0E-03 ± 4.7E-03	6.9E-04 ± 4.0E-03	
Plutonium-238 ^e	D ^b	12	0	4.1E-05 ± 5.0E-05	-7.5E-06 ± 5.9E-05	23	0	8.7E-05 ± 7.4E-05	8.1E-06 ± 6.2E-05	600
	p ^b	12	2	7.9E-04 ± 3.1E-04	7.6E-05 ± 4.4E-04	23	1	3.6E-04 ± 1.6E-04	4.0E-05 ± 1.8E-04	
Plutonium-239/240 ^e	D ^b	12	0	8.3E-05 ± 7.5E-05	1.5E-05 ± 3.2E-05	23	0	6.3E-05 ± 4.7E-05	8.1E-06 ± 4.1E-05	--
	p ^b	12	0	7.5E-05 ± 1.0E-04	2.3E-05 ± 5.9E-05	23	0	1.4E-04 ± 1.3E-04	1.2E-05 ± 1.8E-04	

^a Maximum values are \pm total propagated analytical uncertainty (2 sigma). Averages are \pm 2 standard deviations of the mean.

^b 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).

^c 1 pCi = 0.037 Bq.

^d WAC 173-201A-250 and EPA-570/9-76-003; WAC 246-290; 40 CFR 141.

^e Samples from 2011 were not included as there was no distinguishing characters within the database to differentiate between filter and resin. Plutonium-238 and Plutonium 239/240 were analyzed quarterly in previous years resulting in less samples.

== = No concentration guides available

WA = Washington State

Table C-7. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, Washington). (2 Pages)

Radionuclide ^b		2016				2011-2015				WA Ambient Surface Water Quality Standard ^d
		Number of		Concentration ^a		Number of		Concentration ^a		
		Samples	Detects	Maximum (pCi/L) ^c	Average (pCi/L) ^c	Samples	Detects	Maximum (pCi/L) ^c	Average (pCi/L) ^c	
Composite System										
Strontium-90		14	0	3.59E-02 ± 3.51E-02	2.01E-03 ± 4.27E-02	62	0	5.37E-02 ± 3.74E-02	1.26E-02 ± 4.49E-02	8
Tritium		14	12	2.68E+01 ± 7.26E+00	1.46E+01 ± 1.00E+01	62	61	2.98E+01 ± 8.77E+00	1.77E+01 ± 1.00E+01	20000
Technetium-99		14	0	4.54E-01 ± 4.67E-01	7.16E-02 ± 5.76E-01	62	0	6.01E-01 ± 4.60E-01	6.50E-03 ± 4.18E-01	900
Uranium-234		14	14	3.36E-01 ± 6.49E-02	2.56E-01 ± 9.22E-02	62	62	3.23E-01 ± 7.13E-02	2.28E-01 ± 7.15E-02	--
Uranium-235		14	4	7.07E-02 ± 5.69E-02	2.24E-02 ± 3.47E-02	62	16	7.37E-02 ± 3.25E-02	1.35E-02 ± 2.74E-02	--
Uranium-238		14	14	2.73E-01 ± 1.04E-01	2.10E-01 ± 6.74E-02	62	62	2.41E-01 ± 6.19E-02	1.83E-01 ± 5.46E-02	--
Continuous System										
Cesium-137	D ^b	13	0	2.2E-03± 2.6E-03	1.2E-04 ± 1.7E-03	45	0	4.00E-03 ± 2.3E-03	3.7E-04 ± 1.8E-03	200
	P ^b	13	0	4.9E-03 ± 7.1E-03	9.1E-04 ± 3.3E-03	47	0	5.1E-03 ± 4.9E-03	6.2E-04 ± 4.1E-03	
Plutonium-238 ^e	D ^b	13	0	1.7E-05 ± 4.2E-05	-1.1E-05 ± 5.1E-05	24	0	5.4E-05 ± 7.0E-05	5.4E-06 ± 3.9E-05	600
	P ^b	12	1	4.9E-04 ± 2.8E-04	5.2E-05 ± 2.8E-04	23	2	5.2E-04 ± 5.1E-05	2.4E-05 ± 2.8E-04	
Plutonium-239/240 ^e	D ^b	13	0	3.5E-05 ± 4.8E-05	-4.3E-06 ± 3.5E-05	24	0	8.8E-05 ± 6.30E-05	7.5E-06 ± 4.8E-05	--
	P ^b	12	0	2.0E-04 ± 1.8E-04	4.7E-05 ± 1.0E-04	23	1	2.4E-04 ± 1.1E-04	2.8E-05 ± 1.3E-04	

^a Maximum values are \pm total propagated analytical uncertainty (2 sigma). Averages are \pm 2 standard deviations of the mean.

^b 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).

^c 1 pCi = 0.037 Bq.

^d WAC 173-201A-250 and EPA-570/9-76-003; WAC 246-290; 40 CFR 141.

^e Samples from 2011 were not included as there was no distinguishing characters within the database to differentiate between filter and resin.

NOTE: Plutonium-238 and Plutonium 239/240 were analyzed quarterly in previous years resulting in less samples.

-- = no concentration guides available

WA = Washington State

Table C-8. 2016 Radionuclide Concentrations in Columbia River Transect Water Samples.

Transect/Radionuclide	No. of Detections	No. of Samples	Concentration ^a					
			Maximum <i>pCi/L^b</i>			Average <i>pCi/L^b</i>		
Vernita Bridge (HRM 0.3)								
Strontium-90 ^c	0	8	0.04	±	0.04	0.01	±	0.04
Technitium-99 ^c	0	8	0.14	±	0.54	-0.26	±	0.57
Tritium	8	8	21.5	±	11.1	13.4	±	7.7
Uranium-234	8	8	0.36	±	0.07	0.27	±	0.08
Uranium-235	4	8	0.05	±	0.03	0.03	±	0.04
Uranium-238	8	8	0.28	±	0.06	0.22	±	0.06
100—N Area (HRM 9.5)								
Strontium-90 ^c	0	6	0.05	±	0.04	0.0004	±	0.06
Tritium	6	6	25.1	±	10.5	18.7	±	6.0
Uranium-234	6	6	0.26	±	0.05	0.24	±	0.03
Uranium-235	3	6	0.03	±	0.02	0.016	±	0.012
Uranium-238	6	6	0.20	±	0.04	0.18	±	0.03
Hanford Townsite (HRM 28.7)								
Strontium-90 ^c	0	6	0.020	±	0.03	0.01	±	0.025
Tritium	6	6	108.0	±	37.2	45.7	±	85.5
Uranium-234	6	6	0.28	±	0.05	0.24	±	0.06
Uranium-235	3	6	0.05	±	0.02	0.03	±	0.02
Uranium-238	6	6	0.20	±	0.05	0.18	±	0.05
300 Area (HRM 43.1)								
Strontium-90 ^c	0	5	0.02	±	0.03	-0.0027	±	0.02
Tritium	5	5	39.1	±	9.3	20.1	±	19.7
Uranium-234	5	5	0.59	±	0.10	0.30	±	0.30
Uranium-235	1	5	0.02	±	0.02	0.01	±	0.01
Uranium-238	5	5	0.45	±	0.08	0.24	±	0.08
Richland (HRM 46.4)								
Strontium-90 ^c	0	10	0.04	±	0.04	-0.0013	±	0.05
Technitium-99	1	10	-0.14	±	0.50	-0.30	±	0.27
Tritium	12	10	49.6	±	12.6	23.0	±	24.8
Uranium-234	12	10	0.38	±	0.07	0.31	±	0.10
Uranium-235	5	10	0.07	±	0.03	0.02	±	0.04
Uranium-238	12	10	0.31	±	0.07	0.24	±	0.06

^a Maximum values ± total propagated analytical uncertainty; Average values ± 2stdv.^b 1 pCi = 0.037 Bq.^c Less than the laboratory—reported detection limit.

HRM = Hanford river marker.

**Table C-9. Dissolved Metal Concentrations in Columbia River Transect Water
Near Hanford Site. (3 Pages)**

Metal	No. of Samples	No. of Detections	Maximum (µg/L) ^a	Minimum (µg/L) ^a	Average (±2 SD) (µg/L) ^{a,c}		Minimum Detectable Concentrations (µg/L)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^b
Vernita Bridge								
Antimony	8	0	—	—	—	—	1	N/A
Arsenic	8	2	1.87	1.70	1.74	0.13	1.7	190
Beryllium	8	0	—	—	—	—	0.2	N/A
Cadmium	8	0	—	—	—	—	0.11	N/A
Chromium	8	0	—	—	—	—	2	10
Copper	8	8	0.63	0.43	0.54	0.12	0.35	6
Hexavalent Chromium	4	0	—	—	—	—	1.5	10
Lead	8	0	—	—	—	—	0.5	1.1
Nickel	8	0	—	—	—	—	0.5	83
Selenium	8	0	—	—	—	—	1.5	5
Silver	8	0	—	—	—	—	0.2	N/A
Thallium	8	0	—	—	—	—	0.45	N/A
Uranium	8	8	0.63	0.53	0.58	0.09	0.067	N/A
Zinc	8	2	4.18	3.50	3.66	0.56	3.5	55
100-N Area								
Antimony	7	0	—	—	—	—	1	N/A
Arsenic	7	0	—	—	—	—	1.7	190
Beryllium	7	0	—	—	—	—	0.2	N/A
Cadmium	7	0	—	—	—	—	0.11	N/A
Chromium	7	0	—	—	—	—	2	10
Copper	7	7	0.77	0.51	0.58	0.17	0.35	6
Hexavalent Chromium	6	0	—	—	—	—	1.5	10
Lead ^d	7	1	0.50	0.17	0.45	0.23	0.5	1.1
Nickel	7	0	—	—	—	—	0.5	83
Selenium	7	0	—	—	—	—	1.5	5
Silver	7	0	—	—	—	—	0.2	N/A
Thallium	7	0	—	—	—	—	0.45	N/A
Uranium	7	7	0.63	0.53	0.58	0.09	0.067	N/A
Zinc	7	2	4.20	3.50	3.70	0.56	3.5	55

**Table C-9. Dissolved Metal Concentrations in Columbia River Transect Water
Near Hanford Site. (3 Pages)**

Metal	No. of Samples	No. of Detections	Maximum ($\mu\text{g/L}$) ^a	Minimum ($\mu\text{g/L}$) ^a	Average (± 2 SD) ($\mu\text{g/L}$) ^{b,c}		Minimum Detectable Concentrations ($\mu\text{g/L}$)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^b
Hanford Townsite								
Antimony	6	0	—	—	—	—	1	N/A
Arsenic	6	4	1.86	1.70	1.76	0.12	1.7	190
Beryllium	6	0	—	—	—	—	0.2	N/A
Cadmium	6	0	—	—	—	—	0.11	N/A
Chromium	6	0	—	—	—	—	2	10
Copper	6	6	0.58	0.44	0.50	0.10	0.35	6
Hexavalent Chromium	6	0	—	—	—	—	1.5	10
Lead	6	0	—	—	—	—	0.5	1.1
Nickel	6	0	—	—	—	—	0.5	83
Selenium	6	0	—	—	—	—	1.5	5
Silver	6	0	—	—	—	—	0.2	N/A
Thallium	6	0	—	—	—	—	0.45	N/A
Uranium	6	6	0.51	0.47	0.48	0.03	0.067	N/A
Zinc	6	0	—	—	—	—	3.5	55
300 Area								
Antimony	5	0	—	—	—	—	1	N/A
Arsenic	5	0	—	—	—	—	1.7	190
Beryllium	5	0	—	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	—	0.11	N/A
Chromium	5	0	—	—	—	—	2	10
Copper	5	5	0.54	0.42	0.50	0.08	0.35	6
Hexavalent Chromium	5	0	—	—	—	—	1.5	10
Lead	5	0	—	—	—	—	0.5	1.1
Nickel	5	0	—	—	—	—	0.5	83
Selenium	5	0	—	—	—	—	1.5	5
Silver	5	0	—	—	—	—	0.2	N/A
Thallium	5	0	—	—	—	—	0.45	N/A
Uranium	5	5	1.26	0.54	0.73	0.54	0.067	N/A
Zinc	5	0	—	—	—	—	3.5	55

**Table C-9. Dissolved Metal Concentrations in Columbia River Transect Water
Near Hanford Site. (3 Pages)**

Metal	No. of Samples	No. of Detections	Maximum ($\mu\text{g/L}$) ^a	Minimum ($\mu\text{g/L}$) ^a	Average (± 2 SD) ($\mu\text{g/L}$) ^{a,c}		Minimum Detectable Concentrations ($\mu\text{g/L}$)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^b
Richland								
Antimony	10	0	—	—	—	—	1	N/A
Arsenic	10	4	2.22	1.70	1.79	0.32	1.7	190
Beryllium	10	0	—	—	—	—	0.2	N/A
Cadmium	10	0	—	—	—	—	0.11	N/A
Chromium	10	0	—	—	—	—	2	10
Copper	10	10	0.88	0.37	0.55	0.27	0.35	6
Hexavalent Chromium	5	0	—	—	—	—	1.5	10
Lead	10	0	—	—	—	—	0.5	1.1
Nickel	10	5	1.07	0.50	0.75	0.50	0.5	83
Selenium	10	0	—	—	—	—	1.5	5
Silver	10	0	—	—	—	—	0.2	N/A
Thallium	10	0	—	—	—	—	0.45	N/A
Uranium	10	10	0.88	0.53	0.65	0.19	0.067	N/A
Zinc	10	2	3.99	3.50	3.57	0.31	3.5	55

^a Dashes indicate results at or below minimum detectable concentrations.

^b 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 CaCO₃/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 ($\mu\text{g/L}$) concentrations shown.

^c Average calculated using reporting limit values for all results at or below minimum detectable concentrations.

^d Single detected value.

SD = Standard deviation

C.4 Sediment in Columbia Riverbed and Hanford Shorelines

Table C-10. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site). (4 Pages)

Sediment Location	Radionuclide	2016				2011-2015					
		No. of Samples	No. of Detects	Maximum Concentration ^a		No. of Samples	No. of Detects	Average Concentration ^a			
				pCi/g	pCi/g			pCi/g	pCi/g		
Adjacent to Locke Island	Cesium-137	1	0	1.53E-02	± 2.47E-02	3	0	7.56E-03	± 1.81E-02		
	Cobalt-60	1	0	-1.72E-02	± 1.41E-02	3	0	-4.40E-03	± 2.11E-02		
	Europium-152	1	0	1.49E-01	± 7.66E-02	3	0	-1.29E-02	± 1.04E-02		
	Europium-155 ^b	1	0	N/A		3	0	N/A			
	Plutonium-239/240	1	0	-1.93E-03	± 4.47E-03	3	0	1.78E-03	± 3.91E-03		
	Uranium-234	1	1	1.13E+00	± 1.38E-01	3	3	1.39E+00	± 1.14E-01		
	Uranium-235	1	1	1.11E-01	± 3.00E-02	3	3	9.02E-02	± 2.51E-03		
	Uranium-238	1	1	1.21E+00	± 1.47E-01	3	3	1.34E+00	± 1.72E-01		
Adjacent to Savage Island	Cesium-137	1	1	4.16E-02	± 2.33E-02	3	3	3.66E-02	± 1.36E-02		
	Cobalt-60	1	0	-7.28E-04	± 1.08E-02	3	0	6.01E-03	± 1.06E-02		
	Europium-152	1	0	N/A		3	0	-1.38E-02	± 8.63E-03		
	Europium-155 ^b	1	0	-2.12E-02	± 2.30E-02	3	0	4.45E-03	± 7.28E-02		
	Plutonium-239/240	1	0	4.02E-03	± 6.41E-03	3	0	1.19E-03	± 2.98E-03		
	Uranium-234	1	1	5.88E-01	± 8.18E-02	3	3	8.25E-01	± 3.03E-01		
	Uranium-235	1	1	6.27E-02	± 2.18E-02	3	3	6.50E-02	± 3.39E-02		
	Uranium-238	1	1	6.48E-01	± 8.81E-02	3	3	7.53E-01	± 2.43E-01		
100-D Spring 102-1	Cesium-137	3	3	1.12E-01	± 5.63E-02	4	4	1.39E-01	± 8.25E-02		
	Cobalt-60	3	0	1.99E-04	± 7.10E-03	4	1	1.61E-02	± 5.34E-02		
	Europium-152	3	0	3.90E-02	± 9.26E-02	4	0	1.65E-02	± 5.40E-02		
	Europium-155	3	0	1.08E-02	± 4.72E-02	4	1	4.29E-02	± 7.77E-03		
	Plutonium-239/240	3	1	1.61E-02	± 9.70E-03	4	2	1.22E-03	± 2.93E-03		
	Uranium-234	3	3	5.85E-01	± 1.00E-01	4	4	4.68E-01	± 1.23E-01		

Table C-10. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site). (4 Pages)

Sediment Location	Radionuclide	2016				2011-2015					
		No. of Samples	No. of Detects	Maximum Concentration ^a		No. of Samples	No. of Detects	Average Concentration ^a			
				pCi/g	pCi/g			pCi/g	pCi/g		
100F Slough	Uranium-235	3	3	6.81E-02	± 1.30E-02	4	4	4.91E-02	±	2.09E-02	
	Uranium-238	3	3	5.79E-01	± 1.00E-01	4	4	4.95E-01	±	7.47E-02	
	Cesium-137	1	1	2.01E-01	± 5.03E-02	5	5	1.85E-01	±	5.42E-02	
	Cobalt-60	1	0	1.75E-03	± 2.45E-02	5	0	2.31E-03	±	1.89E-02	
	Europium-152	1	0	4.71E-02	± 6.68E-02	5	0	1.25E-03	±	4.89E-02	
	Europium-155	1	0	-2.97E-02	± 5.90E-02	5	0	4.67E-02	±	3.94E-02	
	Plutonium-239/240	1	0	-5.12E-04	± 7.70E-03	5	2	2.33E-03	±	1.96E-03	
	Uranium-234	1	1	6.58E-01	± 8.87E-02	5	5	5.51E-01	±	1.92E-01	
	Uranium-235	1	1	4.51E-02	± 1.83E-02	5	5	5.97E-02	±	1.93E-02	
	Uranium-238	1	1	6.40E-01	± 8.66E-02	5	5	4.90E-01	±	1.64E-01	
100-K Spring 63-1	Cesium-137	2	2	1.22E-01	± 5.55E-02	2	2	7.14E-02	±	8.92E-02	
	Cobalt-60	2	0	2.84E-02	± 3.04E-02	2	0	4.00E-04	±	5.14E-03	
	Europium-152	2	0	3.84E-03	± 4.09E-02	2	0	-1.61E-02	±	2.90E-02	
	Europium-155 ^b	2	0	N/A		2	0	N/A			
	Plutonium-239/240	2	0	8.31E-03	± 8.54E-03	1	0	2.47E-03	±	7.88E-04	
	Uranium-234	2	2	1.34E+00	± 1.58E-01	2	2	9.03E-01	±	3.74E-01	
	Uranium-235	2	2	7.79E-02	± 2.50E-02	2	2	5.17E-02	±	5.40E-03	
	Uranium-238	2	2	1.24E+00	± 1.48E-01	2	2	8.13E-01	±	2.46E-01	
Hanford Slough	Cesium-137	1	1	2.19E-01	± 3.24E-02	6	6	2.46E-01	±	3.42E-02	
	Cobalt-60	1	0	-8.99E-03	± 1.35E-02	6	0	-5.80E-03	±	4.43E-02	
	Europium-152	1	0	3.20E-03	± 2.44E-02	6	0	3.63E-02	±	5.82E-02	
	Europium-155 ^b	1	0	N/A		6	0	4.74E-02	±	1.06E-01	
	Plutonium-239/240 ^b	1	1	4.79E-03	± 7.78E-03	6	0	2.58E-03	±	1.66E-03	
	Uranium-234	1	1	5.93E-01	± 8.14E-02	6	6	1.33E+00	±	2.50E+00	
	Uranium-235	1	1	6.77E-02	± 2.24E-02	6	5	8.97E-02	±	1.73E-01	

Table C-10. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site). (4 Pages)

Sediment Location	Radionuclide	2016				2011-2015					
		No. of Samples	No. of Detects	Maximum Concentration ^a		No. of Samples	No. of Detects	Average Concentration ^a			
				pCi/g	pCi/g			pCi/g	pCi/g		
McNary Dam	Uranium-238	1	1	6.45E-01	± 8.67E-02	6	6	7.79E-01	±	4.04E-01	
	Cesium-137	2	2	2.23E-01	± 4.68E-02	10	10	2.31E-01	±	4.26E-02	
	Cobalt-60	2	0	1.40E-02	± 2.53E-02	10	0	5.06E-03	±	4.20E-02	
	Europium-152	2	0	7.56E-02	± 7.93E-02	10	0	5.18E-02	±	8.06E-02	
	Europium-155	2	0	3.37E-02	± 6.45E-02	10	0	8.71E-02	±	3.33E-02	
	Plutonium-239/240	2	2	1.33E-02	± 1.20E-02	10	7	9.00E-03	±	8.71E-03	
	Uranium-234	2	2	1.51E+00	± 1.66E-01	10	10	1.45E+00	±	2.54E-01	
	Uranium-235	2	2	1.06E-01	± 3.12E-02	10	10	7.57E-02	±	2.61E-02	
	Uranium-238	2	2	1.22E+00	± 1.38E-01	10	10	1.23E+00	±	1.77E-01	
Priest Rapids Dam	Cesium-137	2	2	2.96E-01	± 7.80E-02	10	10	2.54E-01	±	7.25E-02	
	Cobalt-60	2	0	2.04E-02	± 2.86E-02	10	0	-5.17E-03	±	1.69E-02	
	Europium-152	2	0	2.72E-03	± 7.63E-02	10	10	-8.08E-03	±	8.01E-02	
	Europium-155 ^b	2	0	7.81E-02	± 9.05E-02	10	0	6.07E-02	±	4.98E-02	
	Plutonium-239/240	2	2	1.44E-02	± 1.12E-02	10	10	9.94E-03	±	1.91E-03	
	Uranium-234	2	2	1.41E+00	± 1.59E-01	10	10	1.21E+00	±	3.07E-01	
	Uranium-235	2	2	9.37E-02	± 2.49E-02	10	10	7.63E-02	±	4.50E-02	
	Uranium-238	2	2	1.25E+00	± 1.43E-01	10	10	1.08E+00	±	2.55E-01	
	Uranium-238	2	2	1.25E+00	± 1.43E-01	10	10	1.08E+00	±	2.55E-01	
White Bluffs Slough	Cesium-137	1	1	2.88E-01	± 7.86E-02	5	5	3.74E-01	±	1.27E-01	
	Cobalt-60	1	0	-3.08E-03	± 2.94E-02	5	0	4.84E-04	±	1.41E-02	
	Europium-152 ^b	1	0	7.06E-02	± 8.70E-02	5	0	9.24E-02	±	1.49E-01	
	Europium-155 ^b	1	0	5.87E-02	± 8.14E-02	5	0	7.89E-02	±	2.82E-02	
	Plutonium-239/240	1	0	8.00E-03	± 8.47E-03	5	3	3.39E-03	±	2.36E-03	
	Uranium-234	1	1	1.15E+00	± 1.51E-01	5	5	9.24E-01	±	2.69E-01	
	Uranium-235	1	1	1.21E-01	± 3.41E-02	5	5	6.02E-02	±	5.53E-02	
	Uranium-235	1	1	1.21E-01	± 3.41E-02	5	5	6.02E-02	±	5.53E-02	

Table C-10. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site). (4 Pages)

Sediment Location	Radionuclide	2016					2011-2015				
		No. of Samples	No. of Detects	Maximum Concentration ^a			No. of Samples	No. of Detects	Average Concentration ^a		
				pCi/g		pCi/g			pCi/g		pCi/g
	Uranium-238	1	1	1.09E+00	±	1.44E-01	5	5	9.12E-01	±	3.11E-01
^a Maximum Concentrations ± Analytical Uncertainty; Average Concentrations ± 2stdv ^b Includes samples rejected by the analytical laboratory due to low abundance or no valid peak.											
N/A = Not applicable											

Table C-11. Dissolved Metal Concentration Ranges in Columbia River Sediment (Near Hanford Site).

Metal	Priest Rapids Dam (mg/kg dry weight)	Hanford Reach ^a (mg/kg dry weight)	McNary Dam (mg/kg dry weight)
Antimony	0.86 - 1.1	0.52 - 2.6	0.88 - 0.89
Arsenic	5.3 - 5.5	1.3 - 8.5	4.7 - 6.0
Beryllium	0.91 - 1.05	0.45 - 1.45	1.1 - 1.3
Cadmium	3.1 - 4.5	0.24 - 2.7	0.95 - 0.97
Chromium	31 - 33.8	8.6 - 88.3	22.1 - 22.2
Copper	39.2 - 49.3	7.6 - 31.6	24.8 - 28.9
Lead	33.6 - 37.1	6.7 - 68.4	19.3 - 19.6
Mercury	0.11 - 0.12	0.004 - 0.05	0.07 - 0.09
Nickel	34 - 35.5	6.5 - 19.9	20.4 - 21.6
Selenium	1.8 - 3.2	0.62 - 2.0	2.6 - 2.8
Silver	0.95 - 1.06	0.48 - 0.79	1.0 - 1.03
Thallium	1.3 - 1.5	0.65 - 3.3	1.1 - 1.4
Zinc	338 - 409	57.0 - 383	176 - 200
No. of Samples	2	13	2

^a 100-F Slough (n=1), Hanford Slough (n=1), White Bluffs Slough (n=1), Adjacent to Locke Island (n=1), Adjacent to Savage Island (n=1), 100-H 145-1 (n=2), 100-D Spring 102-1 (n=2), 100-K 63-1 (n=2), 300 Area (n=2); where n = number of samples.

Table C-12. Total Organic Carbon in Columbia River Sediment.

Sediment Location	2016			2011-2015		
	No. of	Concentration^a		No. of	Concentration^a	
	Samples	Minimum	Maximum	Samples	Minimum	Maximum
		mg/kg	mg/kg		mg/kg	mg/kg
Adjacent to Locke Island ^b	0	N/A	N/A	1	N/A	1.17E+03
Adjacent to Salvage Island ^b	0	N/A	N/A	1	N/A	2.24E+03
100-D Spring 102-1	2	3.34E+03	4.35E+03	4	1.59E+03	5.87E+03
100F Slough	1	N/A	2.18E+03	5	1.43E+03	2.61E+03
100-K Spring 63-1	2	5.90E+03	1.81E+04	1	N/A	1.39E+04
Hanford Slough	1	N/A	1.20E+04	6	5.29E+03	1.70E+04
McNary Dam	2	2.34E+04	2.52E+04	10	4.45E+03	2.42E+04
Priest Rapids Dam	2	1.51E+04	3.71E+04	10	1.47E+04	3.95E+04
White Bluffs Slough	1	N/A	1.24E+04	5	6.30E+03	1.68E+04

^a 1 mg/kg = µg/kg divided by 1000

^b Adjacent to Locke and Savage Island sediment was analyzed in 2014, 2015, and 2016 but testing did not include TOC analyses.

C.5 Shoreline Seep Water

Table C-13. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/ Radionuclide	2016		Concentration pCi/L ^(a)			2011-2015		Concentration pCi/L ^(a)			Washington State Ambient Surface Water Quality Standard pCi/L ^(a, b)
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				
			Maximum ^(c)					Average ^(d)			
100-B Area (Spring 38-3)											
Strontium-90	1	0	-1.99E+00	±	5.77E-01	5	0	2.02E-03	±	7.62E-02	8
Tritium	1	1	3.99E+02	±	1.66E+02	5	5	1.02E+03	±	3.21E+02	20,000
100-B Area (Spring 39-2)											
Strontium-90	1	1	1.85E+00	±	3.06E-01	2	2	2.35E+00	±	4.15E-01	8
Tritium	1	1	1.46E+03	±	3.92E+02	2	2	1.98E+03	±	4.45E+02	20,000
100-D Area (Spring 110-1)											
Alpha (gross)	1	0	2.61E+00	±	2.29E+00	6	1	1.33E+00	±	2.31E+00	15
Beta (gross)	1	1	6.93E+00	±	2.21E+00	6	4	5.52E+00	±	7.49E+00	50
Strontium-90 ^e	1	0	5.39E-01	±	5.05E-01	6	3	1.55E+00	±	2.84E+00	8
Technetium-99	1	0	-4.34E+00	±	4.67E+00	5	0	2.32E-01	±	4.72E-01	900
Tritium	1	1	1.85E+03	±	4.06E+02	6	6	1.42E+03	±	2.09E+03	20,000
Uranium-234	1	1	1.18E+00	±	3.97E-01	5	5	5.89E-01	±	8.22E-01	—
Uranium-235	1	0	9.92E-02	±	1.45E-01	5	3	3.24E-02	±	3.84E-02	—
Uranium-238	1	1	1.50E+00	±	4.28E-01	5	5	4.90E-01	±	6.74E-01	—
100-F (Spring 207-1)											
Strontium-90	2	0	2.64E-01	±	3.69E-01	3	0	-1.11E-02	±	4.76E-02	8
Tritium	3	3	4.29E+02	±	1.80E+02	3	3	4.07E+02	±	8.39E+01	900
100-H Area (Spring 152-2)											
Strontium-90	0	0	—			1	1	5.43E+00	±	9.45E-01	8

Table C-13. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/ Radionuclide	2016		Concentration pCi/L ^(a)			2011-2015		Concentration pCi/L ^(a)			Washington State Ambient Surface Water Quality Standard pCi/L ^(a, b)
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				
			Maximum ^(c)					Average ^(d)			
Tritium	0	0	—			2	1	3.67E+02	±	3.99E+02	900
100-H Area (Spring 145-1)											
Strontium-90	0	0	—			3	0	-9.53E-04	±	3.15E-02	8
Tritium	0	0	—			3	2	2.40E+02	±	1.35E+02	900
100-K Area (Spring 63-1)											
Alpha (gross)	1	0	1.70E-01	±	1.91E+00	4	1	1.88E+00	±	2.47E+00	15
Beta (gross)	1	1	5.22E+00	±	2.18E+00	4	4	8.99E+00	±	1.30E+01	50
Carbon-14	4	4	3.02E+02	±	5.76E+01	7	5	4.36E+02	±	1.43E+03	2,000
Strontium-90	1	0	-8.51E-01	±	4.01E-01	4	0	-5.04E-03	±	4.58E-02	8
Tritium	1	0	7.18E+00	±	1.43E+02	4	2	5.55E+02	±	9.32E+02	20,000
100-N Area (Spring 8-13)											
Alpha (gross)	1	0	7.62E-01	±	2.11E+00	5	0	1.22E+00	±	1.92E+00	15
Beta (gross)	1	1	3.95E+00	±	2.19E+00	5	2	2.70E+00	±	3.47E+00	50
Strontium-90	1	0	-6.79E-01	±	3.36E-01	5	0	1.97E-02	±	2.94E-02	8
Tritium	1	1	4.00E+03	±	8.09E+02	5	5	3.00E+03	±	3.87E+03	20,000
100-N Area (Spring 89-1)											
Strontium-90	1	1	5.19E+01	±	8.74E+00	4	4	1.94E+01	±	2.94E+01	8
Tritium	1	1	1.47E+03	±	3.36E+02	4	3	6.89E+02	±	1.10E+03	20,000
Hanford Town site (Hanford Spring 28-2)											
Alpha (gross)	1	1	6.60E+00	±	3.34E+00	4	1	2.54E+00	±	1.46E+00	15
Beta (gross)	1	1	4.07E+01	±	5.07E+00	4	4	3.29E+01	±	2.71E+01	50
Tritium	1	1	2.12E+04	±	4.13E+03	4	4	2.03E+04	±	1.91E+04	20,000

Table C-13. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/ Radionuclide	2016		Concentration pCi/L ^(a)			2011-2015		Concentration pCi/L ^(a)			Washington State Ambient Surface Water Quality Standard pCi/L ^(a, b)
	No. of Samples	No. of Detects	Maximum ^(c)			No. of Samples	No. of Detects	Average ^(d)			
300 Area (300 Area Spring 42-2 and 300 Area Spring DR 42-2)											
Alpha (gross)	2	2	3.10E+01	±	5.61E+00	10	10	3.89E+01	±	5.17E+01	15
Beta (gross)	2	2	2.34E+01	±	3.39E+00	10	10	2.19E+01	±	1.85E+01	50
Tritium	2	2	3.78E+03	±	7.66E+02	10	10	4.24E+03	±	1.19E+03	20,000
Uranium-234	2	2	2.39E+01	±	2.79E+00	10	10	2.20E+01	±	2.67E+01	–
Uranium-235	2	2	2.28E+00	±	5.60E-01	10	10	1.69E+00	±	2.06E+00	–
Uranium-238	2	2	2.57E+01	±	2.97E+00	10	10	2.12E+01	±	2.58E+01	–

^a 1 pCi = 0.037 Bq.^b WAC 246-290, 40 CFR 141; WAC 173-201A-250; EPA-570/9-76-003; Appendix Table D.4^c Maximum values are ± total propagated analytical uncertainty.^d Averages are ± 2 standard deviations of the mean.^e Some sample results were rejected due to analytical laboratory interference.

-- = no concentration guides available.

Table C-14. Metals and Anions in Columbia River Water Shoreline Seep Water. (5 Pages)

Location	Analyte	No. of Samples	No. of Detects	Filtered/ Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c
100B (39-2 and 38-3)	Metals								
	Antimony	2	0	Filtered	1.00E+00			µg/L	N/A
	Arsenic	2	2	Filtered	1.77E+00	-	2.27E+00	µg/L	190
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59
	Chromium	2	1	Filtered	3.00E+00	-	4.93E+00	µg/L	10 ^e
	Chromium	2	2	Unfiltered	4.85E+00	-	3.71E+01	µg/L	96 ^f
	Copper	2	1	Filtered	3.50E-01	-	5.17E+00	µg/L	6
	Hexavalent Chromium	2	1	Filtered	1.50E+00	-	5.10E+00	µg/L	10
	Hexavalent Chromium	2	1	Unfiltered	1.50E+00	-	4.90E+00	µg/L	10
	Lead	2	1	Filtered	5.00E-01	-	6.57E-01	µg/L	1.1
	Nickel	2	1	Filtered	5.00E-01	-	5.00E-01	µg/L	83
	Selenium	2	0	Unfiltered	2.00E+00			µg/L	5
	Thallium	2	0	Filtered	6.00E-01			µg/L	N/A
	Zinc	2	1	Filtered	3.50E+00	-	1.69E+01	µg/L	55
	Anions								
	Nitrate	2	2	Unfiltered	3.56E+03	-	7.17E+03	µg/L	10 ^g
100D (110-1)	Metals								
	Antimony	1	0	Filtered	1.00E+00			µg/L	N/A
	Arsenic	1	0	Filtered	1.70E+00			µg/L	190
	Cadmium	1	0	Filtered	3.00E-01			µg/L	0.59
	Chromium	1	1	Filtered	1.03E+01			µg/L	10 ^e
	Chromium	1	1	Unfiltered	1.12E+01			µg/L	96 ^f
	Hexavalent Chromium	1	1	Filtered	9.10E+00			µg/L	10
	Hexavalent Chromium	1	1	Unfiltered	7.10E+00			µg/L	10
	Copper	1	1	Filtered	5.17E-01			µg/L	6

Table C-14. Metals and Anions in Columbia River Water Shoreline Seep Water. (5 Pages)

Location	Analyte	No. of Samples	No. of Detects	Filtered/ Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c
	Lead	1	0	Filtered	5.00E-01			µg/L	1.1
	Nickel	1	1	Filtered	6.57E-01			µg/L	83
	Selenium	1	1	Unfiltered	2.05E+00			µg/L	5
	Thallium	1	0	Filtered	6.00E-01			µg/L	N/A
	Zinc	1	1	Filtered	5.26E+00			µg/L	55
	Anions								
	Nitrate	1	1	Unfiltered	1.81E+04			µg/L	10 ^g
100F (207-1, 211-1)	Metals								
	Antimony	4	0	Filtered	1.00E+00			µg/L	N/A
	Arsenic	4	4	Filtered	2.50E+00	-	3.28E+00	µg/L	190
	Cadmium	4	0	Filtered	1.00E-01	-	3.00E-01	µg/L	0.59
	Chromium	4	4	Filtered	4.60E+00	-	1.20E+01	µg/L	10 ^e
	Chromium	4	4	Unfiltered	6.81E+00	-	9.65E+00	µg/L	96 ^f
	Hexavalent Chromium	3	3	Filtered	4.20E+00	-	8.90E+00	µg/L	10
	Hexavalent Chromium	3	3	Unfiltered	4.70E+00	-	8.80E+00	µg/L	10
	Copper	4	3	Filtered	3.50E-01	-	8.20E-01	µg/L	6
	Lead	4	1	Filtered	2.10E-01	-	5.00E-01	µg/L	1.1
	Nickel	4	0	Filtered	5.00E-01	-	8.00E-01	µg/L	83
	Selenium	4	0	Unfiltered	1.60E+00	-	2.00E+00	µg/L	5
	Thallium	4	0	Filtered	5.50E-01	-	6.00E-01	µg/L	N/A
	Zinc	4	2	Filtered	3.50E+00	-	9.30E+00	µg/L	55
	Anions								
	Nitrate	4	4	Unfiltered	2.39E+04	-	2.74E+04	µg/L	10 ^g
	100H (145-1, 152-2)	Metals							
Sample collections were unsuccessful in 2016 at both locations.									
Anions									

Table C-14. Metals and Anions in Columbia River Water Shoreline Seep Water. (5 Pages)

Location	Analyte	No. of Samples	No. of Detects	Filtered/ Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c
	Sample collections were unsuccessful in 2016 at both locations.								
100K (63-1)	Metals								
	Antimony	1	0	Filtered	1.00E+00			µg/L	N/A
	Arsenic	1	0	Filtered	1.70E+00			µg/L	190
	Cadmium	1	0	Filtered	3.00E-01			µg/L	0.59
	Chromium	1	0	Filtered	3.00E+00			µg/L	10 ^e
	Chromium	1	0	Unfiltered	3.00E+00			µg/L	96 ^f
	Hexavalent Chromium	1	0	Filtered	1.50E+00			µg/L	10
	Hexavalent Chromium	1	0	Unfiltered	1.50E+00			µg/L	10
	Copper	1	1	Filtered	6.42E-01			µg/L	6
	Lead	1	0	Filtered	5.00E-01			µg/L	1.1
	Nickel	1	0	Filtered	5.00E-01			µg/L	83
	Selenium	1	0	Unfiltered	2.00E+00			µg/L	5
	Thallium	1	0	Filtered	6.00E-01			µg/L	N/A
	Zinc	1	1	Filtered	5.44E+00			µg/L	55
	Anions								
	Nitrate	1	1	Unfiltered	1.55E+03			µg/L	10 ^g
100N (8-13, 89-1)	Metals								
	Antimony	2	1	Filtered	1.00E+00	-	1.16E+00	µg/L	N/A
	Arsenic	2	2	Filtered	3.16E+00	-	1.10E+01	µg/L	190
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59
	Chromium	2	1	Filtered	3.00E+00	-	8.93E+00	µg/L	10 ^e
	Chromium	2	1	Unfiltered	3.00E+00	-	9.19E+00	µg/L	96 ^f
	Hexavalent Chromium	2	1	Filtered	1.50E+00	-	8.50E+00	µg/L	10
	Hexavalent Chromium	2	1	Unfiltered	1.50E+00	-	5.90E+00	µg/L	10

Table C-14. Metals and Anions in Columbia River Water Shoreline Seep Water. (5 Pages)

Location	Analyte	No. of Samples	No. of Detects	Filtered/ Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c	
	Copper	2	2	Filtered	3.80E-01	-	1.07E+00	µg/L	6	
	Lead	2	0	Filtered	5.00E-01			µg/L	1.1	
	Nickel	2	1	Filtered	5.00E-01	-	6.97E-01	µg/L	83	
	Selenium	2	0	Unfiltered	2.00E+00			µg/L	5	
	Thallium	2	0	Filtered	6.00E-01			µg/L	N/A	
	Zinc	2	1	Filtered	3.50E+00	-	4.55E+00	µg/L	55	
	Anions									
	Nitrate	2	2	Unfiltered	2.36E+04	-	2.47E+04	µg/L	10 ^g	
Hanford Townsite (25-4)	Metals									
	Antimony	1	0	Filtered	1.00E+00			µg/L	N/A	
	Arsenic	1	0	Filtered	1.70E+00			µg/L	190	
	Cadmium	1	0	Filtered	3.00E-01			µg/L	0.59	
	Chromium	1	0	Filtered	3.00E+00			µg/L	10 ^e	
	Chromium	1	0	Unfiltered	3.00E+00			µg/L	96 ^f	
	Hexavalent Chromium	1	0	Filtered	1.50E+00			µg/L	10	
	Hexavalent Chromium	1	0	Unfiltered	1.50E+00			µg/L	10	
	Copper	1	1	Filtered	6.94E-01			µg/L	6	
	Lead	1	0	Filtered	5.00E-01			µg/L	1.1	
	Nickel	1	0	Filtered	5.00E-01			µg/L	83	
	Selenium	1	1	Unfiltered	2.58E+00			µg/L	5	
	Thallium	1	0	Filtered	6.00E-01			µg/L	N/A	
	Zinc	1	1	Filtered	3.58E+00			µg/L	55	
	Anions									
	Nitrate	1	1	Unfiltered	2.72E+03			µg/L	10 ^g	
	300 Area ^d (42-2, DR 42-2)	Anions								
		Nitrate	2	2	Unfiltered	1.01E+04	-	1.86E+04	µg/L	10 ^g

Table C-14. Metals and Anions in Columbia River Water Shoreline Seep Water. (5 Pages)

Location	Analyte	No. of Samples	No. of Detects	Filtered/ Unfiltered ^a	Range (min-max) ^b	Unit	Regulatory limit ^c
^a Dissolved concentrations are associated with filtered samples; Recoverable concentrations are associated with unfiltered samples. ^b For non-detects, one value is shown for the method detection limit (MDL); Multiple values are shown on non-detects if the laboratory method detection limit differed during the analyses process. ^c Ambient water quality criteria values or chronic toxicity unless otherwise noted (WAC 173-201A-240). ^d 300 Area seeps did not have metals analyses performed during 2016. ^e Value for hexavalent chromium. ^f Value for trivalent chromium. ^g Washington State drinking water standard utilized (WAC 246-290).							

C.6 References

40 CFR 61. Appendix E, "Compliance Procedures Methods for Determining Compliance with Subpart I," Table 2, "Concentration Levels for Environmental Compliance." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?SID=da9d22320b65cc64e47ba92143fafad7&mc=true&node=ap40.10.61_1359.e&rgn=div9.

40 CFR 141. "National Primary Drinking Water Regulations." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr141_main_02.tpl.

EPA 1975. *National Interim Primary Drinking Water Regulations*. EPA-570/9-76-003. U.S. Environmental Protection Agency, Washington, D.C. Online at <https://nepis.epa.gov/Exe/ZyPDF.cgi/2000J6TU.PDF?Dockkey=2000J6TU.PDF>.

WAC 173-201A-240. "Toxic Substances." *Washington Administrative Code*, as amended. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=173-201a-240>.

WAC 173-201A-250. "Radioactive Substances." *Washington Administrative Code*, as amended. Online at <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-250>.

WAC 246-290. "Group A Public Water Supplies." *Washington Administrative Code*, as amended. Online at <http://apps.leg.wa.gov/wac/default.aspx?cite=246-290>.

Appendix D. Dose Calculations

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D.0 Dose Calculations

R Perona, RT Rytí, AG Fleury

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.

The total annual dose to a hypothetical, maximally exposed individual (MEI) in 2016 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.12 mrem (1.2 μ Sv). This dose is 0.12% of the 100 mrem (1000 μ Sv) per year public dose limit specified in [DOE O 458.1, Radiation Protection of the Public and the Environment](#). For context, a 2009 National Council on Radiation Protection and Measurements report estimated that the overall annual exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv), approximately half of which is related to natural sources and the other half attributable primarily to medical procedures.

D.1 Supporting Information for Calculation of Public Doses

The radiological dose that the public could have received in 2016 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, which are summarized here and described in more detail in [10 CFR 835, "Occupational Radiation Protection Program."](#) The committed 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 (Sv), or more typically the sub-unit mrem (mSv)² for individuals, and in units of person-rem (person-Sv) for the collective dose received by the total population within a 50-mi (80-km) 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 total effective dose accounts for the long-term (50 yrs) internal exposure from radionuclides absorbed into the body during the current year. The committed effective dose equivalent is the sum of individual committed (50 yrs) 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, Hanford-related environmental radionuclide concentrations were estimated from stack effluent measurements (air pathway doses) or

² 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

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. 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 2.10.1* (PNNL-14583; PNNL-14584; PNNL-19168), which employs the internal dosimetry methodology described in ICRP 60 (ICRP 1991) and external dose coefficients described in Federal Guidance Report 12 (EPA 1993). GENII Version 1.485 (PNL-6584), 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. GENII Version 2.10.1 was used for dose calculations starting with 2016 data. 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.

In addition to the GENII calculations for assessing public doses, the computer program CAP-88PC (also known as CAP-88) was used to calculate an air pathway dose to an MEI for compliance with [Clean Air Act of 1963](#) standards, as required by the U.S. Environmental Protection Agency (EPA) through [40 CFR 61, "National Emission Standards for Hazardous Air Pollutants,"](#) Subpart H, from airborne radionuclide effluents (other than radon) released at the U.S. Department of Energy (DOE) facilities. Air pathway calculations performed with the CAP-88PC computer code differ slightly from those performed in GENII. Technical details of the CAP-88PC calculations are provided in [DOE/RL-2017-17, Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2016](#).

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 provides requirements for demonstrating compliance with the public dose limit of 100-mrem (1,000-μSv) total effective dose in a year. Relevant requirements include the following:

- 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 mi [80 km])

- 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 annually depending on the following:

- The relative contributions of the different operational areas to radioactive emissions released to the air
- The contribution of radionuclide releases to the Columbia River from Hanford Site facilities
- Variable differences in meteorology affecting wind dispersion
- The following potentially significant exposure pathways are considered for identifying the location of this hypothetical individual and calculating radiation dose:
 - 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 downstream of the Hanford Site
 - 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
- Recreational activities along the Hanford Reach of the Columbia River, including fishing, hunting, boating, swimming, and exposure to sediments during shoreline activities.

D.1.1.1 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) are considered for identifying the location of 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 mi (26 km) 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 0.87 mi (1.4 km) directly across the Columbia River from the 300 Area, frequently receives 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, 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 2016 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 commonly 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 air pathway receptor locations: at Ringold (200 Area sources), Sagemoor (300 Area sources), Horn Rapids Road (300 Area sources) plus drinking water pathway dose, and Riverview (300 Area sources) plus drinking water pathway dose.

For 2016, air pathway radiological dose calculations conducted using CAP-88PC in support of the *Clean Air Act of 1963* requirements and GENII Version 2.10.1 have identified the Horn Rapids Road as the location with the highest MEI dose. Air pathway calculations performed with the GENII computer code indicate that Sagemoor and Horn Rapids Road air pathway MEI doses in 2016 are similar (0.07 mrem at Sagemoor and 0.10 mrem at Horn Rapids Road). Unlike the Sagemoor receptor, the MEI at Horn Rapids Road receives additional dose from the drinking water pathway. Both Sagemoor and Horn Rapids Road MEI GENII results are shown in Section 4, Figure 4.4 for comparison.

MEI location coordinates relative to Hanford Site operating areas are entered in the GENII computer code to specify the location for the air pathway dose calculations. For Sagemoor, these coordinates are:

100 Area: 26.874 km Easting, 30.064 km Northing	300 Area: 1.35 km Easting, 0.26 km Northing
200 Areas: 24.954 km Easting, 20.814 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	300 Area: 0 km Easting, -1.80 km Northing
200 Areas: 22.6 km Easting, -22.6 km Northing	400 ea: 7.92 km Easting, -7.92 km Northing

D.1.1.2 Water and Air Release Inputs Used In GENII Version 2.10.1. As discussed in Section 4.2, the environmental data needed to perform the GENII dose calculations for the water pathway 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, but area assignment does not affect the dose results. Measured emissions of radionuclides in stack releases are used in the GENII air pathway dose calculations. These air and water pathway 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 Area were historically used to characterize contributions from the 100 Area. The last operating outfall, 1908-K in the 100-K Area, ceased operations at the end of March 2011; therefore, no annual releases were identified from the 100 Area in 2016. 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 riverwater 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. The results of statistical tests were used in conjunction with supporting information such as known releases from groundwater plumes to the river and historical observations in river water to identify Hanford-related contaminants. 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. A p-value of 0.05 is commonly used as the threshold of statistical significance, but a larger, less restrictive value may be used when other factors support evidence of a release. Likewise, when a contaminant does not have any known Hanford Site sources, a smaller threshold could be appropriate to identify radionuclides for the dose assessment.

Both statistical tests identified tritium, uranium-234, and cobalt-60 as potentially Hanford-related contaminants to include in the 2016 water pathway dose assessment using a p-value of 0.05. Concentrations of uranium-238 were greater downstream, but p-values were slightly higher than 0.05 for both the t-test and WRS. Uranium-238 is retained as a potentially Hanford-related contaminant for the 2016 dose assessment because the higher downstream concentrations are considered plausibly site-related. Although uranium-235 might be expected to co-occur with both uranium-234 and uranium-238, yearly average uranium-235 concentrations were higher upstream than downstream and, therefore, uranium-235 is not included in the water pathway dose assessment calculations.

	p-value	
	paired t-test	Wilcoxon Rank Sum
Tritium	0.014	<0.077
Uranium-238	0.17	0.67
Uranium-234	0.0091	0.13
Cobalt-60 (resin)	0.042	0.78

Although statistical tests indicated cobalt-60 values were higher in downstream than upstream samples, cobalt-60 was not measured at levels above the minimal detectable activity in either the upstream or downstream samples. The significant p-values for both the t-test and WRS for cobalt-60 may have been biased due to the inclusion of calculations to normalize negative values as zeroes when summing the downstream filter and resin concentration values. Although cobalt-60 was not identified as a contaminant of potential concern (COPC) because it was not measured above the minimal detectable activity, water pathway calculations were run with cobalt-60 in order to determine whether it would be a significant contributor to dose. These results indicated cobalt-60 was a minor contributor to the irrigation, drinking water, and fish pathways compared to the other COPCs for both individual and population doses. Cobalt-60 would have contributed about 50% of the recreational pathway dose for both the individual and population doses, but the recreational dose makes up less than 1% of the total dose from the water pathway so its inclusion would not affect the overall water pathway results. Table D-1 summarizes the mean annual differences in downstream and upstream concentrations, and calculated annual releases for the 2016 GENII water pathway dose calculations.

Table D-15. Liquid Effluent Radionuclide Releases for GENII Dose Calculations.

Radionuclide	Upstream	Downstream	Difference
<i>Columbia River Annual-Average Radionuclide Concentrations (pCi/L)^a</i>			
Tritium	1.5E+01	2.3E+01	8.1E+00
Uranium-234	2.6E-01	2.9E-01	3.0E-02
Uranium-238	2.1E-01	2.2E-01	8.4E-03
<i>Calculated Radionuclide Releases (Ci/year)^b</i>			
Tritium	NA	NA	8.3E+02
Uranium-234	NA	NA	3.1E+00
Uranium-238	NA	NA	8.6E-01
Thorium-234 ^c	NA	NA	8.6E-01
Protactinium-234m ^c	NA	NA	8.6E-01

^a1 pCi=0.037 Bq

^b Calculated as the product of the difference in downstream and upstream radionuclide concentrations and the 2016 annual-average river flow rate of 3,239 m³/sec at Priest Rapids Dam and the number of seconds in a year.

^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 surfacewater sampling.

NA = not applicable; radionuclide releases calculated based on difference between annual-average downstream and upstream concentrations.

Radioactive air emissions based on monitoring of stacks in the 100, 200, 300, and 400 Areas were used as the basis for the GENII air pathway 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 mi [80 km]) and an assumed (4.9 ft/sec [1.5 m/sec]) average wind speed. The highest short-term (15-hr 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-2017-17, measurements of gross alpha and gross beta radiation in stack emissions were protectively added to the measured emissions of plutonium-239/-240 and cesium-137, 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 air pathway calculations indicate dose is highest for these radionuclides among the group of plausible candidates of alpha- and beta-emitting radionuclides. Annual radionuclide air releases used in the GENII air pathway dose calculations are summarized in Table D-2.

Table D-16. Air Pathway Radionuclide Stack Emissions for GENII Modeling. (2 Pages)

Radionuclide	100 Area	200 Areas	300 Area	400 Area
(Curies)				
Hydrogen-3 (elemental tritium)	NA	NA	23.9	NA
Hydrogen-3 (tritiated water vapor)	NA	NA	242	1.6E-02
Carbon-14	NA	NA	1.2E-04	NA
Sodium-22	NA	NA	NA	2.1E-10
Krypton-85	NA	NA	9.7E-08	NA
Stontium-90	3.2E-06	2.2E-05	1.7E-07	NA
<i>Yttrium-90^{a, b}</i>	4.8E-07	3.4E-06	2.5E-08	NA
Technetium-99	NA	NA	4.1E-06	NA
Ruthenium-106	NA	NA	1.3E-09	NA
Iodine-129	NA	9.8E-04	NA	NA
Cesium-134	NA	NA	NA	NA
Cesium-137 ^c	1.6E-05	7.0E-05	4.9E-06	1.9E-06
<i>Barium-137m^{a, b, c}</i>	1.6E-05	7.0E-05	4.9E-06	1.9E-06
Europium-152	NA	NA	1.9E-09	NA
Europium-154	NA	NA	1.1E-08	NA
Gadolinium-153	NA	NA	8.0E-11	NA
Radon-219	NA	NA	NA	
<i>Lead-211^{a, b}</i>	--	--	NA	
<i>Bismuth-211^{a, b}</i>	--	--	NA	
<i>Thallium-207^{a, b}</i>	--	--	NA	
Radon-220	NA	NA	178	NA
<i>Lead-212^{a, b}</i>	--	--	2.5E-01	NA
<i>Bismuth-212^{a, b}</i>	--	--	2.1E-01	NA
Radon-222	NA	NA	NA	NA
Radium-226	NA	NA	3.7E-10	NA

Table D-16. Air Pathway Radionuclide Stack Emissions for GENII Modeling. (2 Pages)

Radionuclide	100 Area	200 Areas	300 Area	400 Area
	(Curies)			
Actinium-227	NA	NA	3.1E-10	NA
Uranium-232	NA	NA	8.6E-09	NA
Uranium-233	NA	NA	2.7E-08	NA
Neptunium-237	NA	NA	1.4E-08	NA
Plutonium-238	5.0E-07	1.4E-07	3.7E-08	NA
Plutonium-239/240 ^d	1.3E-05	3.8E-05	1.1E-07	7.5E-07
Plutonium-241	8.8E-06	9.9E-08	NA	NA
Americium-241	2.7E-06	2.2E-06	4.8E-10	NA
Americium-243	NA	NA	4.9E-08	NA
Neptunium-239 ^{a, b}	--	--	8.2E-09	NA
(gross alpha)	1.0E-05	2.9E-05	1.0E-07	7.5E-07
(gross beta)	1.3E-05	6.3E-05	4.8E-06	1.9E-06

^a Radionuclides are short-lived progeny of the parent listed above that may ingrow during air dispersion to offsite locations.

^b Values of these short-lived progeny are the highest activity calculated within an estimated 15-hr dispersion time period to an exposure point within a 50-mi (80-km) distance.

^c Values include the addition of gross beta activity.

^d Values include the addition of gross alpha activity.

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NA = Not available or not detected. No stack emissions reported for this radionuclide.

D.1.1.3 Exposure Parameter Values Used in GENII Version 2.10.1. GENII Version 2.10.1 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.

D.1.1.4 Meteorological Data Used in GENII Version 2.10.1. GENII Version 2.10.1 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 2016 meteorological data used in the GENII air dispersion modeling were gathered at monitoring stations in the 100 Area (station 29 100-K; station 13 100-N), 200 Areas (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 100 and 200 Areas, all meteorological data were obtained at a height of 33 ft (10 m). In the 100-K Area, a temporary tower was implemented at 10 ft (3 m) in height, the 100-K and 100-N Area meteorological data were combined for 2016 evaluation. In the 200 Areas, where some active stacks are 200 ft (61 m) in height, the meteorological data used were collected at 200 ft (61 m).

Table D-17. Agricultural Pathway Parameters for Hanford Site Dose Calculations.

Medium	Vegetables		Fruit s	Cereals	Eggs	Poultry	Beef	Milk	Hay (beef cattle, milk cows)	Pasture (milk cows)	Grains (beef cattle, poultry)
	Leafy	Root									
Holdup time ^a ; day (MEI)	1	5	5	180	1	1	15	1	100	0	180
Holdup time ^a ; 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/m ^b	1.5	4	2	0.8	NA	NA	NA	NA	2	1.5	0.8
Irrigation rate; cm/yr	77	88	77	^c	NA	NA	NA	NA	103	103	^{† c}
Irrigation period; month	6	6	6	^{† c}	NA	NA	NA	NA	6	6	^{† c}
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 ^d	55/55 ^e	NA	NA	NA
Contaminated fraction of diet ^b	NA	NA	NA	NA	1.0	1.0	0.25/0.75 ^d	0.25/0.75 ^e	NA	NA	NA
Livestock soil intake; kg/day	NA	NA	NA	NA	0.0	0.0	0.0	0.375 ^f	NA	NA	NA

^a Holdup time is the time between harvest and consumption

^b Pertains to animal feed; 100% of animal water is assumed contaminated surfacewater.

^c No irrigation is assumed to occur for cereal crops or grains.

^d First value pertains to grains, and second value pertains to hay.

^e First value pertains to hay, and second value pertains to pasture grass.

^f Calculated as 0.5 kg soil/day while grazing × 0.75 diet fraction of pasture grass.

MEI=maximally exposed individual;

NA=not applicable

Table D-18. Consumption Parameters for Hanford Site Dose Calculations.

Medium	Consumption Rate ^a	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Leafy vegetables	66 lbs (30 kg)/yr	33 lbs (15 kg)/yr
Root vegetables	485 lbs (220 kg)/yr	310 lbs (140 kg)/yr
Fruits	728 lbs (330 kg)/yr	140 lbs (64 kg)/yr
Cereals	180 lbs (80 kg)/yr	160 lbs (72 kg)/yr
Milk	71 gal (270 L)/yr	61 gal (230 L)/yr
Beef	180 lbs (80 kg)/yr	150 lbs (70 kg)/yr
Poultry	40 lbs (18 kg)/yr	19 lbs (8.5 kg)/yr
Eggs	66 lbs (30 kg)/yr	44 lbs (20 kg)/yr
Fish ^b	88 lbs (40 kg)/yr	-- ^c
Drinking water ^d	193 gal (730 L)/yr	116 gal (440 L)/yr
Inadvertent soil ingestion	1.17 oz (36.5 g)/yr	0.59 oz (18.3 g)/yr

^a A transit time of 11 hrs from the release to receptor locations is assumed.

^b A holdup time of 1 day is used for both MEI and population calculations.

^c Average individual consumption not identified; see text of Section D.1.2.

^d A holdup time of 1 day is used for the Riverview calculations for identification of the location of the MEI.

Table D-19. Residency Parameters for Hanford Site Dose Calculations.

Pathway	Exposure	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Air: Inhalation ^{a, b}	24 hrs/day, 365 days/yr	24 hrs/day, 365 days/yr
Air: external (submersion) ^b	24 hrs/day, 365 days/yr	24 hrs/day, 365 days/yr
Soil: external (ground shine)	12 hrs/day, 365 days/yr	8 hrs/day, 365 days/yr

^a Inhalation rate, adult 1.0 m³/hr (35 ft³/hr).

^b Dispersion time of 15 hrs is protectively assumed for ingrowth of short-lived progeny during transport (50 mi [80 km]) population dose radius and 4.9 ft/s (1.5 m/s) wind speed.

Table D-20. Columbia River Parameters for Hanford Site Dose Calculations.

Activity and Pathway	Exposure ^a	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Shoreline: sediment; external	5.0 hrs/day, 100 days/yr ^b	1.7 hrs/day, 10 days/yr ^b
Boating: river water; external	2.0 hrs/day, 50 days/yr ^c	0.1 hr/day, 50 days/yr ^c
Swimming: river water; inadvertent ingestion ^d , external	2.0 hrs/day, 50 days/yr	0.2 hr/day, 50 days/yr

^a A transit time of 11 hrs from the release to receptor locations is assumed.

^b A shoreline width factor of 0.2 is used.

^c No shielding by the boat is assumed.

^d Ingestion rate of 0.68 oz (0.02 L)/hr.

Because a large amount of data were missing for meteorological station 29 (100-K) and station 13 (100-N), the two data files were combined. The 100 Area air pathway doses were calculated using this combined data file.

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 referenced 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

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-mi (80-km) radius of Hanford Site operations is required by DOE O 458.1. The radiological dose received by the total population within 50 mi (80 km) of site operation areas was calculated to confirm adherence to DOE environmental protection policies, and provide information to the public. The 50-mi (80-km) collective dose is the sum of doses to all individual members of the public within 50 mi (80 km) of the four Hanford Site operations areas (100, 200, 300, and 400 Areas).

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 offsite population size 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.

D.1.2.1 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 wells adjacent to the river. Approximately 182,000 people residing in the Tri-Cities³ are assumed to obtain all of their drinking water directly from the Columbia River or from impacted wells near the river that are assumed to have the same radionuclide concentrations as were measured in near-shore river water. Annual drinking water dose for an average individual is multiplied by the Tri-Cities population to calculate the collective drinking water dose.

D.1.2.2 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 the Columbia River 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. An annual irrigated foods dose for an average individual is protectively multiplied by the estimate population of 2,000 individuals to calculate the collective irrigated foods dose.

³ The Cities of Pasco, Kennewick, and Richland—known as the Tri-Cities—are located in southeastern Washington State. Population estimates from <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.

D.1.2.3 Columbia River Recreation. As described in Section 4.2 and Section D.1.1, recreational activities on the Columbia River 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.

D.1.2.4 Fish Consumption. Population doses from consuming fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 33,000 lb (15,000 kg) per year. It was protectively assumed that 100% of the annual catch was consumed by individuals in the Tri-Cities area, and that tissue concentrations in the fish were in equilibrium with concentrations of radionuclides in river water (which is likely to introduce a protective bias for anadromous fish such as salmon and steelhead). Population dose related to fish consumption was calculated as follows:

Population dose (person-rem) = MEI dose (mrem) \times 0.001 rem/mrem \times (annual catch [kg/yr]/IR_fish [kg/yr/person]), where MEI dose=fish ingestion dose for the MEI; annual catch=15,000 kg fish/yr; IR_fish=individual fish ingestion rate used in the MEI calculation (40 kg/yr/person).

Collective dose related to air-mediated exposure pathways was calculated based on the geographic distribution of the population residing within a 50-mi (80-km) radius of the Hanford Site operating areas, as shown in [PNNL-20631, Hanford Site Regional Population—2010 Census](#). These distributions are based on 2010 United States Census Bureau data and 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 pathway 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 meteorological and population distribution data are organized according to 16 directional sectors based on the four cardinal, four ordinal, and eight cross-wind directions (e.g., N, NNE, NE, ENE). These sectors were transformed into grids using concentric circles with radii of 1, 2, 3, 4, 5, 10, 20, 30, 40, and 50 mi. 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 (PNNL-20631). These files were identified in the GENII Air Dose Report Module.

D.2 Calculation of Biota Doses

The RESidual RADioactivity (RESRAD)-BIOTA 1.8 computer code was used to screen the 2016 radionuclide concentrations in water, sediment, soil, and tissues to see if they exceeded the established biota concentration guides. Biota concentration guides are concentrations published in [DOE-STD-1153-2002, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota](#), 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 water and sediment Tier 1 biota concentration guides for the radionuclides evaluated. Table D-8 presents the soil 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 with multiple media and radionuclides analyses, 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 (Tiers 2 or 3) to evaluate accurate exposure of biota to radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure.

Table D-21. Biota Concentration Guides and Sediment to Water Distribution Coefficients.

Radionuclide	Water (pCi/L) ^a	Limiting Organism	Sediment (pCi/g) ^a	Limiting Organism	Default Kd (mL/g) ^b
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-238	1.76E+02	Aquatic animal	5.73E+03	Riparian animal	2000
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

^a 1 pCi=0.037 Bq. Biota concentration guides (pCi/g or pCi/L) from RESRAD-BIOTA v1.8.

^b Kd=Water to Sediment Distribution Coefficients (mL/g) from RESRAD-BIOTA v1.8.

RESRAD = RESidual RADioactivity

Table D-22. Tier 1 Soil Biota Concentration Guides.

Radionuclide	Soil (pCi/g) ^a	Limiting Organism
Strontium-90	2.25E+01	Terrestrial animal
Cesium-137	2.08E+01	Terrestrial animal
Plutonium-238	5.27E+03	Terrestrial animal
Plutonium-239/-240	6.11E+03	Terrestrial animal
Uranium-234	5.13E+03	Terrestrial animal
Uranium-235	2.77E+03	Terrestrial animal
Uranium-238	1.58E+03	Terrestrial animal
Americium-241	3.89E+03	Terrestrial animal

^a 1 pCi=0.037 Bq. Biota concentration guides (pCi/g) from RESRAD-BIOTA v1.8.

RESRAD = RESidual RADioactivity

In the initial (Tier 1) screening assessment, researchers compare maximum measured concentrations to the biota concentration guides. The maximum detected concentrations evaluated for aquatic biota dose assessment are presented in Table D-9. 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 (Tier 2) is performed using average concentrations and the same Tier 1 biota concentration guides. 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 sediment to water distribution coefficient. These coefficients are tabulated in Table D-7.

The sites for the aquatic biota dose assessment were grouped into upstream (Vernita sediment and Priest Rapids Dam river water samples), the 100 Area (sediments from 100-K, 100-D, 100-H, 100-F and White Bluff; river water from 100-N; and seeps from 100-BC, 100-K, 100-N, 100-D, 100-H, 100-F), the Hanford Town Site (sediments from Hanford slough, Savage Island, and Locke Island; river water; and seep water from Hanford Spring); the 300 Area (river water and springs), and downstream (sediments from McNary Dam and river water from the Richland Pumphouse).

Table D-23. Maximum Detected Concentrations Evaluated for Aquatic Biota Dose Assessment.

Location Group	Radionuclide	Maximum Sediment (pCi/g) ^a	Maximum Water (pCi/L) ^a
Upstream	Hydrogen-3	—	26.8
	Cesium-137	0.296	—
	Plutonium-239/-240	0.0144	—
	Uranium-234	1.41	0.356
	Uranium-235	0.0937	0.0707
	Uranium-238	1.25	0.283
100 Area	Hydrogen-3	—	4000
	Carbon-14	—	302
	Strontium-90	—	51.9
	Cesium-137	0.288	—
	Plutonium-239/-240	0.00161	—
	Uranium-234	1.34	1.18
Hanford Townsite	Uranium-235	0.121	0.025
	Uranium-238	1.24	1.5
	Hydrogen-3	—	21200
	Cesium-137	0.219	—
	Uranium-234	1.13	0.279
	Uranium-235	0.111	0.0469
300 Area	Uranium-238	1.21	0.203
	Hydrogen-3	—	3760
	Cesium-137	0.179	—
	Uranium-234	3.07	23.9
	Uranium-235	0.272	2.28
Downstream	Uranium-238	2.89	25.7
	Hydrogen-3	—	49.6
	Cesium-137	0.223	—
	Plutonium-239/-240	0.0153	—
	Uranium-234	1.51	0.38
	Uranium-235	0.106	0.0732
	Uranium-238	1.22	0.311
^a 1 pCi = 0.037 Bq			
— = Not detected or not measured.			

Radionuclides were selected for the aquatic biota dose assessment based primarily on their detection in sediment or water. In addition, having known or suspected sources from DOE operations, the results for tissue samples compared to reference (i.e., upstream, generally at Vernita Bridge), and the known potential for bioaccumulation was also used to identify which radionuclides should be included in the dose assessment. Most of the detected radionuclides in water – hydrogen-3 (tritium), carbon-14, strontium-90, technetium-99, and isotopic uranium – could readily be associated with known groundwater plumes. Most of the remainder of the detected radionuclides could have sources from DOE operations; however, due to relatively high soil-water distribution coefficients, these radionuclides would most likely be associated with sediments instead of water. Cesium-137 and isotopic plutonium were detected in sediments and may have sources from DOE operations. Although the magnitude of the sediment concentrations onsite is sometimes no greater than upstream, these radionuclides are included in the aquatic biota dose assessment. This is likely protective, as these radionuclides are not elevated above reference in tissues. Potassium-40 has no groundwater plumes or other known DOE sources; therefore, potassium-40 was not included in the aquatic biota dose assessment.

As discussed in Section 4.2.6, biota doses were evaluated for Columbia River water and sediment and West Lake water, sediment, and soils (onsite and offsite). For West Lake, Tier 1 sum of fractions exceeded 1.0; therefore, Tiers 2 and 3 calculations were implemented using the mean water concentrations presented in Table D-10. The tiered screening process is further described in DOE-STD-1153-2002.

Table D-24. West Lake 2016 Water Samples.

Radionuclide	Water Concentration (pCi/L) ^a		Sediment Concentration (pCi/g) ^a	
	Maximum	Average	Maximum	Average
Strontium-90	—	—	0.44	0.313
Technetium-99	—	—	0.598	0.598
Cesium-137	—	—	1.38	0.821
Uranium-234	10700	3880	9.57	5.16
Uranium-235	43.5	25.9	0.647	0.402
Uranium-238	13700	4860	9.31	4.77

^a pCi=0.037 Bq

— = Not detected or not measured.

The Tier 1 and 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. The isotopic ratios of uranium indicate a natural source (granitic erratic's from the Missoula floods) and no uranium-236 was detected, albeit some minor amounts of depleted uranium may be present (PNL-7662). 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 at 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](#)), bioaccumulation factors for uranium isotopes based on the mean concentrations in flies and water were 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) 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-11 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-25. Tier 3 Biota Concentration Guides Calculated using RESRAD-BIOTA v1.8.

Radionuclide	Water BCG (pCi/L) ^a		Sediment BCG (pCi/g) ^a	
	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

^a 1 pCi=0.037 Bq

RESRAD = RESidual RADioactivity

Dose to terrestrial biota were evaluated using the near-field and far-field soil sample results. Table D-12 lists the maximum concentrations of strontium-90, cesium-137, plutonium-238, plutonium-239/-240, uranium-234, uranium-235, and uranium-238. These radionuclides were selected for the terrestrial biota dose assessment based on their detection in soil. In addition, having known or suspected sources from DOE operations, vegetation sample compared to soil results and the known potential for bioaccumulation were used to include or exclude radionuclides for the biota dose assessment.

The biota dose assessment also included supplemental calculations using measured concentrations in tissues. Presented in Section 4.2.6, these supplemental calculations provide a more realistic estimate of biota dose compared to doses calculated using the protective bioaccumulation assumptions made in the Tier 1 dose assessments. Section 4.2.6 lists the detected tissue concentrations evaluated in these supplemental dose calculations. The tissue concentrations are used for the internal dose calculations, whereas external dose is estimated from the relevant soil, sediment, and water concentrations. Maxima were used in the supplemental internal dose calculations, which is more protective than the mean recommended by DOE guidance for these Tier 3 dose calculations. However, the detections were

infrequent for tissues and, therefore, the maximum detected values and mean detected values would be similar.

Table D-26. Maximum Detected Concentrations Evaluated for Terrestrial Biota Dose Assessment.

Location Group	Radionuclide	Maximum Soil (pCi/g) ^a
Near Field	Strontium-90	2
	Cesium-137	10
	Uranium-234	1.1
	Uranium-235	0.14
	Uranium-238	1.1
	Plutonium-238	0.0099
	Plutonium-239/240	0.69
	Americium-241	0.25
^a 1 pCi=0.037 Bq.		

D.3 References

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