



DOE/RL-2019-33, Rev. 0
Hanford Annual Site Environmental
Report for Calendar Year 2018

Two bull elk enjoying the vegetation under the shade of an old settlement tree. The quality foraging habitats and protected boundaries of Hanford provide sanctuary for an elk population thriving within a shrub steppe habitat.



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Hanford Annual Site Environmental Report for Calendar Year 2018

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EXECUTIVE SUMMARY

From 1959 to 1970, the U.S. Department of Energy (DOE) annually published a report titled Evaluation of Radionuclide Conditions in the Vicinity of Hanford. In 1970, DOE expanded the report to include topics on air and water pollution, among other areas of public interest, and began annually publishing the report under the name Hanford Site Environmental Report. The report is published 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 Annual Site Environmental Report for Calendar Year 2018* is to inform the public, regulators, employees, and other stakeholders of environmental and operating performance during the year.

Hanford Site operations are affected by and, in many cases, regulated by numerous federal and state agencies enforcing laws and regulations 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*. 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 *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA); *Endangered Species Act*; and *Migratory Bird Treaty Act*. The EPA has delegated authority to the Washington State Departments of Ecology and Health to implement state laws and regulations in lieu of the *Resource Conservation and Recovery Act* (RCRA), the *Clean Air Act*, and the *Clean Water Act*. In these 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 DOE is responsible for the Hanford Site, one of the largest nuclear cleanup efforts in the world, managing the legacy of five decades of nuclear weapons production. Located in south-central Washington State within the semi-arid Pasco Basin of the Columbia Plateau, the Hanford Site encompasses approximately 581 mi² (1,505 km²) in Benton, Franklin, Adams, and Grant Counties (Figure ES-1). The Hanford Site was established in 1943 to produce plutonium for atomic weapons

during World War II and the Cold War. The site has restricted public access and provides a buffer area around facilities formerly used for 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. 1989) by the Washington State Department of Ecology (Ecology), EPA, and DOE (collectively, TPA agencies), the primary mission of the Hanford Site shifted from production to cleanup. 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.

Cleanup of the Hanford Site is overseen by the U.S. Department of Energy, Richland Operations Office (DOE-RL) and Office of River Protection (DOE-ORP). The DOE-RL and the DOE-ORP 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 54.1 million gal (204.8 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 associated 200 Area facilities and construction and operation of the Hanford Tank Waste Treatment Plant and Immobilization Plant (WTP) located in the Central Plateau.

The DOE, U.S. Fish and Wildlife Service, and Washington State Department of Fish and Wildlife each manage portions of the Hanford Reach National Monument. In 2000, President Clinton created the Hanford Reach National Monument (65 FR 37253). Over 300 mi² (777 km²) of this riparian habitat and buffer lands surrounding active central Hanford Site lands were designated for management by the U.S. Fish and Wildlife Service.

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's Pacific Northwest Site Office (PNSO) manages programs, goals, and objectives at the Hanford Site. DOE chartered the PNSO to oversee the operation of the Pacific Northwest National Laboratory (PNNL). PNNL has been operated by Battelle Memorial Institute for DOE since 1965. PNNL is 1 of 10 DOE national laboratories in the Office of Science.

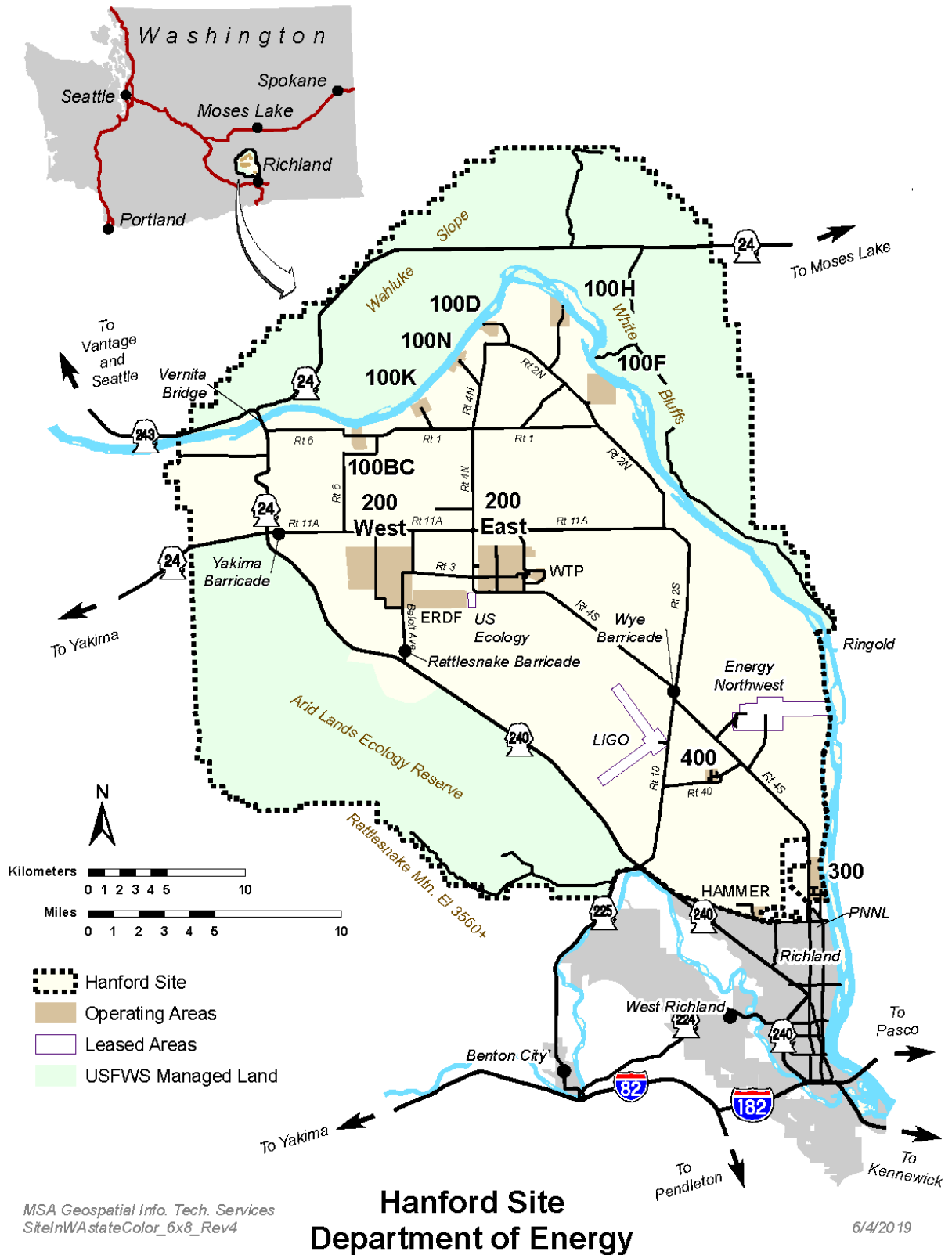


Figure ES-1. Location of the Hanford Site.

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, as well as 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), City of Richland, and the Benton Clean Air Agency. The EPA and Ecology are the two main agencies who regulate Hanford Site 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.

Tri-Party Agreement

From 1989 through December 31, 2018, a total of 1,325 TPA milestones were completed and 341 target dates were met. During 2018, 24 specific cleanup milestones were scheduled for completion; of those, 6 milestones were deleted, 14 milestones were completed on time, 2 milestones were being disputed, and 2 milestones were in negotiation. In addition, two target dates were met, zero target dates were deleted, one target date was being disputed, and zero target dates were in negotiation.

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.

Regulatory Inspections

During fiscal year (FY) 2018, 85 regulatory agency inspections and visits were conducted at DOE facilities on the Hanford Site. There were five RCRA Permit General Inspections of the 100, 200, 300, and 400 Areas, as well as the banks of the Columbia River by boat. These inspections were conducted by Hanford Site contractors with DOE oversight. Some of the agency inspections were conducted jointly between multiple agencies.

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." Generator activities, waste accumulation, and universal waste management areas were also inspected. During 2018, permit modifications were processed to change requirements for TSD units pursuant to WAC 173-303-830, "Permit Changes."

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 calendar year (CY) 2017, DOE/RL-2016-01, *Hanford Site Fourth CERCLA Five-Year Review Report*, addressing 2011 through 2015, was completed and received concurrence from EPA (2017). The next Hanford Site CERCLA 5-year review must be completed by May 2022.

Hanford Site Air Emission Sources

In 2018, the WDOH inspections focused on compliance of point and non-point emission units with the *Hanford Site Radioactive Air Emissions License #FF-01* (FF-01). Ecology inspections included discharge points (e.g., package boilers, emergency engines/generators, and tank farm ventilation systems) regulated under the Hanford Site Air Operating Permit. During FY 2018, regulatory agencies conducted 39 *Clean Air Act* inspections on the Hanford Site. There was one Notice of Violation issued by WDOH requiring action involving airborne radioactive materials pertaining to license requirements and filing annual certificates at Tank Farms.

Environmental Occurrences

Per DOE O 232.2A, *Occurrence Reporting and Processing of Operations Information*, and associated Supplemented Contract Requirements Documents, environmental releases of radioactive and regulated materials from the Hanford Site are reported to DOE and other federal and state agencies as required. The Reporting Criteria provides a set of requirements that must be used to identify reportable occurrences. Three occurrence report levels exist: High (**H**), Low (**L**), and Informational (**I**) to reflect the impact associated with a given occurrence in terms of health, safety, and security to personnel, the public, the environment, and the operational mission. In 2018, there were 45 documented occurrences of legacy contamination.

Emergency Planning and Community Right to Know Act

DOE/RL-2019-10, *2018 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 50 hazardous chemicals that exceeded the reporting thresholds.

Pollution Prevention Program

The Hanford Site maintains a pollution prevention and waste minimization program that contributes to the achievement of sustainability goals. The Hanford Site has recycled 50% of non-hazardous solid waste, excluding construction and demolition (C&D) debris. In 2018, 1,075 metric tons of non-hazardous (i.e., plastic, aluminum, cardboard, paper, wood, and metal), universal waste (i.e., batteries and lamps), and other regulated (i.e. antifreeze and used oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Along with material recycling and diversion, the Hanford Site strives to reduce greenhouse gases Scopes 1, 2, and 3. There was a 42% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2018 from the FY 2008 baseline; emissions in FY 2018 were 24,108 metric tons of carbon dioxide equivalent, whereas emissions in FY 2008 were 41,427 metric tons of 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 measure objectives for 2018 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 2018. The target objectives

for potable and non-potable water, renewable electric energy, facility fuel, facility energy, regulated waste reduction, sanitary waste reduction, and Electronic Product Environmental Assessment Tool acquisitions were met in FY 2018.

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 2018 monitoring efforts are provided below.

External Radiation Monitoring

External radiation fields were monitored in 2018 at 122 environmental dosimeter (thermoluminescent dosimeter) locations near Hanford Site facilities and operations. Quarterly monitoring results were used individually or averaged to determine dose rates in a given area for a specific sampling period. The average dose rate levels measured in the operational areas during 2018 were comparable to the previous years' levels.

Radiological Clearance of Hanford Site Property

No property with anthropogenic (man-made) residual radioactivity above authorized limits was released from the Hanford Site in 2018.

Personal Property. An estimated 36,000 items of personal property were surveyed for residual radioactivity during 2018. All met the limits of DOE O 458.1, allowing them to be cleared from the Hanford Site for unrestricted use by members of the public. Personal property consists mainly of materials and equipment; formal surveys are conducted on items such as power poles, transformers, miscellaneous electrical equipment, air conditioning units, industrial vehicles, excavation equipment, man lifts, and scaffolding. Verification surveys are also performed on common items such as electronics, pallets, batteries, office items, respiratory protection equipment, compressed gas cylinders, vehicles, tools, and physical security items. Some types of debris may be cleared to go to sanitary waste disposal sites. Scrap metal that has been confirmed to not have been in radiological areas can be verified as free of residual radioactivity and cleared from the Hanford Site.

Real Property. No real property (i.e., land and buildings) was cleared during 2018.

Granular Activated Carbon for Offsite Shipment and Regeneration. Approximately 120,000 lb (54,400 kg) of granular-activated carbon was shipped offsite in 2018 for regeneration.

Potential Radiological Doses to the Public and Biota

Scientists evaluated potential radiological dose to the public and biota resulting from modeled exposure to 2018 Hanford Site liquid effluents and airborne emissions to determine compliance with pertinent regulations and limits. The sources of radionuclide releases considered in the dose assessment included gaseous emissions from stacks and ventilation exhausts and contaminated groundwater seeping into the Columbia River. Potential doses were also evaluated based on measured concentrations of radionuclides in samples of Hanford Site drinking water, regional crops from near-by land, and fish from the Columbia River. Potential radiological doses from 2018 Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. The following radiological doses were assessed:

- 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
- Dose from recreational activities (e.g., hunting and fishing)
- Dose to a worker consuming drinking water on the Hanford Site
- Dose to a visitor to the Manhattan Project National Historical Park
- Dose from non-DOE industrial sources on and near the Hanford Site
- Absorbed dose received by biota exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies.

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 2018 from Hanford Site operations was 0.28 mrem (2.8 μ Sv), which is 0.28% 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 inhalation and external exposure to radon isotopes and their radioactive progeny 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 2.5 person-rem (0.025 person-Sv) was calculated as the sum of doses to all individual members of the exposed population.

In addition to the offsite MEI and collective dose calculations, several supplemental dose calculations were performed addressing onsite exposures and exposure for an outdoor recreationalist. Doses to a hypothetical recreational angler were calculated using measured concentrations of radionuclides in fish tissue (Section 4.2.4). A fish ingestion annual dose of up to 0.43 mrem (4.3 μ Sv) was estimated based on concentrations of uranium isotopes in tissue samples of carp and bass fillets collected from the Hanford Reach of the Columbia River. An onsite annual dose of up to 0.079 mrem (0.79 μ Sv) was calculated for ingestion of Hanford Site drinking water based on samples from the 400 Area, where water is supplied by groundwater wells. Lastly, onsite annual doses were calculated for workers and visitors at the Hanford Townsite and White Bluffs Bank tour locations of the Manhattan Project National Historical Park (up to 0.00036 mrem (0.0036 μ Sv). Like the offsite MEI dose, these calculated doses were far below the public dose limit.

To place this information into perspective, these doses were compared with those received by the U.S. population 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

This section includes 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 2018 cleanup and remediation activities at the Hanford Site.

River Corridor

Hanford's River Corridor includes the 100 Area and 300 Area, both of which border the Columbia River. Through 2018, 100 and 300 Area transitions to MSA's Long-Term Stewardship Program are complete with the exception of a portion of the 100-K. The 105-K East and West Reactors, and the 105-K West Spent Fuel Storage Basins are under CH2M Plateau Remediation Contractor (CHPRC) management, portions of the 300 Area under PNNL management, and the 324 Building under CHPRC management.

100 Area Waste Sites

The 100 Area waste sites vary in complexity and waste type. Typical remaining waste sites include liquid effluent waste sites, retired septic systems, and piping systems. In 2018, cleanup activities focused on completion of interim remedial actions in the 100-K Area. Waste generated from the cleanup of waste sites was disposed at the Environmental Restoration Disposal Facility (ERDF) in the 200 Areas.

100-K Area

Design, installation, and readiness were completed on the Engineered Container Retrieval & Transfer System hardware in both the 105-K West Basin and Annex, and removal of engineered container sludge began. Groundwater pump-and-treat operations continued. Remediation of waste sites to protect human health and the environment also continued.

100 Areas Facilities Decommissioning

As of 2018, all deactivation, decommissioning, decontamination, and demolition activities in the 100 Area, with the exception of 100-K Area, have been completed.

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. Low hazard work began at the Plutonium Finishing Plant in September 2018.

300 Area Facilities Decommissioning

Current activities are focused on the remote excavation of the highly contaminated soil beneath the 324 Building B Cell and a portion of B Cell. Future activities in the 300 Area will address the remainder of the 324 facility, as well as the retained facilities and waste sites. In addition, the MSA LTS program manages Institutional Controls required by the *Hanford Site 300 Area Record of Decision* (EPA and DOE-RL 2013).

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.

Solid Waste Management

Solid waste management includes the treatment, storage, and disposal of solid waste produced as a result of Hanford Site operations or received from offsite sources authorized to ship waste to the site. Active onsite solid waste facilities as of 2018 are described below.

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 storage. Waste received includes low-level, transuranic, mixed low-level, and radioactive waste contaminated with polychlorinated biphenyls. Currently, the volume of waste stored in the Central Waste Complex Outside Storage Areas is approximately 178,182 ft³ (5,046 m³), with the remaining enclosed area storage totaling approximately 434,538 ft³ (12,305 m³).

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. The T-Plant Complex received seven shipments of K-Basin sludge for storage.

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.

Low-level Burial Grounds. The low-level burial grounds (LLBG) consist of eight separate burial areas regulated under the *Atomic Energy Act*. Two of the burial grounds are used for disposal of low-level waste and mixed waste (i.e., low-level radioactive waste with a dangerous waste component regulated by WAC 173-303). The first operational layer of waste packages in Trenches 31 and 34 has been covered with compacted gravel and soil; waste is currently being placed on the second waste layer. Trench 31 contains approximately 236,559 ft³ (6,700 m³) of waste in approximately 3,936 waste packages. Trench 34 contains approximately 190,835 ft³ (5,404 m³) of waste in 5,340 waste packages. In 2018, a total of 13,544 ft³ (384 m³) of waste was disposed of in Trenches 31 and 34. The LLBG Trench 94 received two defueled U.S. Navy reactor compartments in 2018.

Waste Receiving and Processing Facility. The Waste Receiving and Processing (WRAP) Facility is a treatment, storage, and disposal facility that began operations in 1997 with the mission to analyze, characterize, and prepare drums and boxes of low-level, mixed, and transuranic wastes for disposal. The WRAP complex is composed of the primary 2336W facility, the 2404-WB and 2404-WC storage buildings, and the High Energy Real Time Radiography and High Energy Neutron Counter.

Waste Encapsulation and Storage Facility. Located in the 200-East Area, the Waste Encapsulation and Storage Facility was constructed in between 1971 and 1973 on the west end of B-Plant and became active in 1974. The Waste Encapsulation and Storage Facility is operating under RCRA interim status standards. Initial RCRA closure of Hot Cells A through F was achieved on April 10, 2017, through grouting these cells to fix any radioactive materials present.

Integrated Disposal Facility. The Integrated Disposal Facility (IDF) is a landfill located in the south-central part of the 200-East Area. The IDF is an expandable lined landfill (i.e., a double high-density polyethylene-lined trench with leachate collection and a leak detection system) with a process design capacity of 2.89 million ft³ (82,000 m³). The landfill was constructed to accept low-level waste as well as mixed waste, such as vitrified low-activity waste (LAW) from the Waste Treatment Plant (WTP), under the Hanford Site RCRA Permit (WA7890008967). Additionally, mixed waste generated by IDF operations will be disposed of in IDF. The RCRA permit for IDF is being revised and will be submitted as a permit modification request under revision 8C of the Hanford Site RCRA Permit.

Environmental Restoration Disposal Facility. The ERDF began operations in 1996 and serves as the central disposal site for hazardous, low-level radioactive, and mixed low-level waste removed during Hanford Site CERCLA cleanup operations. The largest disposal facility in the DOE complex, DOE and its contractors have disposed 18.4 million tons (16.6 million metric tons) of contaminated material at the ERDF since the facility began operations.

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.

200 Area Effluent Treatment Facility (ETF). Located in the 200-East Area, the Effluent Treatment Facility treats liquid 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). Approximately 2.75 million gal (10.4 million L) of wastewater in LERF was treated at ETF in 2018.

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 CY 2018 was approximately 1.77 million gal (6.70 million L). The volume of wastewater being stored in the LERF at the end of CY 2018 was approximately 13.1 million gal (49.6 million L).

200 Area Treated Effluent Disposal Facility (TEDF). 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 non-radioactive, non-dangerous waste disposed to this facility in CY 2018 was approximately 120 million gal (456 million L).

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. At the end of this year's second campaign, the main recirculation pump experienced a malfunction. The pump will be replaced in CY 2019. Routine testing also revealed problems with the secondary containment of the evaporator's slurry lines. While there was no leak or loss of hazardous waste, a project to replace the slurry lines has begun. In CY 2018, upgrades to the facility included enhancements to the building fire detections system.

Underground Waste Storage Tanks

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

Single-shell Tank System. In CY 2018, retrieval of waste from the C Farm tanks was completed, transferring it to newer, safer double-shell tanks (DST) to prepare to feed tank waste to the WTP. At the end of CY 2018 there were 28.6 million gal (108.3 million L) of waste in the single-shell tanks (SST). Waste volumes are provided in HNF-EP-0182. Table 5-5 in this document summarizes the waste retrieved and stored in the SST system from 2010 through 2018.

Double-shell Tank System. The DST system includes 28 double-shell tanks located in the 200-East and 200-West Areas. The DST system is operating under interim status standards specified in the Hanford Site RCRA Permit (WA7890008967), Double-Shell Tank System Part A Form. At the end of CY 2018, there were 25.2 million gal (95.4 million L) of waste in the DSTs. Waste volumes are provided in HNF-EP-0182.

Single-Shell Tank Closure and Corrective Measures Program. The Single-Shell Tank Closure and Corrective Measures Program is responsible for the closure of SST Waste Management Areas (WMAs), conducting performance assessments (PAs), and performing agreed upon interim measures in and around SST WMAs. Closure activities in CY 2018 included field and engineering activities to support WMA C Closure, conducting characterization activities at WMA A-AX, and continued focus on the development and obtaining approval of closure documents.

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 2018, Bechtel National Inc. (BNI) continued executing against its new contract modifications, signed in December 2016 with DOE. These modifications 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.

Pretreatment Facility. In 2018, work continued to resolve the remaining technical decisions that have impacted design and construction at the Pretreatment Facility since 2012. With testing of the Standard High Solids Test Vessel pulse jet mixers and control systems complete, significant progress on the technical decisions continued in 2018 with resolution of the last decisions anticipated in the second quarter of CY 2019.

High-level Waste Facility. At this facility, high-level waste (HLW) is combined with materials in glass forming high-temperature melters, poured into waste containers to form a solid, immobilized glass form. In 2018, HLW design engineering activities resumed, and progress continued to deliver active Facility procurements. In November 2018, components for a specialized 60-ton capacity crane were received. The overhead bridge crane will become the HLW Facility's primary canister cask-handling crane.

Low-Activity Waste Facility. At this facility, low-level waste (LAW) is combined with glass forming materials in high-temperature melters, poured into waste containers to form a solid, immobilized glass form. In 2018, The U.S. Department of Energy approved the LAW Facility Documented Safety Analysis (DSA). The DSA is a federal requirement that sets rules for safety controls at DOE nuclear facilities. In addition, the LAW facility electrical switchgear building received permanent power in 2018.

Analytical Laboratory. Once operational, the Analytical Laboratory will process about 3,000 waste samples annually to support glass formulation and waste-form compliance for the DFLAW approach. The Laboratory electrical system was fully energized and the Washington State Department of Ecology approved the laboratory operating permit, marking the first major facility to complete all phases of the permit lifecycle.

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. Turnovers from construction to startup began in 2016 as the BOFs are non-nuclear industrial buildings. By the end of 2018, workers had completed the startup and testing phase for 49% of BOF's 57 systems.

Effluent Management Facility. Concrete placements of the Effluent Management facility began in March 2017. EMF will involve four structures: the main processing facility, a utility building, an electrical building, and the low-point drain building. In 2017, placement of concrete for the floor slab of the utility and process buildings was completed; 2018 marked a significant year of construction progress for the facility as Ecology granted the permits needed to finish EMF construction.

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, which is bounded by 46 mi (74 km) of Columbia River shoreline. The LTS Program is responsible for managing the post-cleanup obligations for more than 1,700 Waste Information Data System (WIDS) waste sites and six Manhattan-Project-Era production reactors that have been placed in interim safe storage (i.e., cocooned reactors). In 2018, the LTS Program completed annual inspections of 42 accepted and active WIDS sites, as required, to confirm their current status; assessed 226 waste sites with institutional controls as defined in CERCLA decision documents; updated the DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*; performed external inspections on the six cocooned reactors; decommissioned 10 underground-injection-control wells; and continued to manage the LTS library, which now contains over 25,000 documents associated with LTS-managed lands.

Scientific and Technical Contributions to Hanford Site Cleanup

PNNL is providing systematic analyses of integrated system and constraints therein to identify and address technical gaps and operational risks, scientific and technological solutions to enable the baseline and enabling opportunities for improvement in process efficiency, and independent technical basis for near- and long-term decisions and mission needs. They also are reducing technical uncertainties and programmatic/operational risks to support consistency in decision making, technical integration, and resolution of long-term technical issues.

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. The outdoor air is also monitored on the Hanford Site and offsite in nearby and distant communities.

Air Emissions

Small quantities of radionuclides and industrial air pollutants are emitted to the environment from the Hanford Site due to facility operations. Most facility radioactive air emission sources are sampled or monitored if they have the potential to emit radionuclides. The dose to the MEI calculated in 2018 from Hanford Site operations air emissions was 0.22 mrem (1.2 μ Sv), which is 0.22% of the 100 mrem (1,000 μ Sv) annual public dose limit specified in DOE O 458.1. Non-radioactive air pollutant emissions are estimated via sampling or chemical and material use. Pollutant emissions from all sources in 2018 were similar to emissions in 2017.

Onsite Air Monitoring

A network of continuously operating samplers at 77 locations across the Hanford Site was used during 2018 to monitor radioactive airborne materials in air near site facilities and operations. Generally, radionuclide levels measured in the 2018 air composite samples were similar to those measured in previous years.

Offsite Air Monitoring

Airborne radionuclide samples were collected in 2018 by 19 continuously operating samplers in the vicinity of the Hanford Site. Generally, the 2018 air sample results showed very low radiological concentrations (Appendix C, Table C-3).

Regulatory Notifications

One station showed a sample with a radionuclide concentration above the respective reporting threshold value (i.e., 10% of) of 40 CFR 61, Appendix E, 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 if a person stayed in that location for a majority of the year. The values in 40 CFR 61, Appendix E, Table 2 are used as reporting thresholds to the WDOH, pursuant to the FF-01 license Section 5.1.5.1, for those stations listed in Table 4-1 of that license.

Sample results from the first-half of 2018 at the 100-B Reactor location showed an elevated cobalt-60 concentration. This was likely attributable to post-collection cross contamination or to an analytical error as there was no credible scenario to explain the presence of this radionuclide at this location. Cobalt-60 is a fission product (i.e., created during nuclear fission) with a half-life of 5.3 years. The B Reactor was shut down approximately 50 years prior (1968), thereby allowing for complete decay of this radionuclide. Additionally, cobalt-60 has not been detected in any of the air or stack air samples in the vicinity of B Reactor in many years.

ES.7 Section 7, Water Monitoring

In 2018, water samples were collected and analyzed from different sources including Hanford Site drinking water systems, Columbia River surface water, sediment, and seep water; onsite pond water and sediment; offsite irrigation water; and liquid effluent.

Hanford Site Drinking Water Monitoring

Eight DOE-owned, contractor-operated public water systems supply drinking water to DOE facilities on the Hanford Site. MSA operates five of the public water systems. CHPRC operates two systems, and

PNNL operates one system. The City of Richland supplies water to the 300 Area, Richland North Area, and Hazardous Materials Management and Emergency Response facility.

Routine radiological, chemical, physical, and microbiological monitoring of Hanford Site drinking water is performed regularly as mandated by EPA's Community Water System requirements. All of the DOE-owned Hanford Site systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels for 2018. Contaminant concentrations measured during the year were similar to those observed in recent years.

Columbia River Water Monitoring

Radionuclide concentrations measured in cumulative river water samples collected upstream and downstream of the Hanford Site in 2018 were similar to concentrations measured in recent years. Concentrations of radionuclides in samples collected at the City of Richland intake facility were slightly higher than in samples collected upstream at Priest Rapids Dam. Radiological contaminant concentrations were well below the DOE-derived concentration standards.

Radionuclide concentrations measured in cross-river, transect samples were, with one exception, similar to levels measured upstream at Priest Rapids Dam. The tritium concentration measured at the Hanford Townsite transect was higher than at Priest Rapids Dam or at any other transect. Strontium-90 concentrations in Hanford Reach transect samples were comparable to upstream reference concentrations. Strontium-90 concentrations measured in transect samples collected upstream and downstream of the Hanford Site during 2018 were below analytical detection limits. Uranium concentrations in all transect samples were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]).

Transect samples were also analyzed for inorganic and organic constituents. Copper, uranium, and zinc were detected in most samples at levels below the Washington State Ambient Surface Water Quality criteria for the protection of aquatic life. Organic contaminants trichloroethene and dichloroethene, attributable to past Hanford operations, were well below their respective EPA Drinking Water Standard.

Columbia River Sediment Monitoring.

Samples of Columbia River sediment were collected from locations upstream and downstream of the Hanford Site as well as at locations along the Hanford Reach. All samples were analyzed for radionuclides, anions, hexavalent chromium, metals, mercury, and total organic carbon. Analytical results for 2018 were comparable to previous years with cesium-137 and uranium isotopes consistently detected at most sediment collection locations.

Columbia River Seep Water

Samples of Columbia River shoreline seep water were collected along the Hanford Reach and analyzed for radiological, inorganic, and organic contaminants. Tritium concentrations were noticeably elevated in samples collected near the Hanford Townsite and at the 300 Area. These results are consistent with concentrations and plume maps reported by the Groundwater Monitoring program.

Pond Water and Sediment

West Lake is the only naturally occurring pond on the Hanford Site. Remotely located, it is most frequented by the indigenous wildlife. Water and sediment samples were analyzed for radiological contaminants; the 2018 concentrations were similar to previous years.

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 irrigation systems on each side of the Columbia River. Radionuclide concentrations measured in 2018 were at similar levels shown in Columbia River transect water samples collected upstream of the Hanford Site.

Liquid Effluent Monitoring

Liquid effluent disposal is governed by applicable regulations and permits. In CY 2018 there were no liquid effluent discharges to the Columbia River and two permitted liquid effluent streams discharged to the ground. Sampling and analyses are performed to monitor effluent contaminants of concern. Discharge monitoring reports that contain contaminant data from these analyses are submitted to Ecology. All discharges to the ground were compliant with applicable permit limits during CY 2018.

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 and 200-West Areas in the central part of the site, and the 300 and 100 Areas along the Columbia River. Groundwater monitoring data and information about monitoring wells are available through the DOE Environmental Dashboard Application at <https://ehs.hanford.gov/eda>. A detailed discussion of groundwater monitoring results is available in DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2018*, and the interactive online report at <https://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports>.

ES.9 Section 9, Soil Monitoring

Surface soil samples are collected on the Hanford Site to evaluate long-term accumulation trends and provide baseline data used to quantify contaminant level changes due to fugitive or accidental releases of Hanford Site radiological materials. Soil samples for this effort have been collected annually for several decades. These samples are typically collected in the late-spring from locations on or adjacent to waste disposal sites, as well as from locations downwind, 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; sampling is currently on the schedule for summer 2019. Offsite soil sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

Analytical results for soil samples collected in CY 2018 at locations in the 200-East, 200-West, 300, 400, and 600 Areas were consistent with analytical results from previous years. While there are no specific DOE limits for radionuclide concentrations in soil, the CY 2018 onsite soil sample results were compared to other benchmarks including Hanford Site background concentrations (DOE/RL-96-12), dose-based limits for soil developed for a 1 mrem/yr dose threshold to an offsite member of the public (DOE/RL-91-50), and soil radiological preliminary remediation goals (PRGs) for the 200 Area outdoor worker exposure scenario (ECF-HANFORD-16-0133). Generally, radionuclide concentrations in soil samples collected from the 200, 300, 400, and 600 Areas were near or below the Hanford Site background

concentrations and well below the dose-based reporting limits for an offsite member of the public and the PRGs for the outdoor worker exposure scenario.

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 resulting from site activities. Plant and animal species on the site were also monitored to assess abundance, condition, and population distributions. Data collection and analysis were integrated with environmental monitoring of biotic and abiotic media, and analytical results were used to characterize potential risks or impacts.

Agricultural Monitoring

Food and farm products (i.e., corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in 2018 at locations near the Hanford Site. Radionuclide concentrations in most food and farm product samples in 2018 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 were included to show the natural radioactive elements that exist in food products relative to concentrations of potential Hanford Site-produced contaminants.

Fish and Wildlife Monitoring

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during CY 2018 were smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), mule deer (*Odocoileus hemionus*), Rock Mountain elk (*Cervus elaphus*), and California Quail (*Callipepla californica*). Most fish and wildlife samples were 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.

Vegetation Monitoring

Native vegetation samples are collected annually on the Hanford Site to evaluate long-term accumulation trends and provide baseline data used to quantify contaminant level changes due to fugitive or accidental releases of Hanford Site radiological materials. Vegetation samples for this effort have been collected for several decades from locations on or adjacent to waste disposal sites, as well as from locations downwind, near, or within the boundaries of operating facilities and remedial action sites. Vegetation samples from offsite locations are collected every 3 to 5 years and were last collected in 2015; sampling was conducted in the summer of 2019, and the results will be reported in the CY 2019 Annual Site Environmental Report. Offsite vegetation sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*. Analytical results for vegetation samples collected in CY 2018 at locations in the 200-East, 200-West, 100-N, 300, 400, and 600 Areas were consistent with those seen in previous years.

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. A review of radiological contamination incidents reported in CY 2018 identified 38 instances of radiologically contaminated vegetation.

Vegetation Control. Approximately 4,868 ac (1,898 ha) were treated with herbicides in 2018 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 were included in the total treated acres; several areas received more than one herbicide application.

Waste Site Remediation and Revegetation

In CY 2018, 171 ac (69 ha) across the Hanford Site was planted with grass seed in an effort to restore native plant communities.

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.

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 2018, 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 ferruginous hawk nest monitoring, roadside bird surveys, burrowing owls, bats, and riparian vegetation and rare plant species.

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 threatened fish species (bull trout) is occasionally present in the Hanford Reach, which this species uses primarily as a migration corridor. 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, 13 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 15 sensitive plant species occurring or potentially occurring on the Hanford Site.

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 2018, Hanford Site archaeologists completed 94 *National Historic Preservation Act of 1966* (NHPA)

Section 106 cultural resources reviews. Thirty-nine undertakings had the potential to affect cultural resources. Thirty-four 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. Ten projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews. Eleven projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration. A total of 1,163.35 ac (470.79 ha) of new ground was surveyed for cultural resources from NHPA Section 106 project-specific surveys.

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 2018, 31 items were reviewed, cleared for public release, and /or transferred to the Hanford History Project repository for integration with the Hanford Collection. Fifteen artifacts and two linear feet of archival material were evaluated for inclusion in the Hanford Collection. These materials were delivered to the Hanford History Project (HHP) repository at WSU-TC, leaving 26 (3.5%) of the 743 tagged artifacts scheduled for collection between 2018 and 2048. Having transitioned the bulk of the Hanford Collection to the WSU-TC facility in 2016, tasks during 2018 consisted mainly of artifact cataloguing and archival processing.

ES.12 Section 12, Quality Assurance

Quality assurance (QA) and quality control (QC) programs for the Hanford Site and offsite environmental surveillance programs are documented through project-specific QA plans that describe applicable QA elements. Several types of field and laboratory QC samples are employed to ensure the validity of the sampling procedures and the resulting sample data. Samples collected by the Environmental Surveillance program were sent to two laboratories: General Engineering Laboratories, LLC [GEL] and TestAmerica Richland Laboratory (TARL). Additionally, GEL laboratories subcontracted the analysis of low-level tritium in liquids (e.g., water, milk, wine) to ARS Aleut Analytical, LLC (ARS). All three of these laboratories maintain various certifications that allow them to meet plan specifications. Additionally, to demonstrate analytical proficiency all three laboratories participate in independent QA and QC programs including the Mixed Analyte Performance Evaluation Program and DOE Consolidated Audit Program.

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Abbreviations and Acronyms

μS	microsiemens
μSv	microsievert
AEA	Atomic Energy Act of 1954
ALARA	as low as reasonably achievable
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
CX	categorically excluded
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-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
NCO	NEPA Compliance Officer
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
PNSO	Pacific Northwest Site Office
PRG	preliminary remediation goal
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
TSCA	<i>Toxic Substances Control Act</i>
TSD	treatment, storage, and disposal
TTP	transition and turnover package
USFWS	U.S. Fish and Wildlife Service
VPU	vertical pipe unit
WAI	Wastren Advantage, Inc.
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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2018 Highlight

This section presents the following:

- A brief history of the Hanford Site.
- Highlights of Hanford Site contractors and their primary responsibilities.
- Description of the physical characteristics and attributes of the environment in and around the Hanford Site.
- Highlights of Hanford Site stakeholders and their involvement.
- Description of federal, state, and local regulatory agencies, as well as their roles at the Hanford Site.

1.0 Introduction

JR Draper

From 1959 to 1970, the U.S. Department of Energy (DOE) annually published a report titled Evaluation of Radionuclide Conditions in the Vicinity of Hanford. In 1970, DOE expanded the report to include topics on air and water pollution, among other areas of public interest, and began annually publishing the report under the name Hanford Site Environmental Report. This calendar year 2018 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. Annual environmental reports from previous years 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 2018 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, Adams, 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 Hanford Site's eastern boundary. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge are on the southwestern and western boundaries of the Hanford 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 State 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 Mountain to the north. 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; however, 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. Shrub-steppe, inland dunes, and riparian habitats are considered "priority habitats" by the Washington State Department of Fish and Wildlife (WDFW) (DOE/RL-96-32; WDFW 2008). Some of these areas contain species considered rare and/or declining, or are of significant interest to federal, state, or Tribal governments.

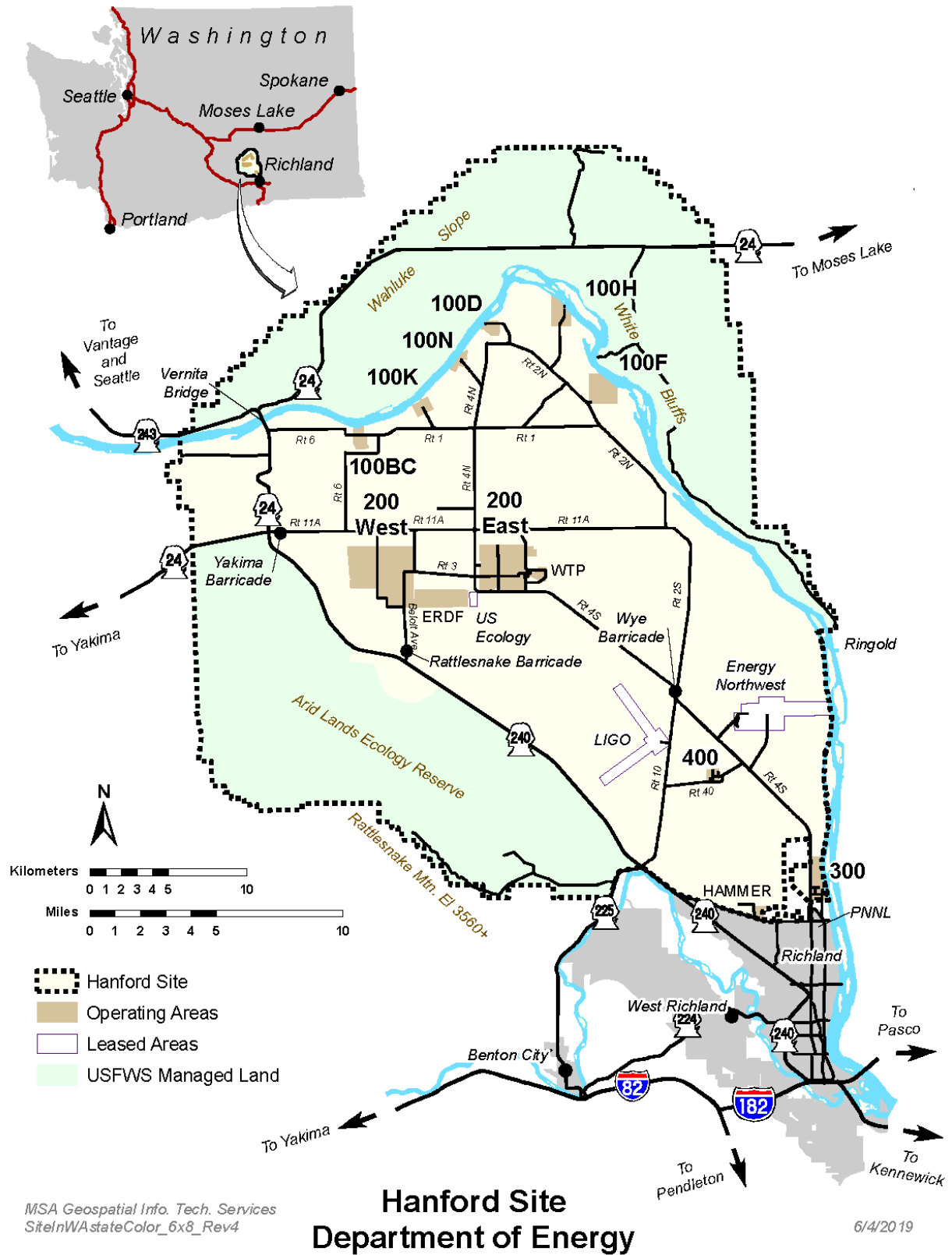


Figure 1-1. Location of the Hanford Site.

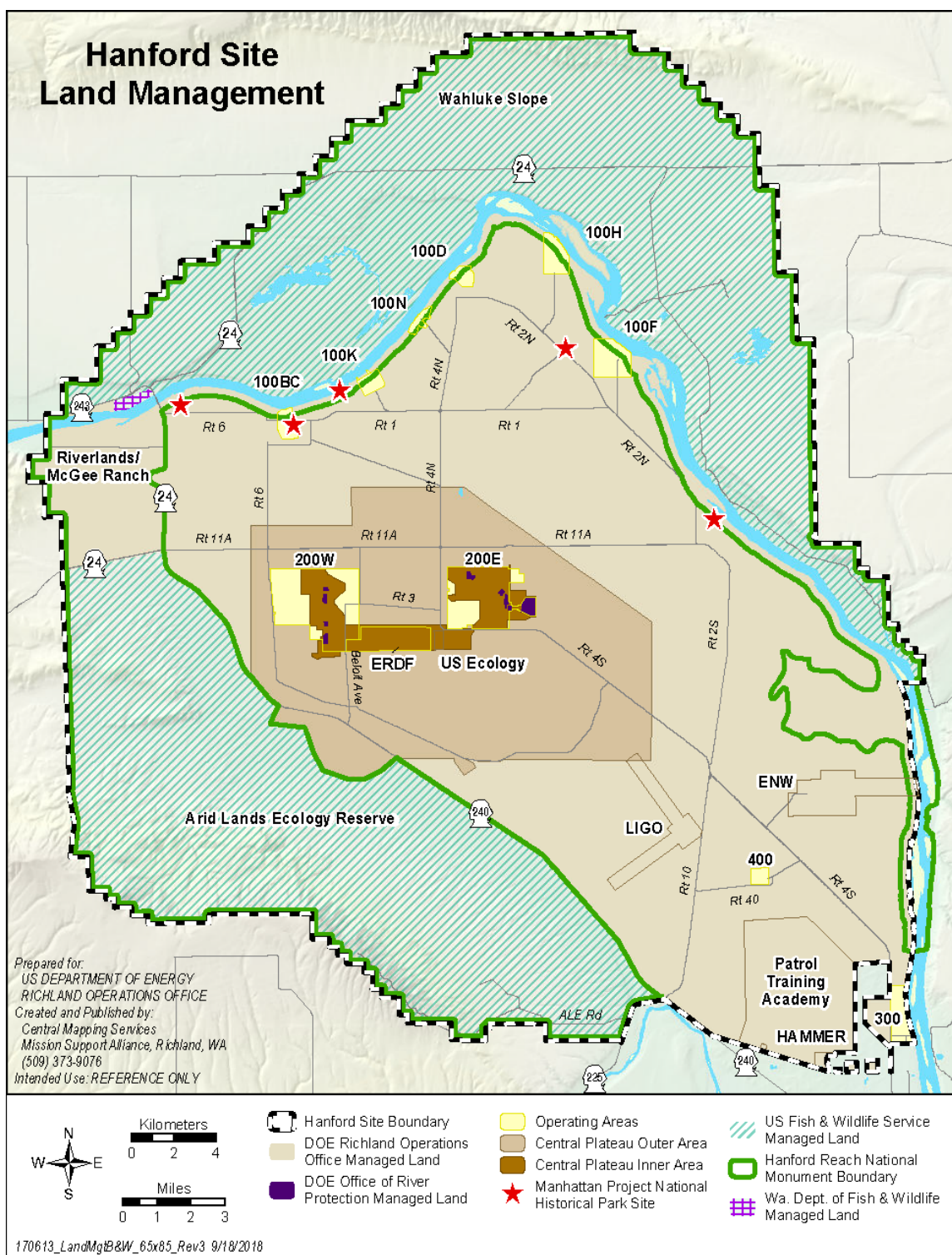


Figure 1-2. Detailed Geography of the Hanford Site, Hanford Reach National Monument, and U.S. Department of Energy Portions of the Hanford Site.

1.2 Hanford Site History and Mission

In February 1943, the federal government, under the authority of the War Powers Act, acquired 625 mi² (1,689 km²) of the mid-Columbia basin for the Hanford Site, known as the Hanford Engineer Works during the Manhattan Project, and offered resident compensation. Approximately 1,500 people living in towns and on farms from Priest Rapids to Richland were ordered to leave their homes and property (Figure 1-3). In some cases, landowners had only 30 days to move (Harvey 2000). Construction of the Hanford Site began in 1943, and over time nine plutonium production reactors were built and along the Columbia River, with one or more reactors operating from 1944 through 1987. Research reactors, including the Fast Flux Test Facility (FFTF) that operated from 1982 to 1992, were located in the southern portion of the Hanford Site. Hundreds of other supporting buildings and extensive infrastructure were constructed to support the program to provide plutonium to fuel atomic weapons during World War II and the Cold War 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 gallons of liquids to soil disposal sites and 54.1 million gallons (204.8 million L) of radioactive waste to 177 large underground tanks.



Figure 1-3. The town of White Bluffs. Buildings Left to right: Post Office, Jess Brown's Barber Shop, Brinson's "Tavern," and Rollinger's Garage (1938).

With the end of the Cold War and the signing of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement [TPA]) in 1989 (Ecology et al. 1989) by the Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and DOE (collectively, TPA agencies), the mission focus 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 nearly three decades of cleanup, considerable progress has been made at the Hanford Site, 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. N Reactor Operated from 1963 until 1987. It was Placed in Interim Safe Storage in June 2012. (Left: N Reactor in 1987; Right: N Reactor in 2015).

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 the nine nuclear reactors built between 1943 and 1963. 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 the Hanford Site DOE reactors are in operation any more with the last reactor, the FFTF Reactor, being shut down in 1992. A public utility, Energy Northwest, continues to operate a commercial Nuclear Regulatory Commission-licensed reactor on Hanford-leased land for the 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, 8 of the 10 reactors at the Hanford Site 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. Every 5 years, Hanford Site crews enter these cocoons to ensure that the structure remains airtight and watertight. These cocoons will be in place over the reactors for approximately 75 years allowing the radiation within the reactors to

safely decay to levels where it doesn't pose a threat to the environment or to the workers performing final demolition. Hanford Site engineers and scientists are already working on plans that will result in these cocooned reactors being removed from the area along the river following the 75-year life span of the cocoon. B Reactor will not be cocooned. It has been named a National Historic Landmark by the United States Department of the Interior and has been preserved as a museum. In 2014 B Reactor was included in the Manhattan Project National Historic Park, consisting of historic facilities at Hanford, Los Alamos, and Oak Ridge. 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-and-treat facilities along the River Corridor. The KR4 system was the first system installed and began operation in 1997. It treats up to 330 gal/min (1,249 L/min). The KW system was the second system installed; it began remediating hexavalent chromium in the KW Reactor area in January 2007 and treats 330 gal/min (1,249 L/min). The third and newest system (KX) began operation in February 2009 and treats 600 gal/min (2,271 L/min). The KX system is used primarily to treat hexavalent chromium in groundwater near N Reactor Area. The DX and HX pump-and-treat systems were designed for hydraulic control and hexavalent chromium mass removal to protect the Columbia River. Both the DX and HX pump-and-treat systems include an extraction well network, transfer building (the DX system has two transfer buildings), a treatment building, and 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 (2,271 L/min) each. Details of the operations and results for these pump-and-treat facilities can be found in DOE/RL-2017-67, *Calendar Year 2017 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*.

1.3.2 200 Areas

The 200 Areas at the Hanford Site are known collectively 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 Areas make 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 (3.8 million L) of capacity. Currently at the Hanford Site, some 54.1 million gal (204.8 million L) of chemical and nuclear waste remain stored in these tanks (HNF-EP-0182).

While much of the Hanford Site'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 the Hanford Site. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being built to process the millions of gallons of high-level waste. 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 WTP 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 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 the Hanford Site. The ERDF has been in operation for over 20 years.

The 222-S Analytical Laboratory, a Hazard Category 3 nuclear facility, plays many roles, which include testing of waste compatibility and physical characteristics to support tank-to-tank waste transfers, performing corrosion rate studies and chemical testing to support tank corrosion inhibition, and providing input to the engineering specifications for each of the 242-A Evaporator campaigns. The laboratory also studies the physical and chemical characteristics of waste necessary to enable waste retrievals, provides data to support tank closure requirements, and supports the Vadose Zone Program.

The 242-A Evaporator is currently the only operating nuclear waste processing facility at the Hanford Site. 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 (3,902-m²) facility in the Hanford Site’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-and-Treat facility was constructed between 2010 and 2011 to remove contaminants of concern found in the Central Plateau groundwater. The 200-West pump-and-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 (9,463 L/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 several areas of contamination. The Pacific Northwest National Laboratory (PNNL), working for the DOE Office of Science's Pacific Northwest Site Office uses some of the buildings within the 300 Area under an agreement between the U.S. Department of Energy, Richland Operations Office (DOE-RL) and the Pacific Northwest Site Office.

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 FFTF, the Maintenance and Storage Facility, 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. The Maintenance and Storage Facility 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. 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 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 the Hanford Site's roads, railroads, fire station, an old concrete batch plant site, the former townsites of Hanford and White Bluffs, the Hanford Site meteorology station, the Wahluke Slope, and the Arid Lands Ecology Reserve (including Rattlesnake Mountain).

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 the Hanford Site'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) corrugated or solid steel drums welded together end-to-end. 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 fiscal year (FY) 2017. Nonintrusive characterization was completed in 2011 at the 618-11 Burial Ground.

1.3.6 1100 Area

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 (e.g., 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.

1.3.7 3000 Area

The former 3000 Area is located northeast of the 1100 Area and accommodated engineering and construction support facilities. This area was used by the engineer/constructor contractor for general office space, warehousing, and shops. The R&D contractor had several privately-owned laboratory facilities located here. The area also included part of the City of Richland.

1.3.8 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.

1.3.9 700 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 Stevens Center in North Richland near where the 1100 Area used to be located.

1.3.10 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 owned by DOE and operated by Mission Support Alliance, LLC (MSA). 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 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.

HAMMER staff manages nationally recognized training and safety programs including:

- Construction Worker Safety Training
- Worker-Trainer Program
- National Training Center Safety and Health Courses
- Energy Infrastructure Protection and Emergency Response Program
- Domestic and International Border Security Training
- Military Training.



Figure 1-5. Workers Practice Skills They Will Use on the Hanford Site During Decontamination and Demolition Work.

1.3.11 Hanford Tank Waste Treatment and Immobilization Plant

Bechtel National, Inc. 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 54.1 million gal (204.8 million L) 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.

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

Energy Northwest operates a commercial nuclear power reactor called the Columbia Generating Station (CGS). It is located north of the 300 Area on 1,090 ac (440 ha) of leased land. The CGS nuclear facility is the third largest electricity generator in Washington State 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) on leased land. 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.

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.

1.3.13 Non-DOE Nuclear Operations

AREVA NP, Inc. operates a commercial nuclear fuel fabrication facility adjacent to the DOE Hanford Site. The facility provides fuel products and related components and services for commercial pressurized water reactor and boiling water reactor customers worldwide.

The Perma-Fix Northwest Richland facility is a commercial treatment, storage, and disposal (TSD) facility 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. The facility can be used for a variety of fabrication projects, chemical mixing, maintenance, repair of hot equipment, and laboratory testing.

1.3.14 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. The U.S. Fish and Wildlife Service (USFWS), WDFW, and 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 south and west shorelines 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.

1.3.15 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). These areas 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:

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- Bruggemann’s Agricultural Warehouse Complex (existed since 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 U.S. Department of Energy, Office of River Protection (DOE-ORP). The DOE-RL and DOE-ORP 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 the Hanford Site), and the U.S. Department of the Interior’s National Park Service, acting as interpreter and 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 the 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 was awarded the Mission Support Contract for the Hanford Site in 2009. MSA is a joint venture between Leidos and Centerra Group as well as several partners with specialized Hanford Site expertise. MSA is responsible for site infrastructure services for the Hanford Site 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.

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- CH2M Hill Plateau Remediation Company (CHPRC) was awarded the Plateau Remediation Contract in 2008. CHPRC is responsible for the safe environmental cleanup of the Central Plateau at the Hanford Site, including waste retrieval and fuels management, groundwater and vadose zone remediation, demolition of facilities and canyons, closure of the Plutonium Finishing Plant, and remediation of 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.
 - 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 Site workers. Besides providing medical monitoring and qualification-for-work exams, services also include operating and maintaining two clinical facilities, epidemiological studies of Hanford Site workers, and maintenance of the medical records of Hanford Site workers.

The DOE-ORP was established by Congress in 1998 as a field office to manage the retrieval, treatment, and disposal of approximately 54.1 million gal (204.8 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 Site's 222-S Laboratory. Technicians test some 25,000 samples of materials that come in from numerous projects on the Hanford Site.
- Bechtel National, Inc. 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 as well as operate the 222-S Laboratory. 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 the Hanford Site's underground tanks.

The DOE Office of Science manages DOE's science and technology programs, goals, and objectives at the Hanford Site. DOE chartered the Pacific Northwest Site Office to oversee the operation of PNNL, operated by Battelle Memorial Institute 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 Fire Protection and Management

RL Hibbs

Following the DOE complex-wide fires of 2000, DOE Headquarters instituted a short moratorium on prescribed burning. In May 2001, field offices were granted approval authority for specific prescribed fire plans. Prescribed fire plans are designed to address areas along designated fire breaks that need improvement and accumulations of biomass fuels (e.g., tumbleweeds). In addition to fire break maintenance and fuel reduction, prescribed fire can be a valuable and cost effective tool for the ecosystem and the mitigation of noxious/invasive plant species.

The Hanford Fire Department vigorously pursues compliance, as directed by DOE, with all applicable environmental compliance regulations. Included in the prescribed fire plan are technical data for use by appropriate personnel for decision making in the fire environment with respect to prescribed fire application. The purpose of each prescribed fire plan is to identify specific accomplishable objectives and to ensure compliance for each type of fire application.

Site-specific burn plans are prepared in support of each application of prescribed fire. Prior to conducting prescribed burning, in accordance with approved plans, burn permits must be in place and *National Environmental Policy Act of 1969* (NEPA) documentation (including cultural and ecological resource reviews) must be completed.

In addition, the requirements for other applicable regulations must be followed pursuant to existing procedures (e.g., *Clean Air Act*, *Clean Water Act*). Each burn plan uses a Specific, Measurable, Achievable, Realistic, and Time framework that is applied to all portions of the burn plan in order to ensure that fire application is appropriate.

Detailed information on Hanford Fire Department's prescribed burning activities is available in HNF-44199, *Hanford Fire Department 2018 Prescribed Fire Plan*.

1.6 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 the Hanford 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 the Hanford 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 3 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, 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 2018 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, due to greater friction with the ground at lower levels.

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.

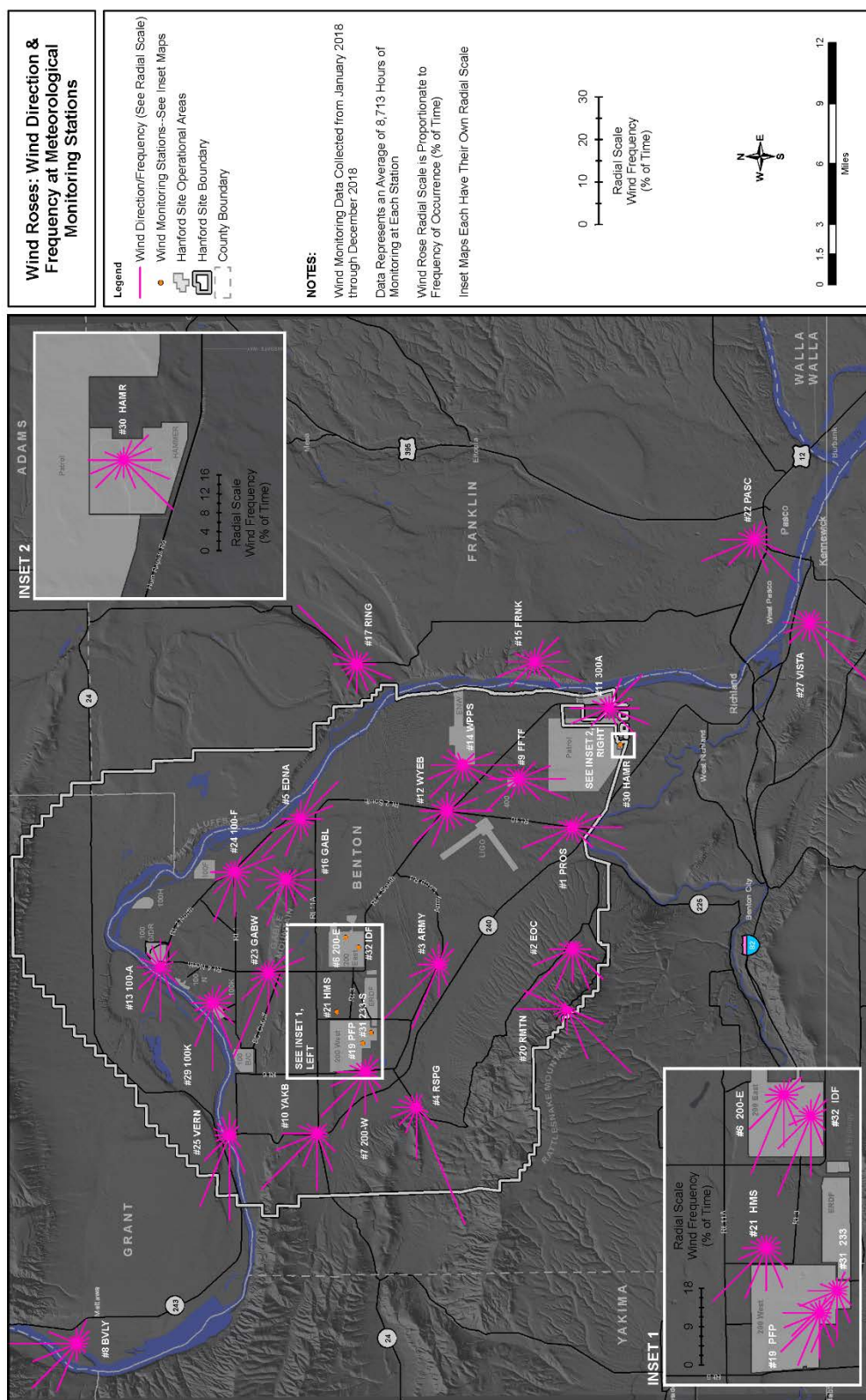


Figure 1-6. Meteorological Monitoring Network Wind Roses from 2018

NOTE: Measured at a height of 30 ft (9 m).

1.6.1 Historical Climatological Information

Records and averages for a wide range of climatological information have been kept since Hanford Meteorology Station's inception. Table 1-1 shows the climatological information for the Hanford Meteorological Station from 1945 through 2018.

Table 1-1. Hanford Meteorological Station Climatological Information for 1945 through 2018.

	Normal annual average	Normal highest monthly average	Normal lowest monthly average	Record highest monthly average	Record lowest monthly average	Highest daily	Lowest daily
Temperature °F (°C)	53.9 (12.2)	77.0 (25.0)	31.4 (-0.3)	82.8 (28.2)	12.1 (-11.1)	113 (45)	-23 (-31)
Relative Humidity %	55.3	80.5	32.7	90.5	21.9	100	6
Precipitation in. (cm)	7.14 (18.13)	-	-	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	11.4 (28.9)	-
Wind Speed mph (m/s)	7.6 (3.4)	9.2 (4.1)	6.0 (2.7)	11.1 (5.0)	2.9 (1.3)	33.7 (15.1)	0.3 (0.1)
Pressure in./Hg (mb)	29.213	29.318	29.130	29.638	28.999	31.12 (1053.8)	28.86 (977.3)

^a Precipitation records are for a year

^b Snowfall records are for a season

- Not reported

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*.

1.6.2 Meteorological Monitoring

The average temperature for 2018 was 55.4 °F (13 °C), which was 1.5 °F (0.8 °C) above normal. During 2018, 8 months were warmer than normal and 4 months were cooler than normal. May had the greatest positive departure at 6.6 °F (3.6 °C) above normal and September had the largest negative departure at 1.0 °F (0.5 °C) below normal.

Precipitation totaled 6.43 in. (16.33 cm), which is 90% of normal precipitation (7.14 in. [18.14 cm]). Greatest monthly total of precipitation was 1.25 in. (3.17 cm) in April and lowest monthly total was a trace in July and September. October 8 and 9 had the greatest 24-hour precipitation at 0.6 in. (1.5 cm). Snowfall for 2018 totaled 2.9 in. (7.3 cm), which was 19% 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 February 17, the peak gust for the year was 57 mph (25.5 m/s).

The growing season was 194 days in 2018. This made 2018's growing season above the normal of 184 days. The last frost in spring was April 3, and the first frost in fall was October 15. The longest growing season was 2016 at 235 days. 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-minute data, monthly climatological summaries, and historical data.

1.7 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.

1.7.1 Role of Native American Tribes

G Phillips

The role of Indian Tribes at the Hanford Site is guided by DOE O 144.1, *Department of Energy American Indian Tribal Government Interactions and Policy*, which communicates departmental, programmatic, and field responsibilities for interacting with American Indian governments. DOE O 144.1 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 and that 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 2018.

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	43.9	31.5	37.7	+4.3	56	27	21	1	1.10	+0.16	T	-4.6	79.4	-0.4	6.4	+0.1	40	SW	29
Feb	49.1	28.0	38.6	+0.4	65	8 ^d	11	20	0.35	-0.35	0.7	-1.6	60.1	-10.6	8.4	+1.5	57	WSW	17
Mar	58.0	33.6	45.8	-0.7	67	29 ^d	23	4	0.35	-0.22	0	-0.4	54.4	-2.8	8.8	+0.9	41	WSW	22
Apr	66.1	41.6	53.8	+0.3	87	27	30	3 ^d	1.25	0.70	0	0	49.9	+1.6	9.9	+1.4	49	W	27
May	82.8	54.6	68.7	+6.6	94	23 ^d	42	2	0.81	0.30	0	0	43.0	-0.2	8.9	+0.1	47	NW	25
Jun	84.6	55.0	69.8	+0.2	95	21 ^d	39	11	0.23	-0.28	0	0	37.0	-2.6	10.3	+1.3	45	W	22
Jul	96.8	64.4	80.6	+3.5	107	17 ^d	52	3	T	-0.23	0	0	25.7	-8.4	9.5	+0.9	43	NW	19
Aug	92.5	60.5	76.5	+0.7	109	10	48	28	0.01	-0.17	0	0	31.6	-4.1	8.2	+0.3	41	NW	23
Sep	79.5	51.2	65.4	-1.0	96	7	42	26	T	-0.31	0	0	37.4	-5.6	8.3	+1.0	44	SSW	16
Oct	65.1	39.9	52.5	-0.6	77	1	32	15	0.93	+0.44	0	0	60.2	+4.1	6.2	-0.5	48	WSW	2
Nov	47.8	31.7	39.6	-0.9	71	2	18	19	0.75	-0.20	0	-2.0	77.1	+3.2	6.3	-0.4	47	SW	1
Dec	42.3	30.1	36.2	+5.1	58	18	19	6	0.65	-0.55	2.2	-3.7	78.6	-2.6	7.0	+1.1	47	SSW	29
Year ^e	67.4	43.5	55.4	+1.5	109	Aug 10	11	Feb 20	6.43	-0.71	2.9	-7.5	52.9	-2.4	8.2	+0.6	57	WSW	Feb 17

Note: Refer to Appendix A, Table A.2, 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*, the NEPA, *Archaeological Resources Protection Act of 1979*, *National Historic Preservation Act of 1966* (NHPA), and the *Native American Graves Protection and Repatriation Act of 1990*.

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, who 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 on site-related draft documents and plans, as well as participate in meetings and activities. Tribal experts in tribal culture, history, and resources often contribute their insight and expertise to Hanford Site decision-making processes and activities. Further information regarding the DOE Tribal Program is available at <http://www.hanford.gov/page.cfm/inp>.

1.7.1.1 2018 Activities. DOE-RL continued to interact with the Tribes regarding Tribal access and use of the Hanford Site. In October 2018, Anne White, DOE's Assistant Secretary for Environmental Management, met with Tribes to discuss a more holistic approach to Tribal involvement in the DOE's Hanford Site decision making and future vision for Long-Term Stewardship at Hanford.

As part of mitigations agreed upon with the Nez Perce, CTUIR, and Wanapum for the transfer of land out of federal control, DOE and the Tribes finalized Tribal revegetation and/or rehabilitation projects to lands within documented Traditional Cultural Properties. The projects are in the planning process and will be conducted in the Preservation Area on lands managed by DOE-RL. The projects will span 5 years and can include plant revegetation, cultural site rehabilitation, weed suppression, and research and publication. DOE coordinated Tribal participation in Project Management Essentials training to assist with these projects.

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 Hanford Tribal Leaders Dialog.

1.7.2 Cultural and Historic Resource Consultations

K Mendez

The NHPA 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 historic properties 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, implemented by MSA staff for DOE-RL, 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 Society and Museum, and the Reach Museum.

The DOE/RL-98-10, *Hanford Cultural Resources Management Plan*, 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*.

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.

1.7.2.1 2018 Activities. In 2018, the Cultural and Historic Resources Program conducted NHPA reviews for 94 proposed projects. DOE-RL hosted 10 monthly meetings with Tribal representatives. DOE-RL consulted on one Memorandum of Agreement (MOA) and completed the signature process during the year. The collection of archaeological artifacts managed by DOE were moved from within the Consolidated Information Center at the Washington State University, Tri-Cities Campus to the Wanapum Heritage Center (repository). The move is per a Memorandum of Understanding for Curatorial Services between the U.S. Department of Energy, Richland Operations Office and the Wanapum Heritage Center, which was signed November 5, 2018.

1.7.3 Hanford Natural Resource Trustee Council

TC Post

The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) 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. A revised MOA was approved by the Trustees in FY 2016 (DOE-RL 2016). The MOA supersedes the 1996 Hanford Site Trustee MOA.

1.7.3.1 2018 Activities. Hanford NRDA work in FY 2018 focused on continuing the FY 2017 injury assessment studies, and began work on five new studies.

The studies are based on the draft *Hanford Natural Resource Damage Assessment Injury Assessment Plan* (HNRT 2012) approved by the Council in 2013. The Council's goal is to complete the injury assessment and prepare a Restoration Plan by 2024. Implementation of the Injury Assessment Plan is a dynamic, iterative process and the list of studies is subject to change as additional data becomes available during the injury assessment process. The Council continued to meet throughout the year to plan, organize, implement, and direct Hanford NRDA activities.

Council project teams delivered project materials or technical updates for nine assessment activities:

- Groundwater vadose and non-use evaluations
- 100-F Area assessment
- Injury thresholds
- Chinook salmon modeling
- Terrestrial disturbance
- Information to help establish aquatic baseline and structure the aquatic assessment
- Shrub-steppe habitat restoration planning
- Aquatic data compilation
- Hanford Site institutional controls.

Five other projects were initiated in FY 2018:

- Aquifer storage and retention evaluation
- Aquatic and terrestrial data visualization
- Terrestrial data compilation
- Aquatic restoration planning
- Phase III 100-F Area evaluation.

Service loss studies are ongoing with each of the three Tribal trustee organizations represented on the Council. Information about the Council, including its objectives, history, and projects, is available online at <http://www.hanford.gov/page.cfm/hnrtc>.

1.7.4 Public Involvement in Hanford Site Decisions

JM Colborn

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 2017) serves as the overall guidance document for public participation and outreach activities at the Hanford Site. 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 calendar year 2018, the Hanford Site worked to the June 2017 Plan (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 Site cleanup decisions. To be added to the electronic mailing list, visit the Listserv website (<http://listserv.ecology.wa.gov/scripts/wa-ECOLOGY.exe?SUBED1=HANFORD-INFO&A=1>) to subscribe or send an email to Hanford@ecy.wa.gov.

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- 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 Public Involvement Opportunities page on the Hanford Site website (<https://www.hanford.gov/page.cfm/Outreach/PublicCommentOpportunities>), 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 from the public (including workers) about the Hanford Site cleanup public involvement opportunities. What began as a challenging, hand-written response interpretation and information gathering at biennial meetings has become an annual electronic survey. Among other lessons learned, the TPA agencies have used the feedback to improve printed communications materials and the structuring of public meetings. 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 Administrative Record 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 federal agencies; Tribal governments; and citizen groups.

Hanford Site cleanup documents are also available to the public through the TPA Administrative Record 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. (2011a), 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) 376-4919

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

1.7.5 State of Oregon

JM Garcia

DOE recognizes Oregon's unique role and interests at the Hanford Site and its concerns with protecting Columbia River resources. In 2017, DOE-RL and DOE-ORP updated a 2004 Memorandum of Understanding with the State of Oregon to consult and, when 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.

1.7.6 Hanford Advisory Board

JM Garcia

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 https://www.hanford.gov/files.cfm/Membership_List_060319.pdf.

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 <https://www.hanford.gov/page.cfm/hab>.

In 2018, the HAB provided DOE with five pieces of advice. The advice and the TPA Agencies' responses may be found at: <https://www.hanford.gov/page.cfm/hab/AdviceandResponses>.

1.8 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, and the Benton Clean Air Agency. The EPA and Ecology are the two main agencies who regulate Hanford Site cleanup as part of the TPA. In addition, the Defense

Nuclear Facilities Safety Board (DNFSB) provides oversight of DOE work. See Section 2.0 for more detail on the oversight at the Hanford Site.

1.8.1 Hanford Federal Facility Agreement and Consent Order

SW Davis, SL Brasher

The TPA is an agreement (Ecology et al. 2011a) among the TPA agencies to achieve compliance on the Hanford Site with the CERCLA remedial action provisions and RCRA TSD unit and corrective action regulations. 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 :

- Defines RCRA and CERCLA cleanup commitments
- Establishes responsibilities
- Provides a basis for budgeting
- Reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones.

Attachment 2 is the Action Plan of the Tri-Party Agreement, which describes how to implement the cleanup and permitting efforts; this includes milestones (in appendix D) for initiating and completing specific work and procedures the TPA agencies will follow (Ecology et al. 2011b).

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 (Ecology et al. 2011a). As new change control forms are approved through the TPA change control process, they are incorporated into the TPA. Electronic copies of Revision 8 of the TPA are publicly available online and can be viewed at <https://www.hanford.gov/page.cfm/TriParty/TheAgreement>. For additional TPA information or questions, call the Washington State Department of Ecology, Nuclear Waste Program office at (509) 372-7950 or e-mail to Hanford@ecy.wa.gov.

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

From 1989 through December 31, 2018, a total of 1,325 TPA milestones were completed and 341 target dates were met. During 2018, 24 specific cleanup milestones were scheduled for completion; of those, 6 milestones were deleted, 14 milestones were completed on time, 2 milestones were being disputed, and 2 milestones were in negotiation. In addition, two target dates were met, zero target dates were deleted, one target date was being disputed, and there were no target dates in negotiation.

1.8.1.2 TPA-Approved Modifications. During 2018, 21 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/>.

1.8.2 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 2018, the DNFSB oversaw projects pertaining to each contractor at the Hanford Site (e.g., Tank Farms, Plutonium Uranium Extraction [PUREX] Plant, 105-KW, 324 Building, Waste Treatment and Immobilization Plant, and Effluent Treatment Facility). Reports produced by the DNFSB reporting on Hanford Site projects can be viewed at <https://www.dnfsb.gov/documents>.

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2018 Highlight

Air Quality and Protection

The Hanford Site continued to comply with the Hanford Site Air Operating Permit that contains requirements for emission sources on the Hanford Site. There was one Notice of Violation requiring action involving airborne radioactive materials pertaining to license requirements and filing annual certificates at Tank Farms. There was a Stop Work Order sent to the U.S. Department of Energy (DOE) from the Environmental Protection Agency and Washington State Department of Ecology concerning the Plutonium Finishing Plant Demolition Project (issued in January 2018.); The Stop Work was lifted for all work to restart in June 2019.

Radiation Protection of the Public and the Environment

Potential sources of radionuclide release from the Hanford Site include airborne emissions, groundwater seeping into the Columbia River, and fugitive emissions from soils and facilities. The annual dose to a maximally exposed member of the public continued to be well below the DOE public dose limit of 100 mrem/yr. The dose to biota of the Columbia River and other offsite locations was also well below the DOE standards. Section 4.0, *Radiological Protection and Doses*, explains the determination of public and biota dose in detail.

Pollution Prevention and Waste Minimization

The Hanford Site diverted 50% (1,075 metric tons) of nonhazardous solid waste for recycling and worked with a company that separates transformer oil and carcasses for recycling, rather than dispose of them as a hazardous waste. The Hanford Site received a three-star 2019 Electronic Product Environmental Assessment Tool Purchaser award for the procurement of sustainable electronics.

External Environmental Audits and Inspections

The U.S. Environmental Protection Agency, the Washington State Department of Ecology, Washington State Department of Health, and the City of Richland representatives conducted audits, inspections, and site visits of various Hanford Site environmental programs to ensure regulatory compliance with state and federal regulations, the Hanford Federal Facility Agreement and Consent Order, and associated permits and licenses.

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 applicable 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 (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. 1989) 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 is intended to ensure that the DOE, including the National Nuclear Security Administration, receives 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 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

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

ME Mills

Enacted by Congress on October 6, 1992, the *Federal Facility Compliance Act of 1992* 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, 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 RCRA 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 Reports pursuant to TPA Milestone M-026-01.

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* amended 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 state of Washington is authorized under RCRA and EPA's implementing regulations to implement state law and regulations in lieu of the federal regulations. The Hanford Site hazardous waste activities are subject to applicable provisions of WAC 173-303, "Dangerous Waste Regulations."

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 as co-operators
 - 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).

The Washington State dangerous waste regulations (WAC 173-303) require Ecology to issue a new permit after a term of up to 10 years. The initial Hanford Facility RCRA permit was issued on September 27, 1994, for a 10-year term. DOE submitted an application for a new permit 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. Because the DOE submitted a timely application for a new permit, and Ecology subsequently determined the application was complete, the DOE is allowed to operate under the expired permit per WAC 173-303-806(7). The 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 permit for public comment (Ecology 2012). Ecology received approximately 1,800 comments from the public and 3,000 comments from the DOE on the draft permit during the comment period held from May 1 to October 22, 2012. 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. The new permit is expected to be issued in the 2023 time frame. The process will include the following activities:

- Review and evaluate the comments received from the first comment period and develop responses to all comments
- Revise the permit based on significant information and issues raised in the first comment period and other changes that have occurred in the intervening years
- Issue a revised draft permit and responses to the original comments

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- Reopen the comment period
 - Prepare responses to the next round of public comments
 - Issue the final permit.

Ecology is working with the DOE to perform the actions in first and second bullets above.

While operating under the expired permit, DOE is required to submit permit modifications reflecting changing operations in order to keep the permit consistent with current operations. During 2018, modifications were made to the expired permit. The changes affected 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 (Operating Unit 11)
- 400 Area Waste Management Unit (Operating Unit 16)
- 1325-N Liquid Waste Disposal Facility (Closure Unit Group 1)
- 1301-Liquid Waste Disposal Facility (Closure Unit Group 2)
- 1324-N Surface Impoundment (Closure Unit Group 3)
- 1324-NA Percolation Pond (Closure Unit Group 3)
- 1706-KE Waste Treatment System (Closure Unit Group 14)
- Purgewater Storage and Treatment Facility (Closure Unit Group 15)
- 300 Area Process Trenches (Post-Closure Unit Group 1).

2.1.2.2 Regulatory Agency Inspections

SA Szendre

During fiscal year (FY) 2018, 85 regulatory agency inspections and visits were conducted at DOE facilities on the Hanford Site. Some of the agency inspections were conducted jointly between multiple agencies.

Ecology inspections were conducted by the Nuclear Waste Program Office located in Richland, Washington. EPA Region 10 inspections focused on TSD facilities and conducting oversight of Ecology and Washington State Department of Health (WDOH) inspections under EPA-delegated authority. WDOH inspections were performed by the Office of Radiation Protection, Richland, Washington. WDOH focused on Major and Minor Emission Units, the progress of work involved with the PUREX Tunnel 1 and 2, and the Plutonium Finishing Plant Demolition Project. The City of Richland inspection focused on the 300 Area of the Hanford Site to evaluate compliance with Industrial Wastewater Discharge Permit (CR-IU010) requirements, including the monitoring of wastewater discharges to the publicly-owned treatment works. The DOE-RL, DOE-ORP, and Pacific Northwest Site Office 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 2.10.

DOE utilizes two internal tracking databases to track regulatory agency inspection activity and agency enforcement actions. 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. 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 (Section 2.9).

RCRA Inspections. The Ecology inspections focused on TSD unit compliance with the Hanford Facility Dangerous Waste Permit (Ecology 2012) and WAC 173-303, “Washington State Dangerous Waste Regulations.” The TSD units and other facilities inspected during 2018 included the following:

- 200 Areas Effluent Treatment Facility
- Waste Encapsulation Storage Facility
- 222-S Laboratory
- 400 Area Waste Management Unit
- 242-A Evaporator
- 325 Building
- 324 Building
- B-Plant
- Liquid Effluent Retention Facility
- 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
- Waste Treatment Facility
- Low-level Burial Grounds.

Section II.O of the RCRA permit addresses general inspection requirements required in accordance with WAC 173-303-320. General Inspections are required to be done by the permittees in addition to the TSD unit inspections specified in Parts III, V, and VI of the RCRA permit. The RCRA permit requires General Inspection of the 100, 200-East, 200-West, 300, and 400 Areas, as well as the Columbia River shoreline. General Inspections are performed annually in these areas by Hanford Site contractors, with oversight

from DOE, 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

SA Szendre and CJ Perkins

In 2018, the WDOH inspections focused on compliance of point and non-point emission units with the Radioactive Air Emissions License (FF-01). Ecology inspections included inspections of discharge points (e.g., emergency engines/generators and passive vents and stacks) and packaged boiler systems regulated under the Hanford Site Air Operating Permit.

2.1.2.3 RCRA Groundwater Monitoring

MJ Hartman

The Soil and Groundwater Remediation Project monitors 25 RCRA units on the Hanford Site. Section 8.0 includes a summary of groundwater monitoring activities for the RCRA units during 2018.

DOE/RL-2018-65, *Hanford Site RCRA Groundwater Monitoring Report for 2018*, includes detailed groundwater monitoring information.

2.1.3 Comprehensive Environmental Response, Compensation, and Liability Act

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 (including radionuclides), 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.

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

- 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.

2.1.3.1 CERCLA Five-Year Reviews

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 review methods, technical assessments, and protectiveness statements. Recommendations to address identified issues are also provided. The results of the four 5-year reviews conducted since 2000 are documented in the *USDOE Hanford Site First Five-Year Review Report* (EPA 2001); 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*.

The Hanford Site Fourth CERCLA Five-Year Review Report (DOE/RL-2016-01), addressing 2011 through 2015, was completed by DOE-RL in 2017 and received EPA concurrence (EPA 2017). This report aligned with EPA's latest guidance on 5-year review reports, as well as recent training provided to multi-federal agencies as they strove for more consistent reports and the use of substantive tables and figures to more concisely present information that supports the protectiveness statements.

This latest CERCLA 5-year review report (DOE/RL-2016-01) evaluates the protectiveness of 30 operable units with remedies that have been documented in interim or final Records of Decision (RODs). Approximately 16 of the Hanford Site's operable units do not have remedies documented in interim or final RODs at this time; however, 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 were 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.

Of the 23 source operable units assessed in Hanford's fourth CERCLA 5-year review, five operable units (100-FR-1, 100-FR-2, 100-IU-2, 100-IU-6, and 1100-EM-1) were determined to be in the EPA protectiveness category of "Protective"; 18 operable units (100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-1, 100-FR-1, 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 and 200-PW-6) were determined to be in the category of "Will Be Protective". Of the seven groundwater operable units assessed in Hanford's fourth CERCLA 5-year review, one operable unit (200-ZP-1) was determined to be in the EPA protectiveness category of "Protective"; five operable units (100-FR-3, 100-HR-3*, 100-KR-4*, 300-FF-5, and 200-UP-1) were determined to be in the category of "Will Be Protective"; and one operable unit (100-NR-2*) was determined to be in the category of "Not Protective". For the operable units in this paragraph that include an asterisk (*), recommendations for issues identified during the 5-year review are described within DOE/RL-2016-01.

Hanford's next CERCLA 5-year review report is due by May 4, 2022.

2.1.3.2 Institutional Controls

GT Berlin

The MSA Long-Term Stewardship (LTS) program is responsible for managing institutional controls (IC) 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 DOE/RL 2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*, 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 through implementation of the remedy and then afterwards. The CERCLA decision documents identify the specific requirements for these ICs.

The 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 (4.6 m), 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 document. 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 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 results of LTS's 2018 annual assessment can be summarized as follows:

- Entry Restrictions
 - Active badging program and barricades in place to control unauthorized entries.
 - Damaged fences were observed in eight locations and repairs have been completed.
- Warning Notices
 - Warning signs required by decision documents are in place.
 - “No Trespassing” signs along road perimeter that were found to be damaged or illegible due to general weathering are being repaired.
- Land Use Management
 - LTS reviewed 20 site evaluations to ensure land-use ICs are kept in place.
 - LTS approval is mandatory on excavation permits.
 - 181 excavation permits were evaluated for IC compliance.
 - No change in land-use designations occurred in FY 2018 (e.g., industrial use).
 - No disturbances or natural subsidence/erosion found on the waste sites with ICs.
 - Thirty-six waste sites in the 300 Area Industrial Complex with enhanced recharge controls:
 - Drainage during storm events was observed to address potential drainage issues
 - Snow-pile staging area plans were developed to prevent enhanced recharge
 - Collaboration continues facilities to minimize impact of discharges from fire testing and to improve/maintain drainage systems to support enhanced-recharge control ICs.
- Groundwater-Use Management
 - Wells drilled in the LTS-managed areas are approved through the site excavation permit process.
- Miscellaneous Provisions
 - Two reportable trespassing incidents on Hanford Site from October 1, 2017, through August 31, 2018.

Operable units in the Central Plateau of the Hanford Site also have a number of ICs in both interim and final ROD documents. In calendar year (CY) 2018, an assessment of ICs at 200-UP-1 Operable Unit, 221-U Facility, and 200-ZP-1 Operable Unit identified no deficiencies.

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

GM Fritz

Title III of SARA, also known as the *Emergency Planning and Community Right-to-Know Act of 1986* (EPCRA), requires owners and operators of facilities that handle certain hazardous chemicals onsite to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. EPCRA has four major provisions: emergency planning, emergency release notification, hazardous chemical inventory reporting, and toxic chemical release inventory reporting. Table 2-1 summarizes sections of EPCRA and its requirements, including two annual reports: the Tier Two Emergency and Hazardous Chemical Inventory, which provides information about hazardous chemicals stored at each facility in amounts exceeding minimum threshold levels, and the Toxic Chemical Release Inventory, which describes total annual releases of certain toxic chemicals and associated waste management activities. Table 2-2 provides an overview of reporting under the EPCRA during 2018.

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
311	40 CFR 370, "Hazardous Chemical Reporting"	The presence at any one time at a facility an OSHA hazardous chemical in quantity greater than or equal to 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	Annually by March 1	Local Emergency Planning Committee; State Emergency

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
		substance in quantity equal to or greater than threshold planning quantity or 500 lbs (230 kg), whichever is less.		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
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act CFR = Code of Federal Regulation CY = calendar year EPA = U.S. Environmental Protection Agency 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	

DOE/RL-2019-10, 2018 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 50 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 2018.

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	3,465,584/1,571,963
00-00-0	Diesel Fuel	10,000	2,761,530/1,252,609
7440-23-5	Sodium	10,000	2,351,029/1,066,409
8012-95-1	Mineral Oil	10,000	798,715/362,291
8052-42-4	Asphalt	10,000	786,120/356,578
8006-61-9	Gasoline	10,000	744,976/337,915
65997-15-1	Portland Cement	10,000	601,688/272,921
00-00-0	Lead Acid Batteries	500	559,160/253,631
74-98-6	Propane	10,000	406,786/184,515
7782-63-0	Ferrous Sulfate Heptahydrate	10,000	400,002/181,438

The DOE/RL-2019-25, *2018 Hanford Site Toxic Chemical Release Inventory*, report was submitted to EPA and Ecology before the annual July 1 deadline. During CY 2018, the Hanford Site exceeded activity thresholds for lead, naphthalene, propylene and toluene. Information concerning these chemicals is described in Table 2-4.

Table 2-4. Toxic Chemicals Exceeding Reporting Thresholds.

CAS No.	Chemical	Non-Exempt Use Description
7439-92-1	Lead	Ammunition fired during range practice by Hanford Safeguards and Security
91-20-3	Naphthalene	Diesel used for stationary equipment
115-07-1	Propylene	Propane gas used sitewide
108-88-3	Toluene	Gasoline used for stationary equipment

2.1.5 Environmental Release Reporting

ME Mills

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 CRD 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 regulations promulgated under the authority granted to EPA by the *Toxic Substances Control Act* (TSCA). TSCA primarily involves regulation of polychlorinated biphenyls (PCBs). TSCA also regulates other constituents (e.g., asbestos, lead-based paint, and radon). The applicability of TSCA to the management of these constituents at the Hanford Site is discussed in the following:

- Lead-based Paint
 - TSCA regulations for lead-based paint are applicable to residential and child-occupied facilities and do not apply to Hanford Site activities.
- Radon
 - The radon regulations under TSCA pertain to schools and public or assisted-housing and do not apply to Hanford Site activities.
- Asbestos
 - Asbestos at the Hanford Site is primarily regulated by the *Clean Air Act* and Occupational Safety and Health Administration.
 - The TSCA accreditation and training requirements found at 40 CFR 763, Appendix C, are applicable at the Hanford Site. These requirements specify the minimum training standards for personnel engaged in asbestos abatement activities.
- PCBs – federal regulations for use, storage, and disposal of PCBs are contained 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 the requirements of 40 CFR 761.
 - Some radioactive PCB waste remains in extended storage onsite pending the development of adequate treatment and disposal technologies and capacities.
 - In service electrical equipment that might contain PCBs is maintained 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 DOE/RL-2018-19, *2017 Polychlorinated Biphenyl Annual Report*, and DOE/RL-2018-20, *2017 Polychlorinated Biphenyl Annual Document Log*, to EPA on June 25, 2018, 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 2018 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 (EPA 2005) 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 2018, DOE is developing plans to place additional K-Basin 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 Federal Insecticide, Fungicide, and Rodenticide Act

JM Rodriguez

EPA administers the *Federal Insecticide, Fungicide, and Rodenticide Act*. The Washington State Department of Agriculture administers standards to regulate implementation of the Act in the state, including 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 National Environmental Policy Act of 1969

JW Cammann

The *National Environmental Policy Act of 1969* (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 NEPA (40 CFR 1500-1508) and DOE’s NEPA implementing procedures (10 CFR 1021) ensure compliance with the letter and spirit of NEPA.

NEPA and its implementing regulations and procedures require federal agencies to integrate NEPA reviews early in project planning to ensure decisions reflect environmental considerations, avoid delays later in the process, and anticipate and resolve conflicts; rather than be an after-the-fact process that justifies decisions already made. NEPA reviews are an “umbrella” for compliance with other federal, state, and local requirements. The evaluation of many resource areas fall within the jurisdiction of other environmental laws and regulations, which may require a specific standard to be met (substantive requirements) or may require a permit, license, or other approval by the agency responsible for administering the law.

Proposed actions are evaluated in accordance with the CEQ on Environmental Quality regulations and DOE NEPA implementing procedures to determine whether an Environmental Impact Statement (EIS) or Environmental Assessment (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 2018. Hanford Site NEPA documentation is available online at <https://www.hanford.gov/page.cfm/Documents>.

2.2.1 Hanford Site Environmental Impact Statements.

There were no Environmental Impact Statements completed or underway at the Hanford Site during CY 2018.

2.2.2 Hanford Site Environmental Assessments.

Hanford Site EAs that were completed or underway in CY 2018 are described in this section.

2.2.2.1 *Environmental Assessment for Rebuild of the North Loop 230-kV Electrical Transmission Line (DOE/EA-2033)*. DOE prepared an EA for the rebuild of approximately 28 mi (45 km) of the North Loop transmission line in the northern part of the Hanford Site. The proposed project would reconfigure switching station and substation components, install equipment and conductors, build and recondition access roads, and remove structures and other ancillary activities. DOE made a determination to prepare an EA for the rebuild of the transmission line on February 1, 2016.

During CY 2018, work continued on the EA and Finding of No Significant Impact (FONSI). The FONSI was signed on May 7, 2018.

2.2.2.2 *Environmental Assessment for Benton-Othello 115-kV Transmission Line Rebuild Project (DOE/EA-2038)*. An EA is under preparation to assess environmental effects of Avista Utilities’ (Avista) proposal to rebuild 12.6 mi (20.27 km) of the Benton-Othello Switching Station electrical transmission line on the Hanford Site. The upgrade on the Hanford Site would begin approximately 0.5 mi (0.8 km) south of State Route 24

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 cultural, ecological, and wetland field studies and a floodplain evaluation. Work continued on the EA during CY 2018.

2.2.3 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/RL NEPA Compliance Officer (NCO) approved a total of 51 categorical exclusions during CY 2018. Of these, 43 were annual categorical exclusions to cover routine and recurring work activities planned to be performed during CY 2018 at the Hanford Site (Mission Support Alliance – 28, CH2M Plateau Remediation Company – 8, and Pacific Northwest National Laboratory – 7). A total of eight activity-specific CXs were approved by the NCO (Mission Support Alliance – six, and CH2M Plateau Remediation Company – two). The Office of River Protection had no CXs for CY 2018. Annual and activity-specific categorical exclusions approved by the DOE NCO may be viewed at <http://www.hanford.gov/page.cfm/CategoricalExclusions>.

2.3 Radiation Protection Statutes, Regulations, and Directives

TA Ikenberry

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.

2.3.1 Atomic Energy Act of 1954

To ensure proper management of radioactive materials, the *Atomic Energy Act of 1954* (AEA) 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 458.1, *Radiation Protection of the Public and Environment*, and DOE O 435.1, Chg. 1, *Radioactive Waste Management*. 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>.

2.3.2 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 to provide radiological protection of the public and the environment. DOE O 458.1 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, DOE O 458.1 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 property with residual radioactive material.

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. DOE O 458.1 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
- Manage real and personal property to control residual radioactivity
- Ensure potential exposures to the public are as far below established limits as low as reasonably achievable (ALARA)
- 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.

Table 2-5 provides the standards (dose limits) for radiation protection of the public and the environment from routine DOE operations. While the public dose limit of 100 mrem/yr (1 millisievert [mSv]/yr) is the primary dose standard, other regulations impose additional constraints on the dose that may be received through specific exposure pathways. The air and water pathways are also regulated by the EPA and Washington State; they are discussed in more detail in Sections 2.4 and 2.5. DOE O 458.1 provides dose limits for protection of aquatic and terrestrial plants and animals in the vicinity of radiological activities on the Hanford Site. In addition, dose constraints are provided for the dose that could be received by a member of the public from certain other activities, including radioactive waste management, storage, and disposal, as well as unrestricted release to the public or clearance of real and personal property.

These radiation standards are dose limits but not DOE's expectation for dose to the public and the environment. DOE O 458.1 requires the application of the ALARA process to all routine radiological activities to further reduce (optimize) radionuclide releases and resulting doses to the extent possible.

Table 2-5. Radiation Protection Standards for the Public and the Environment from All Routine DOE Operations.^a

All Pathways (DOE O 458.1)		
Exposure of members of the public will not cause a total effective dose exceeding 100 mrem (1 mSv) in a year	Total Effective Dose^c	
	mrem/year	mSv/year
Routine public dose	100	1
Temporary public dose ^b , under special circumstances with specific authorization and justification	500	5
Air Pathway Dose Constraints (40 CFR 61 Subpart H, WAC 173-480, WAC 246-247)		
See Section 2.3		
Emissions of radionuclides shall not cause any member of the public to receive an effective dose equivalent of 10 mrem/yr	Effective Dose Equivalent	
	mrem/year	mSv/year
	10	0.1
Water Pathway Dose Constraints (40 CFR 141, WAC 246-290)		
See Section 2.4		
The annual dose equivalent to the total body or to any organ shall not exceed 4 mrem/yr, based on average annual concentrations	Dose Equivalent	
	mrem/year	mSv/year
	4	0.04
Protection of Biota. (DOE O 458.1, DOE-STD-1153-2002)		
Radiological activities must be conducted to protect populations of aquatic animals, terrestrial plants, and terrestrial animals	Absorbed Dose	
	rad/day	mGy/day
Aquatic animal	1	10
Riparian animal	0.1	1
Terrestrial plant	1	10
Terrestrial animal	0.1	1
Radioactive Waste Dose Constraint (DOE O 458.1)		
Exposure from radioactive waste management, storage, and disposal activities shall be ALARA and meet the dose constraint.	Total Effective Dose	
	mrem/year	mSv/year
Public dose constraint	25	0.25
Release and Clearance of Property (DOE O 458.1)		
Exposure from release of real (land and buildings) and personal property shall be controlled to be ALARA and meet dose constraints.	Total Effective Dose	
	mrem/year	mSv/year
Public dose constraint from real property	25	0.25
Public dose constraint from personal property	1	0.01
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 DOE-RL may request specific authorization from DOE-HQ for a temporary public dose limit greater than 100 mrem/yr (1 mSv/yr). It may be no more than 500 mrem (5 mSv)/yr and cannot exceed an average of 100 mrem/yr (1 mSv/yr) over 5 contiguous years. The request must document the justification, alternative considered, and the application of the ALARA process.		
^c Dose units are those in the cited regulation, order or standard. DOE uses the most up-to-date dosimetry system of any United States agency.		
ALARA = as low as reasonably achievable		
CFR = Code of Federal Regulations		
DOE-HQ = U.S. Department of Energy, Headquarters		
mrem = millirem		
mSv = millisievert		
mGy = milligray		
WAC = Washington Administrative Code		
NOTE: International dose units shown in italics are not provided in the order or rules but are provided for information.		

2.3.3 DOE O 435.1, Radioactive Waste Management

I. Siddoway, G Pyles

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. DOE O 435.1 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, "Occupational Radiation Protection"; 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 an Applicable or Relevant and Appropriate Requirement as defined in Section 121(d) of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.

2.4 Air Quality Statutes and Regulations

RA Kaldor

Below is information on federal, state, and local statutes applicable to the Hanford Site air quality program.

2.4.1 Clean Air Act

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* provides the framework for a significant portion of current federal air quality regulations. The Washington *Clean Air Act*, 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 the requirements in WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides," and WAC 246-247, "Radiation Protection – Air Emissions." Applicable federal requirements in 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart A, and 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities," are adopted by reference in WAC 246-247.

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, "National Emission Standards for Hazardous Air Pollutants"; 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, “Ambient Air Quality Standards and Emission Limits for Radionuclides”; 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. Ecology also regulates demolition and asbestos renovation activities at the Hanford Site in accordance with federal requirements in 40 CFR 61, Subpart M, “National Emission Standard for Asbestos.”

The Benton Clean Air Agency regulates outdoor burning activities at the Hanford Site in accordance with state requirements in WAC 173-425, “Outdoor Burning.”

2.4.2 Air Permits Required by Regulations

RA Kaldor, SA Szendre

Hanford Site contractors evaluate each proposed new or modified emission unit using the new source review requirements of radioactive air emissions (WAC 246-247) 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. 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-2019-09, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2018*).

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. An application for renewal of the Air Operating Permit was submitted to Ecology in September 2017 and determined by Ecology to be complete in November 2017. A draft renewal 3 Air Operating Permit was issued for public comment in December 2017 and then again in July 2018. The current permit will continue to be in effect until a renewed permit is issued. 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 2018, regulatory agencies conducted 39 *Clean Air Act* inspections on the Hanford Site. There was one Notice of Violation issued by WDOH requiring action involving airborne radioactive materials pertaining to license requirements and filing annual certificates at Tank Farms.

2.5 Water Quality Permits, Statutes, and Regulations

M Kamberg

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

2.5.1 Federal Permit – Discharges to Columbia River

The *Clean Water Act*, as amended, applies to discharges to surface waters 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.

2.5.2 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 2018: ST0004500, ST0004502, ST0004511, and ST0045514. Ecology’s wastewater discharge permits page is located at <https://fortress.wa.gov/ecy/nwp/permitting/WWD/index.html>. 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.

Two Ecology general permits for sand and gravel were in effect (and issued to Bechtel National Inc.) during 2018: WAG-50-5180 and WAG-50-5181.

2.5.3 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 2018 and will expire March 6, 2023.

2.5.4 Safe Drinking Water Act of 1974

BR Stenson

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

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

The SDWA was amended in 1986 and 1996. 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 2018, all but one of the 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 2018 for microbiological, chemical, physical, and radiological constituents. There were no microbiological detections during the 2018 monitoring cycle and all eight water systems had chemical concentrations in drinking water that 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 2018 radiological monitoring are summarized in Section 7.1.3.

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

Constituent	Drinking Water Standard ^a		Agency ^b
Antimony	6 µg/L	0.006 ppm	EPA, WDOH
Arsenic	10 µg/L	0.01 ppm	EPA, WDOH
Asbestos	7 million fibers/L	7 million fibers/L	WDOH
Barium	2,000 µg/L	2 ppm	EPA, WDOH
Beryllium	0.4 mg/L	0.004 ppm	WDOH
Bromate	10 µg/L	0.010 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
Chlorite	1000 µg/L	1.0 ppm	EPA, WDOH
cis-1,2-Dichloroethene	70 µg/L	0.07 ppm	EPA, WDOH
Copper	1,300 µg/L	1.3 ppm	EPA

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

Constituent	Drinking Water Standard ^a		Agency ^b
Cyanide	200 µg/L	0.2 ppm	EPA, WDOH
Fluoride	4 mg/L	4 ppm	EPA, WDOH
Haloacetic Acids	60 µg/L	0.060 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
Nickle	0.1 mg/L	0.1 ppm	
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
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 greater than 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 less than 50, 20,000, and 8 pCi/L, respectively.

Bq = Becquerel

CFR = *Code of Federal Regulations*

DWS = drinking water standards

EPA = U.S. Environmental Protection Agency

L = liter

Mg = milligrams

MSv = millisievert

pCi = picocuries

ppm = parts per million

µg = micrograms

WAC = *Washington Administrative Code*

WDOH = Washington State Department of Health

yr = year

2.5.5 Surface Water Standards

Washington State 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 Washington State. For the Hanford Site, this primarily encompasses the Columbia River. The standards are contained within WAC 173-201A.

2.6 Natural and Cultural Resources

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

2.6.1 Ecological Compliance

KL Cranna

The DOE/RL-96-32, *Hanford Site Biological Resources Management Plan* (BRMP) requires that all Hanford Site projects with the potential to adversely affect biological resources conduct an ecological compliance review before the project starts. DOE uses the review to determine if the project will comply with the *Endangered Species Act of 1973*, the *Migratory Bird Treaty Act of 1918* (MBTA), and the *Bald and Golden Eagle Protection Act*, as well as Executive Order 11988 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 153 ecological compliance reviews requested during FY 2018 from 17 functional departments on the Hanford Site. Departments with a significant number of requests include Water and Sewer Utilities (27), Soil and Groundwater (25), Remediation (21), Reliability Services (20), and Electrical Utilities (11).

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

2.6.1.2 Migratory Bird Treaty Act. 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 the MBTA. All Hanford Site projects with a potential to affect federal or state-listed species of concern complied with the requirements of the MBTA 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 U.S. Fish and Wildlife Service (USFWS) that allow for certain MBTA-related actions. An Annual Permit Activity Form summarizing all activities conducted under this permit is provided to the USFWS each year.

2.6.1.3 Bald and Golden Eagle Protection Act. The *Bald and Golden Eagle Protection Act* 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. DOE/RL-94-150, *Bald Eagle Management Plan for the Hanford Site, South Central Washington*, 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.

2.6.1.4 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*, 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.

2.6.2 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*, *Historic Sites Act of 1935*, *National Historic Preservation Act (NHPA) of 1966*, NEPA, *Archaeological and Historic Preservation Act of 1974*, *American Indian Religious Freedom Act of 1978*, *Archaeological Resources Protection Act of 1979*, and *Native American Graves Protection and Repatriation Act*.

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 5, "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.

There were 94 NHPA Section 106 compliance reviews completed on Hanford Site in 2018. There were 13 archaeological sites monitored under the NHPA Section 110 Site Conditions Monitoring Program. For additional information, see Section 11.3.1.

2.7 Sustainability

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.

2.7.1 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 the Hanford Site. 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 Hanford 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 Site 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 limitations, and DOE Sustainable Environmental Stewardship goals.

2.7.2 Pollution Prevention Program

MM Oates

The *Pollution Prevention Act of 1990* 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, ecological and cultural resource preservation, and the integration of sustainable practices into management functions and mission activities. DOE-RL 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 2018.

Note: Antifreeze (fleet) and used engine oil (fleet) quantities are included in antifreeze and used oil totals, respectively, and are not included in the regulated solid wastes subtotal. Lead acid batteries (fleet) quantities are not included in lead acid batteries and are an addition to the regulated solid wastes subtotal.

2.7.2.1 Pollution Prevention and Waste Minimization Awards. The Hanford Site received one DOE, federal agency, state agency, or industry-sponsored award for pollution prevention and waste minimization accomplishments in CY 2018. The Green Electronics Council notified The Hanford Site that they received a five-star 2019 Electronic Product Environmental Assessment Tool (EPEAT) Purchasers Award for the combined application MSA submitted on behalf of MSA, CHPRC, and WRPS for CY 2018 (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, televisions, and mobile phones 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. Collectively, the Hanford Site reduced the use of primary materials by 377 metric tons, avoided the disposal of 3.3 metric tons of hazardous waste, eliminated 20.0 metric tons of solid waste, and avoided 2.4 metric tons of water pollutant emissions. These efforts saved 1,410 MWh of electricity, reduced 777 metric tons of greenhouse gas emissions, and generated \$137,990 in lifetime cost avoidance.

Table 2-7. Recycle Quantities.

Material	FY 2018 Total (metric tons)
<i>Non-hazardous Solid Wastes</i>	
Activated Carbon	22.68
Aluminum Cans	3.18
Cardboard	81.30
CI Shredded Paper	457.83
Electronics	29.49
Ferrous Metal	128.90
Furniture	118.18
Miscellaneous	37.12
Non-ferrous Metals	25.07
Plastic Bottles	41.07
Tires	38.19
Transformers	38.74
Wood Pallets	53.33
Total	1075.08
<i>Regulated Solid Wastes</i>	
Aerosol Cans	0.45
Antifreeze	5.37
Ballasts	2.80
Batteries	3.82
Fluorescent Bulbs	6.39
Lamps - Mercury Containing	0.01
Lead Acid Batteries	65.01
Transformer Oil <50ppm	9.94
Toner Cartridges	4.69
Used Engine Oils (Fleet)	0.32
Used Oil	39.54
Total	138.34



Figure 2-1. The 2019 Five-star EPEAT Purchaser Award presented by Green Electronics Council.

2.7.2.2 Accomplishments. The Hanford Site contractors recycled 50% of non-hazardous solid waste, excluding construction and demolition (C&D) debris. In 2018, 1,075 metric tons of non-hazardous (i.e., plastic, aluminum, cardboard, paper, wood, and metal), and 138.34 metric tons of universal waste (i.e., batteries and lamps), and other regulated (i.e. antifreeze and used oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Along with material recycling and diversion, the Hanford Site strives to reduce greenhouse gases Scopes 1, 2, and 3. There was a 42% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2018 from the FY 2008 baseline; emissions in FY 2018 were 24,108 metric tons of carbon dioxide equivalent, whereas emissions in FY 2008 were 41,427 metric tons of 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 2018, contractors at the Hanford Site continued to divert C&D debris from landfill disposal. The Hanford Site diverted approximately 26% (473.6 metric tons) of C&D debris from the inert landfill. The Hanford Site contractors continue to make efforts to divert C&D materials suitable for reuse and recycle from landfills. The following are some ongoing Hanford Site projects and operations expected to increase the generation of C&D debris in FY 2019:

- Upgrading electrical in future support to WTP
- Land clearing operations for construction
- Reducing Hanford Site footprint
- Reducing waterline pipe size and runs
- Excessing Project Technical Services old equipment
- Maintaining site infrastructure and utilities.

2.7.3 DOE O 436.1, Departmental Sustainability

MM Oates

DOE O 436.1, *Departmental Sustainability*, requires developing a Site Sustainability Plan integrated with the Hanford Site operational plans. In addition, DOE O 436.1 requires 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.

In addition, DOE O 436.1 requires that an Environmental Management System be established as the platform for managing environmental goals, as well as other impacts to the environment from Hanford Site operations and establishing environmental objectives.

As the Hanford Site services and infrastructure contractor, MSA updated the sustainability plan (HNF-54800) for the Hanford Site in 2018 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 2018, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship (see Section 3.0).

Environmental performance objectives are established to meet requirements provided by DOE O 436.1 and directed guidance for some Executive Orders. Executive Order 13834, *Efficient Federal Operations*, superseded Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, and established a policy for federal agencies to meet statutory requirements in a manner that increases efficiency, optimizes performance, eliminates unnecessary use of resources, and protects the environment. It allows agencies to conduct legally, environmentally, economically, and fiscally sound environmental and energy-related activities in an integrated, efficient, continuously improving, and sustainable manner.

2.8 Occurrence Reporting and Processing of Operations Information

ME Mills

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. Occurrence Reporting Criteria were based on DOE O 232.2, *Occurrence Reporting and Processing of Operations Information*, from January 2018 through October 2018. Since October 2018, Occurrence Reporting Criteria are based on DOE O 232.2A, *Occurrence Reporting and Processing of Operations Information*, and associated Supplemented Contract Requirements Document. The Reporting Criteria provides a set of requirements that must be used to identify reportable occurrences. Report Levels provide a means to reflect the impact associated with a given occurrence in terms of health, safety, and security to personnel, the public, the environment, and the operational mission. The three report levels are: High (H), Low (L), and Informational (I). The following sections summarize occurrences that may have impacted the Hanford Site environment in 2018.

2.8.1 High-Level Report

Occurrences in this category meet any of the following conditions: Impact to worker or public safety and health, environmental harm, regulatory compliance, or potential for mission interruption. There were no Hanford Site Environmental High-Level Report occurrences.

2.8.2 Low-Level Report

Occurrences in this category are those that do not meet High-Level Report occurrences but involve personnel injury, environmental releases, equipment damage, or hazardous circumstances; additional time is appropriate for written notifications. There were no Hanford Site Environmental Low-Level Report occurrences.

2.8.3 Informational Level Report

Occurrences in this category are those that do not meet High- or Low-Level Report occurrences and generally meet the following conditions:

- Determined to be a safety, environmental, or mission concern
- Provide potential learning opportunities for others.

Discovery of legacy contamination is an “Informational Level Report” occurrence. There were 45 documented occurrences of legacy contamination from January 1, 2018, to December 31, 2018. Section 2.8.3.1 provides further details into legacy contamination spread from environmental conditions.

2.8.3.1 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.

2.9 Environmental Permits

JK Perry, RA Kaldor, M Kamberg, JW Wilde

Hanford Site operations must be performed in accordance with environmental permit requirements. A general description of the primary environmental permits applicable to Hanford Site operations are listed in Table 2-8. Some of these permits are discussed throughout this section in more detail.

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. A permit renewal application was submitted to Ecology in August 2017 and determined to be complete by Ecology in November 2017. As such, Renewal 2 will remain in effect until Renewal 3 is issued. 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 DOE-RL by WDOH. The current permit was effective October 20, 2017, and expires October 20, 2022. 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).

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

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.
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 March 6, 2023.
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 expired June 30, 2017. ST0004502 required 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. A letter was received from Ecology on May 24, 2017, in which they accepted the permit application as complete and extended the term of the current permit for up to 5 years while the new permit is being drafted.
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 expired December 31, 2018. A permit renewal application was submitted to the Washington State Department of Ecology on July 24, 2018, and was received by Ecology on July 25, 2018. A letter was received from Ecology on November 7, 2018, accepting the permit application as sufficiently complete and extended the term of the current permit for up to 5 years while the new permit is being drafted.
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. This permit expired June 30, 2017. A permit renewal application was submitted to the Washington State Department of Ecology on April 3, 2017, and was received by Ecology on April 10, 2017. A letter was received from Ecology on June 22, 2017, accepting the permit application as sufficiently complete and extended the term of the current permit for up to 5 years while the new permit is being drafted.
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 expired March 31, 2018. The permit was extended and reissued as Permit MB60138B-0; the permit expired on March 31, 2021.

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

Review Reference Number 13260-2009-I-0121, Federal Fish and Wildlife Section 10.0 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 7.0 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 17-190, Scientific Collection Permit issued by WDFW to MSA for May 2017 through June 2018, authorizes food fish, shellfish, game fish, and wildlife collection for research purposes. This permit is renewed annually.		
Permit 18-113, Scientific Collection Permit issued by WDFW to MSA for May 2018 through June 2019, authorizes the collection of food fish, shellfish, game fish, and wildlife for research purposes. This permit is renewed annually.		
Agency Contact Information		
State of Washington Department of Ecology P.O. Box 47600 Olympia, WA 98504-7600	U.S. Environmental Protection Agency Region 10 1200 Sixth 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	
DOE = U.S. Department of Energy DOE-EL = U.S. Department of Energy, Richland Operations Office Ecology = Washington State Department of Ecology MSA = Mission Support Alliance RCRA = <i>Resource Conservation and Recovery Act</i> WDFW = Washington State Department of Fish and Wildlife WDOH = Washington State Department of Health WTP = Waste Treatment Plant		

2.10 Environmental Enforcement Actions

SA Szendre

Hanford Site operations are affected and, in many cases, regulated by numerous federal and state agencies enforcing legal requirements that address environmental compliance. The EPA has delegated authority to Ecology and WDOH to implement state laws and regulations in lieu of RCRA, the *Clean Air Act*, and the *Clean Water Act*. State laws and regulations requiring licenses or permits apply to activities at the Hanford Site. Examples of such permits are Hanford Site Radioactive Air Emissions License, the RCRA Permit, the Air Operating Permit, and several 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 the following:

- 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
- 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 2018.

2.10.1 Enforcement Actions by Regulatory Program Area

During 2018 there were 22 regulatory agency compliance actions filed against the DOE and its contractors for alleged violations of regulatory requirements or other enforceable agreements. 21 compliance actions were issued by Ecology, and one by WDOH. Twenty of the 22 compliance actions resulted from regulatory agency inspections of DOE facilities on the Hanford Site (Section 2.1.2.2). The inspection reports also contained 70 concerns. In 2018, WDOH issued a warning letter to DOE for a process description in the licenses for two emission units in the 241-SY Tank Farm did not match the actual current status.

Table 2-9 summarizes the alleged environmental noncompliance notices by program area. Table 2-10 summarizes the 22 alleged environmental noncompliances notices cited against the DOE and its contractors during 2018 including a short 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, 2013–2018.

Program Area	2013	2014	2015	2016	2017	2018
CAA	4	2	3	1	0	1
CWA	0	0	1	0	1	0
RCRA	4	7	16	22	33	21
CERCLA	1	0	0	1	0	0
Others	1	1	7	3	0	0
Total	10	10	27	27	34	22
CAA = Clean Air Act CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act CWA = Clean Water Act RCRA = Resource Conservation and Recovery Act						

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2018. (2Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
Ecology	2019-06	ECOLOGY WARNING LETTER BASED ON INSPECTION OF 222S LABORATORY COMPLEX	Alleged non-compliances for labeling of containers and container inventory. Concerns were for waste codes, major risk labeling, and sample exclusion process.
Ecology	2019-05	ECOLOGY WARNING LETTER BASED ON INSPECTION OF 216-S-10 POND AND DITCH	Alleged area of non-compliance was for not sampling for phenol at well 699-33-75 in 2017. No further action was required.
WDOH	2019-04	WDOH WARNING LETTER FOR THE 296-S-26 AND 296-S-27 EMISSION UNITS AT THE 241-SY TANK FARM	The process description in the licenses does not match the actual status.
Ecology	2019-03	ECOLOGY WARNING LETTER BASED ON INSPECTION OF 325, 331 AND 350D FACILITIES	Alleged non-compliances for Universal Waste storage and performing treatment-by-generator in Satellite Accumulation Areas.
Ecology	2019-01	ECOLOGY WARNING LETTER BASED ON INSPECTION OF 400 AREA WASTE MANAGEMENT UNIT GROUP 16	Alleged non-compliances for designation, facility inspections, water intrusion, waste acceptance, and overpacked reactive waste. Concerns were for waste dispensation, treatment, retention of records, and operating records.
Ecology	2018-28	ECOLOGY WARNING LETTER BASED ON INSPECTION OF LOW LEVEL BURIAL GROUNDS - GREEN ISLANDS	Inadequate sampling of groundwater monitoring well 299-W 10-30.
Ecology	2018-27	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE SINGLE SHELL TANK SYSTEM	Inadequate signage at A Tank Farm and intrusion into Catch Tank 241-TX-302C.
Ecology	2018-26	ECOLOGY WARNING LETTER BASED ON INSPECTION OF LOW LEVEL BURIAL GROUNDS TRENCHES 31 AND 34	Alleged non-compliance for manifest issues and one concern for not conducting "significant storm inspections" in February 2017.
Ecology	2018-25	ECOLOGY WARNING LETTER BASED ON INSPECTION OF 1301N, 1325N, 183H, AND 300 AREA PROCESS TRENCHES	Alleged non-compliance for inadequate sampling of well 199-H4-88.
Ecology	2018-24	ECOLOGY WARNING LETTER BASED ON INSPECTION AT THE 242-A EVAPORATOR	Alleged non-compliance was for inadequate inspections. The concern was for inadequately monitoring drains in the loading room.
Ecology	2018-23	ECOLOGY WARNING LETTER BASED ON INSPECTION AT THE T-PLANT COMPLEX	Alleged non-compliances were for inadequate labeling and inspections. The compliance report states that the concern was for excessive time taken designating an unknown waste.
Ecology	2018-22	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE B PLANT COMPLEX	Alleged non-compliance for not designating a white residue on the floor of the canyon building.
Ecology	2018-21	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE CENTRAL WASTE COMPLEX	Inadequate Major Risk labeling on Containers 0081202, 202A7S013, and 0090043.

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2018. (2Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
Ecology	2018-20	ECOLOGY WARNING LETTER FOR THE DOUBLE SHELL TANK SYSTEM AND 204-AR	Alleged Non-Compliance for labeling, written inspection schedule, and integrity assessments.
Ecology	2018-18	ECOLOGY WARNING LETTER BASED ON INSPECTION OF RELEASES FROM ERDF CANS	Discharges of wastewater from roll-on/roll-off containers do not meet the requirements for authorized discharges in Permit ST4511.
Ecology	2018-17	ECOLOGY WARNING LETTER BASED ON DANGEROUS WASTE COMPLIANCE INSPECTION AT THE 222S LABORATORY	Inadequate Major Risk labeling, inspection records and Operating Records.
Ecology	2018-16	ECOLOGY NOTICE OF NON-COMPLIANCE FOR THE WASTE ENCAPSULATION AND STORAGE FACILITY	Inadequate Dangerous Waste Training Plan and inspection records.
Ecology	2018-15	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE 242-A EVAPORATOR	Inadequate Dangerous Waste Training Plan.
Ecology	2018-14	ECOLOGY NOTICE OF NON-COMPLIANCE FOR CIRCUIT BOARDS AT 2703E	Inadequate designation and mismanagement of electronic circuit boards.
Ecology	2018-12	ECOLOGY LETTER OF NON-COMPLIANCE FOR LOW LEVEL BURIAL GROUNDS TRENCHES 31 AND 34	Inadequate labeling of waste containers, Dangerous Waste Training Plan, Personnel Training, and Recordkeeping.
Ecology	2018-10	NOTICE OF VIOLATION DOCKET #15420 PERTAINING TO FEDERAL AND STATE AIR EMISSION REGULATIONS	Failing to modify their FF-01 RAEL license, failing to provide accurate information in support of an ALARACT demonstration, failure to obtain a license for a modification, filing an inaccurate annual AOP certification.
Ecology	2018-09	EPA/ECOLOGY CREATION OF DANGER STOP WORK LETTER FOR THE PFP DEMOLITION PROJECT (TPA XXXII)	Non-compliances were not cited; however, Ecology and EPA determined, and allege, that recent contamination events at the PFP are creating a danger to the health or welfare of the people on the Hanford Site and to the environment.
ALARACT	= As Low As Reasonably Achievable Control Technology		
AOP	= Air Operating Permit		
Ecology	= Washington State Department of Ecology		
EPA	= U.S. Environmental Protection Agency		
PFP	= Plutonium Finishing Plant		
WDOH	= Washington State Department of Health		

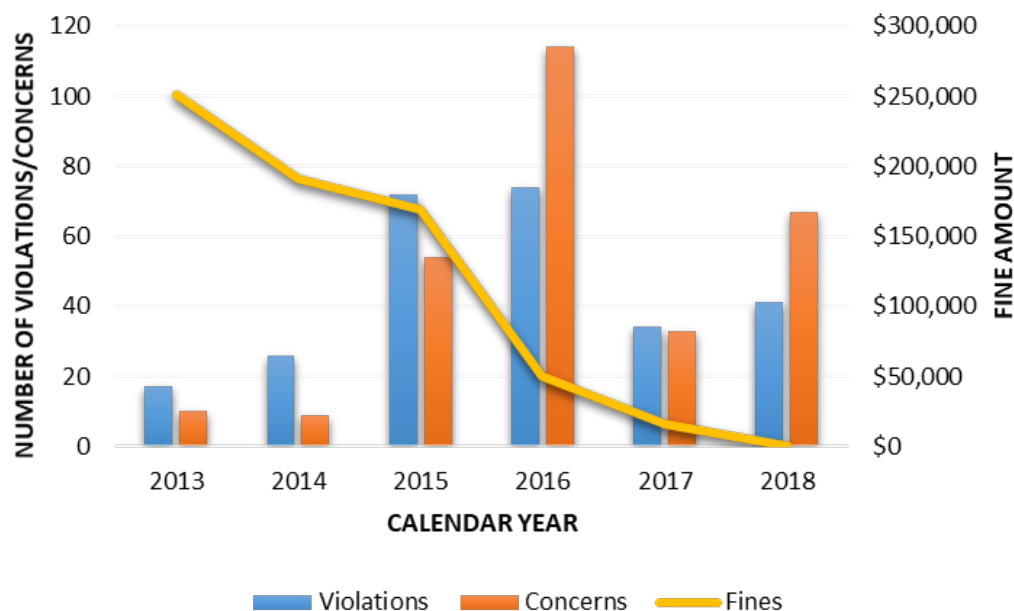


Figure 2-2. Alleged Environmental Noncompliance Violations, Concerns, and Associated Fines Summary.

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.

2.10.2 Wastewater Permit Deviations

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During CY 2018, there were 22 non-compliances reported to regulatory agencies for wastewater permit deviations. Nine of the events involved Large Onsite Sewage System permits and 13 involved State Waste Discharge Permits. In all cases, action was taken to repair and correct the non-compliant conditions and regulatory notifications were made in accordance with 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 2018 Wastewater Permit Deviations. (2 Pages)

Date	Permit Number Deviated	Reported To	Reason(s)
January 10	HAN013	Health	Sewage tank at MO596 building overflowed to the ground due to a continuously flushing toilet.
January 14	ST0004502	Ecology	Small leak at Pump Station 2
January 15	HAN054	Health	Approximately 30 gal of sewage were released to the ground at the 2607-E-10-LS1 lift station near the grout processing facility in 200-East due to a failure of the dosing pump.
January 16	HAN049	Health	Approximately 500 gal of sewage was released to the ground at the 2607-EL Lift Station in 200-East near MO294. The affected area was disinfected with sodium hypochlorite and the affected asphalt parking area was flushed with chlorinated water and twice treated with UV light equipment.
January 31	HAN054	Health	A toilet or sink was left running while the 2607-E10 lift station pump was under repair resulting in an untreated sewage release to the ground.
February 7	ST0004502	Ecology	Small leak in Pump Station 1
February 26	ST0004511	Ecology	A potable water leak occurred near MO2522 at an approximate rate of 1 gal/min. The leak occurred within 300 ft of WIDS sites 216-A-29 ditch and 200-E-286 swamp and ditch.
February 28	HAN054	Health	Approximately 5 gal of sewage was released to the ground from lift station 2607-E10. The area was disinfected with a sodium hypochlorite solution and pumper trucks were used until repairs were completed.
May 31	ST0004502	Ecology	Grab sample taken instead of a required composite sample because of problems with the sampler unit.
June 20	HAN011	Health	A stuck valve resulted in approximately 10 gal of sewage being released adjacent to the 2607-Z lift station.
July 5	ST0004502	Ecology	Leaking vacuum-relief valve in the TEDF line.
July 9	HAN039	Health	Overflow of 50 to 75 gal of sewage from septic vaults.
August 3	ST0004511	Ecology	A potable water leak occurred southwest of 283W at Fire Hydrant 8W when the pressure gage was removed and the hydrant broke. A total of approximately 11,000 gal was discharged to the ground.
August 15	HAN071	Health	A power outage in 200-East resulted in a release of approximately 15 gal of sewage to the ground from the 2607-11 Lift Station.
August 21	HAN049	Health	Approximately 1 gal of sewage was released to the ground as a result of a 2-in. pipe break during Project L-853 construction activities.
September 12	NA (No permit required)	Health	Wastewater discharge valve in MO173 leaked approximately 5 gal of sewer water onto the ground.
October 2	ST0004502	Ecology	Small leak in air relief valves on the transfer line.
October 17	ST0004511	Ecology	A potable water leak occurred adjacent to 216-A-29 ditch at a rate of 0.5 gal/min.

Table 2-11. CY 2018 Wastewater Permit Deviations. (2 Pages)

Date	Permit Number Deviated	Reported To	Reason(s)
November 5	ST0004502	Ecology	Small leak in air relief valves on the transfer line.
December 3	ST0004502	Ecology	Total dissolved solids result for November exceeded the permit monthly average.
December 4	ST0004502	Ecology	Grab samples were taken instead of composite samples due to failure of the composite sampler.
December 5	ST0004511	Ecology	A potable water leak occurred at the intersection of 4 th Street Loop and Grout Drive. The estimated rate was 5 to 10 gal/min and approximately 300 gal discharged within 300 feet of two inactive WIDS sites (ditches 216-A-29 and 200-E-286).
December 11	ST0004502	Ecology	Grab samples were taken instead of composite samples due to failure of the composite sampler.
Ecology = Washington State Department of Ecology Health = Washington State Department of Health TEDF = Treated Effluent Disposal Facility UV = ultraviolet WIDS = Waste Information Data System			

2.11 References

- 10 CFR 820, "Procedural Rules for DOE Nuclear Activities." *Code of Federal Regulations*, as amended. Online at <http://energy.gov/ea/downloads/10-cfr-part-820-procedural-rules-doe-nuclear-activities>.
- 10 CFR 830, "Nuclear Safety Management." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title10/10cfr830_main_02.tpl.
- 10 CFR 835, "Occupational Radiation Protection." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?SID=40dc5b37cae52e891f095e943d5a3d69&mc=true&node=pt10.4.835&rgn=div5>.
- 10 CFR 1021, "National Environmental Policy Act Implementing Procedures." *Code of Federal Regulations*, as amended. Online at <https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:4.0.3.5.14>.
- 10 CFR 1022, "Compliance with Floodplain and Wetland Environmental Review Requirements." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?SID=f0182280d0e89b8f8b419ba359c4de96&mc=true&node=pt10.4.1022&rgn=div5>.
- 29 CFR 1910.1200, "Hazard Communication." *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgi-bin/text-idx?SID=dce08c1f6da7a829b84ddeab99f5dd8e&mc=true&node=se29.6.1910_11200&rgn=div8.

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- 36 CFR 60. "National Register of Historic Places." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=af4fa0b4fb36604e8682834d7d507c8c&rgn=div5&view=text&node=36:1.0.1.1.26&idno=36>.
- 36 CFR 63. "Determinations of Eligibility for Inclusion in the National Register of Historic Places." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5;node=36%3A1.0.1.1.29>.
- 36 CFR 65. "National Historic Landmarks Program." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=36:1.0.1.1.31>.
- 36 CFR 79. "Curation of Federally-Owned and Administered Archaeological Collections." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title36/36cfr79_main_02.tpl.
- 36 CFR 800. "Protection of Historic Properties." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title36/36cfr800_main_02.tpl.
- 40 CFR 52. "Approval and Promulgation of Implementation Plans." *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr52_main_02.tpl.
- 40 CFR 60. "Standards of Performance for New Stationary Sources." *Code of Federal Regulations*, as amended. Online at <https://www.ecfr.gov/cgi-bin/text-idx?SID=24a108a1db51447fd1cfd51ed65a70b7&mc=true&node=pt40.7.60&rgn=div5>.
- 40 CFR 61. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr61_main_02.tpl.
- 40 CFR 61, Subpart A, "National Emission Standards for Hazardous Air Pollutants," *Code of Federal Regulations*, as amended. Online at <https://www.ecfr.gov/cgi-bin/text-idx?SID=dbbce47c16e8c4afde5bfee0c6b16595&mc=true&node=sp40.10.61.a&rgn=div6>.
- 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?SID=f97fad2b7029c4e0446d8d3e7afabf5a&mc=true&node=sp40.9.61.h&rgn=div6>.
- 40 CFR 61, Subpart M, "National Emission Standard for Asbestos." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?SID=17669b88b378edd01fb4fc705950431b&mc=true&node=sp40.10.61.m&rgn=div6>.
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- 40 CFR 61.92. "Standard." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=6453727111a6ce05bdd5e7b9670a7a7a&rgn=div8&view=text&node=40:9.0.1.1.1.8.1.3&idno=40>.
- 40 CFR 63. "National Emission Standards for Hazardous Air Pollutants for Source Categories," *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?SID=7488a2f4120e611881cbab65c27466f0&mc=true&node=pt40.11.63&rgn=div5>.
- 40 CFR 68. "Chemical Accident Prevention Provisions." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr68_main_02.tpl.
- 40 CFR 70. "State Permit Operating Permit Programs." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr70_main_02.tpl.
- 40 CFR 82. "Protection of Stratospheric Ozone." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr82_main_02.tpl.
- 40 CFR 122. "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr122_main_02.tpl.
- 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.
- 40 CFR 143. "National Secondary Drinking Water Regulations." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr143_main_02.tpl.
- 40 CFR 355. "Emergency Planning and Notification." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?SID=c71bb36461a4218f9a9d2a5aef1422f0&mc=true&tpl=/ecfrbrowse/Title40/40cfr355_main_02.tpl.
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2018 Highlight

The U.S. Department of Energy sets goals for carrying out its mission in an environmentally sustainable manner that supports a policy of national energy security and addresses global environmental challenges. Hanford Site contractors continues to make substantial progress in meeting these goals for the Hanford Site. Below are the highlights of the progress cumulative through 2018.

Pollution Prevention and Waste Minimization

The Hanford Site diverted 50% (1,075 metric tons) of nonhazardous solid waste for recycling in fiscal year 2018.

Water Management

The Hanford Site continued to reduce potable water consumption intensity in fiscal year 2018 at 55.9% (gal/ft²) reduction.

Renewable Energy Intensity

The Hanford Site derived **17%** of electricity from renewable energy sources.

Environmental Management System Best Practices

Mission Support Alliance improved the electronic Environmental Activity Screening System for Mission Support Alliance-led projects that ensures inclusion of environmental personnel for the appropriate evaluations.

3.0 Environmental Management System

MM Oates

The U.S. Department of Energy Richland Operations Office (DOE-RL) and Office of River Protection (DOE-ORP) requires Hanford Site contractors to develop and operate under an Integrated Safety Management System (ISMS). In accordance with contract obligations, each contractor maintains an Environmental Management System (EMS) that is an integral part of the ISMS and with the certified conforms to ISO 14001, *Environmental Management Systems*. In 2015, all but one Hanford Site contractor established ISMSs as mandated by their contracts with DOE-RL and DOE-ORP. 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. The ISMSs 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-RL and DOE-ORP verified that Hanford Site entities incorporated appropriate environmental program elements within their ISMS under the authority of DOE O 450.2, *Integrated Safety Management*. The dates of approval for the Hanford Site contractors' ISMS are provided in Table 3-1.

Performance related to EMS must be reported annually to U.S. Department of Energy, Headquarters (DOE-HQ). Each contractor is given an overall ranking of red, not meeting requirements, yellow, on track to meet requirements, or green, meeting requirements, 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-RL, and Office of River Protection (DOE-ORP).

Table 3-1. DOE Contract Actions and Contractor Implementation.

Actions, Implementation	Richland Operations Office				Office of River Protection		
	HPMC	CHPRC	MSA	WCH	VNSFS	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 EO 13423	Oct 2012	Oct 2008	Aug 2009	June 2009	Nov 2015	NA	Oct 2008
Direction to Implement EO 13514	NA	June 2012	May 2011	Oct 2012	Nov 2015	NA	Mar 2011
Direction to Implement CRD O 430.2B	NA	June 2009	Aug 2009	June 2009	NA	NA	Oct 2008
Direction to Cancel CRD O 430.2B	NA	July 2012	July 2012	Oct 2012	NA	NA	Sept 2014
Direction to Implement CRD O 450.1A	Oct 2012	June 2009	Aug 2009	June 2009	NA	NA	Oct 2009
Direction to Cancel CRD O 450.1A	Oct 2012	July 2012	Dec 2012	Oct 2012	NA	NA	Sept 2014
Direction to Implement CRD 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	Sept2009	Sept 2016	NA	Sept 2009
ISO 14001 Certification	NA	Jul 2012/ 2015/ 2018	Sept 2011/ 2014/ 2017	NA	NA	NA	NA
DOE Declared CRD O 450.1A Conformance	NA	Dec 2009	Dec 2009	Nov 2009	NA	NA	Sept 2009
Most Recent Declaration of Conformance	March 2016	Sept 2018	Sept 2018	Sept 2015	Sept 2016	NA	Sept 2018
Contractor EMS Scorecard Rating	Green	Green	Green	NA	Green	Red	Green
DOE EMS Scorecard for 2018	Green			NA	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 VNSFS=Veolia Nuclear Solutions Federal Services WRPS=Washington River Protection Solutions, LLC							

As the services and infrastructure contractor for the Hanford Site, Mission Support Alliance (MSA) developed HNF-54800, *2018 Hanford Site Sustainability Plan*, for the Hanford Site in fiscal year (FY) 2019 with input from 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, *Departmental Sustainability*. This Order mandates that U.S. Department of Energy (DOE) sites use EMSs as the platform for sustainability program implementation. Environmental objectives were established and maintained in FY 2018, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship. Sustainability plans from FY 2001 through present are available on the MSA website link in Table 3-2.

Several contractors have made their environmental policy and environmental aspects available to the public through company internet websites (Table 3-2).

Table 3-2. Hanford Site Environmental Management System Internet Links.

Contractor	Website	Category
CHPRC	http://chprc.hanford.gov/files.cfm/PRC-POL-EP-5054.pdf	Policy
MSA	http://msa.hanford.gov/files.cfm/ems.pdf	Policy, Aspects
VNSFS	http://wadv.wastrencloud.com/?page_id=601	Policy
WRPS	http://wrpstoc.com/tank-operations/environmental-management/	Policy, Aspects

3.1 Environmental Performance Measures

In consultation with DOE-RL, DOE-ORP, 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. The measures developed in response to this Order 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, and greenhouse gas reduction.

Baseline data was obtained in accordance with guidance in the Order. Where no guidance was available, data from FY 2009 or FY 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 FY 2018 (Figure 3-1). DOE-HQ required that a minimum of 75% of all non-mission critical light-duty vehicles purchased during FY 2018 be alternative fuel vehicles (DOE O 436.1). Acquisitions for 67% of Hanford light duty vehicles were hybrid, electric, or use E85 (ethanol) fuel.

3.1.2 Alternative Fuel Use

The alternative fuel use target was surpassed for FY 2018; however, the target for petroleum-based fuel use was missed (Figure 3-2). Mission and contract structure changes since FY 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. This will reduce the amount of petroleum-based fuels used annually by 20% by FY 2015 relative to an FY 2005 baseline and maintain that level thereafter. The requirement includes increasing the amount of alternative fuels used annually by 10% or 2% annually by FY 2015 relative to an FY 2005 baseline and maintain that level thereafter.

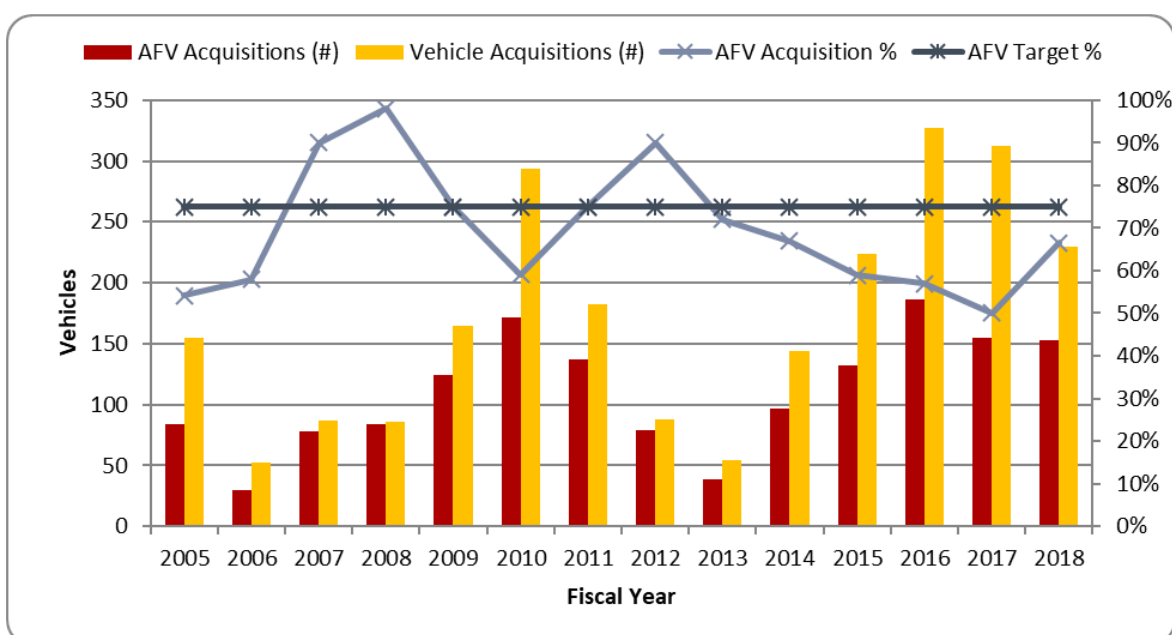


Figure 3-1. Fleet Management – Acquisitions FYs 2005–2018.

NOTE: AFV stands for alternative fuel vehicle

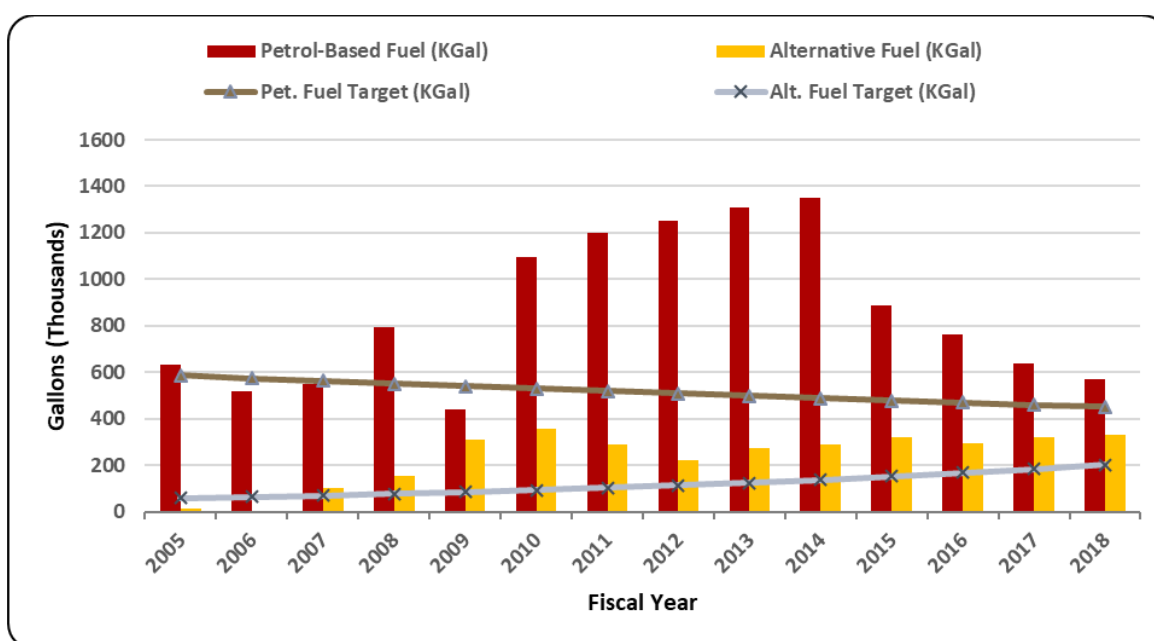


Figure 3-2. Vehicle Fuel Use – FYs 2005–2018.

3.1.3 Potable and Non-potable Water Use

The target objectives for potable water was met in FY 2018 (Figure 3-3). The target objective for non-potable water was not met in FY 2018 due to industrial processes that use large amounts of non-potable water, such as evaporator campaigns. 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. In addition, 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 an 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 no 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 2018 (Figure 3-4) representing 20% 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, micro-turbines, municipal solid waste, or new hydroelectric generation.

3.1.5 Facility Fuel Use

The target objectives for facility fuel use were met in FY 2018 (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.

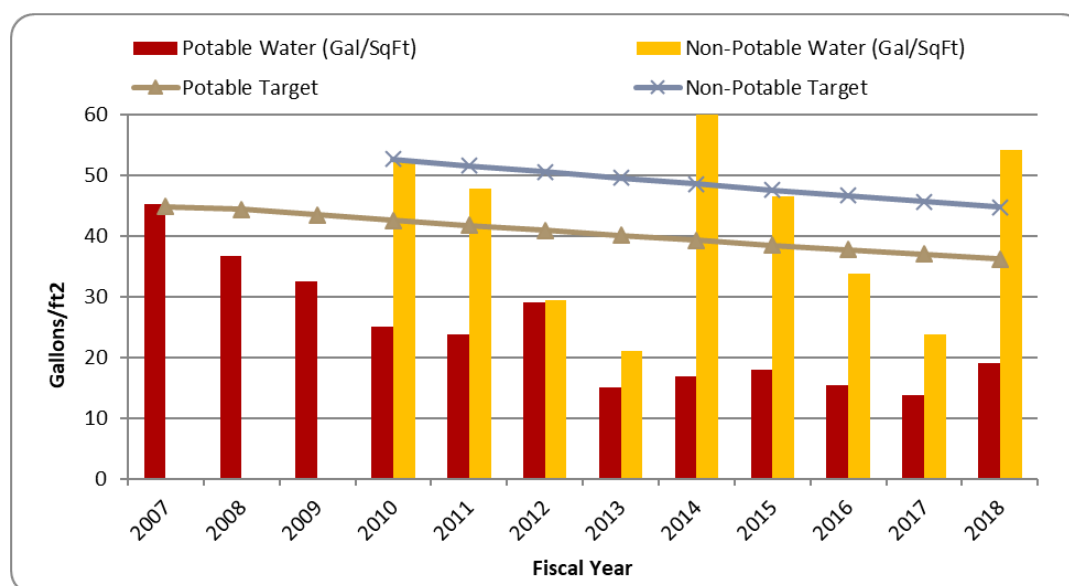


Figure 3-3. Water Use – FYs 2007–2018.

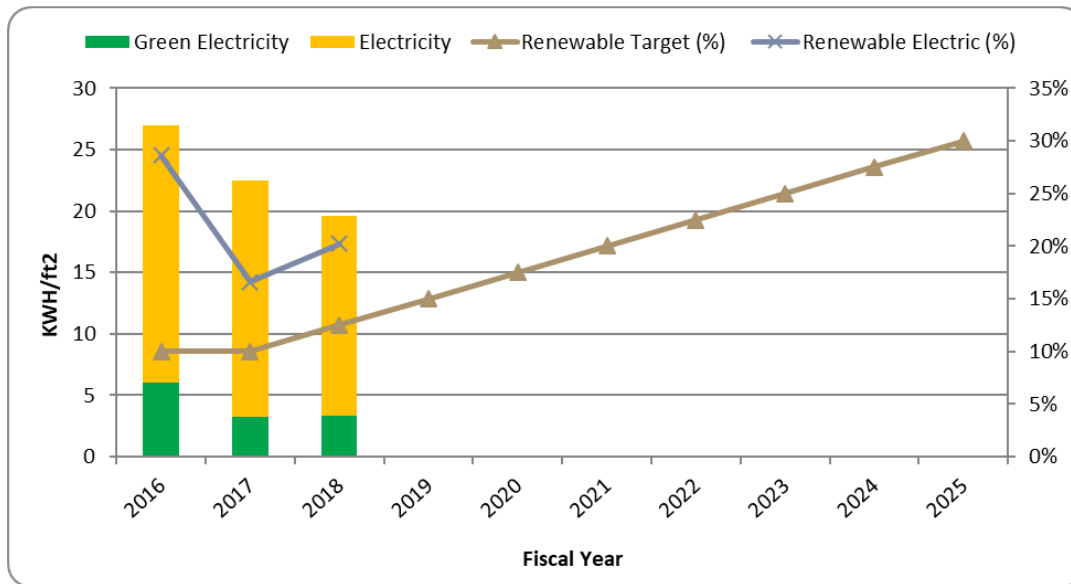


Figure 3-4. Electricity Use – FYs 2016 – 2018 with Target Objectives through 2025.

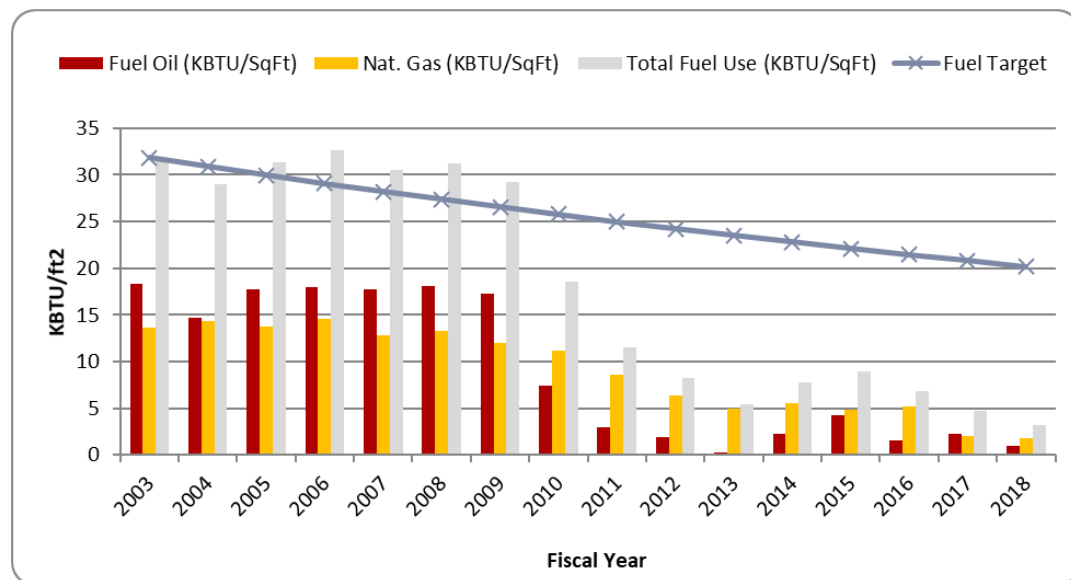


Figure 3-5. Facility Fuel Use – FYs 2003–2018.

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 2.5% annually relative to the FY 2015 baseline. The target objective was met in FY 2018 (Figure 3-6). Note: In Figure 3-6, FY 2015 and FY 2016 data was corrected for data inclusion consistency with Hanford Site contractors, Pacific Northwest National Laboratory, and Hanford Tank Waste Treatment and Immobilization Plant operations.

3.1.7 Electronic Product Environmental Assessment Tool

The target objectives for the Electronic Product Environmental Assessment Tool were met in FY 2018 with 95% 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, monitors, and mobile phones) must comply with the standard in an effort to reduce or eliminate the environmental impacts of electronic assets by incorporating electronic stewardship practices. Fluctuations in the total amount of electronic products purchased can occur due to changes in federal requirements and funding.

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. The sanitary waste objective was achieved in FY 2018. Note: In Figure 3-8, FY 2011 through FY 2016 sanitary waste disposal data was corrected and may reflect different recycling percentages than reports in previous fiscal years. Corrected fiscal year data still meets the sanitary waste objective of 50% reduction.

3.1.9 Regulated Waste Reduction

Efforts toward regulated waste reduction on the Hanford Site include eliminating or minimizing regulated waste 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 the Hanford Site's Environmental Restoration Disposal Facility is not included in Figure 3-9. Waste to this facility decreased in FY 2018 (Figure 3-10).

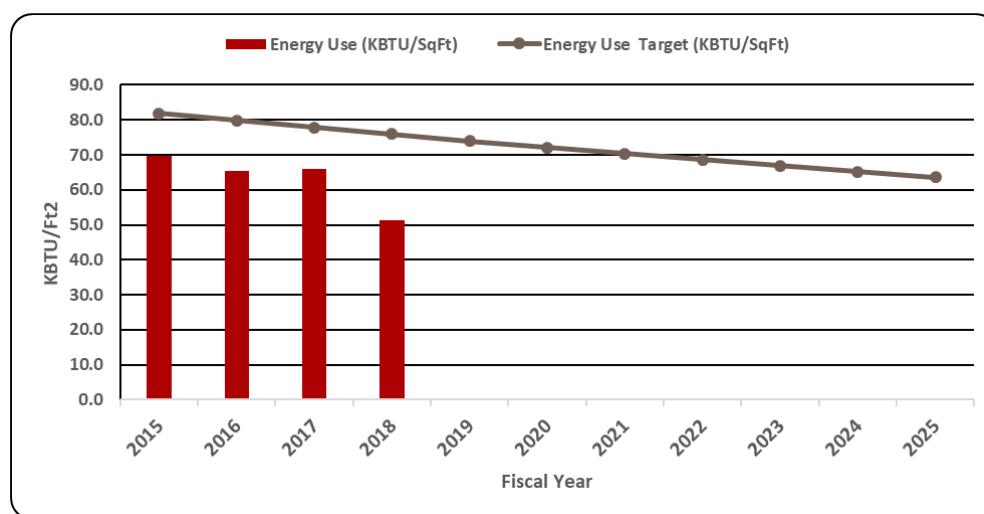


Figure 3-6. Facility Energy Use – FYs 2015-2018 with Target Objectives through 2025.

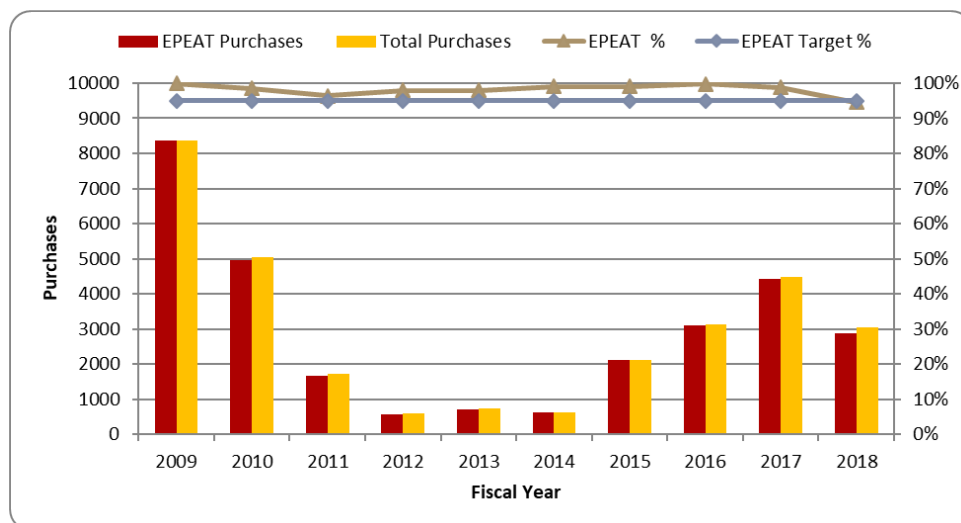


Figure 3-7. Electronic Product Environmental Assessment Tool Standards Compliance.

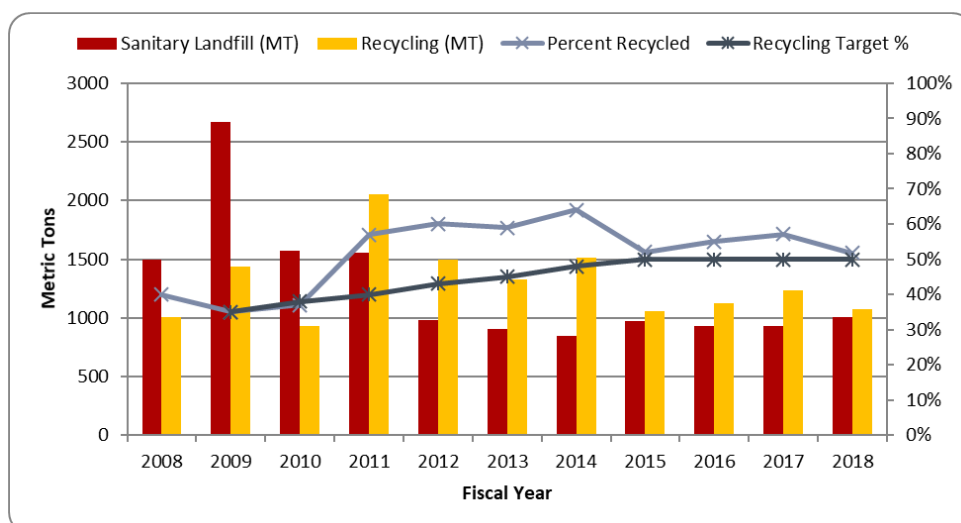


Figure 3-8. Sanitary Waste Reduction.

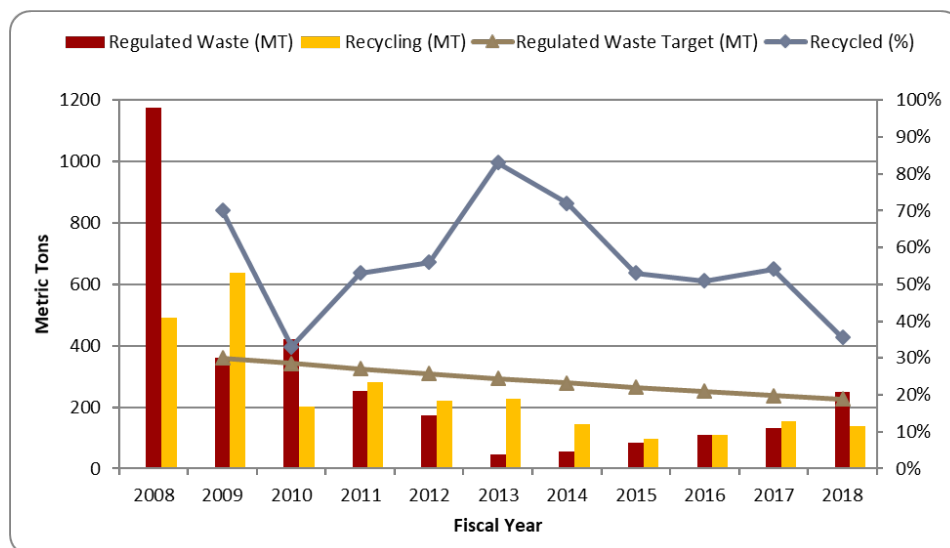


Figure 3-9. Regulated Waste Reduction.

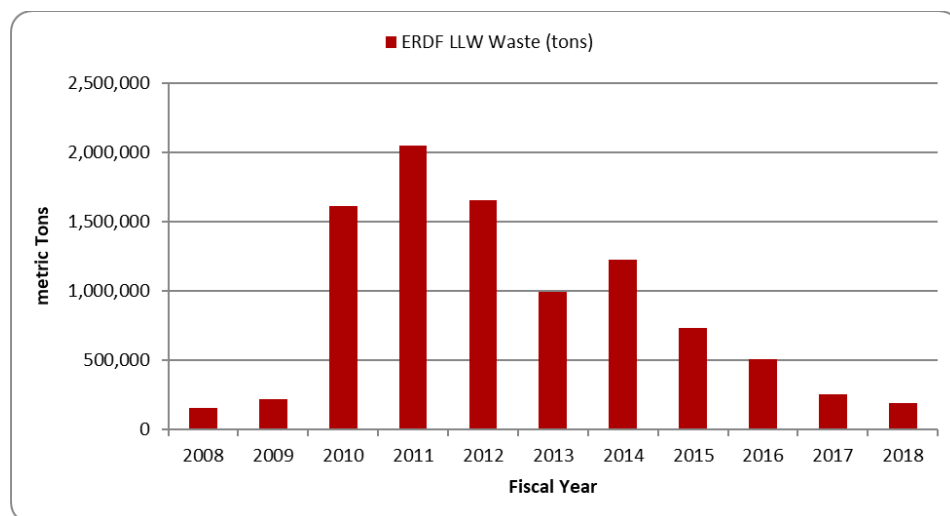


Figure 3-10. Onsite Waste Disposal – FYs 2008–2018 at the Environmental Restoration Disposal Facility.

3.2 Hanford Site Awards and Recognition

Hanford Site contractors strive to achieve awards and recognition for their EMSs. Annual audits provide feedback on system strengths and weaknesses to highlight contractor achievements and provide continual improvement opportunities.

3.2.1 HPMC Occupational Medical Services

HPMC Occupational Medical Services (HPMC-OMS) self-declared conformance to ISO 14001 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. The internal audit completed in December 2018 identified

one minor nonconformity related to training. HPMC-OMS maintained conformance and DOE-RL will conduct the external audit in FY 2019.

3.2.2 CH2M Plateau Remediation Company

CH2M Plateau Remediation Company's (CHPRC) EMS, as described in PRC-MP-EP-40182, *Environmental Management System Manual*, was reviewed for conformance with ISO 14001 in May 2018.

NSF-International Strategic Registrations, Ltd., an American National Standards Institute National Accreditation Board-accredited certification body for the international standard ISO 14001, conducted its full reassessment audit of the CHPRC EMS. Four auditors reviewed CHPRC documents, visited CHPRC Projects, interviewed CHPRC workers to discuss CHPRC implementation of the International Organization for Standardization core elements, and met with CHPRC senior staff members to gauge management commitment. Eight "system strengths" were noted. One minor nonconformity and four opportunities for improvement were issued. The auditors concluded that CHPRC remains compliant with the ISO 14001 standard and recommended certification to the 2015 revision. The FY 2019 external assessment is scheduled for June 2019.

3.2.3 Mission Support Alliance, LLC

MSA completed a surveillance audit in July 2018 to maintain the ISO 14001 registration. There were 11 system strengths, no major nonconformities, 1 minor nonconformity, and 3 opportunities for improvement. Highlights included employee awareness of the environmental policy and environmental aspects, waste stream reduction and recycling efforts, EMS incorporation with ISMS and President's Zero Accident Council (PZAC) meetings, and energy conservation efforts. For the minor nonconformity, a required annual briefing on the Spill Prevention, Control, and Countermeasure (SPCC) Plan was not conducted. Opportunities for improvement included utilizing waste to energy more, measuring environmental performance as rates rather than straight usage, and strengthening environmental requirements and past performance as criteria for subcontractor pre-qualifications. The auditors concluded that MSA remains compliant with the ISO 14001 standard and recommended continued certification to the 2015 revision.

MSA's EMS coordinator also presented the 2018 Environmental Leadership Awards. The awards were established to recognize outstanding environmental performance by employees. The FY 2018 winners were five employees from MSA's Electrical Utilities team for their work recycling transformer carcasses and transformer oil.

3.2.4 Washington River Protection Solutions, LLC

In 2018, Washington River Protection Solutions (WRPS) updated the EMS documentation to reflect the updated ISO 14001 standard and successfully passed both the required documentation and onsite portion of the triennial EMS audit. There were no findings from the audit. The number one best practice was the integration of the EMS with the Integrated Safety Management System (ISMS) and integration with WRPS business practices. WRPS declared conformance to the ISO 14001 standard; the DOE-ORP notified DOE-HQ with a declaration of conformance with the ISO 14001 standard on September 19, 2018.

3.2.5 Veolia Nuclear Solutions Federal Services

During FY 2018, Veolia Nuclear Solutions – Federal Services (VNSFS) contracted with DOE-ORP through the acquisition of Wastren Advantage Inc., Hanford Laboratory. In FY 2018, three assessments were conducted to review implementation of the EMS as described in WHL-MP-1044, "Environmental

Management System Description,” and its conformance with ISO 14001. Four minor findings and no Opportunities for Improvement were identified. VNSFS’s last conformation audit was held in September 2016.

3.3 References

DOE O 436.1. 2011. *Departmental Sustainability*. U.S. Department of Energy, Washington, D.C.

DOE O 450.2. *Integrated Safety Management*. U.S. Department of Energy, Washington, D.C.

Executive Order 13693. March 19, 2015. “Planning for Federal Sustainability in the Next Decade.” *Federal Register*, Office of the President, 80 FR 15871. Online at <https://energy.gov/sites/prod/files/2015/09/f26/EO13693.pdf>.

HNF-54800. 2017. *2018 Hanford Site Sustainability Plan*. Mission Support Alliance. Richland, Washington.

ISO 14001. *Environmental Management Systems*. International Organization for Standardization. Geneva, Switzerland.

PRC-MP-EP-40182. 2019. *Environmental Management System Manual*. Rev. 4. CH2M Hill Plateau Remediation Company, Richland, Washington.

WHL-MP-1044. 2016. *Environmental Management System Description*. Wastren Advantage Inc. Hanford Laboratory, Richland, Washington.

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2018 Highlight

External Monitoring

Overall, the average dose rate levels measured in the operational areas during 2018 were comparable to the previous years' levels. Individual thermoluminescent dosimeter results and detailed maps of monitoring locations are available upon request.

Dose to the Offsite Maximally Exposed Individual

The dose to the offsite maximally exposed individual was 0.28 mrem (2.8 μ Sv)/yr for air emissions releases and releases to Columbia River water combined, which is 0.28% of the 100 mrem/yr U.S. Department of Energy dose standard.

Recreationalist Dose

Wildlife sampling was conducted at the Hanford Site to measure radionuclide tissue concentrations in fish and game animals that could potentially be food sources. A fish ingestion dose of up to 0.43 mrem (4.3 μ Sv)/yr was calculated based on tissue samples of carp and bass. Site-related radionuclides were not detected at levels greater than analytical minimum detectable activities in muscle tissue samples of game animals (elk, mule deer, pheasant, and quail).

Clearance of Property with Potential for Residual Radioactivity

An estimated 36,000 items of personal property were cleared from the Hanford Site during 2018 for unrestricted use by members of the public. These items were considered to have minimal potential for residual radioactivity; they were verified to be free of residual radioactivity and to meet the DOE O 458.1 requirements. The Hanford Site did not release any real property (i.e., land or buildings) in 2018.

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 Hanford Site closure and the likely transfer of property to other entities. Additional information on radiation, dose rates, and dose terminology can be found in Appendices A and B.

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™¹ 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. Reported values include background. 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 2018 at 121 locations on and off the Hanford site. The TLD results were used individually or averaged to determine dose rates in a given area for a specific sampling period (Table 4-1).

Table 4-1. Thermoluminescent Dosimeter Locations and Results (mrem/yr)^a in 2017 and 2018. (2 Pages)

Locations	No. of Dosimeters	2017		2018		% Change ^e
		Maximum ^b	Average ^{c,d}	Maximum ^b	Average ^{c,d}	
100-Areas	5	86	82 ± 7	87	81 ± 10	-1%
100-K	14	196	87 ± 65	205	89 ± 69	2%
200-East	45	180	97 ± 49	178	98 ± 46	1%
200-West	24	212	98 ± 59	208	99 ± 56	1%
200-North (212-R) ^f	1	79	79 ± n/a	80	80 ± n/a	1%
300 Area	8	94	82 ± 11	88	82 ± 6	<1%
300 TDF	6	83	82 ± 3	85	83 ± 3	1%
400 Area	7	91	81 ± 9	90	83 ± 7	2%
CVDF	4	75	74 ± 2	76	75 ± 2	1%
ERDF	3	87	84 ± 5	84	82 ± 3	-1%
IDF ^f	1	88	88 ± n/a	87	87 ± n/a	-1%

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

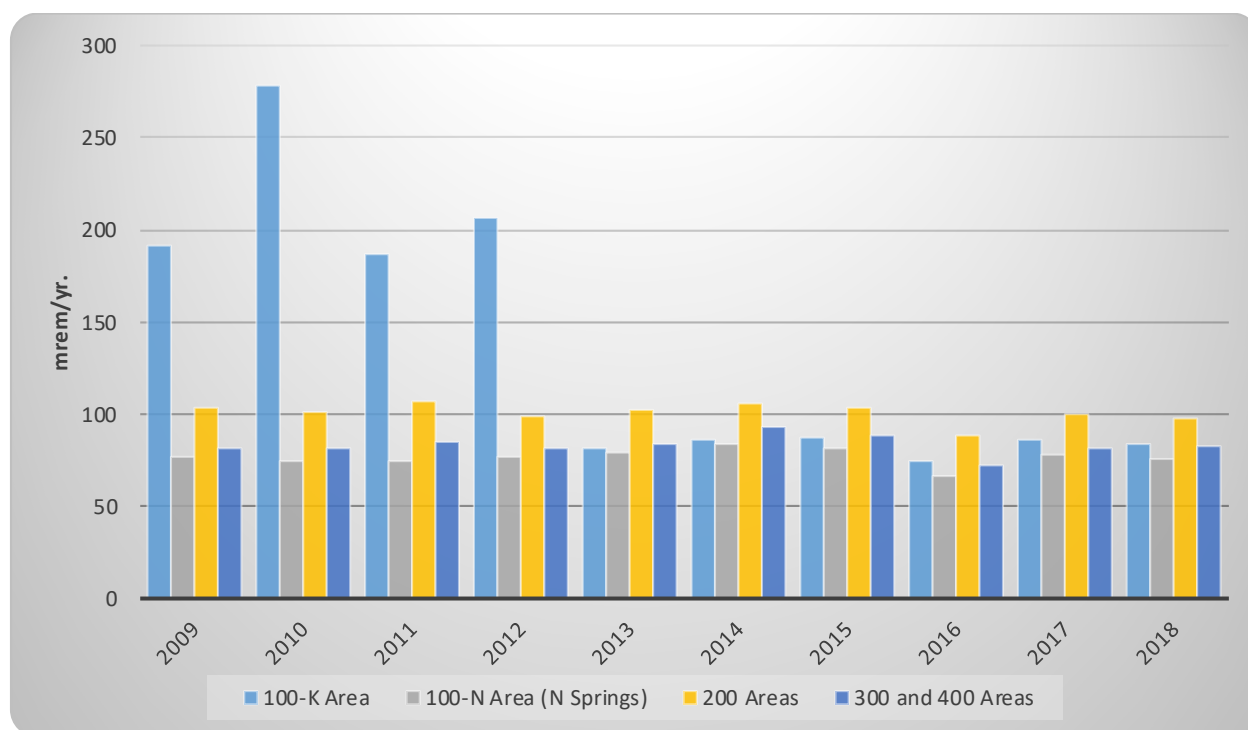
**Table 4-1. Thermoluminescent Dosimeter Locations and Results (mrem/yr)^a
in 2017 and 2018. (2 Pages)**

Locations	No. of Dosimeters	2017		2018		% Change ^e
		Maximum ^b	Average ^{c,d}	Maximum ^b	Average ^{c,d}	
WTP	14	159	94 ± 45	164	95 ± 44	1%
Perimeter (offsite)	3	91	89 ± 3	96	93 ± 4	4%
Reference (offsite)	1	70	70 ± n/a	74	74 ± n/a	5%

^a To convert to international metric system units, multiply mrem/yr by 0.01 to obtain mSv/yr.
^b Maximum values are ± analytical uncertainty.
^c ± 2 standard deviations.
^d Each dosimeter is collected and read quarterly.
^e Numbers indicate a decrease (-) or increase from the 2009 mean.
^f Maximum value represents highest quarterly value ± analytical uncertainty.

CVDF = Cold Vacuum Drying Facility (100 K Area).
ERDF = Environmental Restoration Disposal Facility (200 West Area).
IDF = Integrated Disposal Facility (200 East Area).
TEDF = 300 Area Treated Effluent Disposal Facility.
WTP = Waste Treatment Plant (includes 200-East Area and Perimeter locations previously counted).

The average dose rate levels measured in the operational areas during 2018 were comparable to the previous years' levels (Figure 4-1).



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

4.1.1.1 100-K Area. The 2018 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 the 100-K Area.

4.1.1.2 100 Areas. Dose rates measured along the Columbia River shoreline in the 100-N Area (N Springs) remained low during 2018. Locations established during 2016 along the River Corridor showed typical Hanford background dose rate levels during 2018. A new monitoring location was established during 2018 at the 105-B Reactor site. Dose rate levels measured were at/near typical Hanford Site background levels.

4.1.1.3 200-East Area. Dose rate levels measured during 2018 near the “A” and “C” Tank Farms were higher than other 200-East Area locations.

200-East Area – Plutonium Uranium Extraction Facility (PUREX) Tunnel Monitoring. Continued monitoring in 2018 at locations near the PUREX tunnels showed dose rates at/near typical Hanford background levels.

200-East Area - Waste Treatment Plant Baseline. During 2016, six new TLD monitoring locations were added in support of baseline monitoring for the Waste Treatment Plant: three locations at onsite air sampling locations and three locations at offsite (perimeter) air sampling locations. Data obtained during 2018 showed dose rate levels at each location comparable to typical Hanford Site background levels.

4.1.1.4 200-West Area. Dose rate levels measured during 2018 near the “S” and “T” Tank Farms and at the Solid Waste Operations Complex were higher than other 200-West Area locations.

200-West Area – Plutonium Finishing Plant Demolition. Demolition of the Plutonium Finishing Plant facility continued during 2018. the TLDs nearest the site showed dose rate levels at/near typical Hanford background throughout the year.

4.1.1.5 200-North. Dose rates measured in 2018 were low, and all four quarterly measurements were similar to each other and to recent years.

4.1.1.6 300 Area. Dose rate levels measured during 2018 at all locations in the 300 Area were at/near typical Hanford Site background levels.

4.1.1.7 400 Area. Dose rates measured in 2018 at all seven monitoring locations were low and similar to each other and to recent years.

4.1.1.8 Environmental Restoration Disposal Facility (ERDF). Dose rates measured in 2018 at all three monitoring locations were low and similar to each other and to recent years.

4.1.1.9 Integrated Disposal Facility. Dose rates measured in 2018 were low and all four quarterly measurements were similar to each other and to recent years.

4.1.1.10 Perimeter Locations. Three locations (i.e., Ringold, west end of Fir Road, and Dogwood Met Tower) established in January 2016 showed low dose rate levels in 2018 that were similar to each other and to onsite levels.

4.1.1.11 Reference Locations. A location at the Yakima airport was added during September 2016 to provide a reference (aka background) dose rate level monitoring station. Results obtained during 2018 were approximately 10% less than typical Hanford background dose rate levels.

4.1.2 Waste Disposal Sites Radiological Surveys

JE Cranna and JW Wilde

Radiological surveys are performed at active and inactive waste disposal sites and the surrounding terrain to detect and characterize radioactive surface contamination. Radiation surveys with portable instruments monitor and detect contamination and provide a coarse screening for external radiation fields. The types of areas surveyed include 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 are used to accurately measure the extent of contamination along ERDF haul routes. Routine radiological survey locations include 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 are 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

AG Fleury, R Perona, C Schaupp

Potential radiological doses to the public and biota from Hanford Site operations in 2018 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 2018 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.28 mrem (2.8 μ Sv). This dose is 0.28% of the 100 mrem (1,000 μ Sv)/yr 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 (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.

The offsite MEI dose is one of the following eight radiological impacts of Hanford Site operations that are assessed or summarized in this section:

- Dose to a hypothetical 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 operations 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 (e.g., 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 surface water bodies (Section 4.2.6).

Radiological dose assessments related to environmental releases are ideally based on direct measurements of radionuclide concentrations in specific exposure media; however, amounts of many radioactive materials released to the Columbia River or the atmosphere 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 routine air measurements of tritium at

locations near the 300 Area, radionuclide concentrations may be distinguishable from background levels; these measurements are used to support interpretation of the dose assessment results.

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]), which were 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 applied to dose assessments 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 used 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 permitted discharge of radioactive materials from the 100 or 300 Areas to the Columbia River has occurred since 2011. Radiological doses from the air pathways are calculated based on annual stack emissions measurements from approximately 60 emission points in the four 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 isotopes of uranium were measured in the Columbia River downstream of the Hanford Site (Richland Pump House station, HRM 46.4) in 2018 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 the specific radionuclides measured in 2018 are summarized in Table 6-2. For the GENII Version 2.10.2 (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 and tables of water and air pathway dose calculation inputs 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 2018. This individual's exposure pathways were chosen to maximize the combined doses from all potential 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 population of West Pasco residents obtain their drinking water from the Riverview location via a community water system that draws water from the Columbia River; the domestic drinking water pathway for Columbia River water is, therefore, applied at this location. Residences in the vicinity of Horn Rapids Road receive drinking water from the City of Richland, which has an intake on the Columbia River downstream of the Hanford Site; the domestic drinking water pathway is, therefore, also applied here. Ringold, Riverview, and Horn Rapids Road are locations where Columbia River water is withdrawn for irrigation, and agricultural exposure pathways are applied at these locations.

Dose calculations for 2018 releases indicate that the MEI is located in the vicinity of the Pacific Northwest National Laboratory (PNNL) Laboratory Support Warehouse, an offsite business located at 3475 George Washington Way just to the south of the Hanford Site 300 Area and close to 638 Horn Rapids Road, which is the location used for the MEI receptor air modeling coordinates. 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 grown on soil irrigated with Columbia River water and 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 2.10.2 (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, and other media; and agricultural pathway assumptions for the MEI are provided in Appendix D.

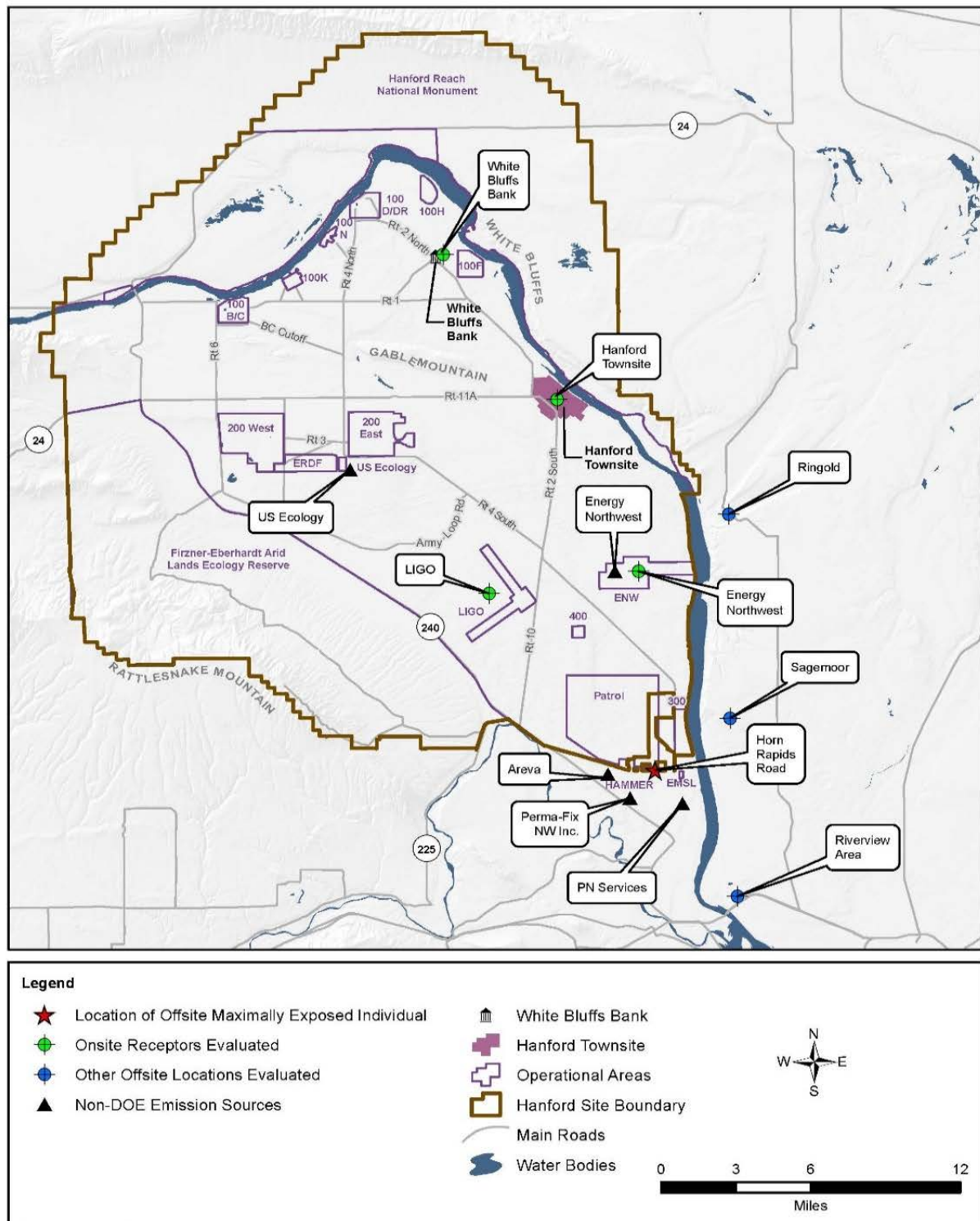


Figure 4-2. Locations Evaluated for Onsite and Offsite Receptors.

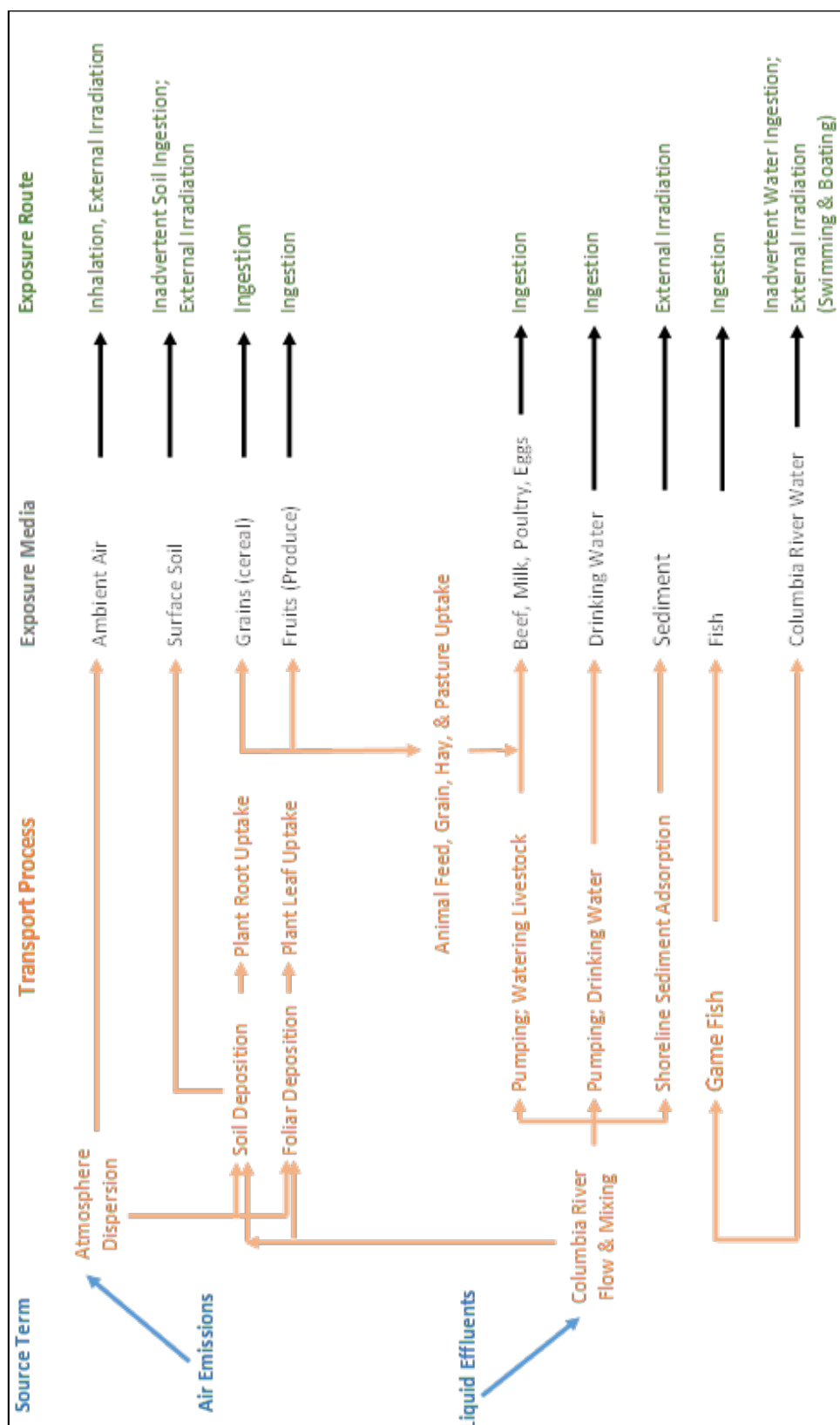


Figure 4-3. Conceptual Site Model of Exposure Pathways Evaluated in Dose Calculations (Horn Rapids Road MEI).

The total dose to the MEI at Horn Rapids Road in 2018 was calculated to be 0.28 mrem (2.8 μ Sv)/yr (Table 4-2; Figure 4-4). This dose is 0.28% of the 100 mrem (1,000 μ Sv)/yr public dose limit specified in DOE O 458.1 and 1.12% 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 sources in the 300 Area contributed 0.20 mrem (2.0 μ Sv)/yr or approximately 71% of the total dose of 0.28 mrem (2.8 μ Sv)/yr. Water pathway sources in the Columbia River contributed 0.071 mrem (0.7 μ Sv)/yr or approximately 25% of the total dose (25%).

The primary radionuclides and exposure pathways contributing to the modeled MEI dose for air emission releases and Columbia River water releases are as follows:

- **Air Releases.** The inhalation exposure pathway in the 300 Area related to radon isotopes and their radioactive progeny accounted for 55% of the total air pathways dose of 0.20 mrem (2.0 μ Sv)/yr. Consumption of food products containing tritium released from the 300 Area contributed approximately 38% of the total air pathways dose.
- **Water Releases.** Consumption of fish from the Columbia River contributed approximately 55% of the total water pathways dose of 0.071 mrem (0.71 μ Sv)/yr, food grown using Columbia River water withdrawn downstream from the Hanford Site contributed approximately 31%, and drinking water ingestion contributed the remaining 14%. Uranium isotopes and their radioactive progeny contributed virtually 100% of the water-pathways dose. Potassium-40 was detected in both upstream and downstream water samples, however, it is a naturally occurring radionuclide and is not associated with releases from the reactors or any groundwater plumes entering the Columbia River. Therefore, to avoid masking of dose associated with potential Hanford Site releases, potassium-40 is not included in the MEI dose assessment. A sampling instrument failure may have affected identification of Hanford Site-related contaminants in Columbia River samples, as discussed in Section 4.2.1.1.

4.2.1.1 MEI Dose Discussion. The 2018 MEI dose of 0.28 mrem (2.8 μ Sv)/yr is larger than the 0.22 mrem (2.2 μ Sv)/yr 2017 MEI dose (DOE/RL-2018-32), and more than double the 0.12 mrem (1.2 μ Sv)/yr MEI dose calculated for 2016 (DOE/RL-2017-24). The difference between the 2018 and 2017 dose estimates is mostly attributable to higher concentrations of uranium isotopes at the downstream Richland Pumphouse sampling location on the Columbia River in 2018, which may in part be attributable to the impact of the failed continuous water sampler in 2017, discussed below. Differences between the 2018 and 2016 MEI dose results are primarily attributable to higher inhalation doses in 2018 from radon isotopes.

In August 2017 the Richland Pumphouse sampling station continuous water sampler failed and a new continuous sampler was not put online until July 2018. Water samples for the period of January through June 2018 were instead collected as single 0.5-gal (2-L) grab samples. The continuous sampler collected 55-mL water samples at 1-hr intervals, which were composited bimonthly and then combined for a single monthly composite (DOE/RL-2018-32; Section 7.2.1).

There are several reasons why continuous samples are preferable in principle to grab samples for characterizing average river water concentrations. Water levels vary during the day due to impoundment and releases for power generation and other purposes. Having water samples collected each hour provides representation of this daily cycle, and collecting many sample increments over the

course of each month better captures seasonal changes in flow. Contaminant discharges along the Hanford Reach will be more or less diluted depending on river flow and elevation. For example, grab samples collected at a time of day with higher Hanford Reach river elevation could inadvertently create a low result in the measured downstream concentrations. For these reasons, there is a higher degree of uncertainty in the representativeness of the 2018 Richland Pumphouse sampling station water data than would be the case if all samples had been acquired with the continuous sampler. In the 2017 water data, the substitution of grab samples during the later summer and fall sampling events when downstream water concentrations are often highest due to lower flow may have contributed to uranium isotopes not being identified as Hanford Site-related contaminants in that year.

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	1.5E-06	1.9E-04	7.90E-02	9.1E-07	0.079
	Inhalation	1.1E-05	8.0E-06	1.19E-01	2.2E-06	0.12
	External, Soil Ingestion	2.0E-08	1.3E-07	5.98E-03	1.7E-08	0.006
	Subtotal Air	1.3E-05	2.0E-04	2.04E-01	3.1E-06	0.20
Water	Irrigation (food and soil ingestion; external)	NA ^{b, d}	0.022 ^c	NA ^d	NA ^d	0.022
	Drinking Water Ingestion	NA ^{b, d}	0.010 ^c	NA ^d	NA ^d	0.010
	Recreation (river water, sediments; external, ingestion)	NA ^{b, d}	2.3E-04 ^c	NA ^d	NA ^d	2.3E-04
	Fish Ingestion	NA ^{b, d}	0.039 ^c	NA ^d	NA ^d	0.039
	Subtotal Water	NA ^d	0.071	NA ^d	NA ^d	0.071
Air + Water Total		1.3E-05	0.071	0.20	3.1E-06	0.28
^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. ^d All liquid discharges reflected in the difference between upstream and downstream radionuclide concentrations are assigned to the 200 Areas. NA = Not applicable. NPDES = National Pollutant Discharge Elimination System						

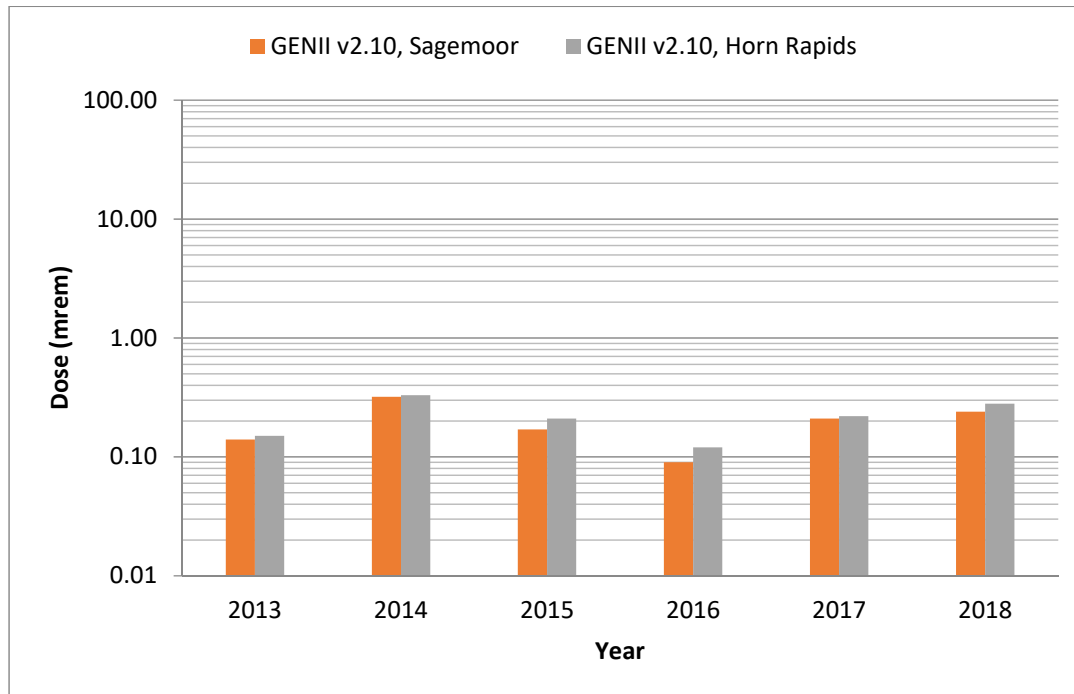


Figure 4-4. Total Dose for the Hypothetical MEI Over Time.

The MEI dose estimate incorporates a number of conservative assumptions to ensure that pathway doses are protective; 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 Site 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 in 2018 from all stacks are a small fraction (23% and 15%, 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 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. 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 (e.g., carp and bass).

Because tritium is measured in air samples from air monitoring station samples, and releases of tritium from the 300 Area are a significant 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 measured concentrations. Figure 4-5 shows the 2018 modeled annual average air concentrations of tritiated water vapor (HTO) at the Horn Rapids Road MEI location and 2018 annual averages based on measured values at locations near 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 in Figure 4-5 in addition to the annual average.

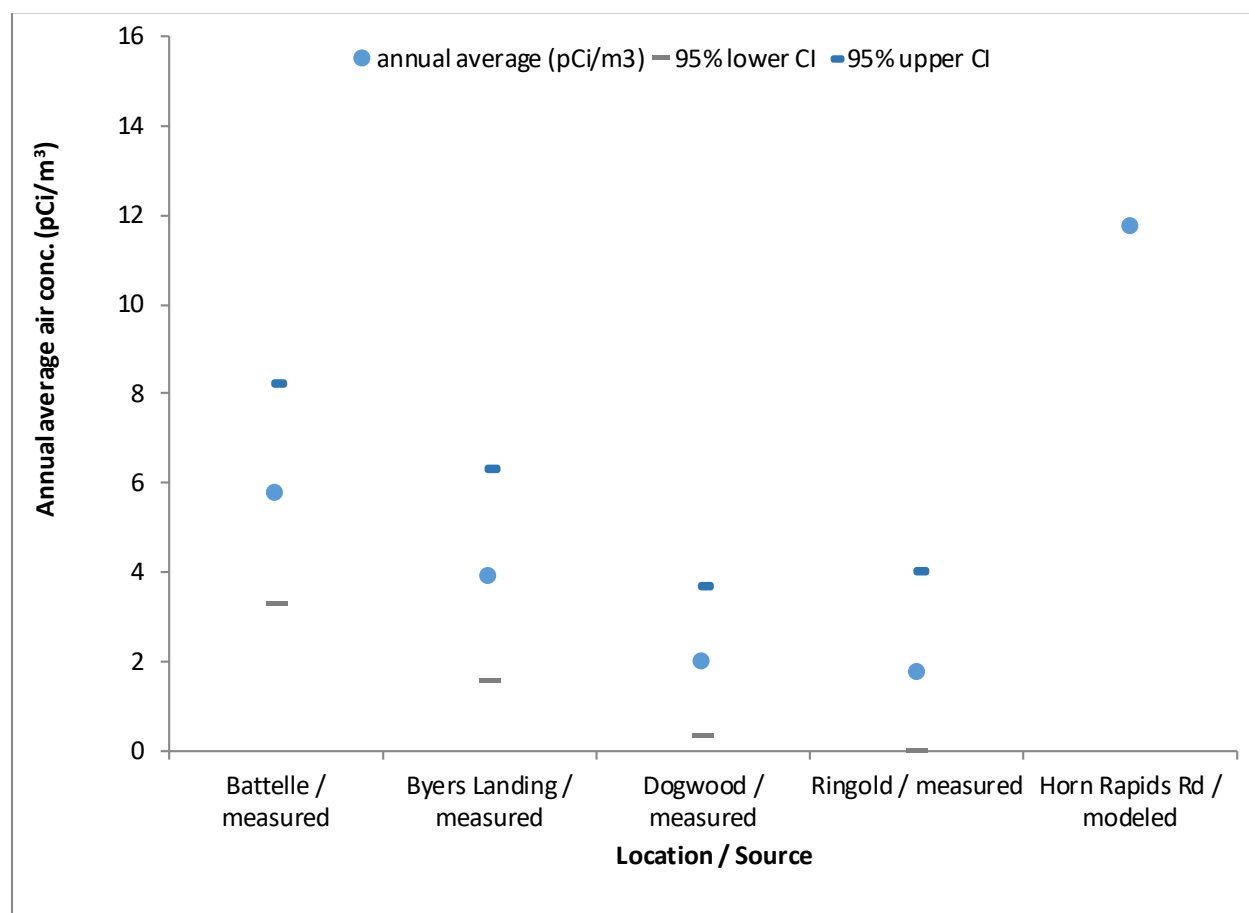


Figure 4-5. Comparison of Measured and Modeled Tritium Air Concentrations Near the 300 Area.

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 all four locations. The modeled MEI tritium air concentration is nearly double the largest measured annual-average tritium concentration, which was measured at the Battelle Complex air station, and about 1.5 times larger than the 95% upper confidence interval of the average at the Battelle Complex. That the modeled air concentration is outside the confidence intervals of measured annual-average concentrations reflects both a relatively large annual stack emission of tritium from the 300 Area (about 335 curies of tritiated water vapor and elemental hydrogen combined) and possibly relatively low natural background levels of atmospheric tritium in 2018. 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.

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. Also, 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).

Samples of locally raised foodstuffs were collected in 2018 from four locations including the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. Sampled foodstuffs included fruits (apples, melons, and tomatoes), leafy vegetables, potatoes, corn, milk, and wine. With the exception of strontium-90 analyses for wine, gamma-emitting radionuclides and strontium-90 were analyzed in all foodstuffs, and tritium was analyzed in tomatoes, wine, and milk. Additionally, carbon-14 was analyzed in all foodstuffs. Reported results for the Hanford-related radionuclides carbon-14, strontium-90, 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 strontium-90 are related to air emissions. Modeled concentrations of tritium are also related to irrigation with Columbia River water. The following observations are drawn from the comparisons:

- Carbon-14 was not detected in any of the 24 crop samples collected from the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. The minimum detectable activities for these samples ranged from approximately 2.6 to 6.4 pCi/g. The modeled carbon-14 concentrations in crops grown at the MEI location of Horn Rapids Road are far below these activities, with a highest value of 0.00001 pCi/g, corresponding to a calculated annual dose of 1E-06 mrem (0.00001 μ Sv)/yr. Carbon-14 was detected in one of the nine milk samples collected from the East Wahluke area with a value of 263 pCi/L. The eight non-detect activities for milk ranged from -1,320 to 101 pCi/L. The modeled carbon-14 concentration in milk at the MEI location of Horn Rapids Road was far below these activities, with a highest value of 0.0022 pCi/L corresponding to a calculated annual dose of 2.2E-04 mrem (0.0022 μ Sv)/yr.
- Strontium-90 was analyzed in 24 crop samples and detected in 2 leafy vegetable samples (0.00562 pCi/g and 0.00418 pCi/g) from the East Wahluke area and 1 leafy vegetable sample (0.00613 pCi/g) from the Riverview area. Strontium-90 was not elevated in downstream Columbia River water samples in 2018 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. The measured concentrations in these samples 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*). Strontium-90 was not detected in any of the nine milk samples collected from the Sagemoor and East Wahluke areas. The minimum detectable activities for these samples ranged from approximately -1.32 to 1.32 pCi/L. For comparison, modeled concentrations of strontium-90 in milk and crops grown at Horn Rapids Road are hundreds of thousands of times below these ambient levels.
- Tritium was analyzed in samples of tomatoes from the Sunnyside and Riverview areas but was not detected at either location with a minimum detectable activity of approximately 0.12 pCi/g. Tritium was detected in samples of milk at average concentrations of approximately 16 pCi/L (Sagemoor)

and 24 pCi/L (East Wahluke). These concentrations are about 20 times below the modeled worst-case tritium concentration in milk for cows grazing at the MEI location of Horn Rapids Road (approximately 500 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 2018 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). 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 2.10.2 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 2018 was 2.5 person-rem (0.025 person-Sv)/yr (Table 4-3), which is the largest collective dose calculated in the past several years (Figure 4-6). Air pathway contributions from releases in the 300 Area contributed effectively 50% of the population dose, with water pathway releases contributing the other 50% of the population dose in 2018.

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

- **Air Releases.** Inhalation exposure contributed approximately 60% of the of the air pathways collective dose of 1.3 person-rem (0.013 person-Sv). The remaining air pathways collective dose is primarily related to consumption of food products grown downwind of the 300 Area. About 53% of the air pathways doses are due to inhalation of the radioactive progeny of radon-220 released from the 300 Area. Approximately another 46% of the total air pathways collective dose is associated with releases of tritium 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 92% of the total water pathways collective dose of 1.2 person-rem (0.012 person-Sv). Uranium isotopes and their progeny contributed 92% of the water

pathways dose. Tritium was the only other contaminant identified in Columbia River samples in 2018 and contributed the remaining 8% of the water-pathways dose.

The collective dose in 2018 of 2.5 person-rem (0.025 person-Sv) is the largest collective dose calculated in the past several years (Figure 4-6). This could be attributable to the fact that in 2018 the air and water pathway calculations were based on relatively large estimated releases of radon and uranium isotopes, respectively. The air dispersion patterns in 2018 could also have contributed to the relatively large collective dose result. There is no specific collective dose metric analogous to the 100 mrem (1,000 mSv)/yr 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	2.58E-04	9.44E-03	5.14E-01	3.62E-05	0.52
	Inhalation	3.86E-03	1.25E-03	7.82E-01	1.31E-04	0.79
	External, Soil Ingestion	4.09E-06	1.09E-05	1.45E-02	6.08E-07	0.015
	<i>Subtotal Air</i>	<i>4.12E-03</i>	<i>1.07E-02</i>	<i>1.31E+00</i>	<i>1.68E-04</i>	<i>1.3</i>
Water	Irrigation (food and soil ingestion; external)	NA ^{b, d}	0.023 ^c	NA ^d	NA ^d	0.023
	Drinking Water Ingestion	NA ^{b, d}	1.1 ^c	NA ^d	NA ^d	1.1
	Recreation (river water, sediments; external, ingestion)	NA ^{b, d}	0.0019 ^c	NA ^d	NA ^d	0.0019
	Fish Ingestion	NA ^{b, d}	0.014 ^c	NA ^d	NA ^d	0.015
	<i>Subtotal Water</i>	<i>NA^d</i>	<i>1.2</i>	<i>NA^d</i>	<i>NA^d</i>	<i>1.2</i>
Air + Water Total		0.0041	1.2	1.3	1.7E-04	2.5

^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.
^d All liquid discharges reflected in difference between up- and downstream radionuclide concentrations assigned to 200 Areas.
 NA = not applicable
 NPDES = National Pollutant Discharge Elimination System

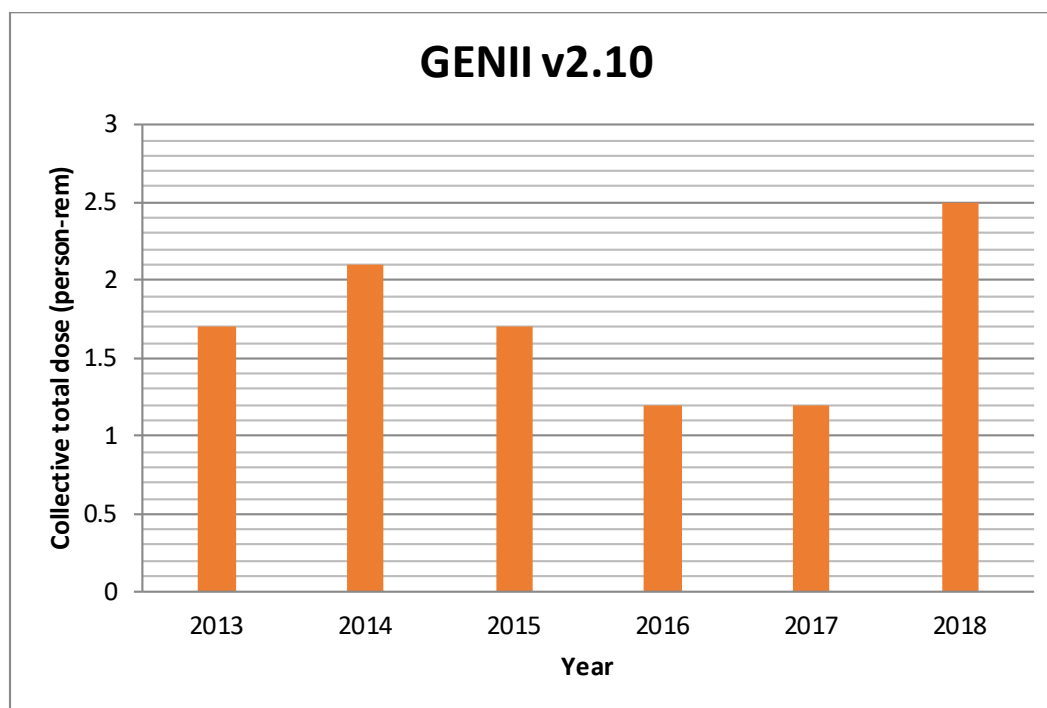


Figure 4-6. Collective Total Dose within a 50-mi (80-km) Radius.

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 (such as the Clean Air Act Assessment Package 1988-Personal Computer program, CAP-88-PC v4.0 [EPA 2013]) 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 calculation of offsite dose for the *Clean Air Act* based solely on an airborne radionuclide emissions pathway.

The assumptions embodied in the CAP88-PC v4.0 computer code differ slightly from the 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 DOE O 458.1 all-pathways MEI if dose from the water pathways is significant (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 40 CFR 61, Subpart H, modeling of dose from 2018 air emissions at the Hanford Site, refer to DOE's report to EPA (DOE/RL-2019-09).

4.2.3.1 Dose from Stack Emissions to an Offsite Maximally Exposed Individual. Using CAP88PC, the offsite MEI for air pathways in 2018 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 evaluated with GENII (Figure 4-2). The potential air pathway dose from stack emissions to an MEI at that location calculated using the CAP88PC computer code was determined to be 0.058 mrem (0.58 μ Sv)/yr, less than 1% of the EPA standard of 10 mrem (100 μ Sv)/yr. The CAP88PC result is approximately one-fifth of the all-pathways dose of 0.28 mrem (2.8 μ Sv) calculated with GENII (Table 4-2).

Dose related to radon-222 and 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 885 curies of radon-220 was calculated from engineering estimates for stack emissions from the 325 Building in the 300 Area. No radon-222 operational releases were reported in 2018. A radon-220 dose of 0.14 mrem (1.4 μ Sv)/yr was calculated using the CAP88PC computer code for the Laboratory Supply Warehouse MEI, far below the WAC 246-247 standard. The sum of MEI dose for radon-220 (0.14 mrem), radon-222 (0 mrem), and dose calculated for compliance with 40 CFR 61, Subpart H using the CAP88PC computer code (0.058 mrem [0.58 μ Sv]/yr) is approximately 0.20 mrem (2.0 μ Sv), which is the same as the Horn Rapids Road air pathways MEI dose of 0.20 mrem (2.0 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-2019-09). Modeled contributions from monitored stack emissions and contributions from background levels of radionuclides are subtracted from perimeter ambient air concentrations measured for each radionuclide. 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, the MEI location determined from Hanford Site stack emissions, was also used for reporting dose from diffuse and fugitive emissions (DOE/RL-2019-09). The estimated dose from diffuse emissions to this MEI was calculated using the CAP88PC computer code to be 0.019 mrem (0.19 μ Sv)/yr. Therefore, the potential combined dose from stack emissions, radon-220 and radon-222 emissions, and diffuse emissions during 2018 at the Laboratory Supply Warehouse location was 0.22 mrem (2.2 μ Sv)/yr, far below the 10 mrem (100 μ Sv)/yr 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 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 2018 EPA air emissions report (DOE/RL-2019-09) as possible MEI locations. Included in these locations were the Columbia Generating Station operated by Energy Northwest and the 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 CAP88PC computer code assuming full-time occupancy because Washington State Department of Health 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 (0.067 mrem [0.67 μ Sv]) was at LIGO. The total dose attributable to 2018 stack emissions, fugitive source emissions, and radon-220 and radon-222 at LIGO was calculated using CAP88PC to be 0.082 mrem (0.82 μ Sv) (DOE/RL-2019-09). Even assuming that a LIGO employee is continuously present, the estimated total dose to non-DOE onsite workers in 2018 was lower than the 0.22 mrem (2.2 μ Sv)/yr total dose calculated with CAP88PC 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 2018 sediment data indicates that concentrations of key radionuclides frequently detected in sediment (including cesium-137, plutonium-239/240, and uranium isotopes) have approximately equal or larger concentrations in upstream (Priest Rapids Dam) samples in comparison to samples from downstream (McNary Dam) locations and samples at slough locations along the Hanford Site near White Bluff and the Hanford Townsite. The 2018 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.

Gamma-emitting radionuclides were analyzed in muscle tissue samples collected in 2018 from mule deer, pheasant, quail, and elk. In addition to muscle tissue, samples of bone tissue were obtained from these animals and analyzed for strontium-90, a radionuclide that accumulates in bone. For estimating dose from ingestion of game meat, radionuclide concentrations in muscle tissue are most applicable. However, the only radionuclide detected in the muscle tissue of any animal was potassium-40, a naturally occurring primordial radioisotope that is not of Hanford Site origin. Because site-related radionuclides were not detected at levels greater than analytical minimum detectable activities, calculations of dose related to ingestion of game meat were not performed.

Fillet tissue and carcass samples were obtained from bass and carp in two river sections of the Hanford Reach and reference locations in 2018. 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 and dose calculations were performed for these analytes.

Uranium-234 was detected in two carp fillet samples from the 100 Area. Uranium-235 was detected in two carp fillet samples and one bass fillet sample from the 100 Area. Uranium-235 was also detected in one bass fillet in the 300 Area. Uranium-238 was detected in three carp fillet samples from the 100 Area. Only carp fillet samples were captured in the upstream reference area. All fillet samples in the reference area were non-detects; the maximum non-detect for uranium-234 was 0.021 pCi/g, for uranium-235 was 0.0109 pCi/g, and for uranium-238 was 0.00521 pCi/g. The carp fillet uranium-234 maximum concentrations measured in the 100 Area (0.0228 pCi/g and 0.0199 pCi/g) were larger and essentially identical to the maximum non-detect for uranium-234 in the reference area. The carp fillet uranium-234 maximum concentrations measured in the 100 Area (0.0193 pCi/g and 0.0112 pCi/g) were both larger than the maximum non-detect for uranium-234 in the reference area. The carp fillet uranium-235 maximum concentrations measured in the 100 Area (0.016, 0.017, and 0.02 pCi/g) are all larger than the maximum non-detect for uranium-235 in the reference area. These uranium-234, uranium-235, and uranium-238 results for carp fillets in 2018 are larger than the values measured in carp fillets in the reference and 100 Areas in 2016 (0.00189 to 0.00315 pCi/g).

The uranium-235 results for bass fillets in 2018 (0.0999 and 0.104 pCi/g) are similar to the values measured in bass fillets in the reference and 100 Areas in 2016 (0.003 to 0.0111 pCi/g), which is the last year when bass fillets were acquired in the 100 and reference Areas. In 2018, it is possible the data indicated that uranium isotope concentrations are higher in carp fillets from fish collected in the 100 or 300 Areas than in reference area fish; however, detected data in the reference area are not available for comparison. Nevertheless, potential radiation dose received from consumption of fish fillets with

isotopic uranium concentrations measured in 2018 was calculated to provide a measure of the significance of these levels.

The potential radiation dose received from consumption of fish fillets with the largest isotopic uranium concentrations measured in 2018 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 fish with tissue concentrations of 0.0228 pCi/g of uranium-234, 0.0193 pCi/g of uranium-235, and 0.02 pCi/g of uranium-238 is estimated to be 0.431 mrem (4.31 μ Sv). The annual dose estimate for fish ingestion was derived using 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:

$$((0.0228 \text{ pCi uranium-234/g} \times 1.8 \times 10^{-4} \text{ mrem/pCi}) + (0.0193 \text{ pCi uranium-235/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi}) + (0.02 \text{ pCi uranium-238/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi})) \times 40 \text{ kg/yr} \times 1,000 \text{ g/kg} = 0.431 \text{ mrem (4.31 } \mu\text{Sv)/yr}$$

4.2.4.2 Hanford Site Drinking Water Dose. Drinking water was sampled and analyzed for tritium, gross alpha radiation, and gross beta radiation during 2018 in accordance with applicable regulations (40 CFR 141); water samples were collected from the 100-K Area, 200-West Area, and two sources in the 400 Area (primary well P-14 and emergency backup well P-15). 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, an isotope of hydrogen with 2 neutrons, is a man-made beta radiation emitter; there are also naturally occurring beta emitters found in groundwater 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. Drinking water concentrations for tritium range from 4,450 to 5,110 pCi/L, and for gross beta from only 0 to 12 pCi/L.

Tritium was measured in four quarterly samples from backup well P-15 in the 400 Area. Tritium was detected in all four drinking water samples collected from the backup drinking water sources for the 400 Area (well P-15), and was not analyzed in samples from primary well P-14 in the 400 Area or in samples from 100-K and 200-West areas. Based on the average of the four 400 Area samples, the annual average 400 Area drinking water tritium concentration was 4695 pCi/L (173 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 2018 would be approximately 0.079 mrem (0.79 μ Sv). This estimate is 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 400 Area drinking water sources 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:

$$4695 \text{ pCi tritium/L} \times 1 \text{ L/day} \times 250 \text{ d/year} \times 6.7 \times 10^{-8} \text{ mrem/pCi} = 0.079 \text{ mrem (0.79 } \mu\text{Sv)/yr}$$

4.2.4.3 Manhattan Project National Historical Park Visitor Dose. The Manhattan Project National Historical Park at the Hanford Site 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 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 2.10.2 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 (24 hrs/day, 365 days per year) 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 (2018).

Release Type	Exposure Pathway	Location	Dose Contributions from Operational Areas, mrem ^a		
			100 Area	200 Areas	Pathway Total
Air	Inhalation	Hanford Townsite	1.4E-04	1.5E-05	1.6E-04
		White Bluffs Bank	3.5E-04	1.2E-05	3.6E-04

^a To convert mrem to International System dose units (μSv), 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 annual dose of 0.20 mrem (2.0 μSv; 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 2018 because the MEI dose of 0.28 mrem (2.8 μSv)/yr from DOE-related sources (Section 4.2.1) was far below the threshold of 25 mrem (250 μSv)/yr at which the contribution of non-DOE sources must be included. DOE O 458.1 paragraph 4.e(1)(c) states::

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

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])/day (DOE-STD-1153-2019). 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, DOE-STD-1153-2019 provides a dose limit for terrestrial plants of 1 rad (10 milligray [mGy])/day and 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) to compare radionuclide concentrations measured by routine monitoring programs to a set of biota concentration guides (BCG).

Biota concentration guides are the soil, water, or sediment concentrations of a radionuclide that would result in a 1 rad (10 mGy)/day dose for aquatic biota or terrestrial plants, or 0.1 rad (1 mGy)/day dose 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 2018 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, cesium-137, plutonium-238, plutonium-239/240, strontium-90, technetium-99, tritium, uranium-234, uranium-235, uranium-236, and uranium-238. RESRAD-BIOTA v1.8 lacks uranium-236 BCGs for estimating radiological dose. As a result, uranium-236 values were added to uranium-235 values due to similar radiological decay emissions between the isotopes and assessed using the uranium-235 BCG from RESRAD-BIOTA v1.8. 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 generally 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 (i.e., upstream, 100 Area, Hanford Townsite, 300 Area, and

downstream) and the maximum measured concentrations in these locations were evaluated. 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 showed the concentrations in all Columbia River sediment and water samples passed the Tier 1 screen and indicated 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 strontium-90 (55%) and carbon-14 (41%); dose in the 300 Area is basically entirely associated with uranium isotopes. Biota doses upstream of 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 a location of planned supplemental characterization (DOE/RL-2009-121). 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 evaluated at West Lake on a less regular schedule. Both sediment and water samples were collected in 2018 and data are tabulated in Appendix C, Tables C-1, C-2.

The results of the 2018 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 six water and seven 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. The variability in the sum of fractions may be due to the water in the pool drying up in non-winter seasons, thus, increasing water concentrations in those seasons.

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. Hanford Site-specific data from West Lake are indicative of 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; DOE/RL-2007-50). Brine flies are the most relevant organisms as they are continually present during the period of time when West Lake contains water (late fall, winter, spring, and early summer), therefore, they have a higher potential for bioaccumulation at West Lake compared to birds (avocets), which are not continually present during the period of time when West Lake contains water. 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.

Table 4-5. Estimated Sum of Fractions 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 (2018)
		2016	2017	2018	
Upstream	Sediment, Water	0.018	0.018	0.015	Pass
100 Area	Sediment, Water	0.71	0.46	0.53	Pass
Hanford Townsite	Sediment, Water	0.014	0.014	0.013	Pass
300 Area	Sediment, Water	0.25	0.27	0.17	Pass
Downstream	Sediment, Water	0.015	0.016	0.014	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 Sum of Fractions to Biota Associated with West Lake^a.

Tier	Exposure Assumptions	Sum of Fractions ^b			Pass or Fail (2018)
		2016	2017	2018	
1	Maximum Sediment, Water Concentration and Default Bioaccumulation	120	6.3	5.2	Fail
2	Average Sediment, Water Concentration and Default Bioaccumulation	41	4.3	3.8	Fail
3	Average Sediment, Water Concentration and Site-specific Bioaccumulation	0.49	0.095	0.11	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 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 2017; however, the 2018 doses were about 3 times less than those calculated for 2016 (Table 4-6). The reason for the change is that the maximum isotopic uranium concentrations in West Lake pond water samples varied quite widely from year to year 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: 2016 (uranium-234 at 10,700 pCi/L, uranium-235 at 43.5 pCi/L, uranium-238 at 13,700 pCi/L), 2017 (uranium-234 at 658 pCi/L, uranium-235 at 34.7 pCi/L, uranium-238 at 623 pCi/L), and 2018 (uranium-234 at 546 pCi/L, uranium-235 at 27.6 pCi/L, uranium-238 at 500 pCi/L). The maximum concentrations measured in 2018 were

approximately 20 to 30 times less than those measured in 2016. 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 was used to evaluate potential effects on biota using the maximum concentrations of radionuclides measured in onsite 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, uranium-238, and americium-241. The results of 2018 screening calculations listed in Table 4-7 show the onsite soil concentrations passed the Tier 1 screen based on the maximum concentration. Nearly the entire estimated 2018 dose for onsite locations results from cesium-137 (89.5%) and strontium-90 (10.3%). See PNNL-20577 for a long-term trend analysis of soil concentrations and associated biota doses on and off the Hanford Site.

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

Location	Tier 1 Screen Sum of Fractions ^b			Pass or Fail (2018)
	2016	2017	2018	
Onsite	0.57	0.86	0.95	Pass
Offsite	Not measured ^c	Not measured ^c	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 Offsite soil samples are collected approximately every 3 to 5 years and are planned for collection in 2019.

In addition to the dose assessments related to soils, sediments, and water, there are also fish and wildlife tissue samples collected from the Hanford Site and reference locations. Although none of the biota dose assessments (except for West Lake) required any additional tiers of analysis, supplemental calculations using these tissue samples were made to characterize more realistic doses based on measured concentrations. Dose to aquatic animals based on the maximum concentrations of uranium-234 (0.0228 pCi/g), uranium-235 (0.0193 pCi/g), and uranium-238 (0.02 pCi/g) in fish was 0.0003 rad/day. Internal dose to terrestrial plants based on the maximum concentrations of plutonium-238 (0.0446 pCi/g), plutonium-239/240 (0.626 pCi/g), strontium-90 (1.76 pCi/g), uranium-234 (0.0176 pCi/g), uranium-235 (0.0228 pCi/g), and uranium-238 (0.0304 pCi/g) in plants was 0.0006 rad/day. Dose to terrestrial animals based on the maximum concentrations of plutonium-238 (0.0152 pCi/g) and strontium-90 (0.0853 pCi/g) in mule deer liver was 0.00009 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 hypothetical annual dose for the MEI in 2018 was 0.28 mrem (2.8 μ Sv; Section 4.2.1). The annual dose for an average individual from Hanford Site operations in 2018, 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 0.0095 mrem (0.095 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)/yr. 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 2018 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 70 times larger than the 2018 Hanford Operations dose to the MEI receptor (0.28 mrem [2.8 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). 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 μ 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 μ 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.

The hypothetical annual dose from 2018 Hanford Operations for the MEI in 2018 was 0.28 mrem (2.8 μ Sv [Section 4.2.1]) and 0.0095 mrem (0.095 μ Sv) for an average individual. The dose to the MEI calculated in 2018 from Hanford Site operations was 0.28 mrem (2.8 μ Sv), which is 0.28% of the 100 mrem (1,000 μ Sv) annual public dose limit specified in DOE O 458.1. Furthermore, the calculated radiological doses from Hanford Site operations in 2018 were a small percentage of the national average annual doses from natural background sources (Figure 4-8). For example, the national annual average radiation dose from natural terrestrial sources (approximately 19 mrem [190 μ Sv]) is approximately 70 times larger than the 2018 Hanford Operations dose to the MEI receptor (0.28 mrem [2.8 μ Sv]) and 2,000 times larger than the 2018 Hanford Operations dose to the average individual (0.0095 mrem [0.095 μ Sv]). Thus, the dose to the MEI receptor from 2018 Hanford Site Operations is very small compared to natural background sources and the acceptable public dose limit.

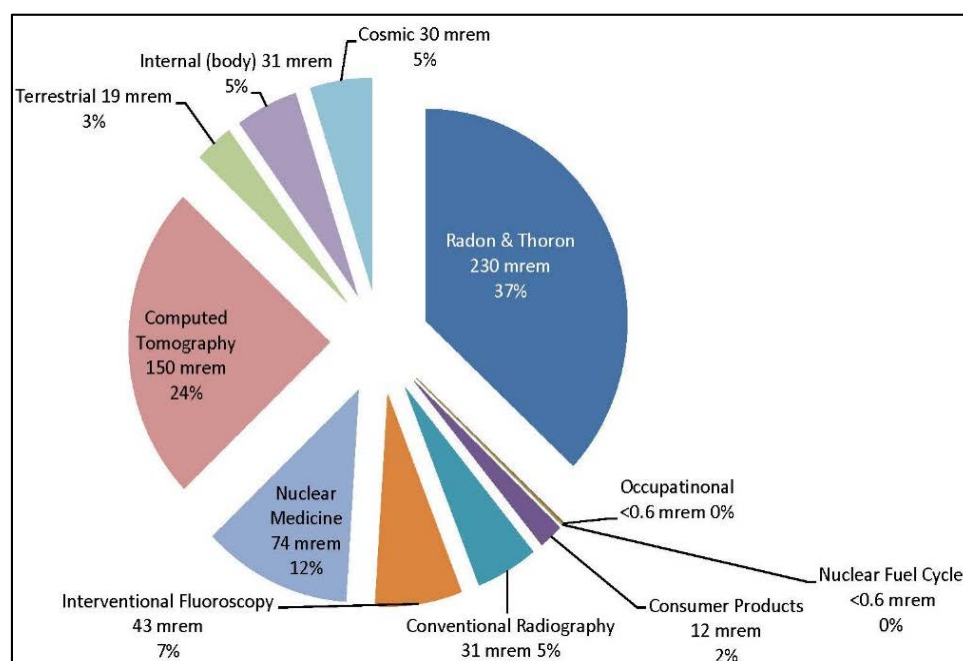


Figure 4-7. U.S. Annual Average Radiological Doses from Various Sources (2009 National Council on Radiation Protection and Measurements).

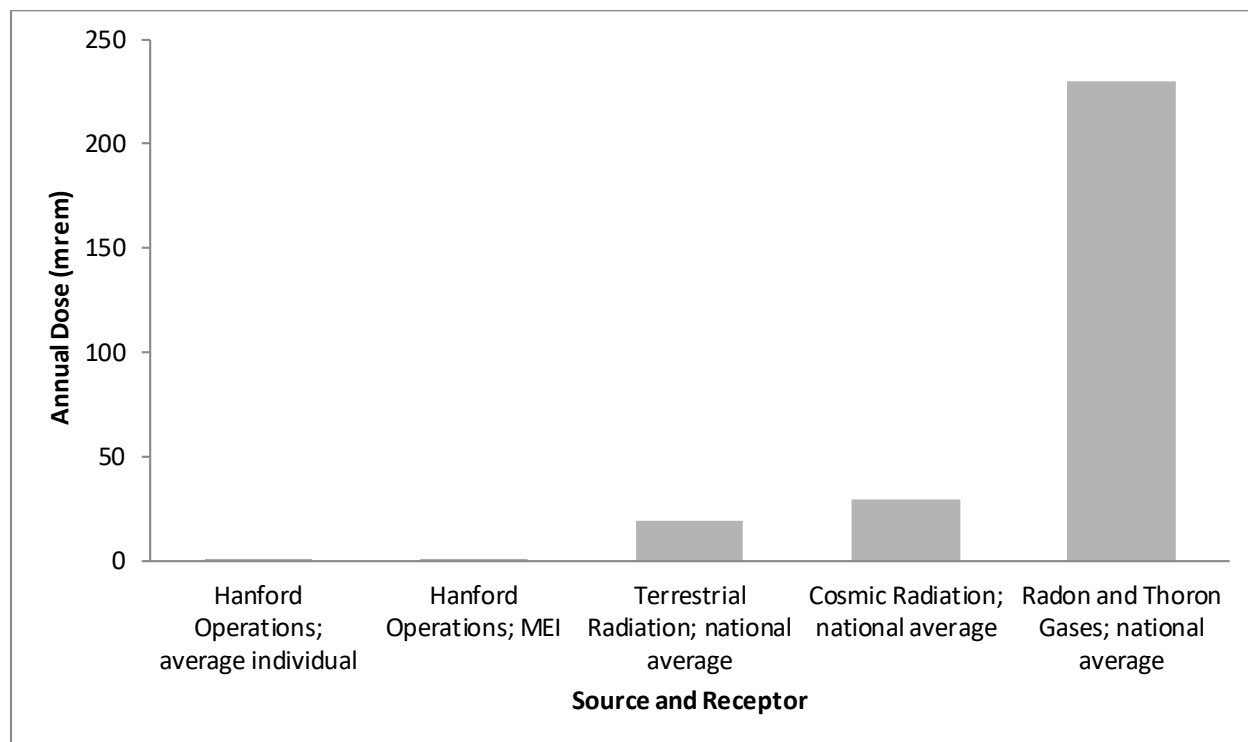


Figure 4-8. Radiological Doses from Hanford Site Operations Compared to Annual Average from Natural Sources.

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 (2018 rate) of 0.28 mrem (2.8 μ Sv)/yr living near Hanford Site for 70 yrs	$0 \text{ to } 0.3 \times 10^{-6b}$

^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).

MEI = maximally exposed individual

4.3 Radiological Clearance of Hanford Site Property

TA Ikenberry

Radiological clearance is a process where property with the potential to contain residual radioactive material is released from DOE control. It may be conducted for personal property (e.g., materials and equipment) or for real property (i.e., land and buildings). After clearance, property is considered suitable

for unrestricted use by members of the public, although in some cases restrictions on some types of use may be included. The requirements for release and clearance of DOE property are found in DOE O 458.1. Key aspects of these requirements are as follows:

- Demonstrate property does not contain residual radioactive material. This accounts for most of the property released from the Hanford Site.
- Evaluate property for the potential presence of residual radioactive material. As determined necessary, appropriately monitor and survey to determine presence (if any), type, and quantity of residual radioactive material. Most surveyed property has no detectable radioactivity above background levels and is considered to be free of residual radioactivity.
- Do not exceed the dose constraints for clearance (Table 4-9) and keep residual radioactivity as near background levels as reasonably practicable, as determined through DOE's as low as reasonably achievable process requirements and authorized limits. In addition to pre-approved authorized limits, Hanford Site-specific authorized limits have been approved for use by Hanford Site contractors.
- Document radiological clearance of property, independently verify clearance of real property, and properly report; address public participation needs; and provide processes to maintain appropriate records.

Table 4-9. Dose Constraints for Release and Clearance of Property, DOE O 458.1.

Exposure from release of real (land and buildings) and personal property shall be controlled to be ALARA and meet dose constraints.	Total Effective Dose	
	mrem/year	mSv/year
Public dose constraint from real property	25	0.25
Public dose constraint from personal property	1	0.01
NOTE: International dose units shown in italics are not in the order but are provided for information. ALARA = as low as reasonably achievable Mrem = millirem mSv = millisievert		

4.3.1 Personal Property

Personal property is considered to be everything except real property, namely material and equipment. Surveys are performed to verify common items cleared from the Hanford Site do not have residual radioactivity (e.g., electronics, pallets, batteries, office items, respiratory protection equipment, compressed gas cylinders, vehicles, tools, and physical security items). Some types of debris may be cleared to go to sanitary waste disposal sites. Formal clearance surveys may also be conducted on property such as power poles, transformers, miscellaneous electrical equipment, air conditioning units, industrial vehicles, excavation equipment, man lifts, scaffolding, and any of the common items as determined necessary and prudent. During 2018 an estimated 36,000 items of personal property were surveyed. Ninety-nine percent were small items, and 1% were large items; less than 10% had any real potential for residual radioactivity. The items were verified to meet the authorized limits for clearance under DOE O 458.1 and able to undergo unrestricted release from the Hanford Site.

Scrap metal that has been confirmed as not being in radiological areas can be verified to be free of residual radioactivity and cleared for release from the Hanford Site. All DOE sites are currently (since 2000) under a moratorium prohibiting the release of volume-contaminated metals for recycling from DOE radiological areas. No scrap metal is released from radiological areas.

4.3.2 Real Property

Real property is land and buildings. There was no radiological clearance of real property in 2018.

4.3.3 Granular-Activated Carbon for Offsite Shipment and Regeneration

Another important area of radiological clearance from the Hanford Site is that of granular-activated carbon (GAC), used to remove carbon tetrachloride from groundwater. Carbon tetrachloride was found in the unconfined aquifer beneath the 200-West Area in the mid-1980s. Groundwater monitoring indicated the carbon tetrachloride plume was widespread and concentrations were increasing. An expedited response action was initiated in 1992 to extract carbon tetrachloride from the vadose zone in the 200-ZP-2 Operable Unit, currently designated as the 200-PW-1 Operable Unit. This action continued during 2018 in the 200-West Area.

Since 2012, the 200-West Area Pump-and-Treat facility has used GAC 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 large GAC canisters. The GAC captures the volatile organic compounds removed during the extraction process. When a GAC canister has reached volatile organic compound saturation, it is removed from the system and the GAC is prepared for shipment to an offsite facility for regeneration and reuse. Regeneration of the GAC 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, it was determined the GAC could potentially contain residual radioactivity. Characterization sampling results were used to determine radionuclides that could be present and of potential concern. Authorized limits for these radionuclides were established under DOE O 458.1 to allow radiological clearance for offsite shipment and regeneration of GAC. The current authorized limits (Table 4-10) resulted from modifications in 2010 because of an increase in volume of GAC from the 200-West Area Pump-and-Treat facility compared to the predecessor treatment systems. This modification did not change the expected dose to the public, which is expected to remain negligible. Approximately 120,000 lb (54,400 kg) of GAC was shipped offsite in 2018 for regeneration.

The predecessor treatment systems are no longer operable. The 200-ZP-1 Operable Unit groundwater pump-and-treat system was installed in 1996 and operated until 2009. The 200-PW-1 Operable Unit soil-vapor extraction system was in full operation by 1995 and operated until 2014. These systems also used GAC to remove organic vapors from groundwater and soil.

Table 4-10. 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

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2018 Highlight

Closure of WMAs

- Received Ecology approval of the WMA C *Resource Conservation and Recovery Act of 1976* (RCRA) Facility Investigation Report and Corrective Measures Study.
- Draft DOE Order 435.1 Tier 1 (WMA C) and Tier 2 (C-200 Series Tanks) Closure Plans were prepared and submitted to U.S. Department of Energy (DOE) for review and approval.
- Receipt of Public comments on the Draft Waste Incidental to Reprocessing (WIR) Evaluation for WMA C was initiated in June 2018 and completed in November 2018.
- Received Ecology comments from reviews of the RCRA Tier 1 (SST Framework), Tier 2 (WMA C), and Tier 3 (C-200 Series Tanks) Closure Plans. This allows the closure permitting process to move forward.
- C-200 Series Tank Grout testing resulted in an evaluation of grouts used throughout the DOE complex, the selection and testing of a highly-flowable grout formula, and initial activities for selection of a bulk grout fill formula.
- A field investigation of the contents of the 241-C-301 Catch Tank was completed. Critical information to support future sampling, retrieval, and closure activities was obtained.
- A sampling plan for the focus area around tanks 241-A-104 and 241-A-105 in WMA A-AX was completed and field work was initiated.

Performance Assessments

- The DOE Order 435.1 performance assessment (RPP-ENV-58782) and the complimentary WIR Evaluation have been undergoing an independent review by the U. S. Nuclear Regulatory Commission as a part of its consultation with U.S. Department of Energy, Office of River Protection on the WIR-related decisions at WMA C.
- The Integrated Disposal Facility Performance Assessment documentation was completed and the review by the Low-Level Waste Federal Review Group was initiated.

Interim Surface Barriers

- Construction of two of three interim surface barrier panels in SX Farm were completed; the last panel began construction activities.
- Design of the third interim surface barrier for TX farm began

Waste Site Remediation

- Completed remediation of eight waste sites located at 100-K Area.

Removal of sludge located at 105-KW Basin.

- Started transfer of sludge from 105-KW Basin and transported to T-Plant.

Plutonium Finishing Plant Demolition

- Low hazard work began with cleanup of 234-5Z Building rubble already on the ground.

5.0 Environmental Restoration and Waste Management

Environmental restoration and waste management activities continued on the Hanford Site during 2018. The following sections describe ongoing 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.

5.1.1 100 Area

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

5.1.1.1 100-K Basins

SA McMahan

The 100-K Area (Figure 5-1) remediation activities included 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, as explained below. 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) document, DOE/RL-2010-63; *Remedial Design/Remedial Action Work Plan for the K Basins Interim Remedial Action*, describes the means of sludge treatment activities, including transferring sludge from KW-Basin engineered containers into sludge transfer and storage containers (STSCs) and transporting the STSCs to T-Plant for storage as remote-handled transuranic prior to treatment and disposal. The STSCs will eventually be disposed of at the Waste Isolation Pilot Plant (WIPP). 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.



Figure 5-1. 2018 Aerial View of 100-K Area Looking North Showing 105-KE, 105-KW, and Remediated Waste Sites.

100-K Area Remediation Progress and Accomplishments (2018)

- Started transfer of sludge from 105-KW Basin engineered containers into sludge transfer and storage containers. Transported filled containers to T-Plant for storage. The transfer of sludge will be completed in 2019.
 - An inventory of well-characterized 105-KW Basin sludge samples for the site to enable testing of future treatment options. As part of this sample stewardship, sludge shear strength as a function of time was measured to better understand how the sludge currently stored in the large engineered containers may develop strength or otherwise change during interim storage. Increased sludge strength may adversely affect sludge transfer operations. Essential characterization activities of the K-Basin water sand filter were conducted; the results are being used for proper waste designation and disposal. Conducting alternatives analysis, engineering evaluations, and process development and process/unit operation validation tests, and will continue these functions as the overall project progresses toward final sludge treatment and disposition
 - The 105 KW -Basin floor sample analysis was conducted to help assess the transuranic (TRU)/dose ratio in support of eventual K-West Basin demolition by quantifying the plutonium, americium, and strontium-90 content in K-Basin floor core samples. The cesium is expected to have preferentially exchanged into the concrete/paint layers relative to actinides and strontium. Thus, the high dose of cesium-137 in the concrete/paint surface is not expected to correlate with the TRU content derived from the K-Basin sludge models. The characterization work will generate a new relationship for the concrete floor of K-West Basin between cesium-137, which

can be determined from gamma energy analysis and dose correlations, and the TRU and strontium-90 content. These correlations will be used to properly designate the final waste form.

- Continued groundwater pump-and-treat operations. In addition to these operations the following actions were also conducted for the 100-K Area groundwater.
 - The site completed a study for the 100-K West pump-and-treat (P&T) system and identified a remaining hexavalent chromium source area prevent attainment of closure. The P&T system was shut down for a period of time with monitoring of the hexavalent chromium concentration response in the aquifer. Based on the response, an analysis was conducted to estimate source location and strength that would result in the observed increases in chromium(VI) concentration during the rebound period. The results were used to target subsequent source treatment options to minimize the overall P&T operations.
 - Sediments are being analyzed to identify the characteristics of a secondary source to a chromium plume in the 100-K Area. PNNL is analyzing sediment samples collected in a suspected chromium source area for a plume in the 100-K Area of the Hanford Site. This analysis will help quantify the geochemical nature of the continuing chromium source and support performance assessment of soil flushing being applied as a treatability test of potential source treatment. This source characterization and treatment are the remaining elements to be addressed prior to termination of active P&T remediation for this portion of the 100-K Area.
 - The site conducted a treatability test of soil flushing for the 100-K West remaining source area. Based on the remaining chromium(VI) source evaluation, a location for applying a flushing solution was identified. The flushing solution dissolves source material and enables it to be captured by the P&T extraction wells. By flushing, the source is rapidly removed and limits the timeframe of P&T operation.
- Completed removal of asbestos from the 165-KE Building in preparation for demolition forecast to start in 2019.
- Completed interim closure and backfill of wastes sites 100-K-13, 100-K-103, 100-K-79.9, 1607-K1, and 1607-K5.
- Waste sites 100-K-47:1, 100-K-50:2, and 100-K-94 are interim closed and scheduled to be backfilled in 2019.

5.1.2 200 Areas – Central Plateau

MJ Hickey

The Central Plateau includes a rectangular area of about 20 mi² (52 km²) in the center of the Central Plateau that is designated in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE/EIS-0222-F) and the “Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement” (64 FR 61615) as the Industrial-Exclusive Area. The Industrial-Exclusive Area contains the 200-East and 200-West Areas, used in the past primarily for Hanford Site nuclear fuel processing and currently used for waste management and disposal activities. The Central Plateau also encompasses the CERCLA 200 Area 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 DOE/RL-2009-10, *Hanford Site Cleanup Completion Framework*, 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. Because of the goals established in DOE/RL-2009-10, the Tri Party Agreement (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. Table 5-1 shows the crosswalk from 23 source operable units on the central plateau to the 10 source operable units.

5.1.2.1 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 the TPA Action Plan (Ecology et al. 1989b). 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. Central Plateau Operable Unit Structure. (2 Pages)

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		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

Table 5-1. Central Plateau Operable Unit Structure. (2 Pages)

New Operable Unit Group	Description	Predecessor Operable Units		Lead Regulatory Agency
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
200-CU-1	U –Plant Canyon: associated waste sites	No change		EPA
Outer Area				
200-OA-1	Sites located in the Outer Area	200-CS-1	200-MW-1	EPA
200-CW-1	200-OA-1 contains soils sites not in 200-CW-3 that were	200-CW-1	200-SW-2	
200-CW-3	in the previous OUs	200-CW-3	200-UR-1	
	200-CW-1 contains ponds not in 200-CW-3	200-IS-1	200-UW-1	
	200-CW-3 contains sites associated with the 200 North Areas.	200-MG-1/2		
Ecology = Washington State Department of Ecology				
EPA = U.S. Environmental Protection Agency				
OU = operable unit				
PFP = Plutonium Finishing Plant				
PUREX = Plutonium Uranium Extraction Plant				
REDOX = reduction-oxidation				

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 DOE/RL-2015-23, *Remedial Design/Remedial Action Work Plan for the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, and the DOE/RL-2015-22, *Sampling and Analysis Plan for the 200-CW-5, 200-PW-1, and 200-PW-6 Operable Units*, was approved by the U.S. Department of Energy, Richland Operations Office (DOE-RL) and EPA on May 19, 2016.

The selected remedy in the record of decision (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 the Environmental Restoration Disposal Facility (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 U Pond and Z-Ditches) will use the remove, treat, and dispose approach to excavate contaminated soils and dispose at ERDF or the WIPP, as appropriate.

Three of the six 200-PW-1 waste sites 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.

To support decision making and remedy implementation, relevant mineralogical transformations caused by the waste releases are being identified and determined how these transformations impact the solubility and adsorption of plutonium and americium. Mobility of these contaminants is affected by both sediment and waste composition. The study is imposing relevant conditions and measuring the mobility of the contaminants so that assessments can use technically defensible transport properties for the site-specific conditions.

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 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, 88.3 tons (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 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 source 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. 1989b); 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). DOE/RL-2010-49, *Remedial Investigation/Feasibility Study Work Plan 200-WA-1 and 200-BC-1 Operable Units*, was issued in January 2017. In addition, the U.S. Department of Energy (DOE) obtained approval of DOE/RL-2009-94, *216-U-8 Crib and 216-U-12 Crib Vadose Zone Characterization Sampling and Analysis Plan*, which supports the 200-WA-1 Operable Unit remedial investigation. Additionally, the following science and technology efforts were conducted:

- Electrical Resistivity Tomography (ERT) to identify waste fluid migration pathways and select characterization borehole locations at U-Plant site within the 200-WA-1 OU. ERT is sensitive to changes in subsurface conductivity that are caused by the presence of high ionic strength waste

fluids. Thus, the ERT can identify the path of nitrate waste migration in the vadose zone. The identified pathways can then be used to target characterization boreholes to collect contaminated sediment and conduct detailed analyses of contaminant conditions for assessing potential future flux to groundwater.

- An integrated approach for geophysical monitoring and modeling is being established to support implementation and interpretation of characterization data and to design and implement monitoring where needed. Multiple geophysical techniques are available to measure subsurface properties and contamination. New data interpretation approaches such as E4D are being applied to improve resolution of data interpretation and to directly link interpretations to computer models. Direct linkage with models enables improved estimates of future contaminant migration and impact to groundwater.
- A 20+-year evaluation of performance for the Prototype Hanford Barrier, identified key surface barrier design elements based on this evaluation, and identified a cost-effective long-term surface barrier monitoring approach. The barrier monitoring demonstrated effective control of surface water infiltration and identified the key barrier elements important for barrier effectiveness. Based on these data, targeted geophysical techniques were identified that can be cost-effectively used for long-term monitoring of barrier performance.
- Future feasibility studies and remedy designs need site-specific guidelines on dust control in the Central Plateau. A practical guide on selecting and implementing dust control measures is being created as well as an actionable guidance document that clearly outlines the necessary steps in establishing and implementing dust control plans specific to the Central Plateau that comply with federal and state laws.

200-EA-1 Operable Unit (200-East Inner Area). This operable unit consolidates the remaining Inner Area source sites in the 200-East Area except for the environmental media underlying tank farm WMAs, 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 Appendix C to the TPA Action Plan (Ecology et al. 1989b); 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 waste site fit within the framework of impacts from the entire Inner Area. The Draft A 200-EA-1 work plan was submitted to Ecology and DOE is resolving Ecology comments.

A 20+-year evaluation of performance for the Prototype Hanford Barrier was completed. The evaluation identified key surface barrier design elements based on this evaluation, and identified a cost-effective long-term surface barrier monitoring approach. The barrier monitoring demonstrated effective control of surface water infiltration and identified the key barrier elements important for barrier effectiveness.

Based on these data, targeted geophysical techniques were identified that can be cost-effectively used for long-term monitoring of barrier performance.

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 (i.e., 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. 1989b).

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. DOE/RL-2010-114, *200-IS-1 Operable Unit Pipeline System Waste Sites RFI/CMS/RI/FS Work Plan*, 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. 1989b). Portions of the burial grounds listed in the Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste (Hanford Site 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. A helicopter radiological survey was completed over the majority of the inner area and a summary report to present the findings of the survey was issued in March 2018.

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. 1989b). DOE/RL-2011-102, *Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-DV-1 Operable Unit*, was approved by Ecology on September 13, 2016. The DOE/RL-2010-89, *Long-Range Deep Vadose Zone Program Plan*, 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 will be completed in 2018.

An evaluation of vadose zone remediation technologies was prepared by the site with support from PNNL, including a compilation of available site-specific testing information. A thorough review of technologies was conducted, supplementing previous reviews and directly relating technology capabilities to 200-DV-1 operable unit contaminant settings. The review specifically considered whether any additional site-specific information was needed prior to consideration of the technology in a feasibility study. Based on this assessment, a number of technologies were identified that need additional laboratory treatability tests. A treatability test plan was prepared and testing has been initiated.

Amendment delivery methods appropriate for Hanford Central Plateau vadose zone sites are being evaluated. Remedy implementation in the vadose zone is difficult because distribution of remedy amendments in an unsaturated setting is more challenging than in aquifers. A review of delivery options examined approaches at other remediation sites and evaluated these delivery options in the context of the Hanford Site vadose zone setting.

Characterization and data interpretation approaches for a contaminated perched water zone were identified by the site. The contaminated perched water zone in the 200-DV-1 operable unit is currently being addressed by a P&T approach. However, more information about the perched water zone is needed to optimize the P&T system or to identify supplemental or replacement approaches if P&T cannot meet treatment goals. A sampling and analysis plan was prepared to guide these characterization efforts.

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) (225-B), along with exterior ventilation system components for each structure (e.g., high-efficiency particulate air filters and sand filter) and 17 soil waste sites within the vicinity. Specific sites are listed in the TPA Action Plan (Ecology et al. 1989b); 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 et al. 2005). The U-Plant Canyon Disposition Initiative is a pilot project for disposition of the five canyon buildings in the 200-East and 200-West Areas. Implementation of the selected remedial action (close in place – partially demolished structure) began in 2009. 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.

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. 1989b); 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 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. 1989b); 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. Additionally, sites 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.

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 remediated 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 as a result of 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 (Table 5-1).

DOE/RL-2011-58, *200-CW-3 Operable Unit Interim Remedial Action Report*, 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 200 Areas' National Priorities List site.

Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill. The Nonradioactive Dangerous 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 SWL is regulated under WAC 173-350, “Solid Waste Handling Standards.”

5.1.3 300 Area

LM Dittmer and RL Cathel

5.1.3.1 618-10, 316-4, and 600-63 Waste Sites. The 618-10, 316-4, and 600-63 are co-located in the 600 Area of the Hanford Site, approximately 4 miles northwest of the 300 Area. (Figure 5-2)



Figure 5-2. Aerial View of the 618-10 Burial Ground and 316-4 Liquid Waste Crib Excavation and 600-63 Waste Sites and Supporting Area Following Backfill, Re-grading, and Re-contouring.

Remediation of the 618-10 Burial Ground, 316-4 Liquid Waste Disposal Crib, and the 600-63 Buried Waste Test Facility waste sites were completed in 2017. Backfill operations of 600-63 were completed in August 2017, and backfill of 618-10 and 316-4 waste sites was completed in March 2018. Following backfill, the three waste site footprints and the supporting infrastructure (trailer areas, container transfer area, parking and roads) encompassing approximately 125 acres were re-graded and re-contoured to return the area to a natural landscape. Revegetation was initiated in November 2018, to be completed during the optimal Hanford revegetation window of November-January.

The three waste sites were transitioned to Long-Term Stewardship in 2018.

5.1.3.2 300-296 Waste Site. The focus of the project is the remote excavation of the highly contaminated soil beneath the 324 Building B-Cell. The 300-296 Remote Soil Excavation Project is designing and procuring equipment and components that will be used to remove debris and grout from the B-Cell, cut and remove the B-Cell floor, and remotely excavate the highly contaminated soil to establish conditions for demolition in the future. In addition to facility modifications to support the installation of soil removal equipment, structural modifications will be performed to underpin the B-Cell to prevent settling during the removal of the underlying contaminated soil.

The project scope also includes the utilization of a Mockup of the B-Cell and the Airlock for equipment performance validation, training, and proficiency development for operations planned for the 324 Building during soil removal. The Mockup will be maintained and operated throughout the project to support refresher training, contingency development and response planning, and provide spare equipment during operations for any unplanned occurrences or challenges.

During 2018, there were 57 entries into the Airlock supporting waste removal from A-, C-, and D-Cells and preparations for moving equipment into B-Cell. These entries resulted in the shipment of 18 boxes of mixed low-level waste, 21 roll off container of low-level waste, and 83 drums of low-level waste to ERDF. Cell cleanout continues in A-Cell and was completed in both C- and D-Cells.

B-Cell gallery installation of 2 of 4 through support assemblies for the B-Cell remote excavator arms was completed. Removal of the sample load out room in the B-Cell gallery prepares the way to install the remaining through support assemblies in early 2019.

5.1.3.3 300 Area Waste Sites. Interim stabilization of three waste sites in the 300 Area (i.e., 300-5, 331-LSLT1, and 331-LSLT2) was completed. The 300-5 site consists of fuel-contaminated soil from previously removed buried fuel tanks. The 331-LSLT1 and 331-LSLT2 sites are former waste trenches that accepted liquid animal waste. All three of these sites were covered by impermeable barriers to prevent water intrusion into the contaminated soil.

5.2 Facility Decommissioning Activities

This section provides information regarding the transition of Hanford Site facilities from stabilization to surveillance and maintenance (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 2018, all deactivation, decommissioning, decontamination, and demolition activities in the 100 Area have been completed with the exception of a portion of the 100-K Area.

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. DOE issued a shutdown order for PFP in 1990. In 1996, DOE-RL authorized the deactivation and transition of plutonium-processing portions of the facility in preparation for decommissioning under a CERCLA non-time critical above-grade removal action.

All special nuclear materials and stored fuel elements were removed from the plant and security downgraded by the end of 2009. Work commenced to decommission and demolish the PFP complex to a slab-on-grade condition. Demolition work stopped in December 2017 when contamination was found outside the radiologically controlled area. Work then focused on stabilization and recovery actions. Figure 5-3 provides a view of the PFP complex in December 2018.

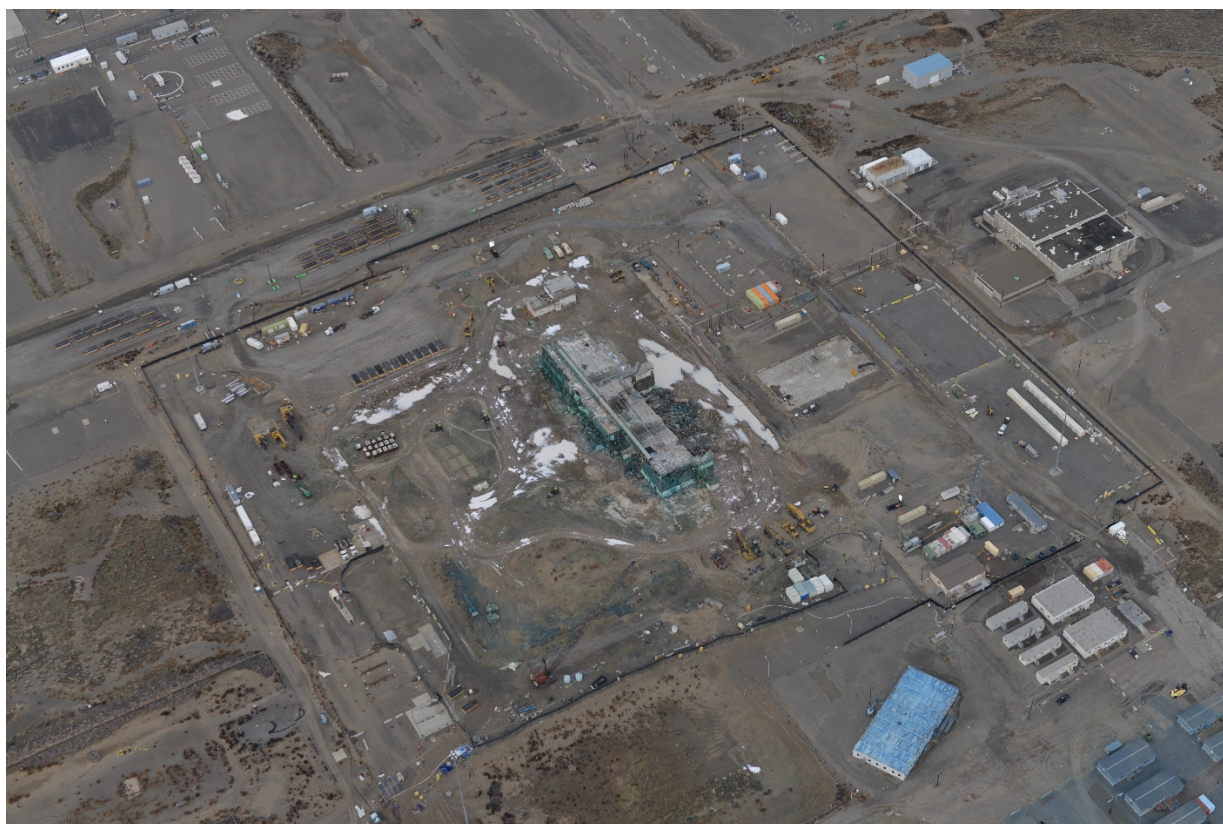


Figure 5-3. December 2018 Aerial View of the Plutonium Finishing Plant.

Plutonium Finishing Plant Complex. Stabilization and recovery actions took place the majority of 2018. Low hazard work was authorized in September and began with cleaning up the rubble already on the ground around the 234-5Z Building. A summary of activities completed in 2018 is provided below:

- Completed stabilization actions directed by DOE.
- Completed recovery actions to include:

- Options Engineering Analysis
 - Development of enhanced demolition controls
 - New air dispersion and ground dispersion modeling
 - Development of resumption work plan
 - Management assessment.
- DOE authorized commencement of low hazard work in September.
- Began cleanup of 234-5Z Building rubble that was on the ground.
- Approximately 200 roll-on/roll-off containers were shipped to the Environmental Restoration Disposal Facility after authorization to cleanup rubble in 2018.

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 DOE/RL-2006-21, Remedial Design/Remedial Action Work Plan for the 221-U Facility. Due to the concerted effort to remove PFP, no action has been taken on this initiative since 2011.

5.2.3 300 Area

Bob Cathel

Future activities in the 300 Area will address the demolition of the 324 facility and 300 Area retained facilities discussed in DOE/RL-2004-77, *Removal Action Work Plan for 300 Area Facilities*. The remediation of the 300-296 waste site will be performed in accordance with DOE/RL-2014-13-ADD1, *Remedial Design Report/Remedial Action Work Plan for 300-FF-2 Soils* and the *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5 and Record of Decision Amendment for 300-FF-1* (EPA and DOE-RL 2013).

5.2.4 400 Area

SA McMahan

The Fast Flux Test Facility (FFTF) is a formerly operating 400-megawatt (thermal) liquid-metal cooled (sodium) research and test reactor located in the 400 Area (Figure 5-4). 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. 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 the Hanford Site. Bulk sodium inventories would be processed at the Hanford Site for use in the WTP.

The 437 Building Maintenance and Storage Facility is a multi-purpose high bay facility supporting the Sludge Treatment Project development and acceptance testing of sludge handling components and systems, and training of operations personnel in the use of this equipment. The Maintenance and Storage Facility complex consists of a main building and a two-story service wing. The main building is 290-ft (88.4-m) long by 95-ft (29-m) wide and provides approximately 28,000 ft² (2,604.3 m²) of area for mockup fabrication and engineering scale testing.

Also at the 400 Area (outside the FFTF Property Protected Area) is a mammoth structure called the Fuels and Materials Examination Facility (FMEF). 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 5-4. Aerial View of the Fast Flux Test Facility.

5.3 Waste Management Activities

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

5.3.1 Waste Classifications

WE Toebe

Hanford Site cleanup operations result in the generation of solid wastes that must be evaluated for proper management. Solid wastes are reviewed as required by 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)*. 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-2018-12, *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 (e.g., 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 the Hanford Site has been shipped to a commercial medical waste treatment and disposal facility.

5.3.2 Solid Waste Inventories

BE Sanders, KL Chase

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, Mission Support Alliance, 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, 2018, 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 current as of December 31, 2018.

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

Waste Category		2012	2013	2014	2015	2016	2017	2018
Mixed	Tons	305	206	140	657	609	452	523
	Metric tons	277	187	127	596	552	410	474
Radioactive	Tons	343	513	572	1550	665	828	2680
	Metric tons	311	465	519	1408	603	751	2434

^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		2012	2013	2014	2015	2016	2017	2018
Mixed	Tons	66	36.5	38.4	97.9	105	83.3	118
	Metric tons	60	33	35	88.9	95.3	76	107
Radioactive	Tons	82	62.8	57	91.4	113	133	130
	Metric tons	74	60	52	82.9	102	121	118

^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		2012	2013	2014	2015	2016	2017	2018
Containerized (DW Only)	Tons	18	65.4	103	76.8	69.4	68.5	84.5
	Metric tons	16.3 ^b	59.3 ^b	93.4 ^b	69.7 ^b	63.0 ^b	62	76.6
Containerized (MW Only)	Tons	91	50.6	33.7	65.7	69.7	90.4	56.9
	Metric tons	82.5 ^c	45.9 ^c	30.6 ^c	59.6 ^c	63.2 ^c	82	51.6
Bulk Solids (DW Only)	Tons	3	—	22.1	—		0	0
	Metric tons	2.7	—	20.1	—		0	0
Bulk Solids (Non-Rad/Non-DW)	Tons	17	—	—	—		0	0
	Metric tons	15.4	—	—	—		0	0
Bulk Liquids (DW Only)	Tons	—	—	22	—	1	0	0
	Metric tons	—	—	20	—	1.36	0	0
Bulk Liquids (Non-Rad/Non-DW)	Tons	—	—	—	—		0	0
	Metric tons	—	—	—	—		0	0
Totals	Tons	129	116	181	142	140	158.9	141.4
	Metric tons	117	105	164	129	127	144	128.2

^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 and nuclear material produced during Hanford Site operations or received back from offsite sources authorized by DOE to ship waste to the Hanford 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 5-5), the Central Waste Complex (CWC) operates under interim status standards specified in the Hanford Site 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 Hanford 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, 2018, the volume of waste currently stored in the CWC Outside Storage Areas is approximately 178,182 ft³ (5,046 m³) and the volume of waste currently stored at CWC is approximately 434,538 ft³ (12,305 m³).



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

5.3.3.2 Waste Receiving and Processing Facility.

J Fullmer

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 5-6). 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 WAC-173-303-400.

Waste destined for the WRAP Facility includes stored and newly generated waste from current Hanford Site cleanup activities and consists primarily of 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 are 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 5-6. 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.

J Fullmer

The T-Plant Complex (Figure 5-7) 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 Hanford Site RCRA Permit (WA7890008967), T-Plant Complex Part A Form. The T-Plant Complex received seven shipments of K-Basin sludge for storage during calendar year (CY) 2018.



Figure 5-7. 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 412 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 can be placed in a National Repository. The CSB was originally planned to be used for the storage of glass logs of vitrified tank wastes. Per the NEPA ROD to the DOE/EIS-0245, *Draft Environmental Impact Statement Management of Spent Nuclear Fuel from the K Basins at the Hanford Site, Richland, Washington*, it was decided to store spent nuclear fuel in the CSB. Construction of CSB was completed in May 2000 and commenced receiving K Basins spent nuclear fuel in December 2000.

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

J Fullmer, KL Chase

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 applicable sections of WAC 173-303, "Dangerous Waste Regulations." In addition, the remedial investigation/feasibility study work plan (DOE/RL-2004-60) supports remediation of the CERCLA areas within the LLBG and coordinates with the RCRA TSDs closure.

Low-level Waste Burial Ground 218-W-5, Trenches 31 and 34. Trenches 31 and 34 (Figure 5-8) 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 on 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, 2018, Trench 31 contains approximately 236,599 ft³ (6,700 m³) of waste in approximately 3,936 waste packages. Trench 34 contains approximately 190,835 ft³ (5,404 m³) of waste

in 5,340 waste packages. In 2018, a total of 13,544 ft³ (384 m³) of waste was disposed of in Trenches 31 and 34.



Figure 5-8. 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 2018. The total number of reactor compartments received into Trench 94 (218-E-12B Burial Ground) is 133 as of December 31, 2018. 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 Hanford Site RCRA Permit (WA7890008967), WESF Part A Form (WAC 173-303-400). The WESF is a storage only unit for strontium- and cesium- salts encapsulated in double-containment stainless-steel capsules in underwater pool cells. The water provides cooling and shielding for the capsules, which 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. Initial RCRA closure of Hot Cells A through F was achieved on April 10, 2017, through grouting the hot cells to fix any radioactive materials present. 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. On November 16, 2017, DOE-RL transmitted to Ecology for review and approval the RCRA Part B Permit application for the packaging and transfer of capsules to dry storage and RCRA Part B Permit application for capsule interim storage (18-AMRP-0013). Site selection of the new Capsule Storage Area and site ecological and cultural resources reviews have been completed.

5.3.3.7 Integrated Disposal Facility

L. Dittmer

The IDF (Figure 5-9) is an unused landfill located in the south-central part of the 200-East Area. The IDF is an expandable lined landfill (i.e., a double high-density polyethylene-lined trench with leachate collection and a leak detection system). 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 west cell is a permitted TSD facility under the Hanford Site RCRA Permit (WA7890008967). The landfill was constructed to accept low-level waste as well as mixed waste (e.g., vitrified low-activity waste [LAW] from the Waste Treatment Plant [WTP] and Demonstration Bulk Vitrification System). Additionally, mixed waste generated by IDF operations will be disposed of in IDF.

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.

A programmatic agreement (PA) for the IDF was completed in CY 2017, reviewed by the Low-Level Waste Federal Review Group, and approved by U.S. Department of Energy, Headquarters on June 30, 2018. This PA addresses the requirements outlined in DOE O 435.1. The overall objective of this PA is to provide a basis for making informed decisions pertinent to operation and eventual closure of the IDF.



Figure 5-9. Aerial View of the Integrated Disposal Facility.

One of the inputs to the PA is the estimation of radionuclide release rates from the engineering portion of the disposal facility (source term). These estimates are expected to be based on chemical reaction that occur in the near field and are controlled by the dissolution of the LAW waste forms. In support of the IDF PA, PNNL serves as the lead laboratory, integrating across the complex to provide the technical basis for the disposal strategies, including defining data needs and testing protocols, for both glass and cementitious waste forms. For glass, PNNL is delivering critical PA input data (rate model parameters) for the enhanced glass compositional envelope through standardized and high-throughput test methods. The outcomes of this work, when integrated with the DOE-ORP vitrification support program, provide a link between the IDF and facility operations with respect to long-term glass performance, enable flexibility for facility operations (larger compositional region of acceptability), allow for higher waste loadings to be targeted for facility operational efficiency and, in turn, reduce WTP mission life. Field lysimeter testing has also been initiated to validate PA release model parameter estimations and reduce uncertainty in waste form degradation prediction in the IDF. Additionally, expertise in material science, waste form fabrication, mineralogy, and geochemistry, and performance testing capabilities are being used to support the tank farm contractor in evaluating low-temperature waste forms for both WTP liquid secondary wastes, including processes at the Hanford Site 200 Area Effluent Treatment Facility (ETF) and the Effluent Management Facility (EMF), and solid secondary wastes, including non-debris and debris wastes produced from full WTP operations. The data generated and analyses are critical to qualifying these waste forms for disposal in the Hanford IDF or offsite facilities and will help provide the defense in depth for IDF PA maintenance activities. The technologies can be extended to evaluate the potential for low-cost, low-temperature, supplemental LAW treatment options.

5.3.3.8 Environmental Restoration Disposal Facility

WA Borlaug, BL Lawrence

The ERDF (Figure 5-10) is the largest disposal facility in the DOE cleanup complex. The landfill located near the 200-West Area covers 107 ac (43.7 ha) and has a current capacity of approximately 21 million tons (19.1 million metric tons).



Figure 5-10. Aerial view of the Environmental Restoration Disposal Facility.

Regulated by the EPA, the facility began operations in July 1996 and serves as the central disposal site for hazardous, low-level radioactive, and mixed low-level waste removed during Hanford Site cleanup operations conducted under CERCLA. The total available expansion area of the ERDF site was authorized in EPA/ROD/R10-95/100, *Declaration of the Record of Decision for USDOE Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington,* 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 composite liner system consisting of a 3-ft (0.9-m)-thick layer of compacted bentonite-admixed soil covered with high-density polyethylene (HDPE) geomembrane. An aggregate or geocomposite leak detection system lies immediately above the lower composite liner. A second liner consisting of HDPE geomembrane sits on top of the leak detection system and is covered with a 1-ft (0.3-m)-thick aggregate or a geocomposite leachate collection layer. The leachate collection layer is covered with a 3-ft (0.9-m)-thick layer of soil to protect the underlying layers of the liner system.

Designed to be expanded as needed, ERDF consists of disposal areas called cells. There are currently 10 cells at ERDF. After completion of waste disposal operations, a 15-ft (5-m)-thick enhanced RCRA Subtitle-C final cover will be placed over the cells.

As of December 31, 2018, DOE and its contractors have disposed of 18.4 million tons (16.6 million metric tons) of contaminated material at the ERDF since the facility began operations in 1996. The majority of cleanup waste disposed at ERDF is from the 220 mi² (570 km²) River Corridor located along the banks of the Columbia River. The waste consists mainly of soil contaminated during operation of the Hanford Site’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 Site locations.

5.3.4 Liquid Waste Management

M Gerle

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 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 from the 200 Area ETF 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 processed 2.75 million gal (10.4 million L) of wastewater from LERF in CY 2018.



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 permitted 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 very low-density polyethylene or chlorosulfonated polyethylene (CSPDE) to keep out windblown soil and weeds and minimize evaporation of organic compounds and tritiated water 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.

The volume of wastewater received for the LERF basin storage in CY 2018 was approximately 1.77 million gal (6.70 million L). The largest single contributor to wastewater received into LERF was approximately 0.36 million gal (1.36 million L) of process condensate from the 242-A Evaporator. Approximately 0.44 million gal (1.67 million L) of wastewater was received by tanker trucks from various other facilities. Approximately 2.75 million gal (10.4 million L) of wastewater in LERF was treated at ETF

in CY 2018. 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 CY 2018 was approximately 13.1 million gal (49.6 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 Areas' 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. 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 disposed to this facility in CY 2018 was approximately 120 million gal (456 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.

The 242-A conducted two campaigns in CY 2018. These campaigns processed a volume of 1,144,000 gal (4,330,500 L), which resulted in a volume reduction of 256,000 gal (969,065 L). At the end of this year's second campaign, the main recirculation pump experienced a malfunction. The pump will be replaced in CY 2019. Routine testing also revealed problems with the secondary containment of the evaporator's slurry lines; there was no leak or loss of hazardous waste. A project to replace the slurry lines has begun. In CY 2018, upgrades to the facility included enhancements to the building fire detections system.

5.3.5 Underground Waste Storage Tanks

Hanford's 53.8 million gal (203.6 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. There are 149 single-shell tanks (SSTs) of which 17 tanks have been declared retrieval complete per HNF-EP-0182, Rev. 372, *Waste Tank Summary Report for Month Ending December 31, 2018*. There are 28 DSTs of which 1 tank has been declared retrieval complete. The SST and DST tanks 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 CY 2018 related to their operation and closure.

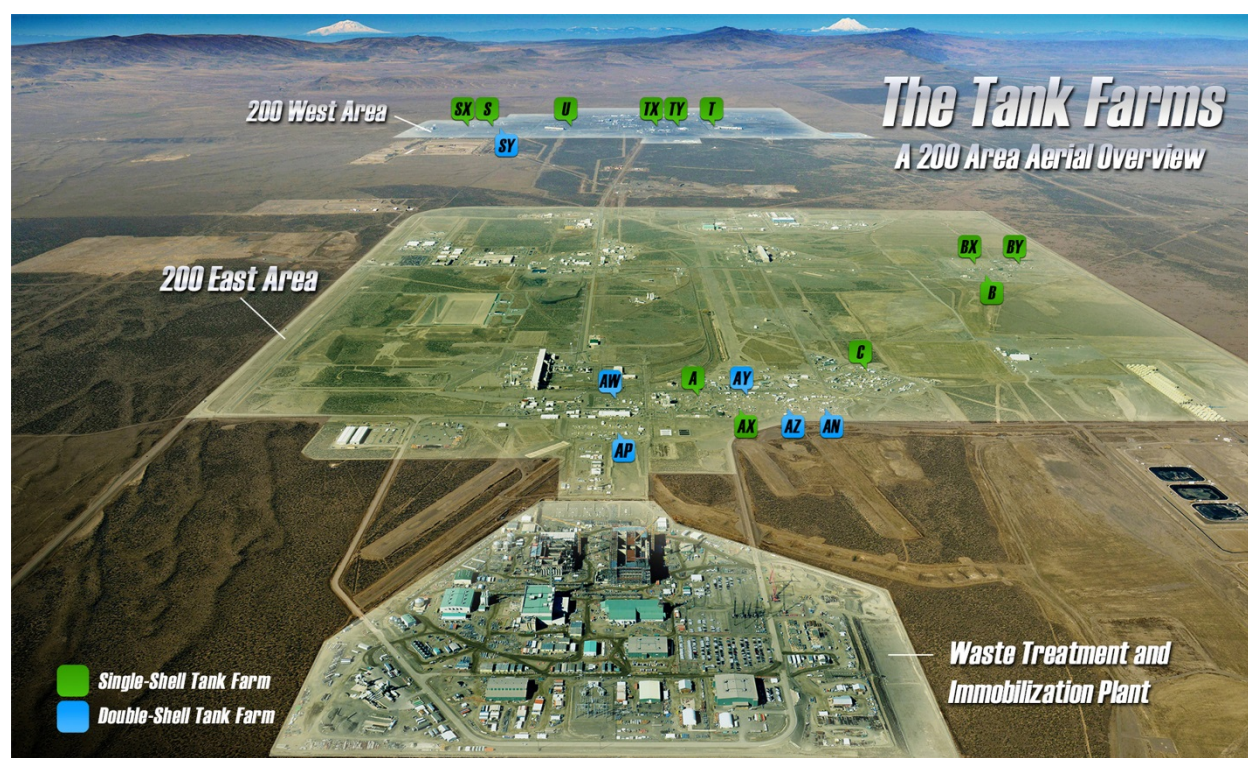


Figure 5-14. Aerial Over of the 200 Areas Tank Farms.

5.3.5.1 Single-Shell Tank System

The SST system was constructed between 1943 and 1964 to store mixed waste generated on the Hanford Site; 60 of the tanks are assumed leakers. Pumpable liquids in the SSTs were transferred to the newer and safer DSTs several years ago under the Interim Stabilization Program in order 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 CY 2018, retrieval of waste from the C Farm tanks was completed, transferring it to newer, safer DSTs to prepare to feed tank waste to the WTP (Figure 5-15).

At the end of CY 2018 there were 28.6 million gal (108.3 million L) of waste in the SSTs. Waste volumes are provided in HNF-EP-0182. Table 5-5 in this document summarizes the waste retrieved and stored in the SST system from 2010 through 2018.



Figure 5-15. Work Retrieving Tank Waste was Completed at the C Farm.

5.3.5.2 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.

The tanks contain liquids and settled solids from past nuclear operations, including waste transfers from older SSTs. The DST system storage capacity is approximately 31.6 million gal (120 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 of 1.27 million gal (4.8 million L) available at all times.

At the end of CY 2018, there were 25.2 million gal (95.4 million L) of waste in the DSTs. Waste volumes are provided in HNF-EP-0182. Table 5-5 summarizes the waste retrieved and stored in the DST system from 2010 through 2018.

Table 5-5. Tank Farm System Quantities of Waste Retrieved and Stored.

Type of Waste	Units ^a	2010	2011	2012	2013	2014	2015	2016	2017	2018
Double Shell Tanks										
DSTs year-end waste total volume ^b	gal	25,835	25,948	26,580	26,733	26,575	25,791	25,542	25,487	25,182
	L	97,796	98,224	98,000	101,195	100,597	97,630	96,676	96,481	95,314
DSTs year-end waste solids volume ^b	gal	12,869	9,331	5,948	5,897	6,215	6,351	6,257	6,294	6,378
	L	48,817	98,223	22,516	22,323	23,526	24,041	23,685	23,825	24,141
DSTs year-end waste supernatant volume ^b	gal	12,966	16,617	20,632	20,836	20,360	19,440	19,285	19,193	18,804
	L	49,082	62,902	78,101	78,873	77,071	73,588	73,002	72,653	71,173
242-A Evaporator										
242-A Evaporator volume evaporated	gal	548	0	0	0	793	1,329	305	557	220
	L	2,074	0	0	0	3,002	5,031	1,154	2,108	833
Single Shell Tanks										
SSTs year-end waste total volume ^b	gal	29,434	29,573	29,272	29,185	28,789	28,586	28,533	28,724	28,578
	L	111,420	111,945	110,806	110,477	108,978	108,210	108,009	108,732	108,168
SSTs year-end waste solids volume ^b	gal	29,403	29,429	29,182	29,073	28,655	28,445	28,418	28,578	28,461
	L	111,302	111,401	110,466	110,053	108,471	107,676	107,574	108,179	107,725
SSTs year-end waste supernatant volume ^b	gal	31	144	90	112	134	141	115	146	118
	L	117	545	340	424	507	534	435	553	447
^a Multiply volumes shown by 1,000. 1 gallon = 3.785 liters. ^b Tank waste volume data is calculated from HNF-EP-0182, Rev. 372 DST = double-shell tank SST = single-shell tank										

Safe storage, retrieval, and transfer of radioactive waste liquids, salts, and sludges are the primary focus within the tank farms. This includes safeguarding the overall integrity of the tanks and tank infrastructure, leak detection, tank life extension, structural analysis, and vapors detection/monitoring, management, and action plan guidance. In support of safe tank farm operations, PNNL is providing the technical underpinning for baseline processing, risk reduction, and/or alternative management strategies in a number of key areas. Those include:

- Subsurface Transport Over Multiple Phases – Water-Air-Energy (STOMP-WAE) modeling to understanding the possible pathways for water intrusion into the DSTs. The STOMP-WAE model is used to determine the effects of the DST ventilation system on potential water intrusion through construction joints and possible cracks in the concrete dome. The leak detection pits on the DSTs were designed to detect waste leaks in the event of failure of both the primary tank and secondary liners. Many of the leak detection pits are subject to constant ingress of water that shows no evidence of tank waste. The ingress water likely exposes portions of the bottom of the secondary liner to either continuous water exposure or high ambient humidity, both of which increase the risk of corrosion of the bottom of the secondary liner of the DSTs. Temperature effects on two-phase flow and seasonal variation of recharge rate are also investigated. The results will help in decision-making that will reduce the corrosion of DSTs and extend their service life.
- Ultra-sonic nondestructive examination (NDE) for under-tank inspection. A technical basis for the selection of commercial and near-commercial NDE sensor technologies for Hanford tank bottom inspection was provided to the Hanford Tank Operations Contractor. Technical oversight was provided for design and acceptance testing to ensure the inspection systems meet the functional, performance, and other requirements established for the Non-visual (Volumetric) Nondestructive Examination Technology Development Program. The process that will be followed to qualify adapted and integrated robotic NDE inspection systems for primary tank bottom inspection, and the data processing and data reduction strategy that will be used to convert NDE inspection results to provide flaw location and size information needed to inform operational decisions on remaining tank service life or repair for tank life extension.
- Tank life extension through in-service repair. A Solid Phase Processing investment is being used to demonstrate the feasibility of repairing a pitted carbon steel plate with Cold Spray – a candidate method for in-service repair of high-level waste tanks on the Hanford Site. Feasibility tests are being conducted to provide the basis for developing a full set of Cold Spray process parameters for carbon steel primary tanks and secondary liners that would result in long-term, metallurgically sound repairs. The process parameters would be used with commercial Cold Spray technology by the tank operations contractor to restore the leak integrity of primary tanks and secondary liners, and thereby extend tank service life.
- Thermal oxidation system to treat selected chemical of concerns. Data is being supplied to advance the NUCON Thermal Oxidation System toward implementation in the Hanford tank farms. Additional sample data has been analyzed from previously conducted demonstration testing that confirmed the performance of the NUCON Thermal Oxidation System for WRPS and quantified the ability of the system to treat selected chemicals of potential concern. Based on the successful demonstration testing, PNNL is partnering with the tank farm contractor to design a tank farm production demonstration system to be installed on SST BY-108. The demonstration testing is a key

component of the Vapor Consent Decree with the state of Washington. The installation and testing of the NUCON TOS on BY-108 will provide a set of field data on chemical of potential concern destruction that advises the tank farm contractor whether the technology can be used to treat other SSTs. The data will also provide critical information that guides future installations across SSTs in tank farm.

- Data analysis tools to support industrial hygiene functions, including exposure assessments. The Tank Vapors Data Access and Visualization application was developed in FY 2018. The plans for FY 2019, include deploying a set of analysis and visualization tools to assist industrial hygiene analysts in performing routine exposure assessments for tank farms, facilities, and job-specific work activities. Enhancements to prior tools are also being deployed to increase access to underlying data sets and to accommodate data feeds from newly deployed Vapor Monitoring and Detection System (VMDS) components, including stack monitors. Additional work is applying the Chemical Mixture Methodology to historical sampling results to supplement the exposure assessment process.
- Numerical and computational evaluation of planned AP-106 cesium-rich heel retrieval and mixing operations to “repurpose” AP-106 as a treated LAW lag storage vessel. A technical evaluation for risk mitigation of planned AP-106 operations is being provided by conducting computational fluid dynamics modeling; underpinned by analytical calculations to bound, inform, and support planned WRPS operations including dilution, mixing, dense layer additions, and decanting of the cesium-rich supernatant layer. Initial results informed baseline operations changes and additional analytical and computational evaluations are being conducted to establish tolerable risk levels for AP- 106 “repurposing” operations.
- Structural integrity analysis of record to qualify the AN and AW DSTs for increased storage volume. Since 2003, PNNL has performed the structural integrity analyses of record for the DSTs and SSTs at Hanford. These analyses dictate the maximum waste level allowed in the DSTs. In 2008, PNNL completed a structural analysis that demonstrated that the AP tanks could safely store an additional 38 in. (96.5 cm) of waste, representing 720,000 gallons of additional storage volume in the eight AP tanks. In 2017, PNNL performed a similar analysis to qualify the AN and AW tanks for increased waste height. In 2019, the seismic spectra are being updated to the 2014 probabilistic seismic hazard analysis (PSHA) and the analysis is scheduled for completion in 2020. Conclusions similar to those of the AP analysis are expected, which could increase the storage capacity of the 13 AN and AW tanks by 1,170,000 gal (4,428,929 L). PNNL has also used our verified tank structural models to assess the addition of new tank dome risers for increased access during waste retrieval. These models will be used in 2019 to evaluate the current as-built condition of the AX single shell tanks.
- Structural integrity analysis of the A-Farm SSTs to evaluate the addition of multiple large penetrations in the domes to facilitate easier waste retrieval. The major conclusions from the PNNL assessment were a) new access holes can be located within the 39-ft (4-m)-diameter center of the domes where the concrete is in compression in both the radial and hoop directions; b) the tanks meet the ACI-349 strength requirements with new 6-ft (2-m)-diameter access holes bored in the tank dome (and smaller holes will have even higher safety margins); and c) multiple access holes can be installed as long as the center-to-center distance is greater than 4.5 times the diameter of the largest hole.

- Online configured sensors for in situ, real-time chemical analysis of Hanford Site waste in tanks and pipes. Laboratory testing was performed with an online configured Raman spectroscopy system to detect and quantify Raman-active analytes in a Hanford tank waste sample. Measurements on waste simulants were performed to populate the training data set of a chemometric model that will be used to automate the interpretation of Raman spectra in tank waste for chemical analyte identification and quantification, both of which are ultimately necessary to support tank farm and WTP waste management and processing operations. An online Raman spectroscopy system and other complementary on-line instruments could be qualified and configured for field deployment (tank farms and/or WTP) in the future to provide real-time chemical analysis results, offset the demand for traditional sampling and offline analysis, and improve worker safety.

5.3.6 Single-Shell Tank Closure and Interim Measures Program

P Rutland

The SST Closure and Interim Measures Program is responsible for the closure of SST WMAs, conducting PAs, and performing agreed upon interim measures in and around SST WMAs.

Current efforts are focused on the development, submittal, and review of closure documents for WMA C; conducting PAs for WMA C, WMA A-AX; 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.

Closure activities in CY 2018 included field and engineering activities to support WMA C Closure, conducting characterization activities at WMA A-AX, and continued focus on the development and obtaining approval of closure documents. All closure documents requiring regulatory approvals for closure of WMA C were with the approving organizations in FY 2018. By the end of CY2018, the WMA C Phase 2 RCRA Facility Investigation (RFI) Report (RPP-RPT-58339) was approved by Ecology; the WMA C RCRA Corrective Measures Study (CMS) (RPP-RPT-58379) was approved by Ecology; the Waste Incidental to Reprocessing (WIR) Basis Document had undergone public review and was undergoing review by the U.S. Nuclear Regulatory Commission; comments had been received from Ecology on the RCRA Tiers 1, 2, and 3 Closure Plans; comments from review of the WMA C Appendix I Performance Assessment were being resolved; and the DOE Order 435.1 Tier 1 and 2 Closure Plans were with DOE.

In addition, grouts for closure of the C-200 Series tanks and associated pipe encasement were developed and tested, characterization activities for the 241-C-301 Catch Tank were underway, and the evaluation for removal of remaining equipment is nearly completed.

RPP-PLAN-62041, *Sampling and Analysis Plan for WMA A-AX Focus Area 1 (Tanks 241-A-104 and 241-A-105)*, was developed for a focus area around tanks 241-A-104 and 241-A-105 in WMA A-AX in CY 2018 and field work was initiated. By the end of the calendar year, three of the five direct push logging holes were completed and sampling was initiated on one of the five locations. This effort leverages previous work for the 200-DV-1 operable unit in providing advanced characterization that enables improved assessment of contaminant flux in the vadose zone and potential impacts to groundwater.

5.3.6.1 Performance Assessments. Work was conducted during CY 2018 to support ongoing PA development and documentation updates associated with 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.

Review by Ecology of three of the four WMA C HFFACO Appendix I initial drafts of PA documents (RPP-ENV-58806, Rev 0; RPP-RPT-58329, Rev 2; RPP-RPT-59197, Rev 1) was completed and Ecology's comments were received in July 2017 (17-NWP-085). Dispositioning the Ecology comments in a comment resolution process was initiated in the latter half of CY 2017 and continued in FY 2018.

In addition, Maintenance and Monitoring Plans and an Unresolved Waste Management Question (UWMQ) procedure were developed to support the WMA C PA maintenance effort. 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 (RPP-ENV-58782, Rev 0; RPP-ENV-58806, Rev 0; RPP-RPT-58329, Rev 2; RPP-RPT-59197, Rev 1), 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]).

In CY 2018, DOE Order 435.1 performance assessment (RPP-ENV-58782) and the complimentary WIR Evaluation have been also undergoing an independent review by the U. S. Nuclear Regulatory Commission as a part of its consultation with DOE-ORP on the WIR-related decisions at WMA C. A public comment period on the Draft Waste Incidental to Reprocessing (WIR) Evaluation for WMA C was held from June 2018 and November 2018 and response to comments received are being developed. PNNL provided different types of technical support to the PAs during CY 2018, including technical peer reviews of PA documents, and response disposition to regulator comments. In addition, PNNL strengthened the conceptual model basis for tank farms by identifying the potential impacts of small-scale heterogeneities on both past leak and closure scenarios.

Preparation of a draft preliminary PA for WMA A-AX to meet the requirements of DOE O 435.1, *Radioactive Waste Management*, continued in CY 2018. Other WMA A-AX HFFACO Appendix I PA documentation will be prepared to meet federal, state, and TPA (Ecology et al. 1989a) requirements. The work supports risk assessment and modeling efforts needed to help guide retrieval and RCRA Facility Investigation/Corrective Measures Study characterization activities. The draft preliminary PA documents prepared in CY 2018 include model package reports for the geologic framework model and the flow and contaminant transport numerical model, a tank residual data package and an engineered system data package.

5.3.6.2 Interim Surface Barriers. Two interim surface barriers (ISBs) 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. The most recent report on vadose zone monitoring at the T & TX tank farm interim barrier sites in FY 2017 (RPP-RPT-60833, Rev. 0) was released in October of 2018.

Two additional interim surface barriers have been completed over portions of the SX Tank Farm. Construction activities and the third panel at SX Tank Farm began in 2018. The SX Tank Farm interim surface barriers are being constructed of modified asphalt and a single evapotranspiration basin. Located south of SX Tank Farm, the evapotranspiration basin will be used to dispose of water collected by the ISBs. In addition, the design of a third ISB for TX Farm was developed in CY 2018.

5.4 Hanford Tank Waste Treatment and Immobilization Plant

M. Lihosit

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, LAW Facility, and Analytical Laboratory) along with support buildings and associated infrastructure (BOF)). Construction of the WTP is managed in accordance with the RCRA Permit. In 2018, Bechtel National Inc. continued executing against its new contract modifications, signed in December 2016 with DOE, that prioritize finishing the LAW Facility, BOF, and Analytical Laboratory to feed waste directly from the Hanford Tank Farms to the LAW facility under an approach called Direct Feed Low-Activity Waste (DFLAW). The DFLAW approach calls for the treatment of tank waste in the LAW facility as soon as 2022. During DFLAW operation, the WTP will utilize a new facility called the EMF).

A description of the WTP facilities and the progress at each facility in 2018 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 2018, work continued to resolve the remaining technical decisions that have impacted design and construction at the Pretreatment Facility since 2012. With testing of the Standard High Solids Test Vessel pulse jet mixers and control systems complete, significant progress on the technical decisions continued in 2018 with resolution of the last decisions anticipated in second quarter CY 2019.

With respect to DFLAW operations, TankSide Cesium Removal (TSCR) plays a vital role in the overall flowsheet with filtration and cesium removal being the key processes in this unit operation. In support of developing the technical baseline process, PNNL completed a series of technical support activities, employing expertise in simulant development; waste filtration; ion exchange; column drying dynamics; and hydrogen gas generation to strengthen the technical underpinnings of the TSCR system. As TSCR was being rapidly conceived and designed, PNNL pivoted quickly to collect full-height column data needed to validate planned operations with crystalline silicotitanate. These data impacted key operational aspects of TSCR, such as the number of ion exchange columns needed, filter media selection, and the duration of the column drying process. PNNL continues to support the tank farm contractor and its design agent in maturing technologies in the areas of ion exchange performance, gas generation, simulant development, filtration, and TSCR's safety basis.

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 2018, HLW design engineering activities resumed and progress continued to deliver active facility procurements. In November 2018, components for a specialized 60-ton capacity crane were received. The overhead bridge crane will become the HLW Facility's primary canister cask-handling crane.

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 melter; poured into containers; and allowed to cool to form a solid, immobile glass form. In 2018, The U.S. Department of Energy approved the LAW Facility Documented Safety Analysis, which identifies the potential hazards associated with treating low-activity tank waste and the controls that will be used to address those hazards in order to protect workers, the public, and the environment. The Documented Safety Analysis is a federal requirement that sets rules for safety controls at DOE nuclear facilities. In addition, the LAW Facility electrical switchgear building received permanent power in 2018. Energizing the switchgear building provides workers the ability to systematically begin startup testing of the LAW Facility installed electrical components and process equipment.

To support DFLAW operations, baseline glass models and an algorithm were issued to ensure both melter process and product performance properties will meet predefined constraints. Development and implementation of enhanced glass property models and glass formulations will lower the cost of Hanford tank waste management by reducing the schedule for tank waste treatment and reducing the amount of HLW and LAW glass for storage, transportation, and disposal. Enhanced glass formulations may also result in more cost-effective direct vitrification of the HLW fraction without significant pretreatment.

5.4.4 Analytical Laboratory

Once operational, the Analytical Laboratory will process about 3,000 waste samples annually to support glass formulation and waste-form compliance for the DFLAW approach. In 2018, the Laboratory realized several significant accomplishments. The Laboratory electrical system was fully energized and the Washington State Department of Ecology approved the Laboratory operating dangerous waste permit, marking the first major facility to complete all phases of the permitting process – from initial design, through groundbreaking and construction to an approved operating permit. Work also began at a 3,300-ft² (306.6-m²) laboratory at Columbia Basin College (CBC) in Pasco, Washington, that will prepare the Laboratory's future staff for work inside the WTP Laboratory. At the CBC lab, methods, processes, and procedures are currently being developed to support future DFLAW commissioning work.

With respect to CBC activities, PNNL is providing technical expertise in laser ablation, fusion digestion, and mass spectrometry to CBC technical staff to develop the test methods and procedures. These test methods and procedures will be used to support analytical measurement of both incoming waste streams and melter feeds for LAW vitrification. Part of this support is the development or identification of matrix matched glass standards that could be used to calibrate the analytical equipment within the compositional region of interest for LAW vitrification.

5.4.5 Balance of Facilities

The WTP's BOF 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 systems; steam systems; and communication and control systems. Turnovers from construction to startup began in 2016 as the BOFs are non-nuclear industrial buildings. By the end of 2018, workers had completed the startup and testing phase for 49% of BOF's 57 systems. These accomplishments included completed startup testing for: a Non-Radioactive Liquid Waste Disposal System (the first transfer of an entire building for commissioning), a Water Treatment Building, a Main Site Electrical Switchgear Building, a BOF Electrical Switchgear Building, and a Fire Water Pump House. 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

Concrete placements of the Effluent Management Facility (EMF) began in March 2017. 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. In 2017, placement of concrete for the floor slab of the utility and process buildings was completed; 2018 marked a significant year of construction progress for the facility as Ecology approved the dangerous waste permit modifications needed to finish EMF construction. The permit preceded workers completing concrete placements for the main processing facility followed by structural steel interior and roofing installations. By the end of 2018, major commodity installations were well underway at the EMF including electrical, piping, and mechanical as well as large process vessel installations.

The EMF exhaust stack designs were evaluated and led to verification testing for the LAW facility stack. Federal regulations mandate the sampling and monitoring of releases from airborne radioactive substances from exhaust stacks. Sample collection systems must be designed to extract samples that are representative of the airborne effluent stream.

5.4.7 General Integrated Flowsheet Support

Developing an integrated flowsheet that successfully links all of the unit operations (e.g., tank farm operations, pretreatment, vitrification, disposal) is a challenging endeavor. Establishing the technical baseline and ensuring safe and efficient transition from start-up/commissioning to steady state operations requires lines of communications between facilities, defining process envelopes or windows that provide each facility with operational flexibility, and sound technical underpinnings for each unit operation. Additional risk reductions will continually be sought as the flowsheet develops and matures through initial and steady state operations. During operations, emerging technical issues will surface that were not anticipated and the ability to respond effectively and efficiently will be paramount to avoid facility downtimes. Therefore, general flowsheet support and developing critical capabilities or test beds to support baseline operations, emerging operational issues, or to evaluate alternative process strategies or unit operational changes prior to implementation are invaluable.

Development and operations of the Hanford radioactive test platform in the Radiochemical Processing Laboratory is one effort in support of the general flowsheet. The radioactive waste processing test platform is being used to optimize the baseline DFLAW flowsheet with respect to integrated unit operations, provide process data (such as technetium speciation) to inform critical decisions on disposal options, and evaluate a wide variety of proposed changes to the baseline flowsheet (before facility implementation, lowering risks) with actual waste samples from the Hanford tank farms. Design and operational options evaluated included assessing changes to the DFLAW flowsheet, including dead-end filtration planned for the Low-Activity Waste Pretreatment System and crystalline silicotitanate media for TSCR and Low-Activity Waste Pretreatment System. In addition, vitrification was completed of samples from AP-105 and AP-107 that were received and pretreated. These tests represent the first continuous melter runs of actual LAW in support of DFLAW. Use of this test platform capability to process actual waste slated to be processed through DFLAW provides valuable data and insight on the performance of the plant in upcoming planned operations.

5.5 Long-Term Stewardship

J. Shoemake

The Hanford Site's Long-Term Stewardship (LTS) Program is responsible for managing over 220 mi² (570 km²) of the Hanford Site, an area which includes 1,716 Waste Information Data System (WIDS) waste sites and six Manhattan-Project-Era production reactors that have been placed in interim safe storage. The LTS Program works to the direction of the DOE/RL-2010-35, *Hanford Long-Term Stewardship Program Plan* to manage the post-cleanup requirements specified in the associated cleanup decision documents.

As cleanup is completed (i.e., remedial action objectives are achieved as defined in the applicable decision documents) in a geographic area of the Hanford Site, the area's mission transitions from cleanup to LTS. Accordingly, contractual responsibilities are transitioned from DOE-RL's cleanup contractor to the mission support contractor. Since 2010, through collaborative efforts with DOE-RL and its prime contractors, cleaned-up waste sites and other facilities in 14 geographic areas and six cocooned reactor facilities were transitioned from the River Corridor Closure Contractor to Mission Support Alliance'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. The LTS program maintains an internal library of documents referenced in the TTPs and additional information that may be relevant to the closure history. More than 25,000 cleanup and historic documents have been identified, indexed, and tagged as LTS records that are associated with LTS-managed land areas and WIDS waste sites.

The LTS Program manages post-cleanup obligations to ensure continued protection of human health and the environment. The LTS Program routinely assesses waste sites with institutional controls (IC) as defined in CERCLA decision documents. ICs are designed to be protective of human health and the environment, and are used to protect the integrity of a response action and minimize the potential for exposure to residual contamination. The Program is also responsible for coordinating with other Hanford Site contractors and leading the preparation and publication of the Hanford Site CERCLA Five-Year Review. The Site's fourth CERCLA 5 year review was completed in 2017 (DOE/RL-2016-01) and the next review is due in 2022.

Part of managing post-cleanup obligation involves S&M of interim-stabilized reactor facilities (i.e., safe storage enclosures [SSEs]), WIDS sites, institutional controls, radiological control posted areas, and revegetated site areas as well as other post-cleanup obligations along with responsibility for coordinating Hanford Site CERCLA Five-Year Reviews. In 2018, the following activities included:

- S&M activities of the 7 cocooned reactors (i.e., SSEs), which included conducting an annual exterior visual inspection; annual radiological monitoring around the outside of the SSEs and inside the vestibules, as required; preventing activities in proximity to the SSEs from affecting the final hazard categorization of the SSEs; conducting exterior visual assessments after off-normal events; and maintaining an area free of vegetation around the SSEs to reduce the potential for fire.

Note: The SSEs are designed to protect the reactor for 75 years while radioactive decay continues, ultimately making the structures safe for demolition and removal. The next reactor entries and

internal assessments will be conducted in 2025 to evaluate the condition of the structures and identify potential deterioration of the reactor core, shield walls, and roof.

- S&M of WIDS sites, which included annual inspections of 42 accepted WIDS sites and active WIDS sites, as required; assessing 226 waste sites with institutional controls as defined in CERCLA decision documents and managing inactive WIDS sites in accordance with their hazard categorization. These activities support the CERCLA 5-year review assessments for waste sites where hazardous substances, pollutants, or contaminants will remain at the site above levels that allow for unlimited use and unrestricted exposure.
- S&M of 24 remaining radiological posted areas, which included inspections of proper postings, conducted annual contamination surveys, and implementing biological controls as needed to maintain radiation protection.
- S&M of controls for bat habitats, which included ensuring access controls and signage were in place.
- S&M of revegetated sites including revegetation monitoring of representative sites, reporting on revegetation monitoring results, management of noxious weeds, and conducting rectification and other plantings, as needed. This resulted in a total of 95 acres that either needed complete rework of the site or supplemental work with shrubs and/or forb plugs. In 2018, 63 ac (25.5 ha) were completed, and the additional 32 acres will be completed in FY 2019/2020.
- Management and decommissioning of underground injection control (UIC) wells. This included maintaining the Hanford Sitewide list of UIC wells, supporting UIC reports to Ecology, and decommissioning inactive UICs as resources and priorities allow. In 2018, the LTS Program decommissioned 10 underground-injection-wells.
- Management and maintenance of the Hanford Site's LTS Records Library. In 2018, 3,800 records and 6,900 records were captured and indexed in the LTS electronic records database. These records include historical cleanup information, as well as records created during the execution of LTS activities.
- Updated Sitewide Institutional Controls Plan for the Hanford Site CERCLA Response Actions and RCRA Corrective Actions (DOE/RL-2001-41) within 180 days after the *Hanford Area Superfund Site 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* was signed to include ICs required by the new ROD (DOE and EPA 2014)..

Note: The LTS Program continuously maintains current information regarding IC requirements specified in RCRA and CERCLA decision documents, and will update DOE/RL-2001-41, *Sitewide Institutional Controls Plan for the Hanford CERCLA Response Actions and RCRA Corrective Actions*, as the EPA approves/published new CERCLA records of decision.

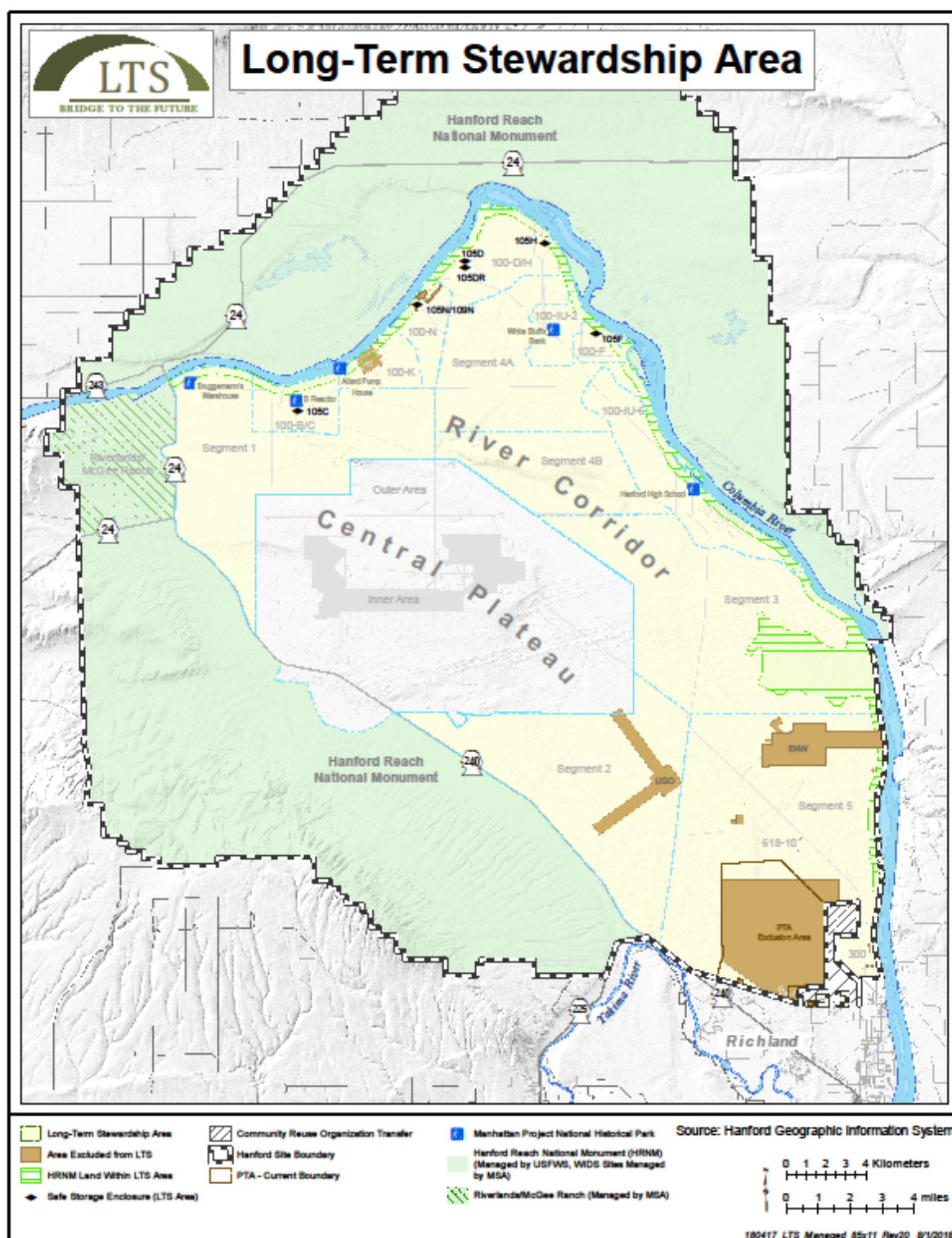


Figure 5-16. Land Areas Managed by the Long-Term Stewardship Program as of 2018.

5.6 Scientific and Technical Contributions to Hanford Site Cleanup

DM Wellman

PNNL is providing scientific and technological contribution to the Hanford Site cleanup mission that enhance credibility and defensibility for cleanup decisions and actions with regulatory and stakeholder acceptance and reduce technical risks to the Hanford Site mission. Overall, PNNL is:

- Providing systematic analyses of integrated system and constraints therein to identify and address technical gaps and operational risks
- Providing scientific and technological solutions to enable the baseline and enabling opportunities for improvement in process efficiency
- Providing independent technical basis for near- and long-term decisions and mission needs
- Reducing technical uncertainties and programmatic/operational risks to support consistency in decision making, technical integration, and resolution of long-term technical issues.

Specific contributions are integrated with Section 5 except for groundwater remediation scientific and technical support, which is provided below.

5.6.1 Groundwater Remediation

In addition to the waste and source area efforts described above, PNNL is providing scientific and technical support for multiple technical aspects of the groundwater remediation and monitoring efforts for the Hanford Site.

5.6.1.1 Remediation Support. Candidate remediation technologies is being evaluated in support of the 200-UP-1 operable unit ROD-required iodine-129 remedy evaluation. While other contaminants in the 200-UP-1 operable unit could be addressed with an existing remedial technology, the iodine-129 contamination required additional evaluation to identify an appropriate remedy. The results are being used to support a decision of whether or not to conduct treatability testing for iodine-129 and to help determine whether a technical impracticability waiver is appropriate. A technical basis for a Technical Impracticability (TI) waiver for iodine-129 is being provided by PNNL. Relevant parameters and information are being compiled to support the TI waiver process, including integrating geochemical process descriptions relevant at the field-scale to identify potential risks for leaving iodine-129 in place. PNNL is also providing a technical basis for risk-informed iodine-129 standards and a strategy for iodine-129 plume management to use in conjunction with the technology and TI waiver assessment efforts.

Technical defensibility for assessing attenuation mechanisms for the carbon tetrachloride plume in the 200-ZP-1 operable unit is provided by PNNL. A rigorous review was conducted of carbon tetrachloride degradation mechanisms and the types of conditions where these may be relevant to natural attenuation in the 200-ZP-1 operable unit aquifer. This review also examined the 200-ZP-1 operable unit monitoring data and identified indicators of degradation in the aquifer. Analysis of this information included developing a range of carbon tetrachloride degradation rates that are consistent with the

monitoring data. This information is being used by the operable unit to plan remedy optimization activities with respect to the transition from active to passive remediation components.

Biofouling constituents are being analyzed in new 200-West P&T injection wells being installed in the 200-ZP-1 operable unit. Aquifer sediment samples were analyzed for microbial and chemical constituents associated with well fouling in an effort to determine the potential for fouling in the new injection wells. Injection wells returning treated groundwater from the Hanford 200-West P&T facility are becoming fouled over time, decreasing overall injection capacity, which adversely affects operation of the 200-West P&T facility.

Potential short- and long-term system performance effects of the 200-West P&T effluent injection impacts to the 200-West aquifer are also being identified. PNNL is leading the development of quantitative conceptual models to determine the impacts of the P&T system on the aquifer and provide performance evaluations of operational changes and aquifer-system injection limits. This work supports remedy optimization efforts and short- and long-term remedy decisions related to multiple operable units within the Hanford Central Plateau.

Performance assessment of enhanced remediation being implemented for a uranium source zone in the 300-FF-5 operable unit is also being supported. Real-time monitoring was provided of amendment injection using electrical resistivity tomography to assess distribution of phosphate in the targeted portion of the periodically rewetted zone of the 300-FF-5 operable unit aquifer. This information supported operational decisions during implementation and provided data used as part of remedy performance assessment. PNNL conducted the laboratory assessment of sediment sample to quantify the uranium mobility change induced by the phosphate treatment. This information is a key aspect of the performance assessment and role of the enhanced attenuation portion within the overall passive attenuation approach for the plume.

5.6.1.2 Monitoring and Data Analysis Support. Innovative approaches are being identified for using geophysical methods to identify key stratigraphic features that create preferential flow paths impacting contaminant transport and remedy applications. High-transmissivity paleo-channels and the configuration of mud units affect contaminant transport in the 200 Areas of the Hanford Central Plateau, but geologic boreholes only provide data at a single location and the geology in the large distances between boreholes can only be estimated. The geophysical methods identified more continuous subsurface geologic information, providing pertinent input to predictive models of contaminant transport used for decision making.

In support of 100-HR-3 Area plume assessments and remedy closure, a characterization approach is being demonstrated for identifying chromium transport between the upper and lower aquifers. The characterization approach identifies the hydraulic connection between the upper, unconfined aquifer and the lower Ringold Upper Mud because it impacts the selection of an optimal P&T strategy and an appropriate closure strategy for the 100-HR-3 remedy. Traditional well-based approaches available for contractor implementation are expensive and provide limited data. Thus, an advanced method based on integrated use of multiple data types is needed. This includes the use of data from existing wells, tracer tests, and geophysics to enable more cost-effective P&T operations. The innovative approach supports remedy design and closure and 100-HR-3 and other sites within the River Corridor.

Improvement of the PHOENIX (PNNL-Hanford Online Environmental Information Exchange) web application that provides universal access to decades of Hanford site data. PHOENIX continues to provide easy access to a suite of public-facing web-GIS applications that inform decision-making. PHOENIX continues to support monthly updates to the Remediation Dashboard to visually represent the remediation progress of the Hanford Site's groundwater treatment systems. This tool provides open and transparent access to and visualization of data to facilitate evaluation and communication, furthering public trust and engaging the regulatory and stakeholder communities. PHOENIX enables DOE to communicate cleanup progress and risk reduction as a direct result of cleanup activities.

Online decision-support tools (SOCRATES) were created to meet DOE needs for groundwater assessments, real-time remedy support, and P&T exit strategies. A new NQA-1 qualified tool is being created that enable users to analyze water-level or contaminant data and provide the technical basis for shutting down P&T systems and reaching site closure. The tools provide rapid online access to data and data analytics relevant to contaminant transport and remedy decisions, enabling identification of transition points from active to passive remediation. An additional tool within SOCRATES enables access to real-time geophysical imaging of in situ subsurface amendment delivery, providing critical feedback to field operators to optimize remedy performance. The new tools also enable users to visualize remotely-sensed data and identify elevation changes relevant to waste site management and early response to potential structural collapses. This is accomplished through an automated data acquisition process that provides data at regular frequencies and analytical tools that provide decision support. In addition, remotely sensed data provides seasonal estimates of groundwater base flow to the Columbia River, which can improve predictive simulations that are used to make decisions on waste site remedies, site closure, and long-term protectiveness of human health and the environment. Use of remote sensing data is cost-effective and eliminates the need for manual flux measurements at the groundwater-surface water interface.

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2018 Highlight

Effluent Releases

Nonradiological and radiological air effluent releases for calendar year 2018 were similar to calendar year 2017 releases and below permit limits and applicable standards.

Surveillance Program

Air sampling was conducted at 96 stations either on the Hanford Site or at offsite locations. For the year, the operational availability for all stations was approximately 99% and approximately 98% of all scheduled samples were collected.

6.0 Air Monitoring

CJ Perkins, DL Dyekman

Air quality is monitored using stack sampling at the sources and 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 standards. This report presents 2018 measurement results.

6.1 Air Effluent Monitoring

DL Dyekman

DOE contractors monitor airborne pollutants from site facilities to quantify emissions, determine compliance with federal and state regulatory requirements, monitor the effectiveness of emission control equipment, and assess environmental impacts. Most facility radioactive air emission point sources are actively ventilated stacks sampled prior to the point of release to the environment. Airborne emissions with potential to contain radioactive materials are sampled for gross alpha, gross beta and radionuclides specified in the Hanford Site Air Operating Permit (AOP) [Ecology 2016]. Nonradioactive air pollutants are sampled or estimated based on material and chemical use.

Quantified emissions estimates are documented in annual reports available to the public. The DOE annually prepares and submit reports of Hanford Site radionuclide air emissions and non-radioactive chemical emissions as required per the Hanford Site AOP.

6.1.1 Radioactive Airborne Emissions

Small quantities of radionuclides are emitted to the environment through radioactive emission point sources (i.e., stacks and vents) during routine operations. The federal and state permit requirements contained in the AOP define which stacks require sampling, how and how often to collect the samples, and the isotopes to be measured. The commonly measured isotopes include: tritium (i.e., hydrogen-3), strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, and americium-241.

Emission points are sampled and monitored continuously if they have the potential to emit radionuclides that exceeds 1% of the 40 CFR 61, Subpart H public dose limit of 10 mrem/yr or

100 microsievert (μSv)/yr. Continuous sampling is defined and described in more detail in the American National Standards Institute (ANSI) N13.1, *Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stacks and Ducts of Nuclear Facilities* (ANSI 1999). For other release points, periodic confirmatory measurements are made to verify low emissions.

Offsite radiological dose assessments related to stack releases are ideally based on direct measurements of radionuclide concentrations in specific environmental media such as air, water, and food measured at offsite locations. However, amounts of many radioactive materials released to the atmosphere from Hanford Site sources are too small to be measured in media after they are released from stacks and diluted through miles of dispersion in the environment. Radioactive air emissions from the Hanford Site are decreasing over time because the production and processing of nuclear materials ceased more than 30 years ago. For the radionuclides present in measurable amounts, it can be difficult to distinguish the small contribution of Hanford Site stacks from other contributions caused by fallout from historical nuclear weapons testing and naturally occurring radionuclides such as uranium and its decay products. As a result, the dose assessment process incorporates conservative assumptions to ensure that calculated doses are likely to be overestimated. In the air pathways calculations, gross alpha and gross beta radiation measurements in stack emissions are added to the measured emissions of plutonium-239/240 and cesium-137, respectively. The actual measured air releases of plutonium-239/240 and cesium-137 are a fraction of assumed releases that include gross radioactivity values. Although gross alpha and gross beta levels in stack emissions are similar to air background levels, the addition of these values ensures that contributions from any unmeasured radionuclides are added into the estimated doses. The dose to the Maximally Exposed Individual calculated in 2018 from Hanford Site operations was 0.22 mrem (1.2 μSv), which is 0.22% of the 100 mrem (1,000 μSv) annual public dose limit specified in DOE O 458.1. Radon-219 and tritium emitted from the 325 Building stack contributed 99% of this offsite dose. For more information on doses due to radiological releases (Section 4.2).

Radioactive air emission points are located on the Hanford Site in the 100, 200, 300, and 400 Areas. Table 6-1 lists the 43 stacks that operated on the Hanford Site during calendar year (CY) 2018. Table 6-2 shows the curies released from these stacks in CY 2018.

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (3 Pages)

Stack ID	Facility	Individual Sample Analyses	Additional Sample Analyses
105-KW	KW Fuel Storage Basin	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{239}Pu , ^{238}Pu , ^{241}Pu , ^{241}Am
105-KW Annex	KW Fuel Storage Basin	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{239}Pu , ^{238}Pu , ^{241}Pu , ^{241}Am
291-A-1	PUREX	Alpha, Beta	^{129}I , ^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu , ^{241}Am
296-A-18	241-AY-101 Annulus	Alpha, Beta	None
296-A-19	241-AY-102 Annulus	Alpha, Beta	^{137}Cs
296-A-20	241-AZ Tank Farm Annuli	Alpha, Beta	None
296-A-21A	242A Building Vent	Alpha, Beta	None
296-A-22	242A Evaporator Vessel Vent	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{239}Pu , ^{238}Pu , ^{241}Am
296-A-28	241-AW Tank Farm Annuli	Alpha, Beta	None
296-A-30	241-AN Tank Farm Annuli	Alpha, Beta	None
296-A-41	241-AP Tank Farm Annuli	Alpha, Beta	None

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (3 Pages)

Stack ID	Facility	Individual Sample Analyses	Additional Sample Analyses
296-A-42	241-AY/AZ Tank Farm	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-A-43	702AZ Building Exhauster	Alpha, Beta	None
296-A-44	241-AN Tank Farm	Alpha, Beta	^{90}Sr , ^{137}Cs , ^{154}Eu , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{241}Pu
296-A-45	241-AN Tank Farm	Alpha, Beta	^{90}Sr , ^{137}Cs , ^{154}Eu , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{241}Pu
296-A-46	241-AW Tank Farm	Alpha, Beta	^{90}Sr , ^{137}Cs , ^{154}Eu , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{241}Pu
296-A-47	241-AW Tank Farm	Alpha, Beta	^{90}Sr , ^{137}Cs , ^{154}Eu , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{241}Pu
296-A-48	241-AP Tank Farm	Alpha, Beta	^{90}Sr , ^{137}Cs , ^{154}Eu , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{241}Pu
296-A-49	241-AP Tank Farm	Alpha, Beta	^{90}Sr , ^{137}Cs , ^{154}Eu , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{241}Pu
296-B-1	B Plant	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-B-10	WESF	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-E-1	Effluent Treatment Facility	Alpha, Beta	None
FFTF-CB-EX	FFTF	None	Emissions estimated by calculation
437-MN&ST	FFTF MASF	Alpha, Beta	None
437-1-61	FFTF MASF	Alpha, Beta	None
296-H-212	CSB	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-P-22	241-SY Tank Farm Annuli	Alpha, Beta	None
296-P-23	241-SY Tank Farm	Alpha, Beta	None
296-P-45	241-T-111 Tank Exhauster	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-P-49	241-AX Tanks Exhauster	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-P-50	241-AX Tanks Exhauster	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-P-107	241-C Tanks Exhauster	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
291-S-1	S Plant	Alpha, Beta	None
296-S-16	219-S	Alpha, Beta	None
296-S-21	222-S	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-S-25	241-SY Tank Farm	Alpha, Beta	None
291-T-1	T Plant	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-T-7	2706T	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
296-W-4	WRAP	Alpha, Beta	^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
EP-324-01-S	324 Building	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
EP-325-01-S	325 Building	Alpha, Beta	Tritium, Radon, numerous additional isotopes
EP-331-01-S	331 Building	Alpha, Beta	^{137}Cs , ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am
EP-331-01-09-S	331 Building	Alpha, Beta	^{14}C
CSB = Canister Storage Building			
FFTF = Fast Flux Test Facility			

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (3 Pages)

Stack ID	Facility	Individual Sample Analyses	Additional Sample Analyses
MASF	= Material and Storage Facility	PUREX	= Plutonium Uranium Extraction Facility
WESF	= Waste Encapsulation and Storage		
WRAP	= Waste Receiving and Processing		

The quantity of radionuclide air emissions reported in 2018 were similar in magnitude to those reported in 2017. Table 6-2 summarizes Hanford Site radioactive airborne emissions in 2018.

Table 6-2. Hanford Site Radioactive Airborne Emissions in Calendar Year 2018. (2 Pages)

Radionuclide	100 Area (Ci)	200-East Area (Ci)	200-West Area (Ci)	300 Area (Ci)	400 Area (Ci)	Totals (Ci)
Actinium-227	NA	NA	NA	2.1E-10	NA	2.1E-10
Alpha (gross)	8.2E-06	4.2E-07	2.1E-05	4.6E-06	2.9E-07	3.5E-05
Americium-241	8.3E-06	7.8E-07	2.3E-08	2.2E-09	NA	9.1E-06
Americium-243	NA	NA	NA	1.6E-07	NA	1.6E-07
Beta (gross)	1.5E-05	1.3E-05	6.4E-06	1.4E-05	1.9E-06	5.0E-05
Carbon-14	NA	NA	NA	1.1E-04	NA	1.1E-04
Cesium-137	1.1E-05	4.3E-06	ND	2.4E-08	1.1E-11	1.5E-05
Cobalt-60	ND	ND	ND	7.7E-08	NA	7.7E-08
Europium-152	ND	ND	ND	2.0E-09	NA	2.0E-09
Europium-154	ND	ND	ND	2.2E-08	NA	2.2E-08
Gadolinium-153	NA	NA	NA	3.7E-10	NA	3.7E-10
Iodine-129	NA	1.3E-03	NA	NA	NA	1.3E-03
Krypton-85	NA	NA	NA	1.1E-06	NA	1.1E-06
Neptunium-237	NA	NA	NA	1.4E-08	NA	1.4E-08
Plutonium-238	1.1E-06	5.0E-08	ND	3.7E-08	NA	1.2E-06
Plutonium-239	7.2E-06	9.4E-07	7.2E-07	6.7E-09	2.3E-13	8.9E-06
Plutonium-241	2.8E-05	ND	ND	3.8E-07	NA	2.8E-05
Radium-226	NA	NA	NA	3.6E-10	NA	3.6E-10
Radon-219	NA	NA	NA	5.59E+02	NA	5.59E+02
Radon-220	NA	NA	NA	8.85E+02	NA	8.85E+02
Radon-222	NA	NA	NA	0.0E+00	NA	0.0E+00
Ruthenium-106	ND	ND	ND	3.0E-09	NA	3.0E-09
Sodium-22	NA	NA	NA	NA	2.1E-10	2.1E-10
Strontium-90	1.8E-05	7.6E-06	2.2E-07	1.8E-07	NA	2.6E-05
Technetium-99	NA	NA	NA	4.2E-06	NA	4.2E-06
Tritium (elemental)	NA	NA	NA	8.25E+01	NA	8.25E+01

Table 6-2. Hanford Site Radioactive Airborne Emissions in Calendar Year 2018. (2 Pages)

Radionuclide	100 Area (Ci)	200-East Area (Ci)	200-West Area (Ci)	300 Area (Ci)	400 Area (Ci)	Totals (Ci)
Tritium (tritiated water vapor)	NA	NA	NA	2.52E+02	1.6E-02	2.52E+02
Uranium-232	NA	NA	NA	8.5E-09	NA	8.5E-09
Uranium-233	NA	NA	NA	1.9E-08	NA	1.9E-08
Gross Alpha	2.4E-05	3.5E-06	1.3E-06	1.5E-07	5.6E-07	3.0E-05
Gross Beta	5.0E-05	2.7E-05	1.8E-06	4.9E-06	3.1E-06	8.7E-05
Ci = curies NA = Not applicable ND = Not detected						

6.1.2 Non-Radioactive Air Pollutants

Non-radioactive air pollutants are emitted from Hanford facility operations and fossil fuel combustion. The non-radioactive air emissions fall under two general categories of pollutants: criteria pollutants and hazardous or toxic air pollutants. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, volatile organic compounds, particulate matter, and sulfur dioxide. These criteria pollutants are named after EPA regulations that establish national ambient air quality standards criteria that define allowable concentrations of the compounds in air. Hazardous and toxic air pollutants are defined in federal and state regulations and are known or suspected to cause cancer or other serious health effects. The federal *Clean Air Act Amendment of 1990* included a list of 187 hazardous air pollutants (HAPs) that are considered dangerous to human health and the environment. In addition to the federal HAP list, the Washington Administrative Code lists toxic air pollutants that include the federal list of 187 HAPs and adds approximately 200 more substances and compounds.

The Hanford Site AOP and WAC 173-400-105 require the DOE to prepare an annual Air Emissions Inventory [DOE 2018] report for submittal to the Washington State Department of Ecology. The Air Emissions Inventory report includes measured and estimated emissions of the criteria and toxic air pollutants for permitted emission units listed in the AOP. The most significant source of emissions is from combustion of the fossil fuels diesel, gasoline, natural gas, and propane. Fossil fuels are burned during routine operations to produce steam and provide a local source of light and electricity. The emission estimates are calculated using published EPA formulas (*Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources* [EPA 1995]). The fossil fuel combustion sources accounts for nearly 100% of carbon monoxide, oxides of nitrogen, particulate matter, and sulfur dioxide emissions reported annually. Other sources exhibiting a large fraction of total emissions are the tank farm exhausters producing roughly 96% of reported ammonia and 70% of the toxic air pollutants, and fuel dispensing stations (i.e. vehicle gas refueling stations) emitting greater than 64% volatile organic compounds due to evaporation. Table 6-3 summarizes the Hanford Site emissions of nonradioactive criteria and toxic air pollutants discharged to the atmosphere in CY 2018.

**Table 6-3. Calendar Year 2018 Hanford Site Criteria
and Toxic Air Pollutant Emissions.**

Constituent	2018 Releases		
	Ton	lb	Kg
Criteria Pollutants			
Particulate matter	1.5	2,947	1,337
Lead	0	0	0
Nitrogen oxides	20.7	41,403	18,777
Sulfur oxides	1.1	2,118	961
Carbon monoxide	0.0	17,904	8,120
Volatile organic compounds	6.4	12,839	5,823
Ammonia	2.2	4,350	1,973
<i>Toxic Air Pollutants</i>	0.0	4.2	2

6.2 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 air-monitoring efforts, including detailed descriptions of air sampling and analysis techniques, is provided in DOE/RL-91-50, *Hanford Site Environmental Monitoring Plan*.

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 air.

6.2.1 Hanford Site Air Monitoring

A network of continuously operating samplers at 77 locations across the Hanford Site was used during 2018 to monitor radioactive airborne materials in air near Hanford Site facilities and operations (Table 6-4). 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 2018 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 6-4. Hanford Site Monitoring Locations and Analyses
for Air Monitoring Samples. (2 Pages)**

Air Monitoring Locations		EDP Codes	Bi-Weekly	Semi-Annual Composite
On-Site				
100-K Area	N476, N534, N535, N575, N576 ^a , N578, N900 ^b	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA	
100-B Area	N588 ^a	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am	
200-East Area	N019, N158, N498, N499 ^a , N582, N957, N967, N968, N969, N970, N972, N976, N977 ^a , N978, N984, N985 ^a , N999, N931 ^b , N932	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
WTP (200-East Area)	N583, N584, N920 ^b , N924	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am	
CSB (200-East Area)	N480, N481	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA	
IDF (200-East Area)	N532, N559	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
200-West Area	N161, N168, N304, N441, N442, N449, N456, N457, N956, N963, N965, N966, N974, N987, N994, N901	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
Plutonium Finishing Plant (200-West Area)	N155, N165, N433, N554 ^a , N555 ^a , N964, N975 ^a	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA	
300 Area	N130 ^{a, b} , N557, N902 ^b , N903 ^{a, b} , N904 ^b , N905 ^{a, b} , N918 ^b	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
400 Area	N911, N912 ^b	Alpha, Beta	⁹⁰ Sr, Pu-iso, GEA	
600 Area	N928, N929, N930, N587 ^a	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
ERDF	N482 ^a , N517, N518	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
Wye Barricade	N906, N981 ^a	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
LIGO	N589 ^a	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA	
Perimeter				
Ringold Met Tower	N933 ^b	Alpha, Beta	Pu-iso, GEA, ²⁴¹ Am	
W End of Fir Road	N934 ^{a, b}	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am	
Dogwood Met Tower	N935 ^b	Alpha, Beta	⁹⁰ Sr, U-iso, GEA, ²⁴¹ Am	
Byers Landing	N936 ^b	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am	
Battelle Complex	N937 ^{a, b}	Alpha, Beta	U-iso, GEA, ²⁴¹ Am	
Horn Rapids Substation	N938	Alpha, Beta	⁹⁰ Sr, Pu-iso, GEA, ²⁴¹ Am	
Prosser Barricade	N939 ^{a, b}	Alpha, Beta	⁹⁰ Sr, Pu-iso, GEA, ²⁴¹ Am	
Yakima Barricade	N907 ^a	Alpha, Beta	⁹⁰ Sr, Pu-iso, GEA, ²⁴¹ Am	
Rattlesnake Springs	N940	Alpha, Beta	⁹⁰ Sr, Pu-iso, GEA	
Wahluke Slope	N941 ^b	Alpha, Beta	⁹⁰ Sr, Pu-iso, GEA, ²⁴¹ Am	
S End Vernita Bridge	N942	Alpha, Beta	⁹⁰ Sr, Pu-iso, GEA, ²⁴¹ Am	

**Table 6-4. Hanford Site Monitoring Locations and Analyses
for Air Monitoring Samples. (2 Pages)**

Air Monitoring Locations	EDP Codes	Bi-Weekly	Semi-Annual Composite
Offsite Nearby Community			
Basin City School	N943 ^b	Alpha, Beta	Pu-iso, U-iso, GEA, ²⁴¹ Am
Leslie Groves-Richland	N944 ^b	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
Pasco	N945	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
Kennewick-Ely Street	N946	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA
Benton City	N947	Alpha, Beta	GEA, ²⁴¹ Am
Mattawa	N948	Alpha, Beta	GEA
Othello	N949	Alpha, Beta	U-iso, GEA, ²⁴¹ Am
Offsite Distant Community			
Yakima	N909 ^b	Alpha, Beta	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am

^a Collocated sampling location with WDOH

^b Tritium air sampler

CSB = Container Storage Building

EDP Code = environmental data point code = sampler location code

ERDF = Environmental Restoration Disposal Facility

GEA = Gamma Energy Analysis

IDF = Integrated Disposal Facility

LIGO = Laser Interferometer Gravitational-Wave Observatory

WTP = Waste Treatment Plant

WDOH = Washington State Department of Health

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 6-4) 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.

Atmospheric water vapor was collected for tritium analysis at 20 locations in 2018 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 6-1 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 (40 CFR 61, Appendix E, Table 2) are dose-based reference values that would result in a dose of 10 mrem (100 μ Sv)/yr under conditions of continuous exposure. The 2018 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-3 shows the annual average and maximum concentrations of radionuclides in air samples collected during 2018.

6.2.1.1 Monitoring Results

100-K Area. Air was monitored in 2018 at 7 locations in the 100-K Area, and analytical results showed radionuclide concentrations at or below typical Hanford Site levels. Uranium-234 and uranium-238 were detected in approximately 40% of the samples, and tritium was detected in approximately 8% of the samples. All other radionuclides of concern were below analytical detection limits.

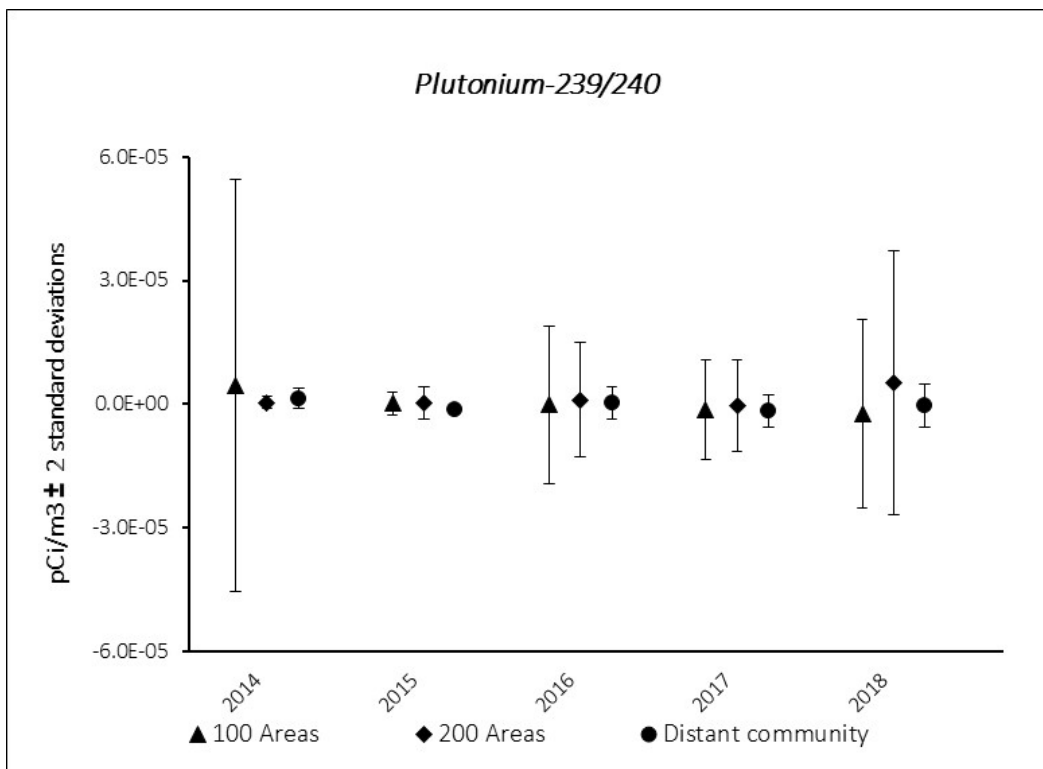
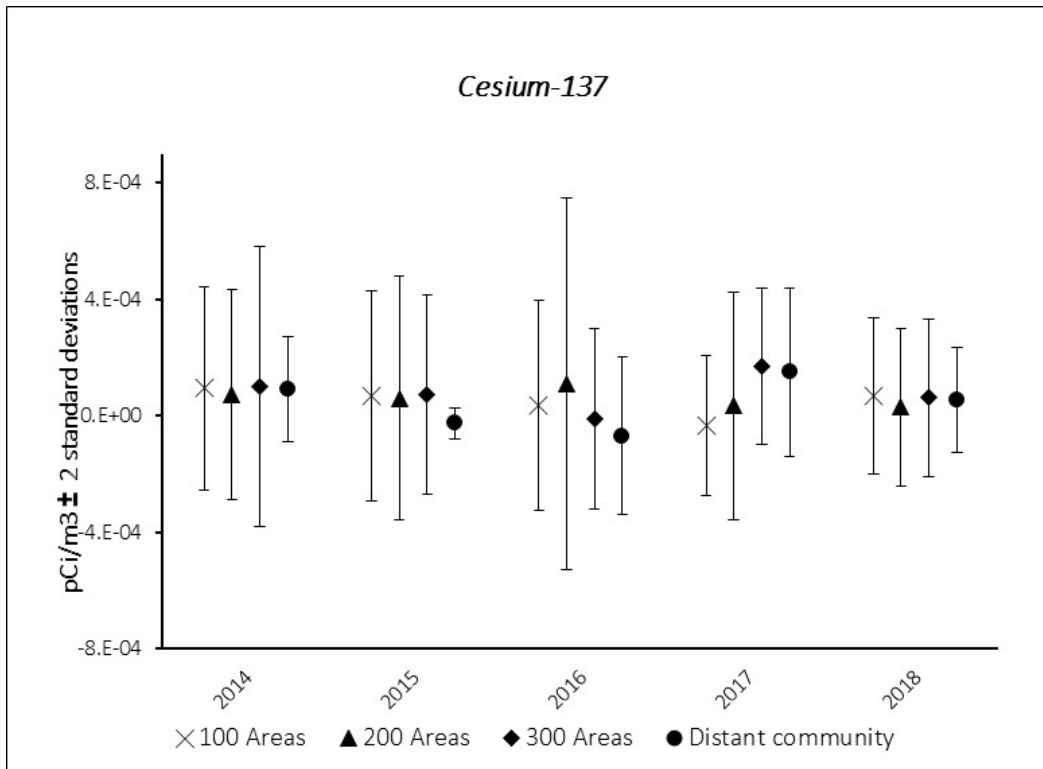
200-East Area. Air sampling was conducted at 27 locations in the 200-East Area during 2018. Generally, radionuclide levels measured in the 2018 air composite samples were similar to those measured in previous years. Uranium-234 and uranium-238 were detected in approximately 40% of the samples.

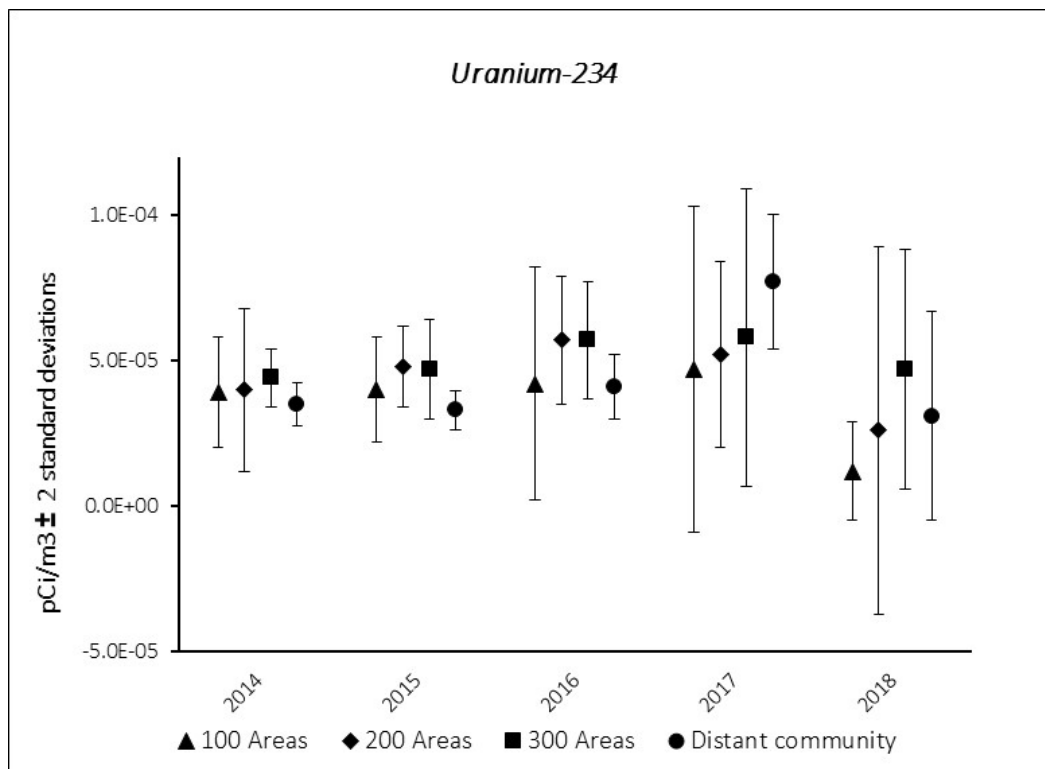
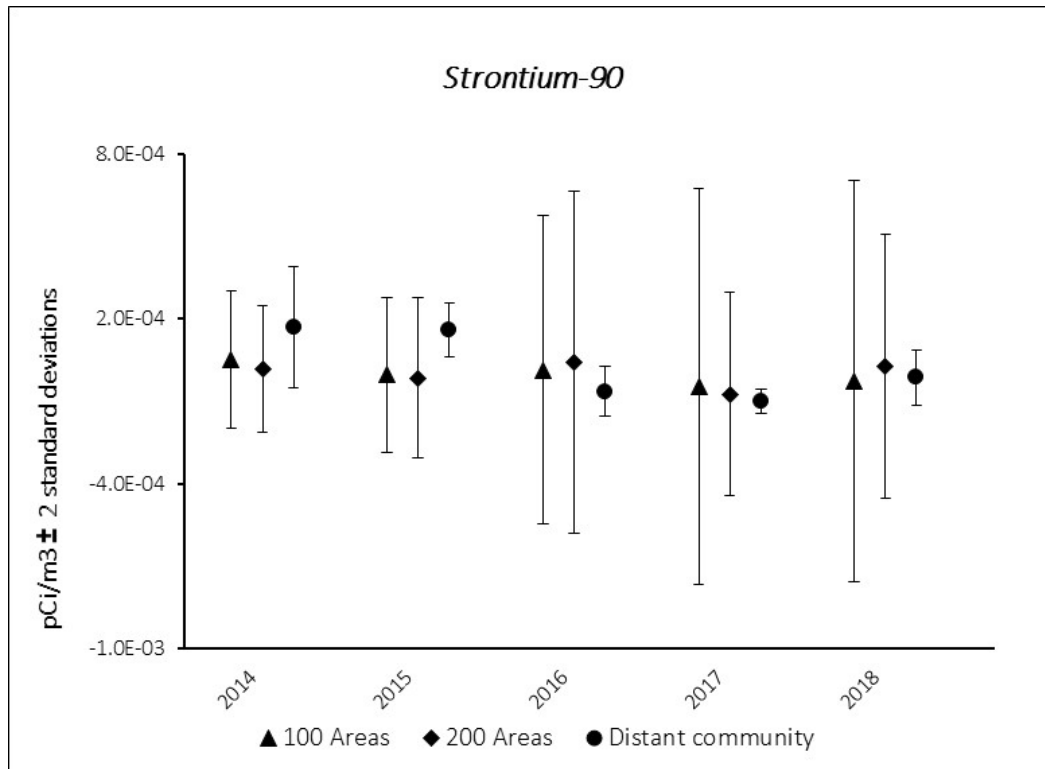
200-West Area. Air sampling was conducted at 23 locations in the 200-West Area during 2018. Radionuclide levels measured were, in general, similar to results for previous years. Uranium-234 and uranium-238 were detected in approximately 34% and 30% of the samples, respectively. Plutonium-239/240 was detected in approximately 17% of the samples and americium-241 was detected in approximately 13% of the samples.

Plutonium Finishing Plant (200-West Area) Demolition. Low-risk clean-up activities were conducted at the Plutonium Finishing Plant during 2018. Activities generally consisted of size-reducing, packaging, and shipping of demolition debris. No airborne releases of radiological materials occurred during the year and air sample results obtained from 7 sampling stations were at levels typically measured in the 200-West Area. Plutonium-239/240 was detected in approximately 50% of the samples and americium-241 was detected in approximately 20% of the samples.

300 Area. Air sampling was conducted at 7 locations in/near the 300 Area during 2018. At stations within the 300 Area, analytical results showed radionuclide concentrations similar to previous years' results. Uranium-234 and uranium-238 were detected in approximately 90% of the samples; tritium was detected in approximately 38% of the samples. All other radionuclides of concern were below analytical detection limits. At the 300 Treatment Effluent Disposal Facility station located just north of the 300 Area, air sample results were similar to those measured in previous years with tritium detected in only approximately 23% of the samples.

Environmental Restoration Disposal Facility (ERDF). Air sampling in support of ERDF operations was conducted at five locations at ERDF. These locations included 3 project-specific stations and 2 upwind stations that are part of the 200 West Area monitoring network. Radionuclide levels measured at this site were comparable to previous years. Uranium-234 and -238 were detected in approximately 57% and 40% of the samples, respectively.





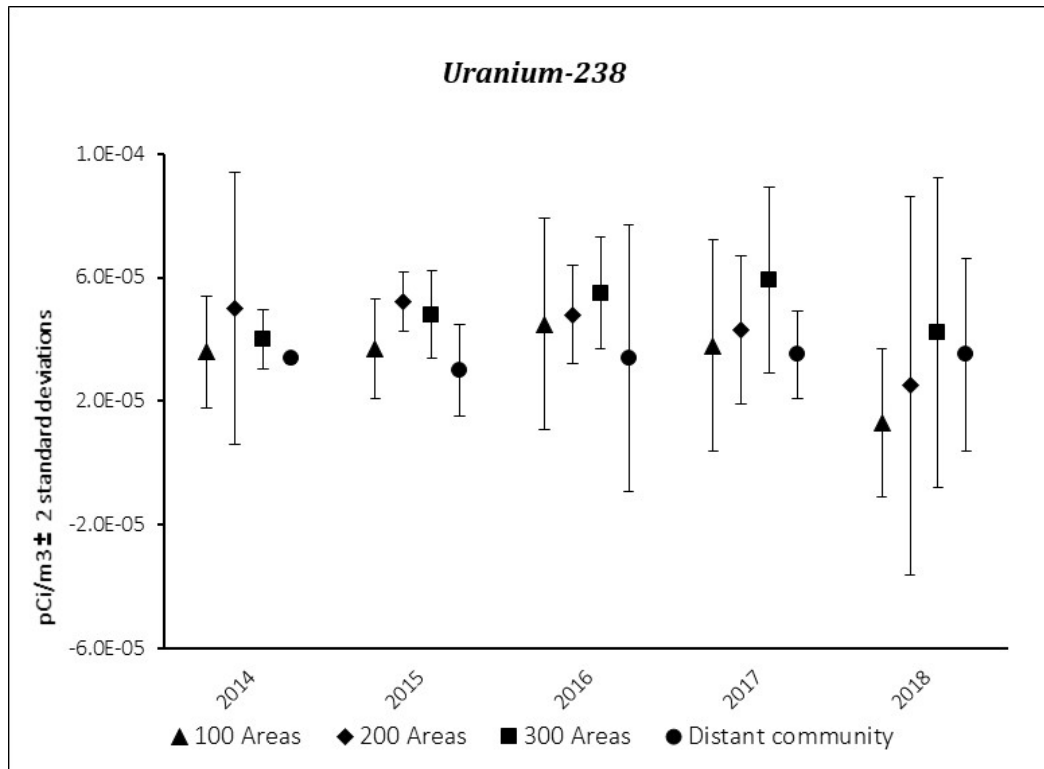


Figure 6-1. Hanford Site Average Radionuclide Concentrations in Air Samples Compared to Distant Community Samples.

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

6.2.2 Perimeter and Offsite Air Monitoring

Airborne radionuclide samples were collected in 2018 by 19 continuously operating samplers in the vicinity of the Hanford Site. The stations were grouped into 3 proximity categories: perimeter (11 stations), nearby Hanford Site communities (7 stations), and distant community (1 station; Figure 6-2; Appendix C, Table C-3). 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.

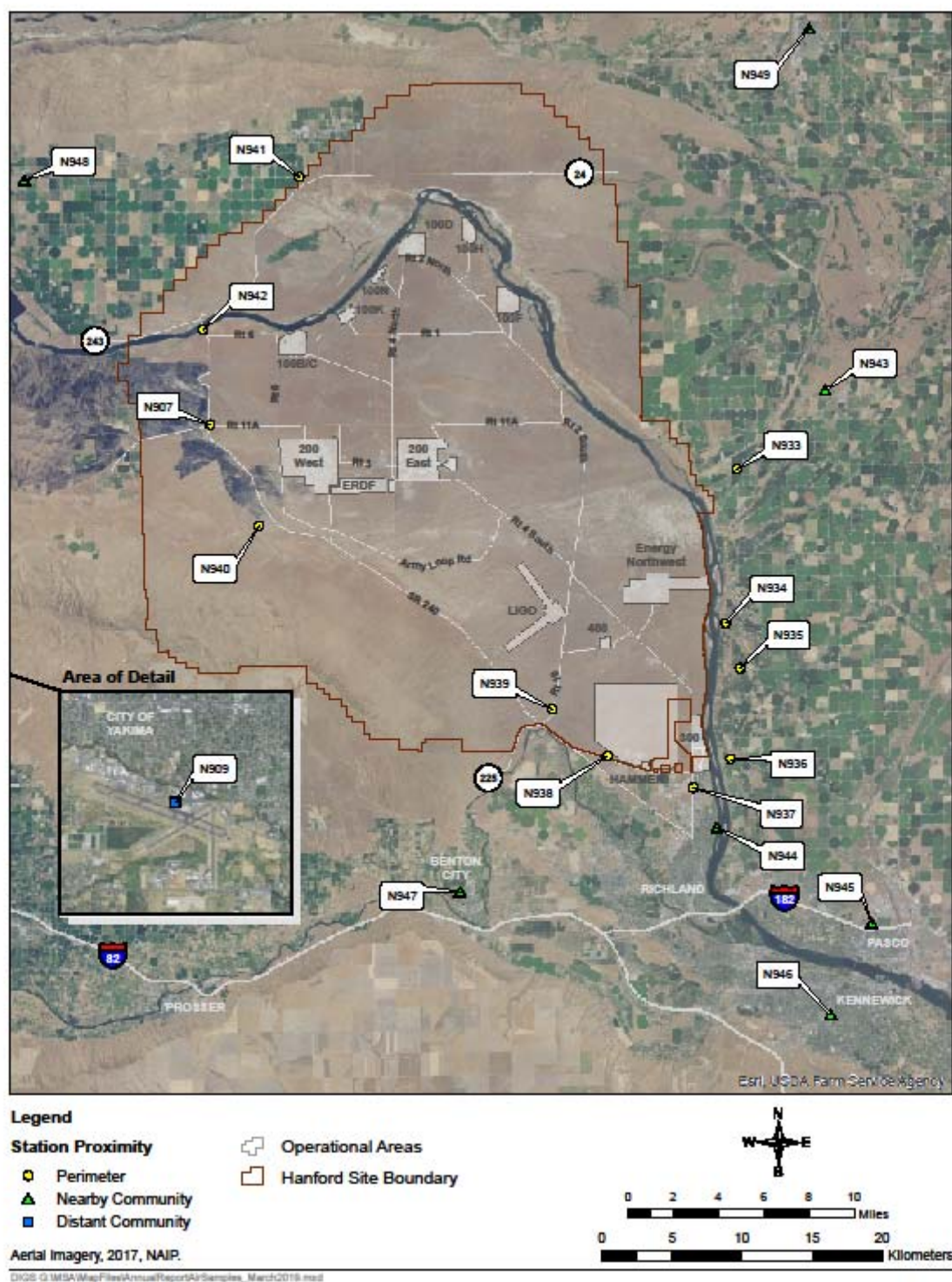


Figure 6-2. Offsite Air Sampling Locations for Calendar Year 2018.

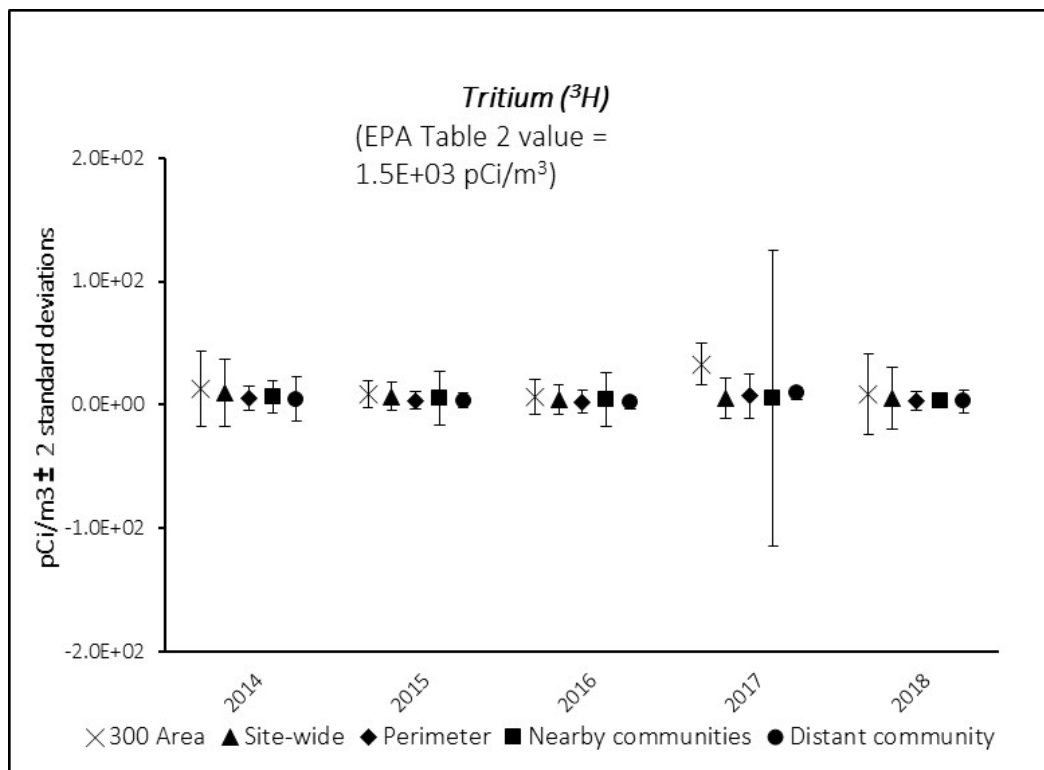
Monitoring Results. Sample results in 2018 showed very low radiological concentrations in air. Gross alpha and gross beta concentrations in the air samples collected in 2018 from the perimeter and nearby Hanford Site communities were comparable to each other and slightly higher than samples from the distant community. Concentrations in 2018 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.

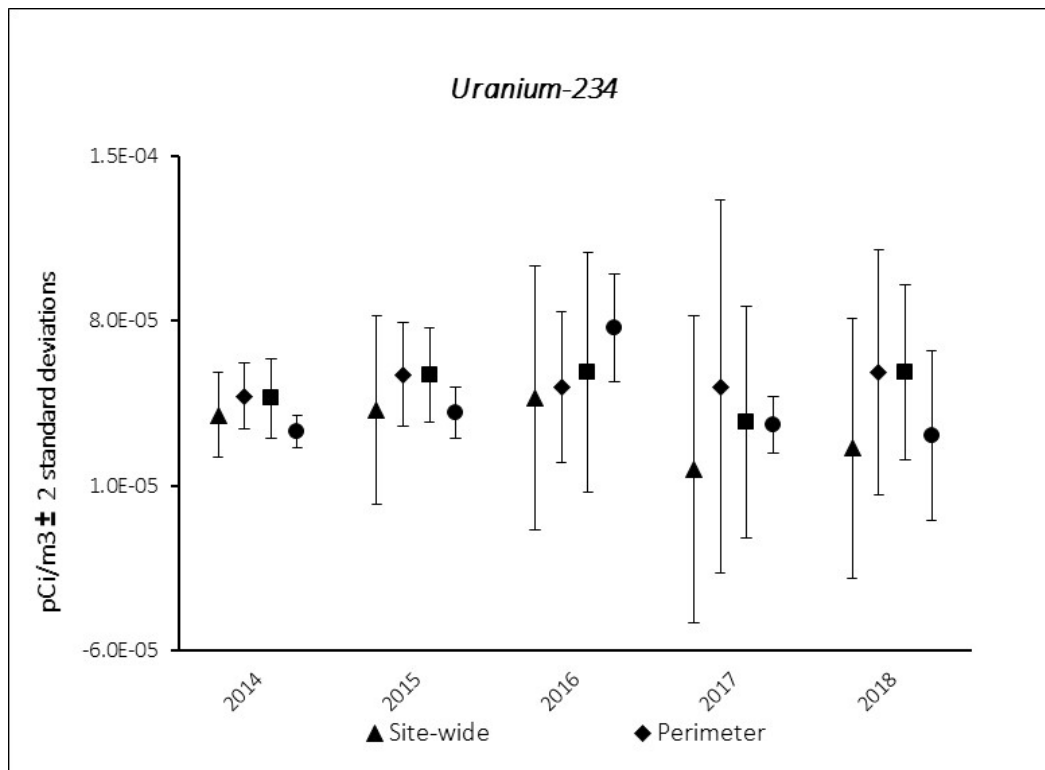
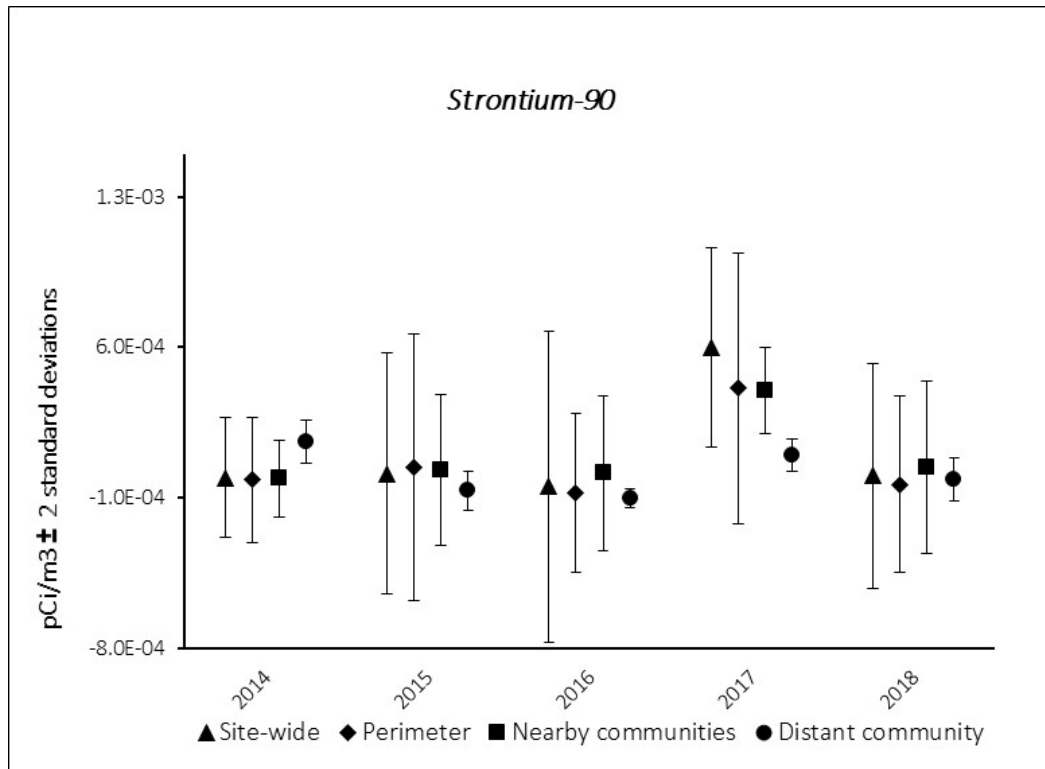
Uranium-234 and -238 were both detected in approximately 50% of the air samples collected in 2018 from all locations. Uranium-234 and uranium-238 concentrations were at levels similar to those measured in previous years. The maximum concentrations measured in all locations were less than 10% of the EPA concentration values for both radionuclides.

Tritium was detected in approximately 8% of the samples collected in 2018.

Cesium-137, strontium-90, and plutonium isotopes were not detected in any of the offsite air samples collected during 2018.

Annual average results from 2014 through 2018 for selected radionuclides are compared to onsite values in Figure 6-3.





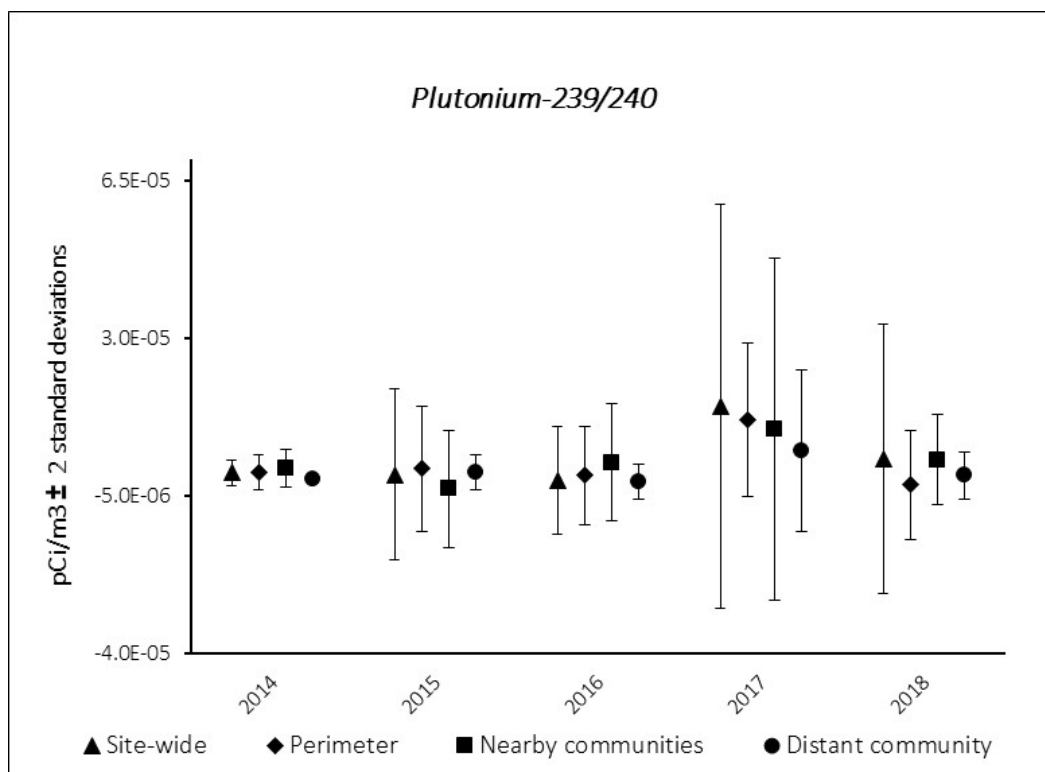
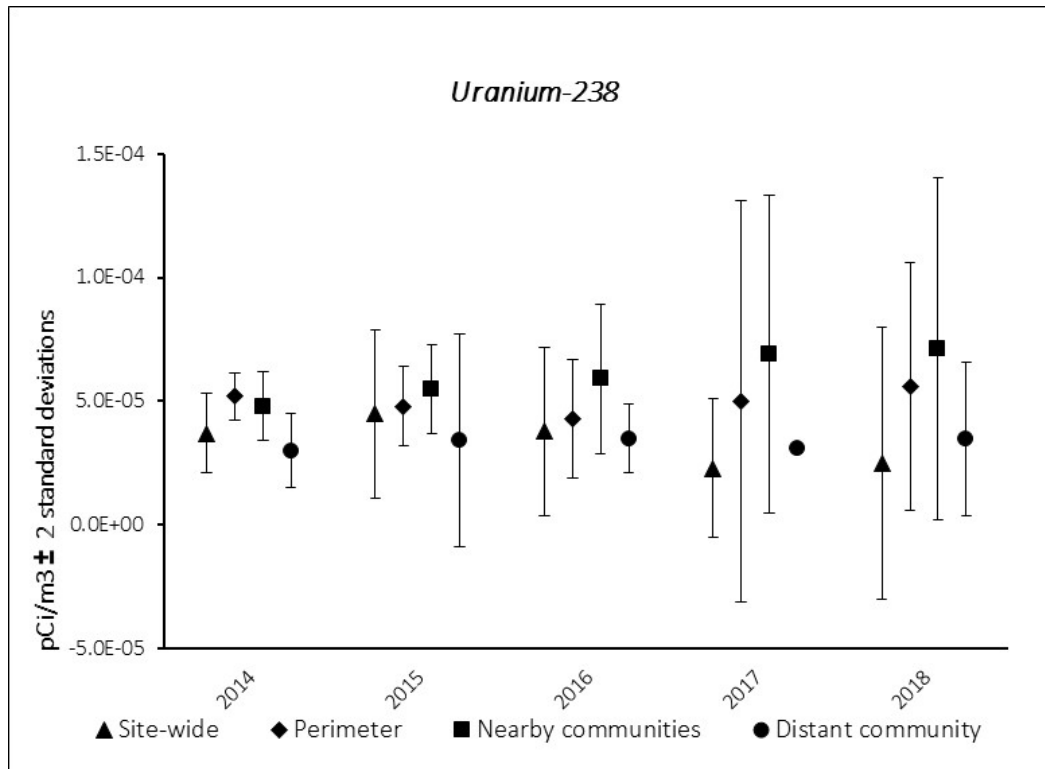


Figure 6-3. Radionuclide Concentrations in Air Samples (1 pCi = 0.037 Bq).

6.3 References

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2018 Highlight

Effluent Releases

Liquid effluent releases were below permit limits and applicable standards.

Onsite Drinking Water

Routine radiological, chemical, physical, and microbiological monitoring of Hanford Site drinking water is performed regularly as mandated by the U.S. Environmental Protection Agency's Community Water System requirements. All of the U.S. Department of Energy-owned Hanford Site systems were in compliance with drinking water standards for 2018. The 400 Area source of supply was groundwater provided from one of three wells. The primary 400 Area well suffered an equipment malfunction in October 2016; therefore, a backup well became the water supply to 400 Area consumers during 2018.

Columbia River Surface Water

Concentrations of radionuclides in samples collected at the City of Richland intake facility were slightly higher than in samples collected upstream at Priest Rapids Dam. Radionuclide concentrations measured in cross-river, transect samples were, with one exception, similar to levels measured upstream at Priest Rapids Dam. The tritium concentration measured at the Hanford Townsite transect was higher than at Priest Rapids Dam or at any other transect. Strontium-90 concentrations measured in transect samples collected upstream and downstream of the Hanford Site during 2018 were below analytical detection limits. Uranium concentrations in all transect samples were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]).

Columbia River Sediment

Analytical results for 2018 were comparable to previous years with cesium-137 and uranium isotopes consistently detected at most sediment collection locations.

Columbia River Shoreline Seep Water

In 2018 sample collections, tritium concentrations were noticeably elevated in samples collected near the Hanford Townsite and at the 300 Area.

Hanford Site Pond Water and Sediment

2018 West Lake water and sediment samples were collected and analyzed for radiological contaminants, and concentrations were similar to results shown in previous years.

Offsite Irrigation Water

Radionuclide concentrations measured in 2018 were at similar levels shown in Columbia River transect water samples collected upstream of the Hanford Site.

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 five of the public water systems, CH2M Plateau Remediation Contractor (CHPRC) operates two systems, and Pacific Northwest National Laboratory (PNNL) operates one system. The City of Richland supplies water to the 300 Area, Richland North Area, and Hazardous Materials Management and Emergency Response facility.

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)	PNNL
400 Area	400 Area Groundwater Wells	CHPRC
609 Fire Station	Trucked Water from Water Treatment Plant 283-W	MSA
CHPRC = CH2M Plateau Remediation Contractor PNNL = Pacific Northwest National Laboratory 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) encountered an equipment malfunction in October 2016; therefore, backup well 499-S0-07 (P-15) was the source of drinking water for 2018. Emergency backup well 499-S0-8 (P-14) did not supply water to 400 Area consumers during the reporting period.

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=8640>.

7.1.3 Radiological Results

Scientists conducted radiological monitoring of drinking water at one DOE-owned pump and three water treatment facilities. In addition, routine chemical, physical, and microbiological monitoring of Hanford Site drinking water was performed. Individual water systems operated by MSA, CHPRC, and PNNL (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. Chemical, physical, and microbiological data are reported to the state directly by the state-accredited laboratory performing the analyses, however, the reports are not published.

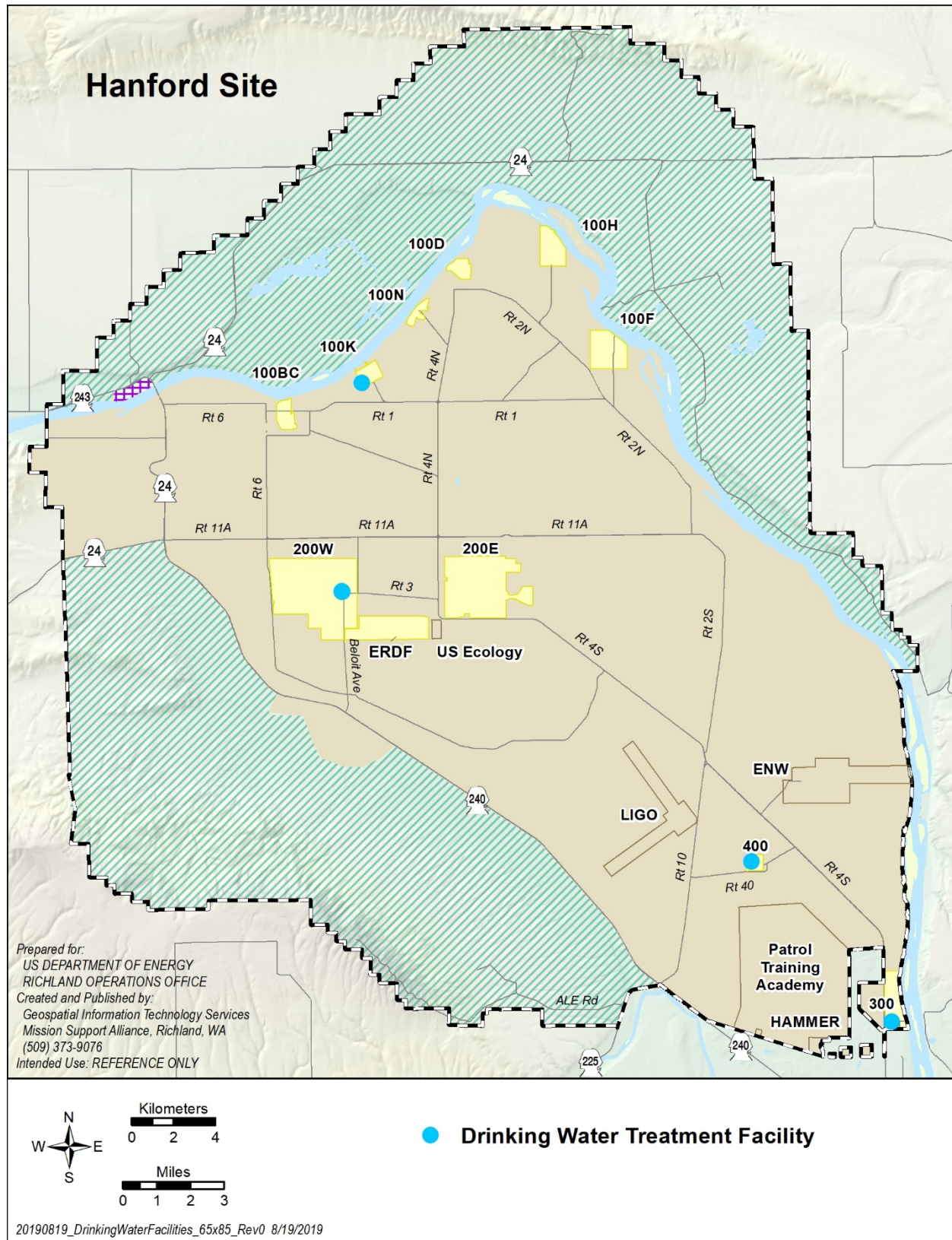


Figure 7-1. Drinking Water Treatment Facilities.

All of the DOE-owned Hanford Site drinking water systems were in compliance with drinking water standards for radiological, chemical, physical, and microbiological contaminant levels during 2018. Contaminant concentrations measured during the year were similar to those observed in recent years as described in the annual Hanford Site environmental reports for 2016 (DOE/RL-2017-24) and 2017 (DOE/RL-2018-32).

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 2018 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 supply was backup well 499-S0-7 (P-15). Gross beta and tritium were found in all 400 Area water samples; the tritium annual average was slightly elevated in comparison to historical data where the 400 Area primary well (499-S1-8J) was the main water source 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 2018, Environmental Assessment personnel collected raw (untreated) water samples from 400 Area drinking water backup well 499-S0-8 (P-14). Samples were collected quarterly, composited for a single annual tritium analysis ($4,950 \pm 1,090$ pCi/L), and fell below the 20,000-pCi/L (740-Bq/L) federal and state annual average drinking water standards. CHPRC Soil and Groundwater Remediation Project personnel collected and analyzed raw (untreated) water samples from two of the three 400 Area drinking water wells. The primary well suffered a malfunction in October 2016 and the two backup wells were sampled and analyzed for tritium (Figure 7-2; Table 7-3).

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

Constituent	System	Frequency	Sample From	Samples Analyzed at Each Location	Annual Average (pCi/L) ^{a, b}			Standard
Gross alpha	100-K Area	Quarterly	Tap	4 ^c	0.58	±	1.02	15 ^{d, e}
	200-West Area	Quarterly	Tap	4 ^c	1.13	±	1.43	
	400 Area	Quarterly	Tap	4 ^c	0.17	±	1.89	
	400 Area Well P-14	Quarterly	Well	4 ^c	0.69	±	1.73	
Gross beta	100-K Area	Q Comp ^f	Tap	4 ^c	1.17	±	1.12	50 ^e
	200-West Area	Q Comp ^f	Tap	4 ^c	0.09	±	1.91	
	400 Area	Q Comp ^f	Tap	4	8.22	±	6.84	
	400 Area Well P-14	Q Comp ^f	Well	4	7.52	±	2.50	
Tritium	100-K Area	A Comp ^g	Tap	1 ^c	430	±	401	20,000 ^e
	200-West Area	A Comp ^g	Tap	1 ^c	-143	±	346	
	400 Area	Quarterly	Tap	4	4,695	±	574.46	
	400 Area Well P-14	A Comp ^g	Well	1	4,950	±	1,090	
Strontium-90	100-K Area	A Comp ^g	Tap	1 ^c	-0.17	±	0.67	8 ^{d, e}
	200-West Area	A Comp ^g	Tap	1 ^c	0.25	±	0.67	
	400 Area	A Comp ^g	Tap	1 ^c	-0.31	±	0.81	
	400 Area Well P-14	A Comp ^g	Well	1 ^c	-0.52	±	0.36	

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

^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 Samples were collected monthly and composited quarterly for analyses.

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

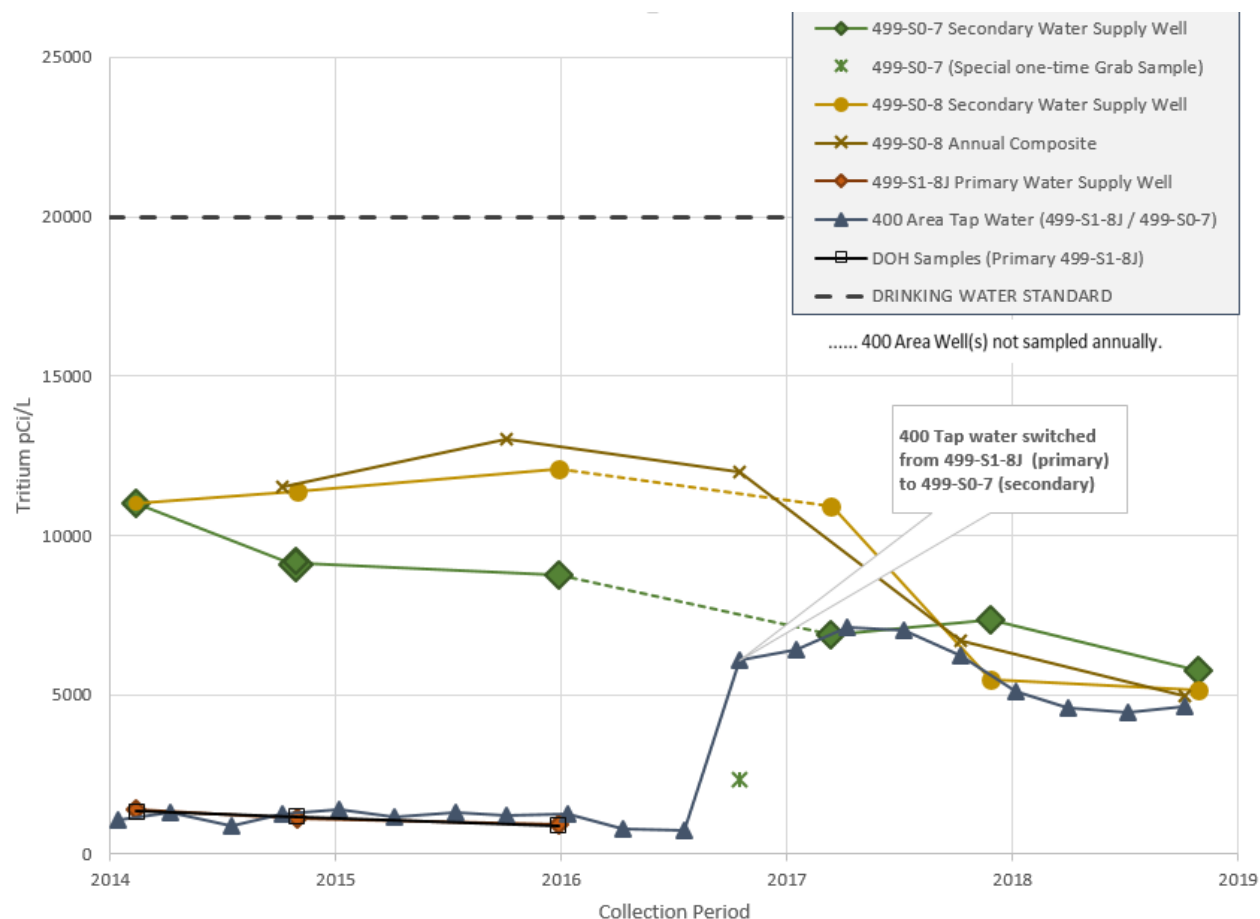


Figure 7-2. 400 Area Tritium Concentrations in Drinking Water (2014-2018)
(multiply pCi/L by 0.037 to convert to Bq/L).

Table 7-3. Tritium Concentrations in Hanford Site 400 Area Drinking Water Wells.

Sampling Date	Primary Drinking Water Well 499-S1-8J (P-16; pCi/L)	Backup Drinking Water Well 499-S0-8 (P-14; pCi/L) ^{a, b}	Backup Drinking Water Well 499-S0-7 (P-15; pCi/L) ^{a, b}
November 1, 2018	No Sample	5,140 ± 1,070	5,780 ± 728
^a Reported concentration ±2 total propagated analytical error.			
^b Multiply pCi/L by 0.037 to convert to Bq/L.			

7.2 Columbia River Surface Water

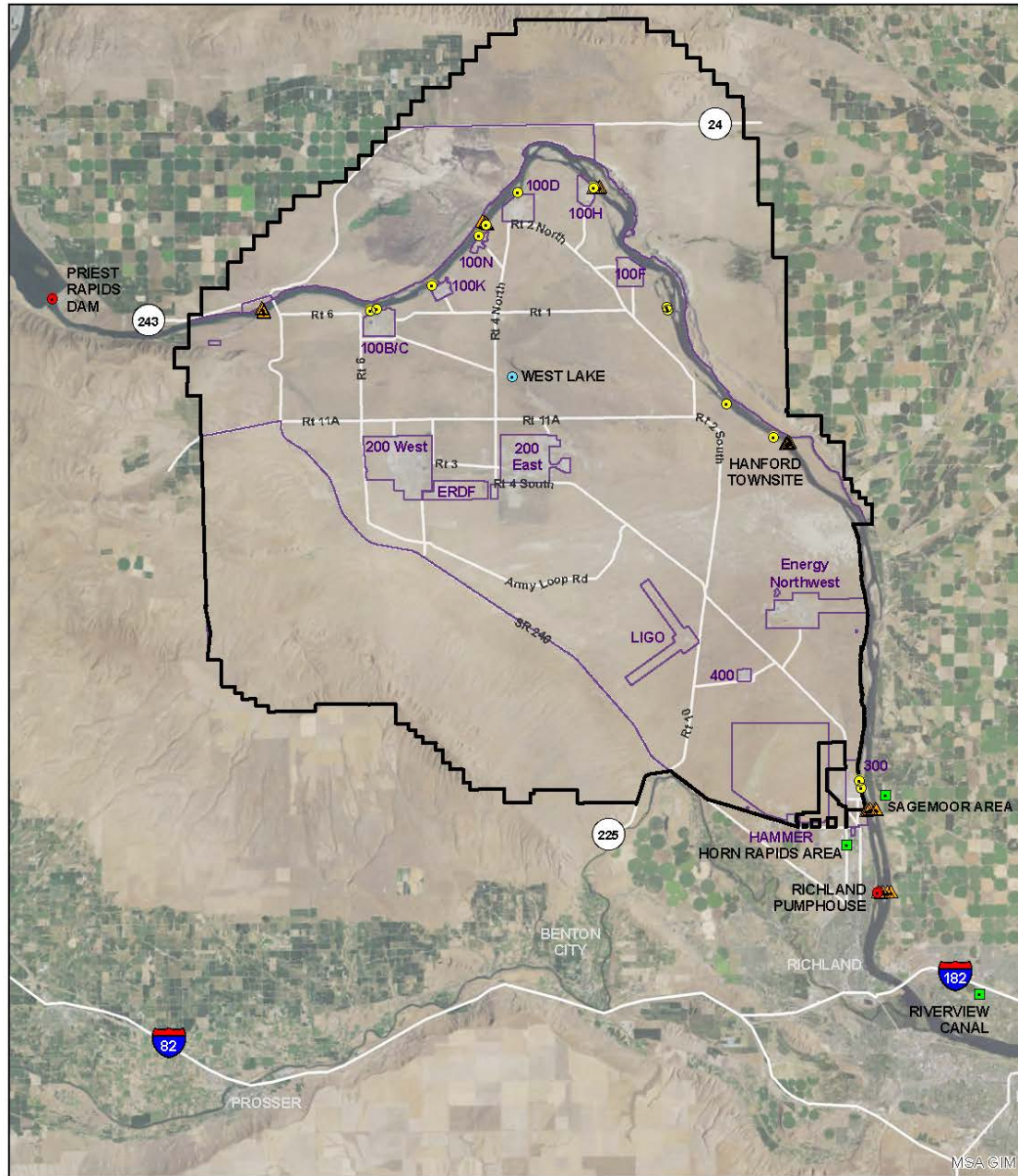
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Samples of Columbia River surface water were collected upstream and downstream of the Hanford Site as well as from locations along the Hanford Reach. Tables 7-4 and 7-5 summarize the sampling locations, types, frequencies, and sample analyses included in surface water monitoring.

The Columbia River is one of the largest rivers in the continental U.S. in terms of total flow and is the dominant surface water body at the Hanford Site. The original selection of the Hanford Site for plutonium production was based partly on the abundant water supply offered by the Columbia River.

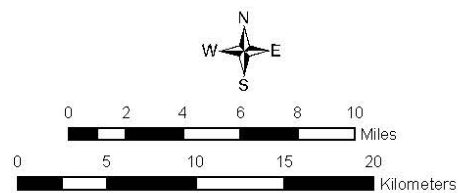
The river flows through the northern portion of the Hanford Site and forms part of the eastern boundary of the Site. The river is used as a source of drinking water for Hanford Site facilities and communities downstream of the Hanford Site. River water is also used for irrigation purposes downstream 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; 4 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 the City of Richland. The Hanford Reach is the last free-flowing stretch of the Columbia River. River flow through the Hanford Reach is controlled primarily by operations at upstream dams, which over the course of the year 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 2018. The annual average flow of the Columbia River downstream of Priest Rapids Dam was approximately 129,253 ft³ (3,660 m³)/sec, slightly above the most recent 10-year average annual flow rate of 115,831 ft³ (3,280 m³)/sec (USGS 2013). The highest monthly average flow rate occurred during May (299,183 ft³ [8,473 m³]/sec; Figure 7.4). The lowest monthly average flow rate occurred during September (54,155 ft³ [1,534 m³]/sec) based on mean daily flows. Daily average flow rates varied from 37,973 to 389,045 ft³ (1,075 to 11,018 m³)/sec in 2018. 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.



Legend

- Continuous Surface River Water
- Onsite Pond Water
- Offsite Irrigation Water
- Shoreline Seep Water
- ▲ River Water Transect
- Operational Areas
- Hanford Site Boundary



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Figure 7-3. Surface Water and Sediment Sampling Locations.

Table 7-4. Surface Water Surveillance. (2 Pages)

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
	Grab	Quarterly	Anions
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-H, 100-N, 300 Areas and Hanford Townsite	Grab (transects)	Annually	Gamma energy analyses, low tritium ^b , strontium-90, isotopic uranium ^c , uranium-236 (300 Areas only)
Columbia River - Inorganics and Organics			
Vernita Bridge	Grab (transects)	Semi-annual	Anions, mercury, metals (filtered and unfiltered), hexavalent chromium (filtered and unfiltered)
	Grab (transects)	Semi-annual	Volatile organic compounds
Richland	Grab (transects)	Semi-annual	Anions, mercury, metals (filtered and unfiltered), hexavalent chromium (filtered and unfiltered)
	Grab (transects)	Semi-annual	Volatile organic compounds
100-H, 100-N, 300 Area and Hanford Townsite	Grab (transects)	Annually	Anions, metals (filtered and unfiltered), hexavalent chromium (filtered and unfiltered), volatile organic compounds (300 Area only)
Onsite Ponds			
West Lake Seep	Grab	March	Tritium, technetium-99, isotopic uranium ^c
West Lake Water	Grab	May	Tritium, technetium-99, isotopic uranium ^c
Offsite Irrigation Water			
Riverview Irrigation Canal	Grab	3/year	Alpha, beta, low tritium ^b , strontium-90, gamma energy analyses
Horn Rapids Battelle Sports Complex	Grab	3/year	Alpha, beta, low tritium ^b , strontium-90, gamma energy analyses
Sagemoor Irrigation Canal	Grab	3/year	Alpha, beta, low tritium ^b , strontium-90, gamma energy analyses

Table 7-4. Surface Water Surveillance. (2 Pages)

^a M Comp indicates river water was collected at set intervals and composited monthly for analyses.

^b Low tritium = Low-level tritium analysis (10-pCi/L detection limit).

^c Includes uranium-234, uranium-235, and uranium-238.

^d M Cont = 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 7-5. 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 (Adjacent to 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, uranium-236 (300 Area only), and uranium-238 ^c Plutonium-238 and plutonium-239/240 ^d Hanford Reach consists of sediment collected in the following areas: 100-D Spring 102-1, 100-K Spring 63-1, 100-H Spring 145-1, 100-F Slough, Hanford Slough, White Bluffs Slough, and 300 Area Spring DR 42-2.		

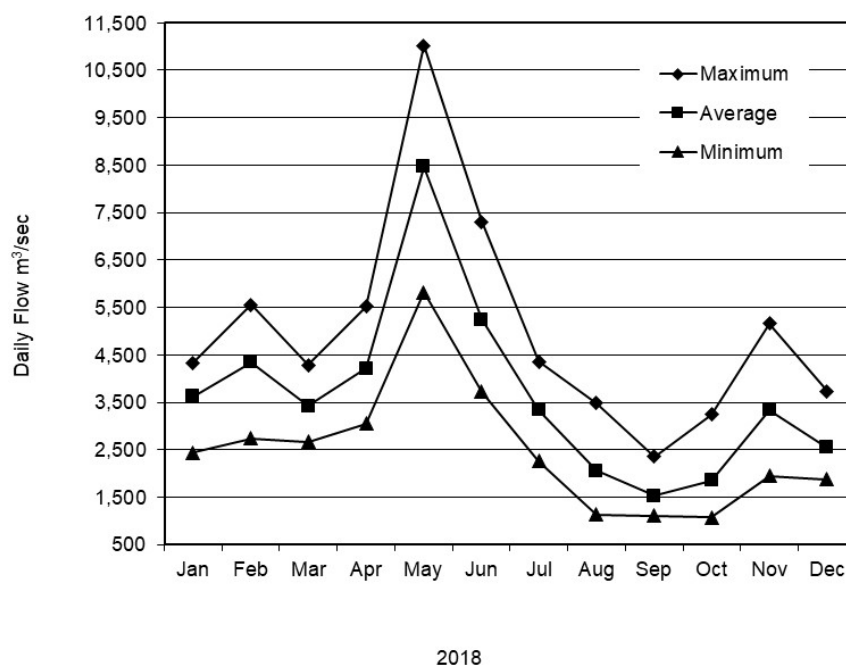


Figure 7-4. Columbia River Flow Rates at Priest Rapids Dam (multiply m³/sec by 35.31 to obtain ft³/sec).

7.2.1 Monitoring

In 2018, 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 transect samples near Vernita Bridge, 100-N Area, 100-H Area, Hanford Townsite, 300 Area, and the City of Richland were also collected and 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 7.4). The continuous flow system was used to collect particulate and soluble constituents in Columbia River water by passing water through a filter and then through a resin column. Filter and resin samples were exchanged approximately every 14 days and were combined into 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: strontium-90, technetium-99, tritium, plutonium-238, plutonium-239/240, uranium-234, uranium-235, and uranium-238. 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 2018. 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). 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 2018, the Richland Pumphouse and Vernita Bridge transects were collected twice (spring and late summer). The 100-N Area, 100-H Area, Hanford Townsite, and 300 Area locations were all sampled once in 2018 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 Pumphouse, 300 Area, Hanford Townsite, 100-H Area, and 100-N Areas were comprised of five locations. The Vernita Bridge station is made up of four locations due to safety concerns associated with an inability to anchor at the midstream location because of the smooth riverbed and high flow rates.

Columbia River transect water samples collected during 2018 were analyzed for radiological, inorganic, and organic contaminants (Table 7.4). The contaminants of concern (specifically hexavalent chromium [filtered and unfiltered], metals [filtered and unfiltered], anions, and radionuclides that were selected for analyses) were based upon previous studies of groundwater plume migration, reviews of existing

surface water and groundwater upwelling/discharge data, various remedial investigation/feasibility study work plans, and preliminary Hanford Site risk assessments (DOE/RL-92-67; WCH-380). Hexavalent Chromium and metals analyses included both unfiltered (recoverable) and filtered (dissolved) samples.

7.2.2 Radiological Results

7.2.2.1 Fixed-location Samples. Individual radiological contaminant concentrations measured in Columbia River water during 2018 were well below the DOE-derived concentration standards. The DOE-derived concentrations are based on a 100 mrem/yr (1 mSv/yr) standard; dividing by 25 allows for more direct comparison to the 4 mrem/yr (0.04 mSv/yr) drinking water standards and Washington State ambient surface water quality criteria (40 CFR 141; WAC 173-201A;). Results of radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the City of Richland raw water intake facility in 2018, and for the previous 5 years, are summarized in Appendix C, Tables C-5 and C-6.

Due to operational issues with the Richland Pumphouse sampling system during the first half of calendar year (CY) 2018, grab samples were obtained from the Columbia River directly adjacent to the pumphouse structure every 2 weeks to maintain sample scheduling and analyses.

Radionuclide concentrations in Columbia River water were low throughout 2018. Tritium, uranium-234, and uranium-238 were consistently detected at both locations. Uranium-234 and uranium-238 results were measured at less than 10% of their respective DOE-derived concentration standards. One up-gradient sample from Priest Rapids had detectable plutonium-239/240 results and two down-gradient samples from the Richland Pumphouse had detectable concentrations of technetium-99. All other radionuclides were below minimum detectable concentrations.

The 2018 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years (Figure 7-5). Tritium concentrations in river water samples at the City of Richland raw water intake facility were slightly higher than in samples from Priest Rapids Dam. The maximum concentration detected at the Richland Pumphouse was 45.5 pCi/L (1.7 Bq/L), while Priest Rapids Dam had a maximum concentration of 21.5 pCi/L (0.8 Bq/L). Average tritium concentrations in Columbia River water samples collected at the City of Richland raw water intake facility were well below the Washington State ambient surface water quality criterion of 20,000 Ci/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 tritium 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 and at shoreline seep locations during 2018 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.

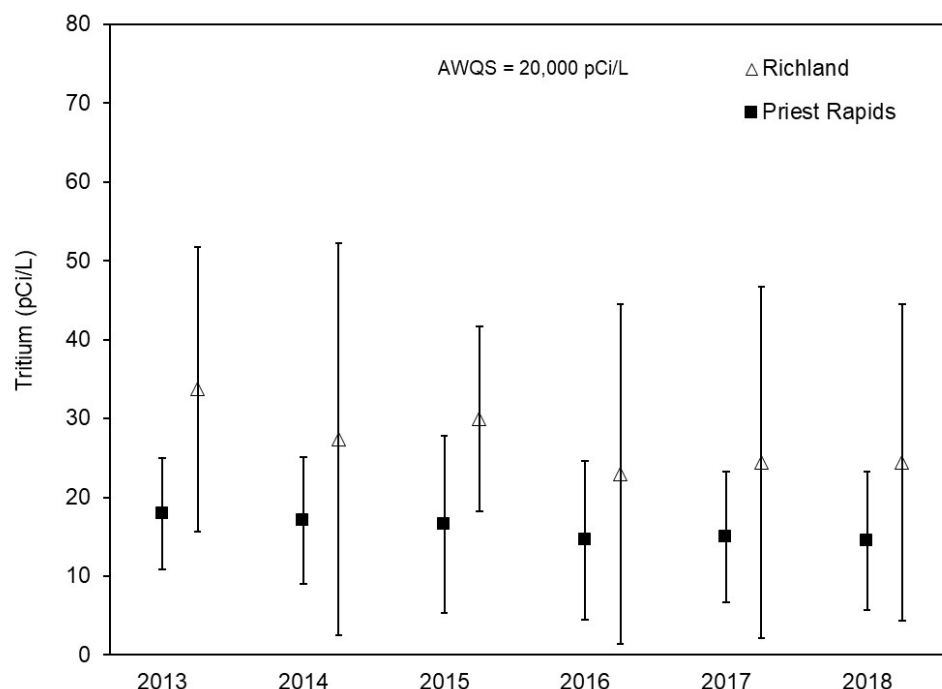


Figure 7-5. 2018 Annual Tritium Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site ($\pm 2X$ standard deviations, AWQS=ambient water quality standard; Washington State AWQS for tritium is 20,000 pCi/L [740 Bq/L]).

Average strontium-90 levels measured in Columbia River water, collected upstream and downstream of the Hanford Site during 2018 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 and the City of Richland intake had similar maximum concentrations of 0.04 pCi/L (0.0015 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.

Annual averages of total uranium concentrations measured in water samples collected upstream and downstream of the Hanford Site in 2018 were similar to those observed during recent years (Figure 7-7). Average monthly uranium concentrations measured at Priest Rapids Dam (0.52 pCi/L total uranium) in 2018 were slightly lower than those averages measured at the City of Richland (0.58 pCi/L total uranium). Uranium is present in the groundwater beneath the 300 Area as a result of past Hanford Site operations, it has also been previously 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 surface water quality criterion directly applicable to uranium; however, total uranium levels in the river during 2018 were well below the EPA drinking water standard of 30 $\mu\text{g/L}$ (approximately 20 pCi/L [0.74 Bq/L]).

Plutonium-238 and plutonium-239/240 concentrations in river water samples collected at the City of Richland in 2018 were below analytical detection limits. One sample collected upstream at Priest Rapids Dam did show plutonium-239/240 at an extremely low concentration.

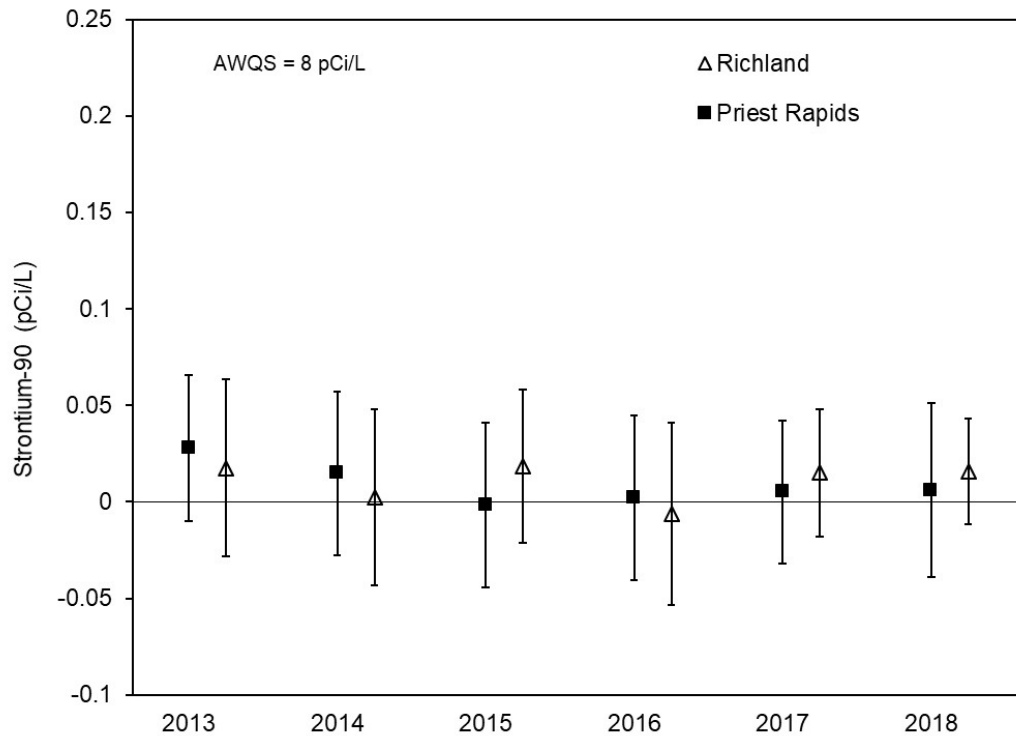


Figure 7-6. 2018 Annual Strontium-90 Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (± 2 standard deviations, AWQS = ambient water quality standard).

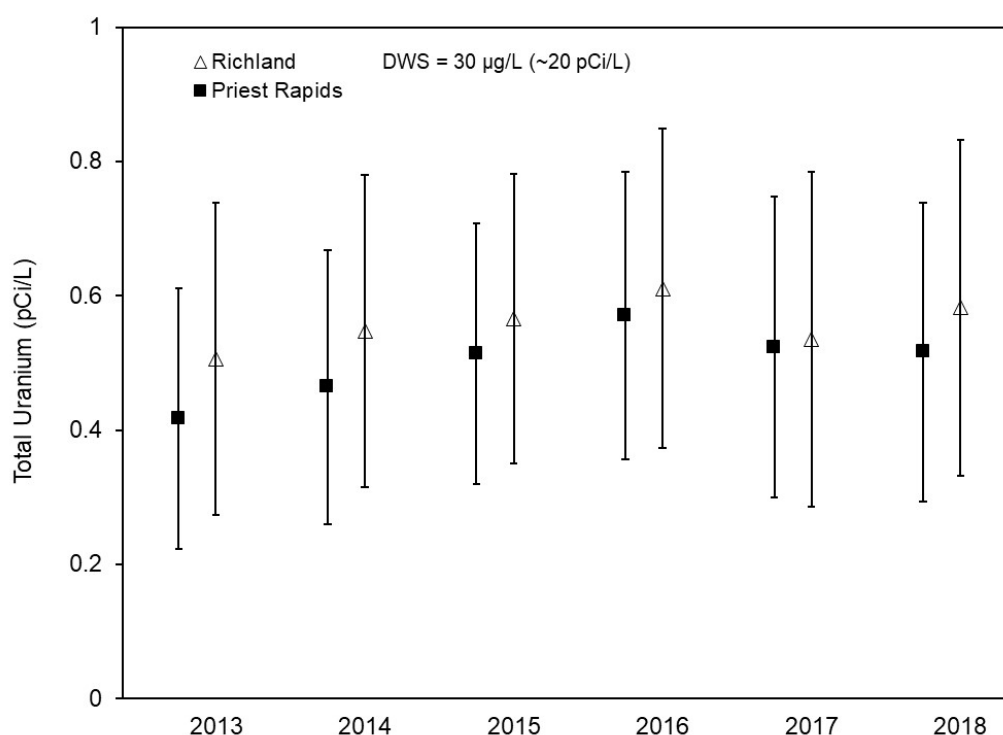


Figure 7-7. 2018 Annual Uranium Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (± 2 standard deviations; DWS = drinking water standard).

7.2.2.2 Columbia River Transect Samples. Radiological results from samples collected along Columbia River transects near Vernita Bridge, 100-N Area, 100-H Area, Hanford Townsite, 300 Area, and the City of Richland are presented in Appendix C, Table C-7. 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 detected included tritium, uranium-234, uranium-235, and uranium-238. All measured concentrations of these radionuclides were less than applicable Washington State ambient surface water quality criteria and EPA drinking water standards.

Tritium concentrations measured along Columbia River transects at Vernita Bridge, 100-N Area, 100-H Area, Hanford Townsite, 300 Area, and the City of Richland during 2018 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.

Average concentrations of tritium in a sample collected from the City of Richland fixed station were comparable to levels observed in the Benton County shoreline transect sample (Richland Pumphouse

Hanford River Mile [HRM] 46.4 station-1). The highest tritium concentration measured in a cross-river transect water was at the Hanford Townsite at a concentration approximately 5% of the Washington State Drinking Water Quality Standard of 20,000 pCi/L.

Strontium-90 concentrations in Hanford Reach transect samples collected in 2018 were similar to upstream reference concentrations for most locations. The maximum strontium-90 concentration was from a sample collected along the Hanford Townsite transect. Average strontium-90 concentrations at the Priest Rapids Dam fixed-location monitoring station were less than those measured at the Richland Pumphouse and in all Richland Pumphouse HRM 46.4 transect samples.

Uranium concentrations in all transect samples collected during 2018 were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]). The highest uranium-234 concentration was measured in a sample collected near the Benton County shoreline (300 Area–1 HRM 43.1). Uranium-236 concentrations were below analytical detection limits.

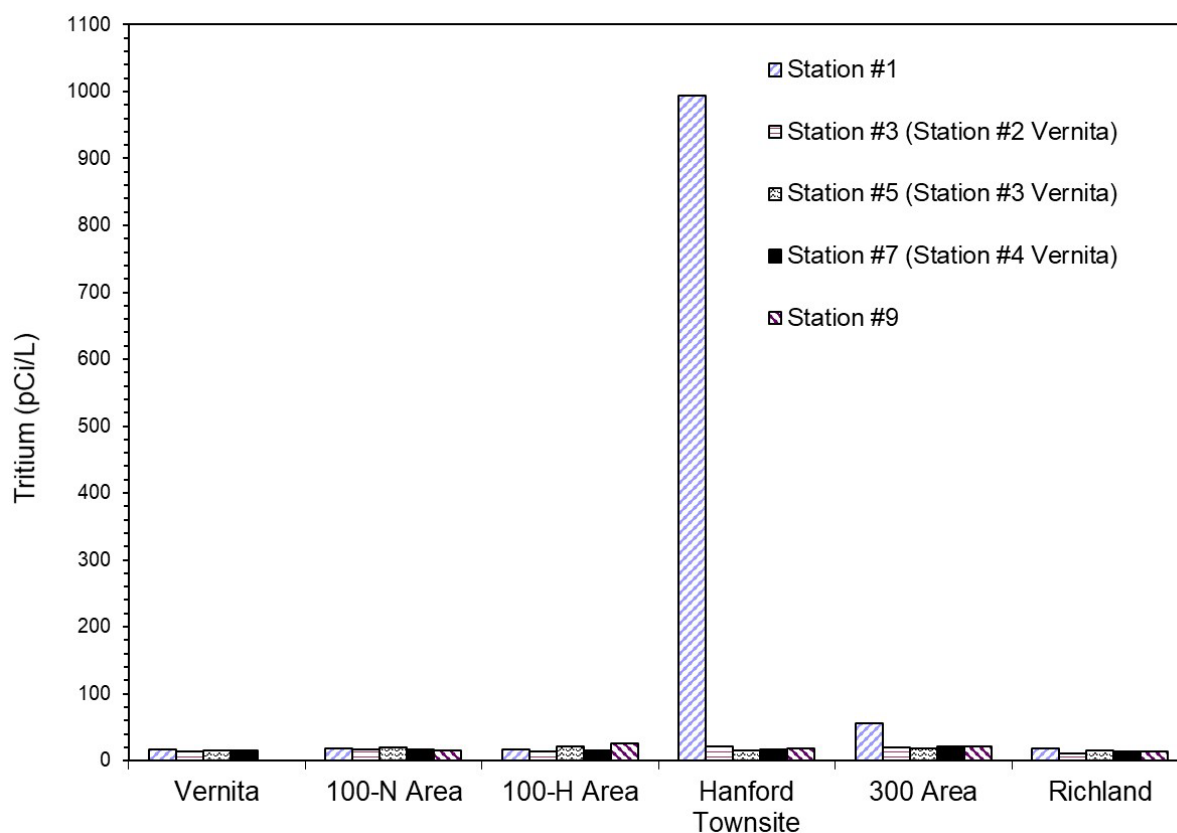


Figure 7-8. 2018 Tritium Concentrations in Cross-River Transect Water Samples (Hanford Reach, Columbia River).

7.2.3 Inorganic and Organic Chemical Results

Inorganic and organic water quality data were compiled in 2018 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. Analytical results showed detections of arsenic, copper, uranium, and zinc. All dissolved metal concentrations in river water were less than the Washington State ambient surface water quality criteria for the protection of aquatic life (Appendix C, Table C-8).

Washington State ambient surface water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A). Increased water hardness (i.e., primarily higher concentrations of calcium and magnesium ions) can reduce the toxicity of some metals by limiting their absorption into aquatic organisms. Criteria for Columbia River water were calculated using a total hardness of 66 mg/L as calcium carbonate, the lowest value in recent years based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge (USGS 2007) and the City of Richland.

The 300 Area HRM 43.1 station-1 (Benton County shoreline) had maximum nitrate concentrations slightly higher than the next highest transect result found at the Hanford Townsite. All other samples collected throughout the Hanford Reach, Richland, and Vernita Bridge were approximately three times less than the 300 Area HRM 43.1 station-1 location. Concentrations of chloride were slightly elevated at Richland Pumphouse HRM 46.4 station-9 and 300 Area HRM 43.1 station-1 when compared to other transect locations (Figure 7-9) found throughout the Hanford Reach. Richland Pumphouse HRM 46.4 concentrations of sulfate were also slightly elevated when compared to transect samples collected throughout the Hanford Reach. In some cases, the highest anion concentrations were found in samples collected along the Grant-Franklin County shoreline. These elevated results are likely attributable to 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 upstream and downstream concentrations of chloride measured at the City of Richland and Vernita Bridge transects were similar. The highest concentrations of nitrates were measured at the 300 Area HRM 43.1 transect and the Hanford Townsite. All other transect locations had detectable levels of nitrates as well. Anion analysis of Columbia River transect samples showed detectable levels of fluoride at very low concentrations in all samples. The overall average concentration of fluoride in transect samples has dropped from 109 µg/L in 2010 to 80 µg/L in 2018.

Concentrations of chromium (Appendix C, Table C-8) 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 2018 had chromium concentrations below the minimum detectable concentration.

Results from organic analyses of water samples are voluminous and not all results are included in this report. A complete listing may be found in the Hanford Environmental Information System (HEIS)

database. The two major organic contaminants monitored in 2018 were trichloroethene and dichloroethene, compounds used during past reactor fuel fabrication in the 300 Area. These contaminants were measured in transect water collected upstream and downstream of the Hanford Site and in the vicinity of the 300 Area. Analytical results for these samples showed concentrations below their respective EPA Drinking Water Standards (Appendix C, Table C-9).

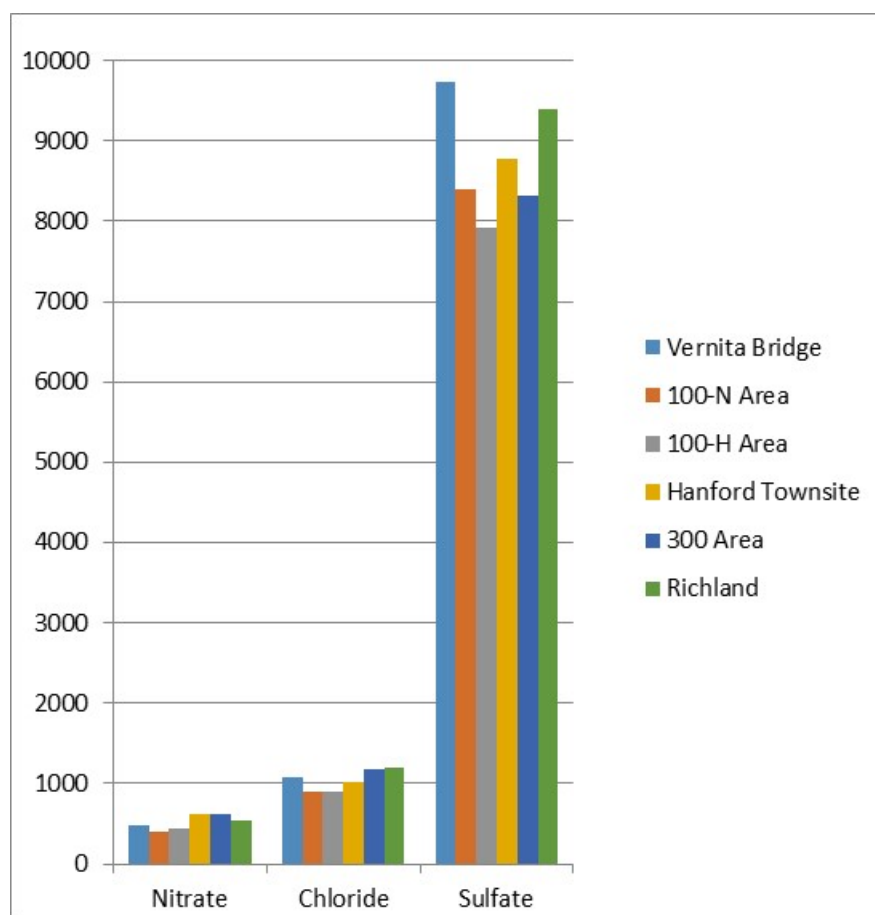


Figure 7-9. 2018 Selected Anion Concentrations in Columbia River Transect Samples (micrograms/liter).

7.3 Columbia River Sediment

During peak operating years at the Hanford Site, large volumes 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 (e.g., 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; PNNL-16990). Periodic sediment sampling confirms that concentrations are low and that no significant changes in concentrations have occurred. The accumulation of radioactive materials in sediment can lead to human exposure from ingestion of aquatic organisms associated with 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 100-K Spring 63-1 shoreline sediment location, White Bluffs and Hanford Sloughs 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). Sediment was collected using a clamshell-style sediment dredge sampler (Petite Ponar), capturing several years of sediment deposits. Estimated average sediment deposition rates are 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. Deposition rates have not been estimated for shoreline or slough sediment collection 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 Hanford 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 (locations, analyses, frequency, and contaminant results are presented in Table 7-5, Table 7-7, and Appendix C). The majority of these sites are located along the Hanford Reach of the Columbia River in slack-water areas where fine-grained material is known to deposit or in shoreline spring areas known to contain groundwater contaminated by past Hanford Site practices.

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, plutonium-238, plutonium-239/240, uranium-234, uranium-235, uranium-238, 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 2018 included cesium-137, uranium-234, uranium-235, uranium-238, and decay products from naturally occurring radionuclides. The concentrations of all other radionuclides 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 2018 showed similar concentrations of cesium-137 at Priest Rapids and McNary Dam sediment collection locations. Average 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 at Priest Rapids as higher concentrations were reported than those sediment results along the Hanford Reach (Figure 7-11). However, cesium-137 concentrations from McNary Dam were slightly lower than those concentrations reported for the Hanford Reach. 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.

Uranium-234 concentrations were slightly elevated at the McNary Dam location compared to other sediment samples collected from the Hanford Reach and Priest Rapids Dam samples in 2018. Other radionuclide concentrations in river sediment were similar to those reported for previous years and there were no significant glaring differences between locations.

Total uranium averaged 1.9 pCi/g for the Hanford Reach, while Priest Rapids and McNary Dam concentrations averaged 2.9 pCi/g and 2.3 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 and Hanford Slough locations of the Hanford Reach were slightly elevated (0.25 pCi/g maximum concentration) compared to other Hanford Reach sample locations (0.09 pCi/g average concentration). McNary Dam had a slightly lower cesium-137 average concentration compared to Priest Rapids Dam sediment results (0.18 pCi/g and 0.22 pCi/g, respectively). The average, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (2013 to 2018) are presented in Figures 7-10, 7-11, and 7-12.

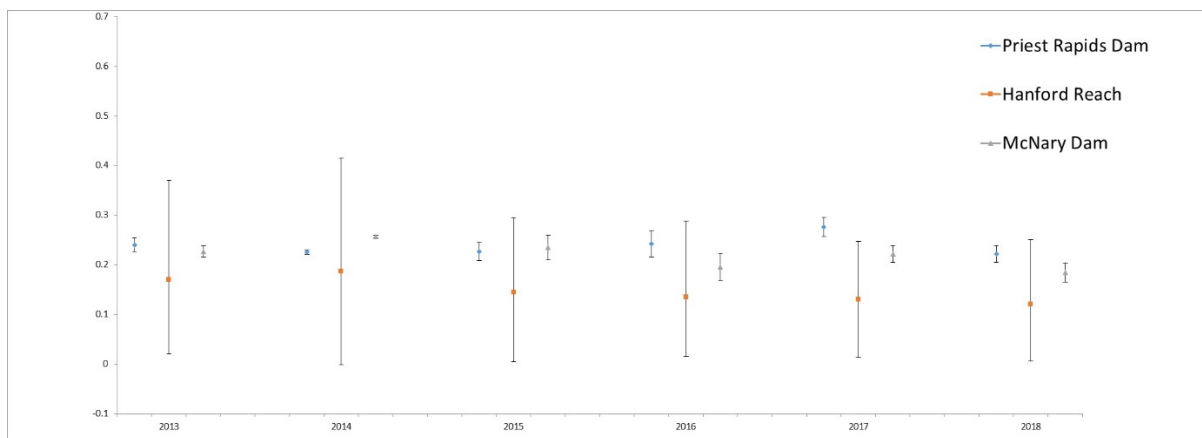


Figure 7-10. Cesium-137 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (results shown are in pCi/g ± 2 standard deviations).

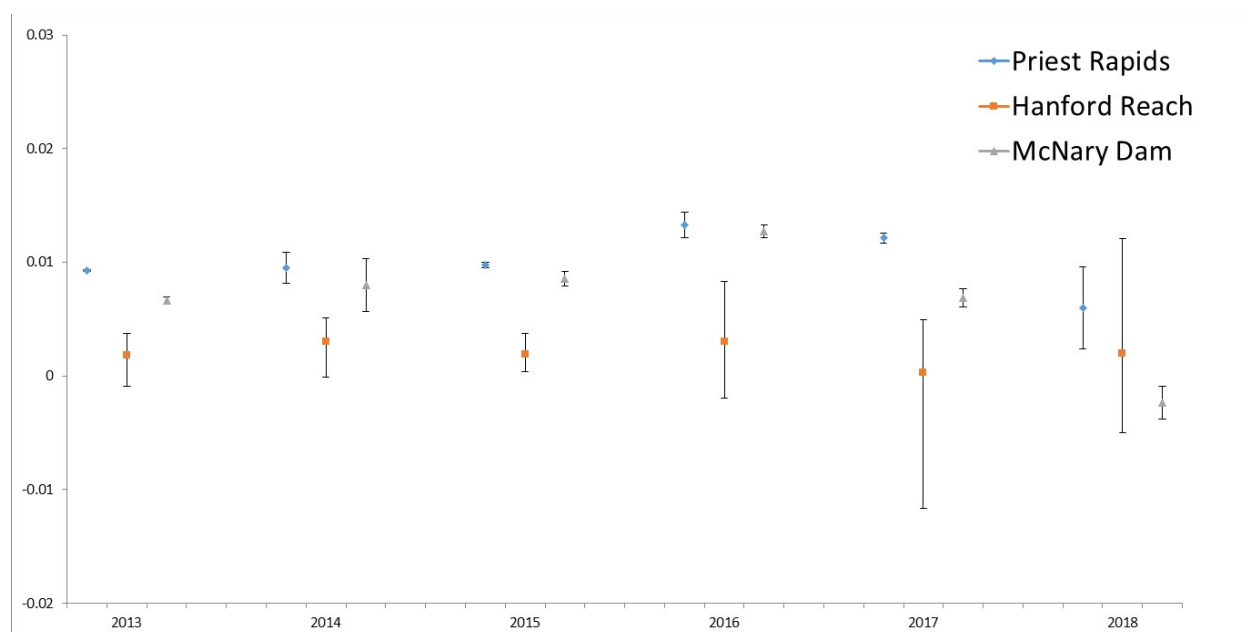


Figure 7-11. Plutonium-239/240 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (results shown are in pCi/g ± 2 standard deviations).

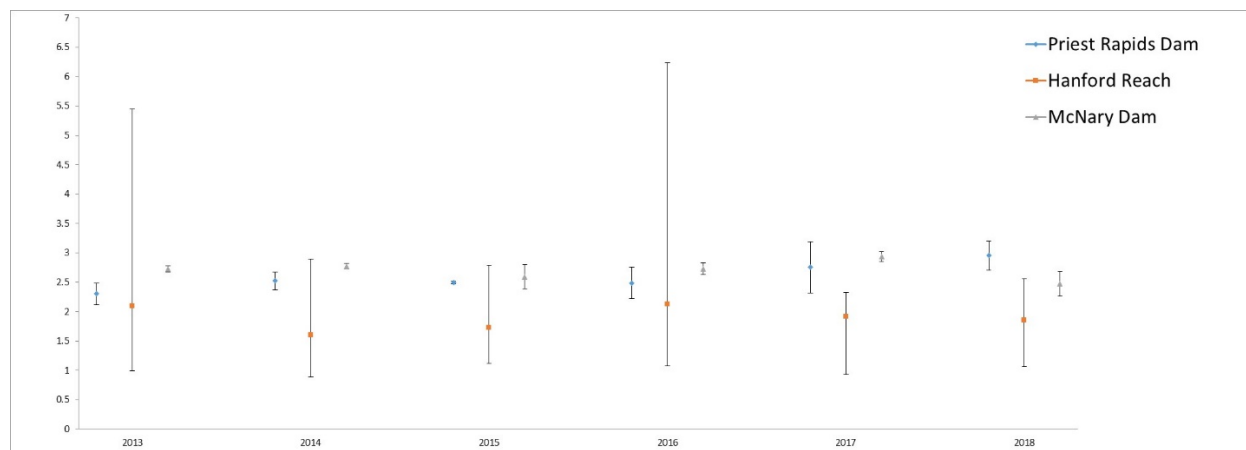
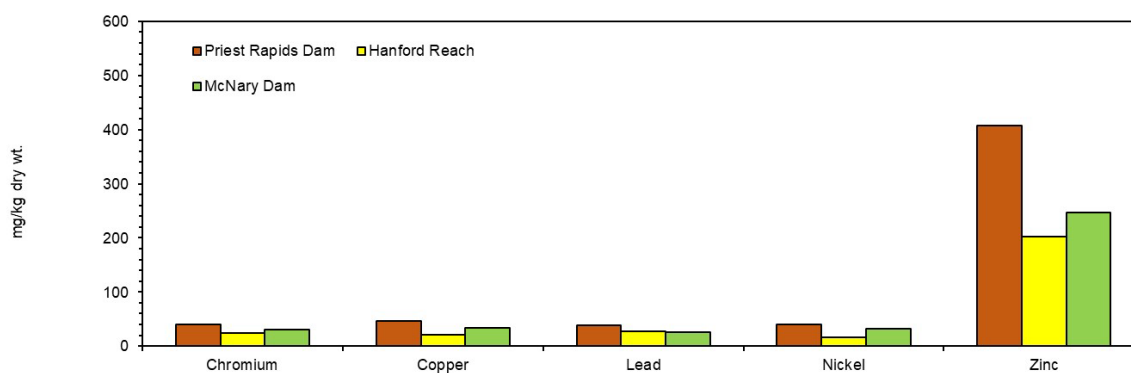


Figure 7-12. Uranium Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (results shown are in pCi/g ± 2 standard deviations).

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. Average concentrations of antimony, cadmium, chromium, copper, lead, mercury, nickel, selenium, 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, chromium, lead, thallium, and zinc were higher for sediment collected in the Hanford Reach than in sediment collected at 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.



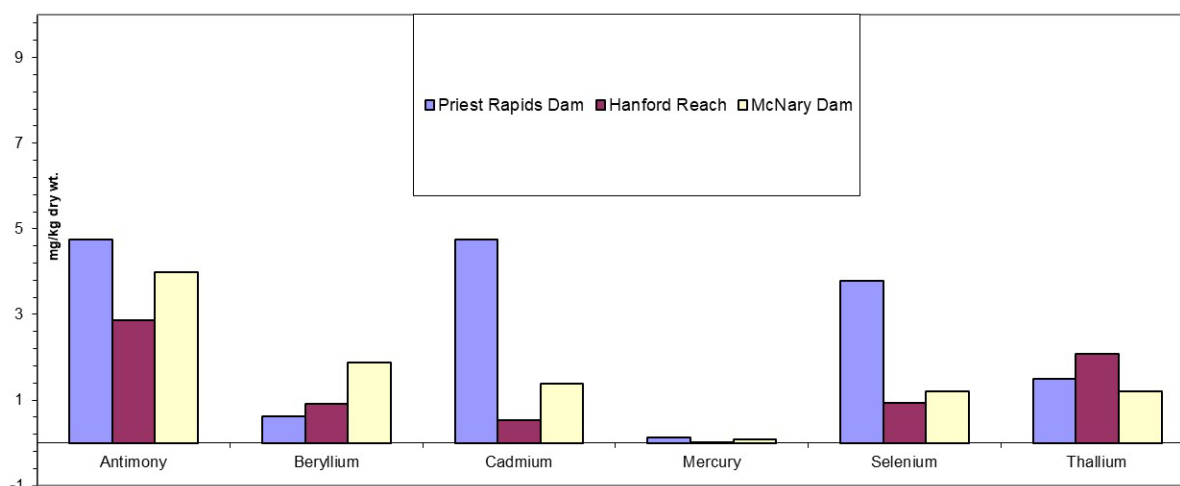


Figure 7-13. Selected Metals Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (Washington and Oregon), 2018.

7.4 Columbia River Seep Water

In 2018, samples of Columbia River seep water and three associated shoreline sediment samples were collected along the Hanford Reach (Figure 7-3). These samples were 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 surface water 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 Tables 7-5 and 7-6 and in tables in Appendix C.

Table 7-6. Columbia River Seep Monitoring. (2 Pages)

Location ^a	Sample Type	Sampling Frequency	Analyses
100-B Area	Grab	Annually	Alkalinity, anions, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, tritium, VOA
100-D Area	Grab	Annually	Alkalinity, alpha, anions, beta, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, technetium-99, tritium, isotopic uranium ^b
100-F Area	Grab	Annually	Alkalinity, anions, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, tritium, VOA
100-K Area	Grab	Annually	Alkalinity, alpha, anions, beta, carbon-14, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, technetium-99, tritium, VOA

Table 7-6. Columbia River Seep Monitoring. (2 Pages)

Location ^a	Sample Type	Sampling Frequency	Analyses
100-N Area	Grab	Annually	Alkalinity, alpha, anions, beta, hexavalent chromium (filtered/unfiltered), metals (filtered and unfiltered), strontium-90, TPH, tritium
300 Area	Grab	Annually	Alkalinity, alpha, anions, beta, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), tritium, isotopic uranium ^(b) , uranium-236, VOA ^c
Hanford Townsite	Grab	Annually	Alkalinity, alpha, anions, beta, hexavalent chromium (filtered/unfiltered), iodine-129, metals (filtered/unfiltered), strontium-90, technetium-99, tritium, VOA

^a Refer to Figure 7.3; Locations may contain multiple shoreline seeps with differing analyses.

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

TPH = total petroleum hydrocarbon

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.

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 influenced strongly 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 while Hanford Site groundwater typically has readings greater than 180 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 7-6 summarizes the sampling locations and frequencies as well as sample types and analyses included in Columbia River seep monitoring during 2018. 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 2018, 12 of 13 scheduled seeps samples were successfully sampled. All samples collected were analyzed for tritium. Some samples from selected seeps were analyzed for alkalinity, alpha, anions, beta, carbon-14, hexavalent chromium, metals, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, and volatile organic compounds. Unfiltered samples were analyzed except for hexavalent chromium and metals analyses, in which case both filtered and unfiltered samples were analyzed (Table 7-6).

7.4.2.1 Radiological Results. Contaminants of Hanford Site origin continued to be detected in 2018 in water from riverbank seeps entering the Columbia River along the Hanford Site. A listing of the 2018 sampling results is provided in Appendix C, Table C-10.

Tritium concentrations varied widely with location. The highest tritium concentration measured in riverbank seeps was at the Hanford Townsite 28-2 riverbank seep ($22,700 \text{ pCi/L} \pm 4,420 \text{ pCi/L}$ [$840 \pm 164 \text{ Bq/L}$]), which was slightly above the Washington State ambient surface water quality criterion of $20,000 \text{ pCi/L}$ (740 Bq/L). No tritium results exceeded the Biota Concentration Guide (DOE/EH-0676) level for Riparian Animal receptors ($265,000,000 \text{ pCi/L}$). Tritium concentrations in riverbank seep water samples were higher compared to maximum concentrations in 2018 Columbia River fixed-station location samples at Priest Rapids Dam and the City of Richland, as well as Columbia River transect samples. Overall, results in 2018 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 2018 and submitted to a laboratory for iodine-129 analysis using an ultra-trace analytical method. Laboratory results showed the concentration to be below analytical detection limits.

All water samples from riverbank seeps were analyzed for strontium-90 and the highest concentration was in the 100-N Area, at approximately 7% of the DOE-derived concentration standard. Historically, groundwater in the 100-N Area has had the highest strontium-90 levels measured at the Hanford Site.

Uranium isotopes' concentrations measured in the 300 Area riverbank seep water samples were higher than those at the 300 Area HRM 43.1 transect location as well as at all other transect locations. 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.

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 seep water collected at the 300-DR 42-2 riverbank seep site. This location is down gradient from the retired 300 Area process trenches. The uranium concentrations in this seep water sample were slightly lower ($17 \text{ pCi/L} \pm 1.7 \text{ pCi/L}$ uranium-234) than the EPA drinking water standard limit of $30 \text{ } \mu\text{g/L}$ (approximately 20 pCi/L [0.74 Bq/L]). The 2018 concentrations of uranium-234, uranium-235, and uranium-238 were slightly higher than those measured during 2013 through 2017.

During 2018 riverbank seep collections, two detections of gross alpha were recorded. The 300 Area Spring 42-2 and 300 Area Spring DR 42-2 riverbank seep had both detections ($7.8 \text{ pCi/L} \pm 3.2 \text{ pCi/L}$ and $25 \text{ pCi/L} \pm 5.8$), of which one sample exceeded Washington State Ambient Water Quality criteria (15 pCi/L ; DOE O 458.1).

Gross beta detections occurred in 100-D, 100-K, Hanford Spring 28-2, and both 300 Area seeps during 2018. Detectable concentrations in riverbank seep water at Hanford Spring 28-2 and the 300 Area Spring DR 42-2 were elevated compared to maximum gross beta concentrations in irrigation water collected from the Horn Rapids Battelle Sporting Complex ($6.1 \text{ pCi/L} \pm 2.1 \text{ pCi/L}$) and Riverview ($2.1 \text{ pCi/L} \pm 1.1 \text{ pCi/L}$) collection locations. Additional gross beta detections from the 100-D and 100-K Areas were similar to irrigation water results from the Horn Rapids Battelle Sporting Complex. The highest gross beta concentration was measured in the Hanford Townsite 28-2 riverbank seep ($25 \text{ pCi/L} \pm 4.2 \text{ pCi/L}$

[0.93 ± 0.16 Bq/L]), which was 50% of the Washington State ambient surface water quality criterion of 50 pCi/L (1.85 Bq/L; WAC 173-201A and 40 CFR 141).

7.4.2.2 Chemical Results. Inorganic and organic contaminants originating from the Hanford Site continued to be detected in water from riverbank seeps entering the Columbia River. Metals and anions of interest (i.e., 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.

Nitrate concentrations were highest in seep water samples from the 100-N Area. Dissolved chromium concentrations were highest in the 100-D Area. Hexavalent chromium concentrations were also highest in the 100-D Spring 110-1 Area. Appendix C, Table C-11 presents concentration ranges of selected metals and anions measured in riverbank seep water during 2013 through 2018.

Concentrations of most metals measured in water collected from seeps along the Hanford Site shoreline during 2013 through 2018 were below the Washington State ambient surface water chronic toxicity levels (WAC 173-201A). All 2018 riverbank seep nitrate concentrations exceeded the Washington State drinking water standard of 10 µg/L (WAC 246-290). However, it is extremely unlikely that members of the public would ever consume riverbank seep water.

Results from organic analyses of water samples are voluminous and not all results are included in this report. A complete listing may be found in the HEIS database. The two major organic contaminants monitored in 2018 were trichloroethene and dichloroethene, compounds used during past reactor fuel fabrication in the 300 Area. These contaminants were measured in transect and shoreline seep water collected upstream and downstream of the Hanford Site and in the vicinity of the 300 Area. Analytical results for these samples showed concentrations below their respective EPA Drinking Water Standards (Appendix C, Table C-12).

7.4.3 Sediment Monitoring

Beginning in the 1990s, periodic studies were conducted to collect and analyze sediments at 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 sediment sampling began in 1993 at the Hanford Townsite and the 300 Area. Sampling in the 100-B, 100-K, and 100-F Areas began during 1995 and the 100-H Area was added in 2004.

Over the years, as a result of fluctuating groundwater shoreline discharge patterns, sediment collection locations have been moved, added, and/or abandoned. In 2018, sediment samples were collected from riverbank seep locations in the 100-D, 100-H, 100-K, and 300 Areas. (Table 7-7).

Table 7-7. Sediment Samples at 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, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, total organic carbon, and uranium-236
^a Refer to Figure 7.8		
^b Uranium-234, uranium-235, and uranium-238		
^c Plutonium-238 and plutonium 239/240		

7.4.3.1 Radiological Results. Radiological results for the 2018 shoreline seep sediment samples were similar to those measured in Columbia River sediment samples collected at Priest Rapids and McNary Dams. Cesium-137, plutonium-238, plutonium-239/240, and uranium isotopes were consistently detected at low levels at most sediment sample locations. Table C-13 in Appendix C shows radionuclide concentrations in Columbia River and shoreline seep location sediment samples from 2013 through 2018.

7.4.3.2 Metals Results. Concentrations of metals in shoreline seep sediment samples collected in 2018 were similar to concentrations in Columbia River sediment samples with the exception of arsenic, copper, lead, mercury, selenium, silver, and thallium where higher shoreline concentrations were seen. Shoreline sediment collected from the 100-H Spring 145-1 area had the highest levels of arsenic, cadmium, copper, lead, mercury, nickel, silver, and thallium than those measured in any other Columbia River sediment samples (excluding other shoreline sediment locations). The 300-Area DR 42-2 seep had the highest levels of selenium in comparison to all other sediment collection locations (Appendix C, Table C-14). Currently, there are no Washington State freshwater sediment quality criteria to compare against the measured values.

7.4.3.3 Hexavalent Chromium Results. The 300 Area Spring DR 42-2 and 100-D Spring 102-1 Areas had the highest levels of hexavalent chromium. The 100-D Area has two separate hexavalent chromium plumes that have been recorded; surrounding soil and water sampling have shown elevated concentrations (Appendix C Table C-15).

7.4.3.4 Total Organic Carbon Results. All Columbia River sediment samples collected in 2018 had detections of Total Organic Carbon. Results were similar to those observed in previous years from the same locations. The highest result was found in a 2018 Priest Rapids Dam sample that mirrored historical observations (Appendix C, Table C-16).

7.5 Pond Water and Sediment

West Lake pond water and sediment (Figure 7-3 and Figure 7-14) sampling was conducted twice (during early spring/late spring) during 2018. West Lake is accessible to migratory waterfowl, deer, and other wildlife, creating a potential biological pathway for the dispersion of contaminants.

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.

7.5.1 West Lake Water

Water monitoring continued at West Lake in 2018 with sampling conducted twice (early and late spring). Surface water samples collected from West Lake were analyzed for tritium, uranium-234, uranium-235, uranium-238, and technetium-99. Technetium-99 and tritium concentrations were below the laboratory detection limits and were well below applicable DOE-Biota Concentration Guide levels (DOE/EH-0676) for Aquatic Animal receptors. Radionuclide concentrations from surface water samples collected during 2018 and in the previous 2 years are shown in Appendix C, Table C-2.

Isotopes of uranium were detected in all samples at varied concentrations, all within the historic range of sample results for this location.

7.5.2 West Lake Sediment

Biannual Sediment (Figure 7-3) samples were collected during early and late spring from West Lake during 2018. 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 2018 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 2018 and a summary of those collected during the previous 5 years are shown in Appendix C, Table C-1.

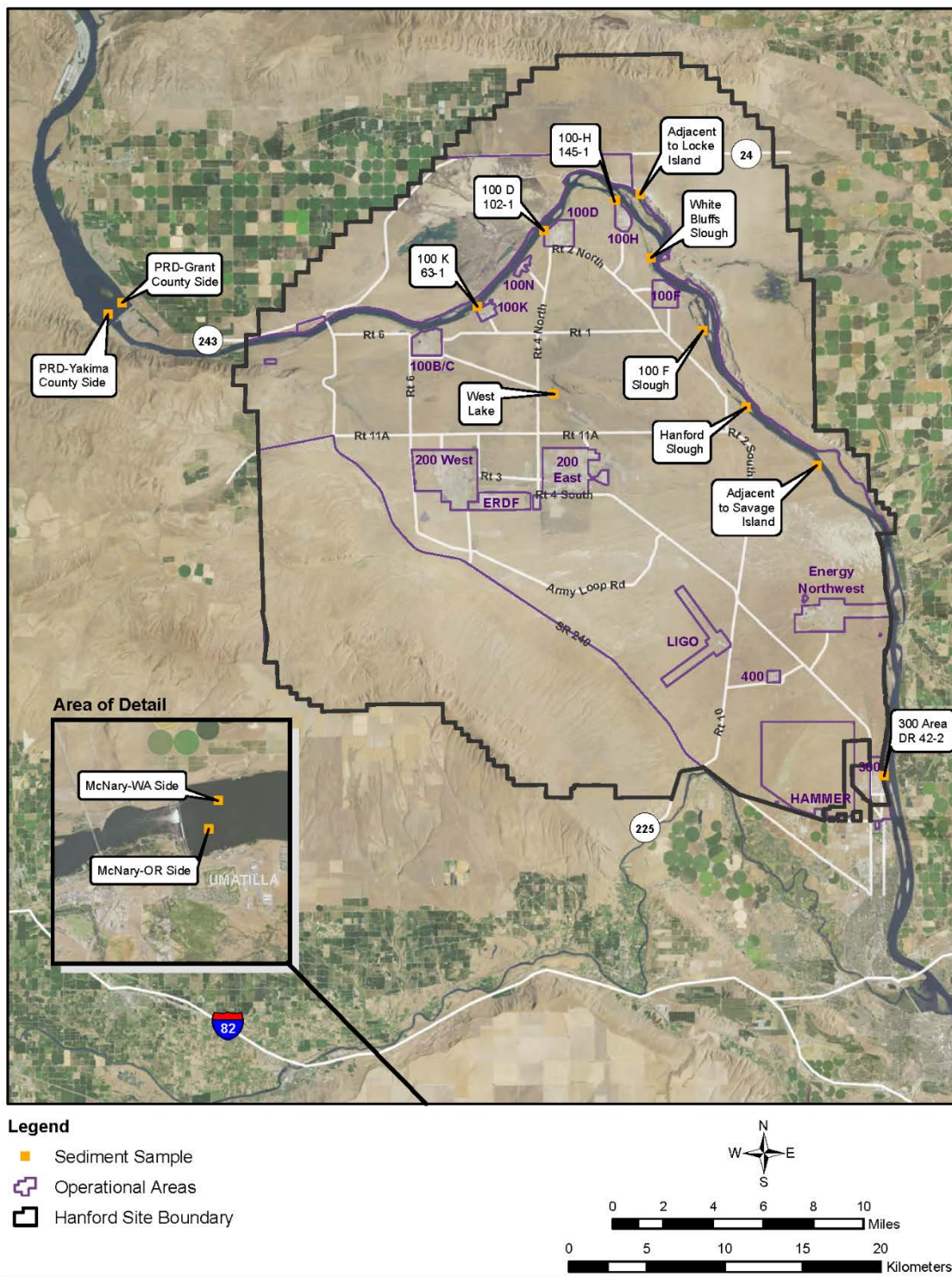


Figure 7-14. Sediment Sampling was Conducted Twice During Early Spring/Late Spring During 2018.

7.6 Offsite Irrigation Water

Water is extracted from the Columbia River immediately downstream of the Hanford Site is used to irrigate agricultural areas in Benton and Franklin counties. The majority of irrigation water utilized in Franklin County originates at Grand Coulee Dam and is provided through its extensive water delivery systems (i.e., canals). Similarly, Benton County relies heavily on the Yakima River for irrigation.

Sampling of irrigation water is conducted to monitor for the presence radionuclides. The consumption of food products (see Section 10.1) 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 (see Section 4.2.1).

7.6.1 Offsite Irrigation Water Monitoring.

Irrigation water samples were collected in 2018 from a canal located on the east side (left bank) of the Columbia River downstream of the Hanford Site at Riverview (Road 68, Pasco), from another irrigation line located on the west side (right bank) of the Columbia River just downstream of the 300 Area (Battelle Sporting Complex), and from an additional canal located in the Sagemoor area that is utilized as a reference location (water drawn from the potholes area). Samples from the Horn Rapids irrigation pumping station (Figure 7-3) were collected at the Battelle Sporting Complex. Each location was sampled three times during the irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, strontium-90, and tritium.

7.6.2 Sample Results.

Radionuclide concentrations measured in irrigation water samples collected during 2018 were comparable to levels detected in Columbia River transect water samples collected upstream of the Hanford Site. Tritium was the only radionuclide detected in any of the samples collected during 2018. At the Horn Rapids location the tritium concentrations were slightly higher than the Riverview and Sagemoor irrigation system samples. Radionuclide concentrations from irrigation water samples collected during 2018 and in the previous 5 years are shown in Appendix C, Table C-17.

7.7 Liquid Effluent

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During peak operating and production years at the Hanford Site from the 1940s through the 1990s, billions of gallons of effluent waste containing millions of kilograms of pollutants from reactor operations and chemical fuel processing were discharged to the Columbia River and soil column. Most of the discharges occurred in the 100 Reactor Areas along the river, 200-East Area, 200-West Area, and the 300 Area. As the mission of the Hanford Site shifted from production of nuclear materials to environmental cleanup, all discharges to the Columbia River were ceased. The last permitted discharges to the Columbia River stopped operating in March 2011. In CY 2018, two permitted point sources discharged effluents to the ground and several permitted nonpoint sources also operated. Six groundwater pump and treat systems operated in the 200 West and 100 Areas discharging treated liquid effluents to the ground in CY 2018. See Section 8.0, Groundwater Monitoring, for more information on groundwater pump and treat systems.

7.7.1 Point Source Discharges

The U.S. Environmental Protection Agency (EPA) describes a point source of pollution as a single identifiable source from which all pollutants are discharged (e.g., a pipe, factory, or facility). Two liquid effluent point sources discharging liquids to the ground operated in CY 2018 on the Hanford Site: the Effluent Treatment Facility and Treated Effluent Disposal Facility.

7.7.1.1 200 Area Effluent Treatment Facility. Hanford's Effluent Treatment Facility (ETF) located in the 200 East Area treats liquid waste and has been in operation since 1995. The ETF influent consists of individual waste streams from multiple Hanford facilities. Source streams received for treatment include process condensate from the 242-A Evaporator, and leachate from land waste disposal sites. Most liquid waste streams to be treated at ETF are initially stored at the Liquid Effluent Retention Basin Facility (LERF), located near the ETF. The ETF waste treatment system removes toxic metals, radionuclides, and ammonia in addition to destroying organic compounds. The ETF waste treatment system does not remove tritium, a radioactive isotope of hydrogen, which cannot be easily removed. After the liquid is treated, it is stored in tanks, sampled and analyzed, and then discharged to the ground at the State-Approved Land Disposal Site (SALDS). The SALDS is located north of the 200-West Area (Figure 7-15). The ETF is the only Hanford facility permitted to discharge radioactive effluents to the ground. Table 7-8 contains the volume of liquid discharged and curies of tritium released during CY 2018. See Section 5.3.4 for more information on ETF.

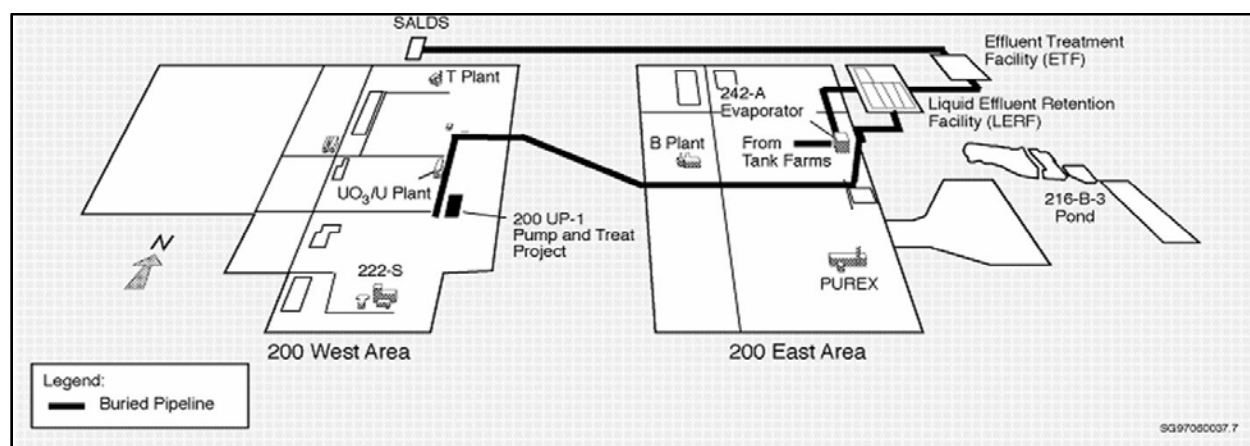


Figure 7-15. Location of Effluent Treatment Facility and State-Approved Land Disposal Site.

Table 7-8. Calendar Year 2018 Tritium Discharges to SALDS^a.

Month	Effluent Discharge (gal)	Tritium Released (Ci)
January	0	0
February	0	0
March	0	0
April	350,393	1.01
May	0	0.0
June	607,347	1.71
July	859,634	2.55
August	411,170	1.32
September	0	0
October	0	0
November	0	0.0
December	0	0
TOTAL	2,228,544	6.59
^a Information from RPP-RPT-61178 Ci = curies SALDS = State-Approved Land Disposal Site		

7.7.1.2 200 Area Treated Effluent Disposal Facility. The Treated Effluent Disposal Facility (TEDF) provides a collection, conveyance, and disposal system for treated effluent from buildings in the 200 Areas (Figure 7-16). It is located in the 200-East Area and consists of an 11-mi (17.7-km)-long pipeline and two adjacent 5-ac (2-ha) infiltration ponds. The TEDF is a piped collection system that does not have any treatment or retention capacity. Wastewater generating processes include: cooling water, steam condensate, dryer condensate, air conditioning condensate, reverse osmosis unit brine, reverse osmosis permeate, potable water, raw water, rainwater, miscellaneous effluents, water softener regenerant, filter backwash, boiler blowdown, and cooling tower blowdown. The water from individual waste streams must be treated prior to transfer to TEDF. State Waste Discharge Permit Number ST0004502 (Ecology 2012a) provides the terms and conditions that regulate the discharge of this wastewater to the ground and ensures the discharges meet state standards in WAC 173-200, "Water Quality Standards." The volume of non-radioactive, non-dangerous waste disposed to this facility in 2018 was approximately 120 million gal (456 million L). See Section 5.3.4 for more information on TEDF.

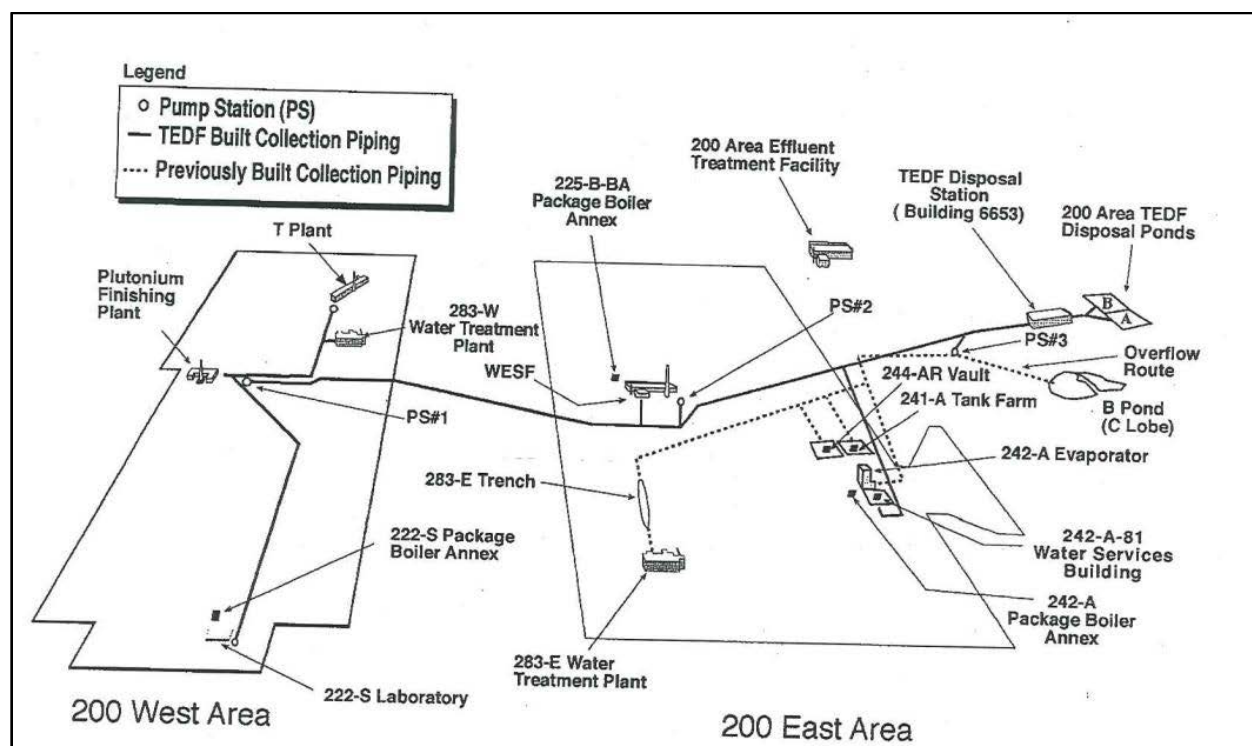


Figure 7-16. Location of the Treated Effluent Disposal Facility.

7.7.1.3 300 Area Discharges to the City of Richland Sewer. The City of Richland regulates industrial wastewater discharges to its sewer collection system. DOE holds Permit No. CR-IU010, which allows discharges from contractor-operated facilities in the 300 Area.

7.7.2 Nonpoint Source Discharges

Nonpoint source discharges are effluents that are also described as diffuse, which occur over an area and are not easily attributed to a single point source. An example of a nonpoint source discharge is rain water or snowmelt runoff. Several permitted nonpoint discharges operated in CY 2018 on the Hanford Site.

7.7.2.1 Miscellaneous Wastewater Discharges. The routine operations conducted at various locations on the Hanford Site periodically generate discharges of liquid waste streams. These types of miscellaneous wastewater discharges include hydrotesting water, construction, and maintenance wastewater; the discharge of cooling water and condensate; and the collection and the discharge of industrial stormwater. The terms and conditions regulating these wastewater discharges are included in a categorical State Waste Discharge Permit number ST0004511 (Ecology 2013).

7.7.2.2 Waste Treatment Plant. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) operates two state permitted sand and gravel locations. The concrete batch plant facility supports the construction of the WTP with the primary function of making concrete. The Pit 30 quarry also supports the construction of the WTP with the primary function of making gravel. The types of discharges include process water, storm water, and activities associated with sand and gravel operations and rock quarries. Permit conditions require the permit holder to provide environmental protection through best management practices and wastewater treatment.

7.7.2.3 200-West Area Evaporative Sewage Lagoon. The 200-West Area Evaporative Sewage Lagoon is a domestic wastewater treatment facility located northeast of the 200-West Area of the Hanford Site (Figure 7-17). The facility consists of double-lined evaporative lagoons and is designed and operated to have zero liquid discharge to the ground. The system provides domestic wastewater treatment for domestic wastewater transported from other locations within the Hanford Site. The DOE constructed the 200-West Area Evaporative Sewage Lagoon to replace the previously existing 100-N Sewage Lagoon, which was near the end of its service life. The majority of future Hanford Site cleanup activities are anticipated to be located in the vicinity of the 200 Areas and the siting of this treatment facility near 200-West better serves the cleanup mission over time. Although this facility is not permitted to discharge, except in the case of emergencies, State Waste Discharge Permit Number ST0045514 (Ecology 2012b) governs the operation and maintenance of this facility.

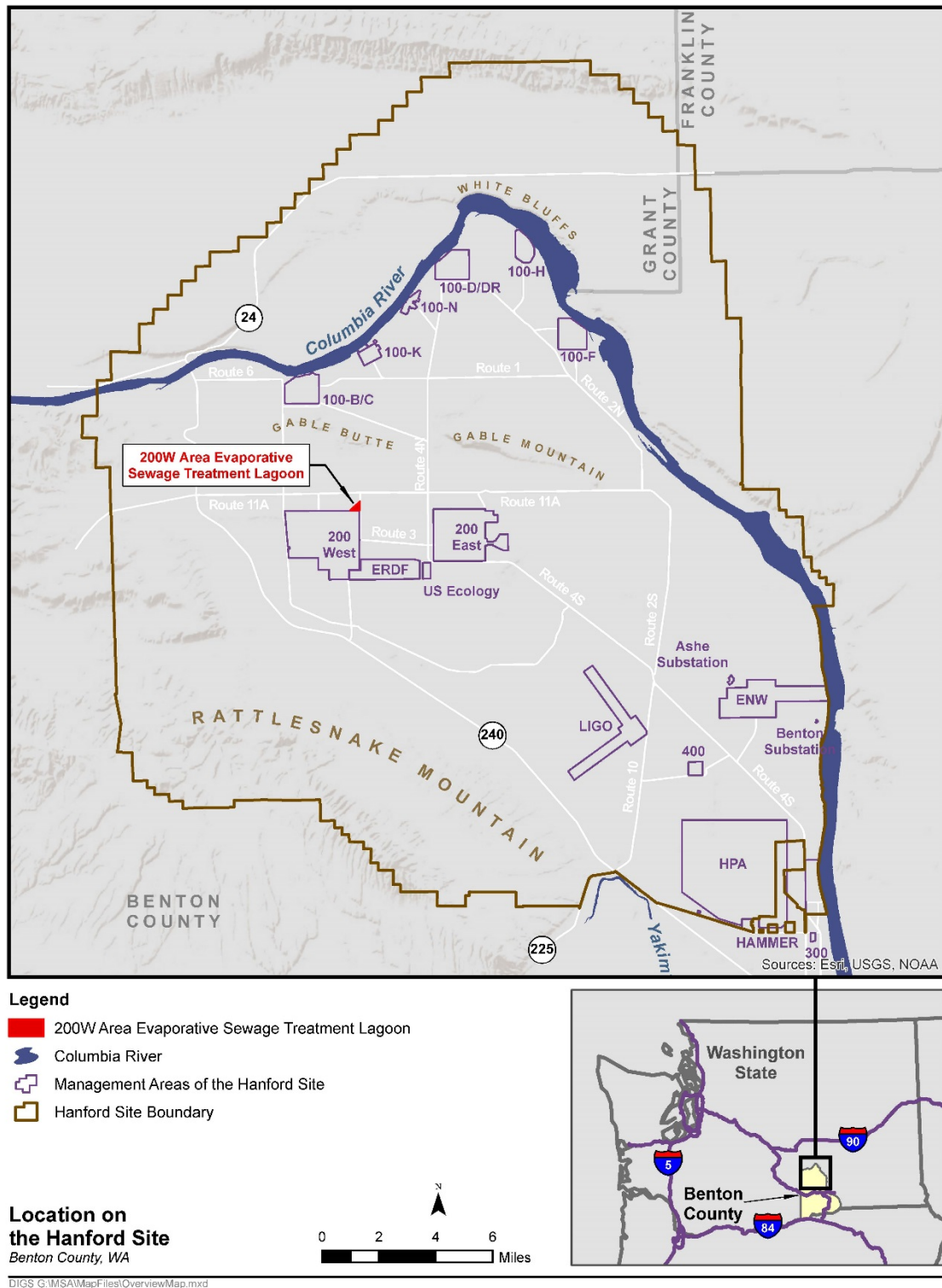


Figure 7-17. Location of the Evaporative Sewage Treatment Lagoon.

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2018 Highlights

Contaminant Plume Areas

The estimated area of Hanford Site groundwater contaminant plumes above regulatory standards in 2018 was 65 mi² (168 km²), about the same as 2017. The combined plume area has declined since 2000 as a result of remediation and natural attenuation.

Groundwater Remediation

- Pump-and-treat systems in the 100 Areas removed 91 kg of hexavalent chromium in 2018, and 3,485 kg in their lifetimes.
- Pump-and-treat systems in the 200-West Area removed 2,231 kg of carbon tetrachloride in 2018, and 29,034 kg since 1994. Other groundwater contaminants removed by pump-and-treat systems in the 200 Areas include nitrate, cyanide, technetium-99, and uranium.
- DOE continued to make progress on other groundwater remedial actions in 2018, including a permeable reactive barrier in 100-N Area, enhanced attenuation in the 300 Area, hydraulic control in the 200 Area, and monitored natural attenuation of selected plumes in the 100, 200, and 300 Areas.

Well installation: In 2018, the U.S. Department of Energy drilled 43 wells and boreholes for monitoring, groundwater remediation, and characterization.

8.0 Groundwater Monitoring

MJ Hartman

This section summarizes results of Hanford Site groundwater monitoring for 2018. DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2018*, contains detailed information and is accessible through the Internet at <http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports>. The U.S. Department of Energy (DOE) provides groundwater data to the public via the Internet at <https://ehs.hanford.gov/eda>.

Chemical and radioactive wastes contaminated the soil and groundwater beneath portions of the Hanford Site. The majority of the contamination is found in the 200-East Area, 200-West Area, 300 Area, and 100 Area (Figure 8-1).

DOE operates an extensive groundwater monitoring program on the Hanford Site. Groundwater is monitored for *Resource Conservation and Recovery Act of 1976* (RCRA) units; for *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) groundwater operable units; for other Washington State-required programs; and for the *Atomic Energy Act of 1954*, as required by DOE Orders. Figure 8-1 shows the location and extent of the most widespread groundwater contaminants: iodine-129, tritium, nitrate, and carbon tetrachloride. Figure 8-2 shows how the sizes of these three plumes and the combined plume footprint (all contaminants) have changed over the years.

8.1 River Corridor

The 100 and 300 Areas comprise the River Corridor of the Hanford Site. About 94% of the waste sites in this region have been remediated or were determined not to require remediation, reducing the possibility of continued contaminant migration to groundwater. Remedial action decisions for the remaining 6% of the waste sites are in progress. Groundwater in this region migrates slowly through the aquifer and into the Columbia River. Figure 8-3 illustrates River Corridor contaminant plumes where concentrations exceeded cleanup levels in 2018. Table 8-1 compares the maximum concentrations measured in 2017 and 2018 for the contaminants in each of the River Corridor groundwater interest areas.

River Corridor groundwater is being remediated under CERCLA (Table 8-2). The size of the hexavalent chromium plume has decreased markedly since 2002 due to groundwater remediation and natural attenuation (Figure 8-4). Tritium and trichloroethene plume sizes have declined due to natural attenuation; however, the uranium and strontium-90 plumes are attenuating more slowly.

Figure 8-5 illustrates maximum contaminant concentrations in the River Corridor over time. The detected maximum concentrations of some contaminants (e.g., hexavalent chromium, technetium-99 and uranium) increased in recent years because new wells were installed in areas near suspected contaminant sources. Data from these characterization wells are used to develop and select remedial alternatives. Maximum concentrations of other contaminants such as tritium, strontium-90, trichloroethene, and nitrate have declined.

DOE has established derived concentration standards for use in conducting radiological environmental protection programs. The standards represent the concentration of a given radionuclide in water or air that would result in a person receiving a 100 mrem total effective dose following continuous exposure for 1 year. Figure 8-6 illustrates the total effective dose that would occur if a person consumed River Corridor groundwater for 1 year. The dose in wells with values greater than 100 mrem/yr is primarily from strontium-90 in the 100-K and 100-N Areas.

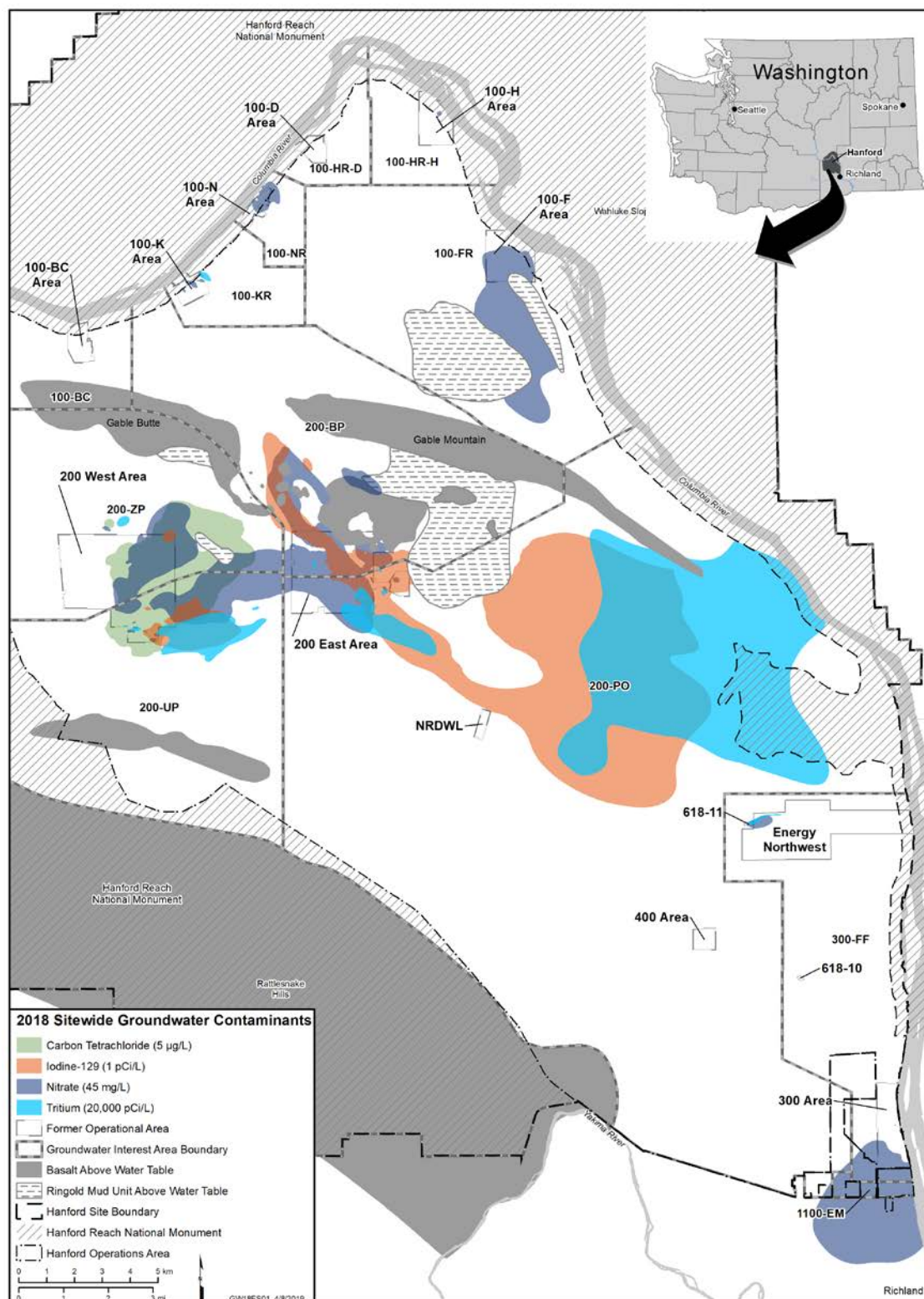


Figure 8-1. Regions of the Hanford Site and Largest Contaminant Plumes.

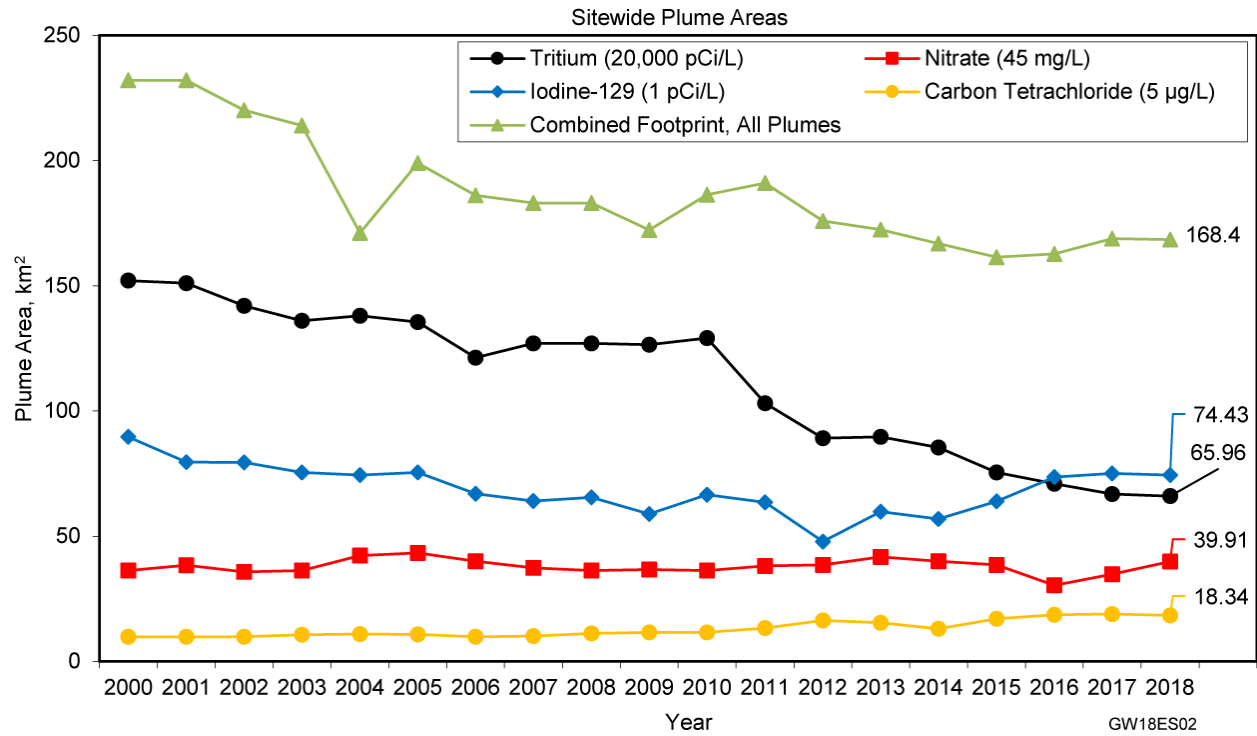


Figure 8-2. Hanford Site Plume Areas.

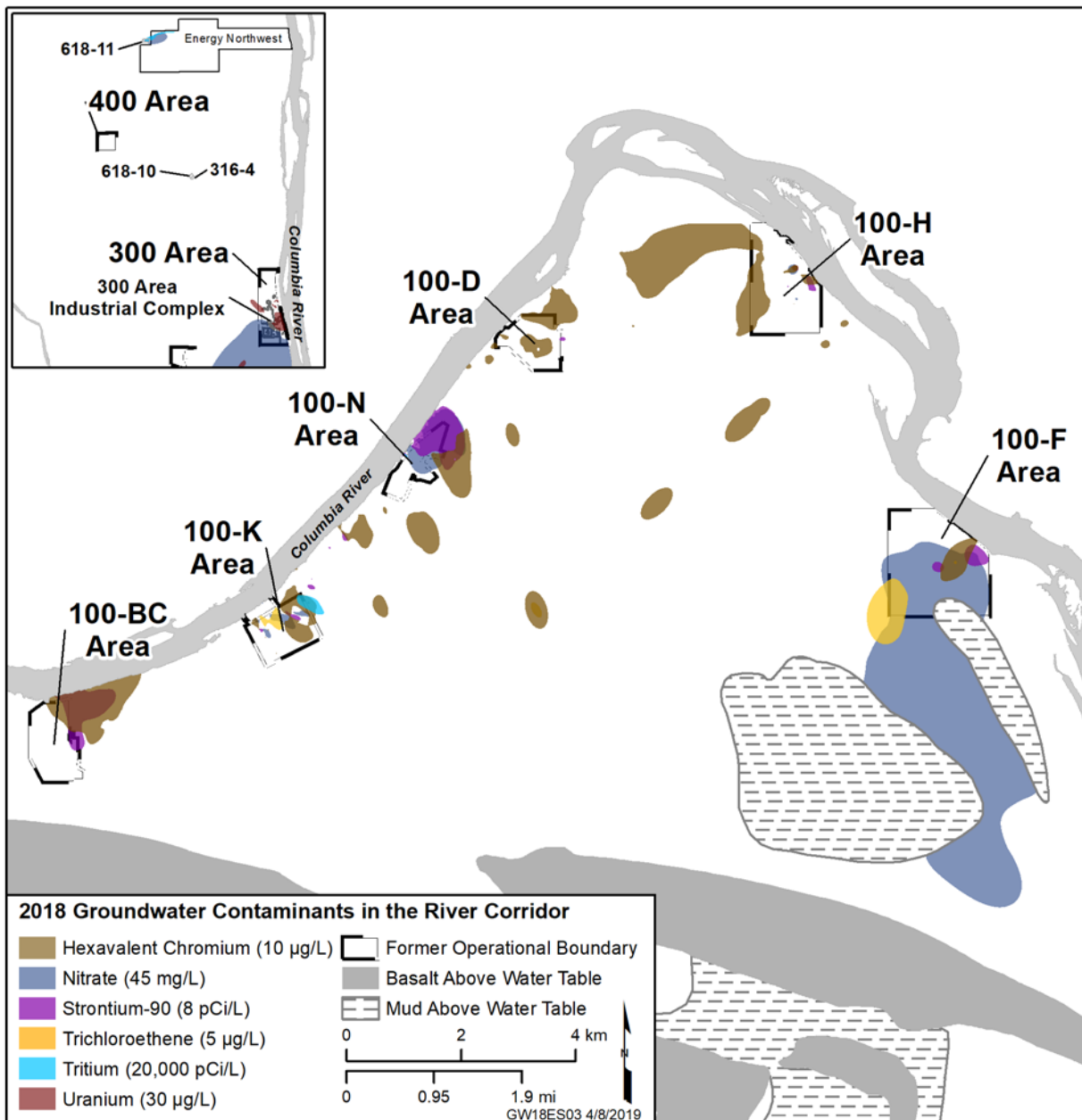


Figure 8-3. Groundwater Contaminant Plumes in the River Corridor.

Table 8-1. River Corridor Groundwater Contaminants, 2017 and 2018.





Ground-water Interest Area	Maximum Concentrations							
	Year	C-14 (pCi/L)	Cr(VI) (µg/L)	Nitrate (mg/L)	Sr-90 (pCi/L)	TCE (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
100-BC	2018	N	57	19.5	61.8	6.19	8,840	6.9
	2017	N	50	21.9	43.6	5.49	11,900	5.4
100-FR	2018	63.8	58	304	135	15	3,180	27.7
	2017	N	42	342	120	13	3,030	14
100-HR	2018	N	800	416	24.5	N	16,200	89
	2017	N	730	217	27.8	N	9,440	142
100-KR	2018	32,900	528	88.5	4,050	7.3	225,000	22.4
	2017	28,500	840	115	15,600	8.1	3,810,000	34.9
100-NR	2018	274	123	190	11,600	N	383,000	13.4
	2017	325	130	319	14,200	0.3	282,000	8.9
300-FF	2018	N	20.5	208	4.38	1.5	450,000	3,600
	2017	N	10	186	N	1.99	570,000	8,450
1100-EM	2018	14	N	137 ^a	N	N	N	35.4 ^a
	2017	N	N	150 ^a	N	0.46	N	34.5 ^a
Standard ^b		2,000	10	45	8	5	20,000	30
Half-life		5,730 yr	N/A	N/A	28.8 yr	N/A	12 yr	>159,000yr
Mobility		High	High to moderate	High	Slight	Moderate	High	Moderate
Colors and listed values indicate maximum concentration, as follows:								
		 >Standard and ≤10 × standard						
		 >10 × standard and ≤100 × standard						
		 >100 × standard and ≤1,000 × standard						
		 >1,000 × standard						
a. Originate from offsite sources.								
b. Drinking water standards for all but hexavalent chromium (aquatic standard).								
Cr(VI) = hexavalent chromium								
MNA = monitored natural attenuation								
N = not detected or not analyzed								
N/A = not applicable								
TCE = trichloroethene								

Table 8-2. Summary of CERCLA Groundwater Remediation in the River Corridor.

Groundwater Operable Unit	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern ^a	Current Groundwater Remediation	Mass Removed
100-BC-5	Rev. 0 RI/FS report and proposed plan anticipated in 2019	Cr(VI), strontium-90, TCE, tritium	No interim action required; final action pending	Not applicable
100-FR-3	ROD for final action signed in 2014	Cr(VI), nitrate strontium-90, TCE	Monitored natural attenuation	Not applicable
100-HR-3	ROD for final action signed in 2018	Cr(VI), total chromium, nitrate, strontium-90	Pump-and-treat from 1997–2018 and monitored natural attenuation	Cr(VI) 2018: 55.9 kg Total: 2,460 kg
100-KR-4	Interim ROD; Draft B RI and Draft A FS report in progress	Cr(VI), total chromium, carbon-14, nitrate, strontium-90, TCE, tritium	Interim action pump-and-treat for Cr(VI) from 1997–2018	Cr(VI) 2018: 35.0 kg Total: 939 kg
100-NR-2	Draft B RI/FS report in progress	Strontium-90, TPH-D, nitrate, Cr(VI), total chromium, tritium	Interim action permeable reactive barrier for strontium-90; removal of TPH-D	Strontium-90: not applicable; TPH-D 2018: 2.05 kg; TPH-D total: 19 kg
300-FF-5	ROD for final action signed in 2013	Uranium, gross alpha, cis 1,2-dichloroethene, TCE, nitrate, tritium	Enhanced attenuation (sequestration) for uranium; monitored natural attenuation for others	Not applicable
1100-EM-1	ROD signed in 1993	TCE	No longer required; remedial action objectives achieved	Not applicable

^a Contaminants of concern are listed for operable units with RODs for final action. The primary contaminants of potential concern are listed for the other operable units.

^b The July 2018 ROD (EPA et al. 2018) selected continued pump-and-treat as the remedy for total chromium and Cr(VI); monitored natural attenuation is the selected remedy for nitrate and strontium-90.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

Cr(VI) = hexavalent chromium

RI/FS = remedial investigation/feasibility study

ROD = Record of Decision

TCE = trichloroethene

TPH-D = total petroleum hydrocarbons-diesel range

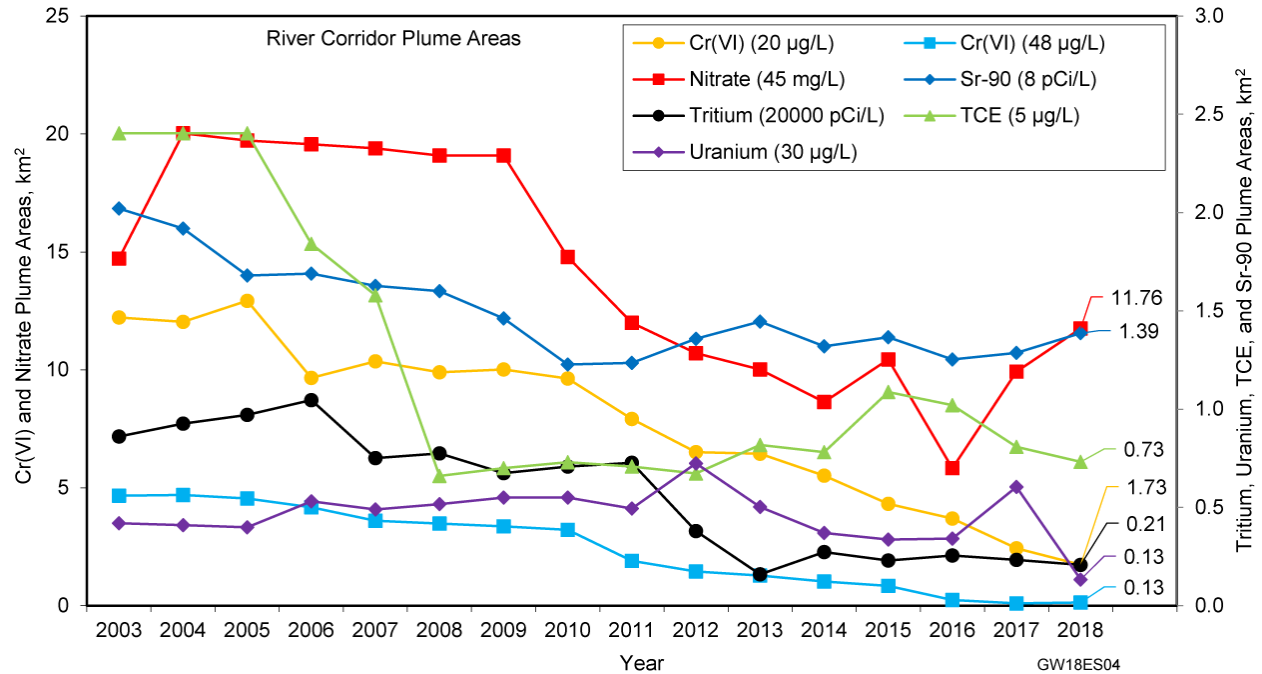


Figure 8-4. River Corridor Plume Areas.

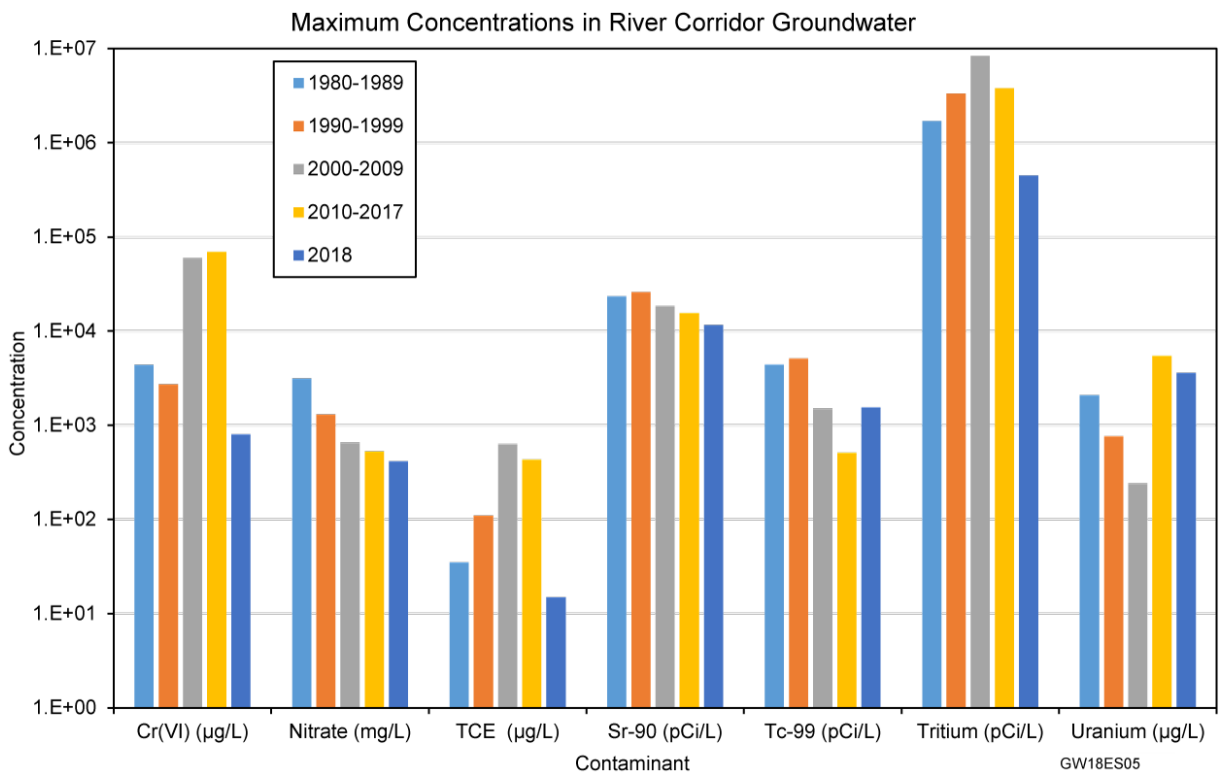


Figure 8-5. Maximum Concentrations of River Corridor Contaminants over Time.

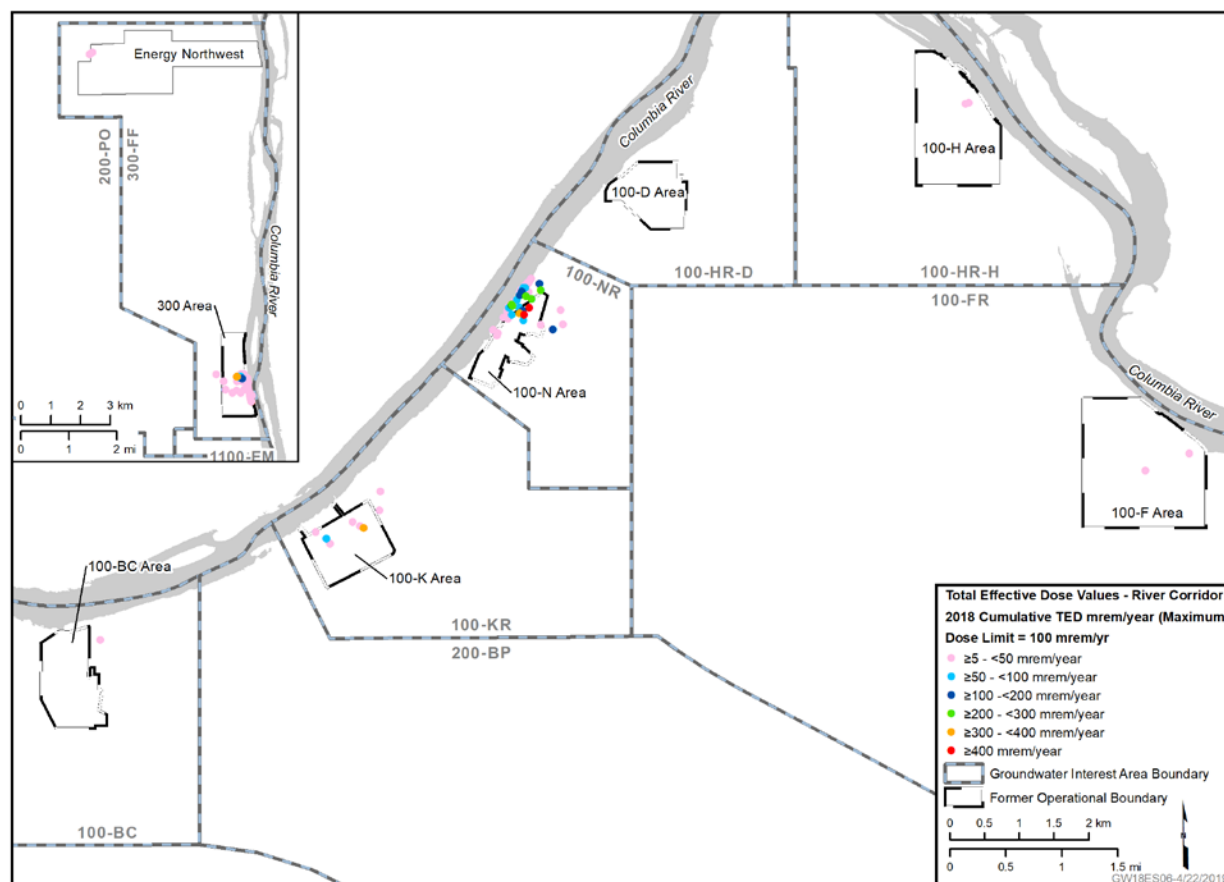


Figure 8-6. Groundwater Dose Calculation for the River Corridor.

The following activities or changes occurred in the River Corridor in 2018:

- **100-BC**
 - Hexavalent chromium concentrations continued to decline, and the plume size continued to decrease, especially in the southern part of the plume.
- **100-FR**
 - Nitrate concentrations increased in some wells in 2018. The causes of the increases are being investigated.
- **100-HR**
 - The U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology, and DOE signed a Record of Decision for the 100-HR-3 Groundwater Operable Unit and associated source OUs in July 2018 (EPA et al. 2018). The selected remedy for groundwater is expanded pump-and-treat for total chromium and hexavalent chromium. The selected remedy for nitrate and strontium-90 is monitored natural attenuation.

-
- The hexavalent chromium plumes across the OU continued to shrink in response to ongoing groundwater remediation, and concentrations continue to decline.
 - **100-KR**
 - DOE and EPA approved a soil flushing treatability test plan and a sampling and analysis plan in 2018 that will target deep vadose zone contamination that is a source of groundwater contamination. This test, which is planned to occur in 2019, will use treated effluent water from the KW pump-and-treat system to saturate the vadose zone beneath the former 183.1KW Headhouse area and mobilize residual hexavalent chromium into groundwater. Groundwater bearing the flushed hexavalent chromium will be extracted using current pump-and-treat extraction wells and treated at the plant.
 - DOE installed five new wells for monitoring and potential groundwater extraction. Two of the wells were installed to support the soil flushing treatability test. Data collected from these two locations helped define the hexavalent chromium plume at the 183.1KW Headhouse.
 - **100-NR**
 - Concentrations of strontium-90 and total petroleum hydrocarbons increased temporarily in some wells during a period of high river stage in 2018. Plume areas did not notably change between 2017 and 2018.
 - **300-FF**
 - In September 2018, DOE conducted Stage B of the uranium sequestration remedy, injecting a phosphate solution into 48 wells. Groundwater monitoring showed declines in uranium concentration after the injections.
 - **RCRA**
 - The 1301-N, 1324-N/NA, and 1325-N units were approved as clean closed and retired from the Hanford RCRA Permit.
 - **New wells**
 - Table 8-3 lists wells installed or decommissioned in the River Corridor in 2018.

Table 8-3. Summary of River Corridor Wells or Boreholes Drilled or Decommissioned in 2018.

Groundwater Interest Area	Wells or Instrument Boreholes Completed	Wells or Boreholes Decommissioned	Comment
100-BC	0	0	
100-FR	0	0	
100-HR	0	0	
100-KR	5	1	Dual-purpose monitoring wells installed.
100-NR	0	0	
300-FF	1	2	Replacement well installed at the 316-4 Crib.
1100-EM	0	0	
Total	6	3	

8.2 Central Plateau

The Central Plateau, located in the middle of the Hanford Site, includes the 200-West and 200-East Areas. Ponds, cribs, and ditches used for liquid waste disposal were the primary sources of groundwater contamination. Seven single-shell tank waste management areas are also located in the 200 Areas. Contamination is still present at some locations in the thick Central Plateau vadose zone and may continue to migrate into the groundwater. DOE has begun characterizing these sites in preparation for remediation.

Figure 8-7 shows the Central Plateau groundwater contaminant plumes in 2018, and Table 8-4 compares the maximum contaminant concentrations measured in 2017 and 2018.

Groundwater beneath portions of the Central Plateau is being remediated under CERCLA. Table 8-5 summarizes the status of CERCLA remediation for Central Plateau groundwater and deep vadose zone operable units. In 2018, pump-and-treat systems continued to remove carbon tetrachloride, nitrate, technetium-99, uranium, and other contaminants from groundwater.

The size of the Central Plateau tritium plume continued to decline in 2018 due to natural attenuation, which includes radioactive decay (Figure 8-8). The size of the carbon tetrachloride plume appears to have increased since 2010, partly due to better characterization (new wells) and partly due to migration of the distal lobes of the plume, which the pump-and-treat remedy is not designed to capture. The estimated extent of hexavalent chromium contamination increased in 2017 when data from new wells became available; the area stayed the same in 2018. The technetium-99 and uranium plume areas continued to decline gradually due to groundwater remediation.

Maximum concentrations of most Central Plateau groundwater contaminants have decreased over time (Figure 8-9) due to remediation, migration, dispersion, and, in some cases, radioactive decay.

Figure 8-10 illustrates the total effective dose from hypothetical exposure of members of the public by drinking Central Plateau groundwater. Radionuclides contributing to doses greater than 100 mrem/yr include iodine-129, strontium-90, technetium-99, tritium, and uranium.

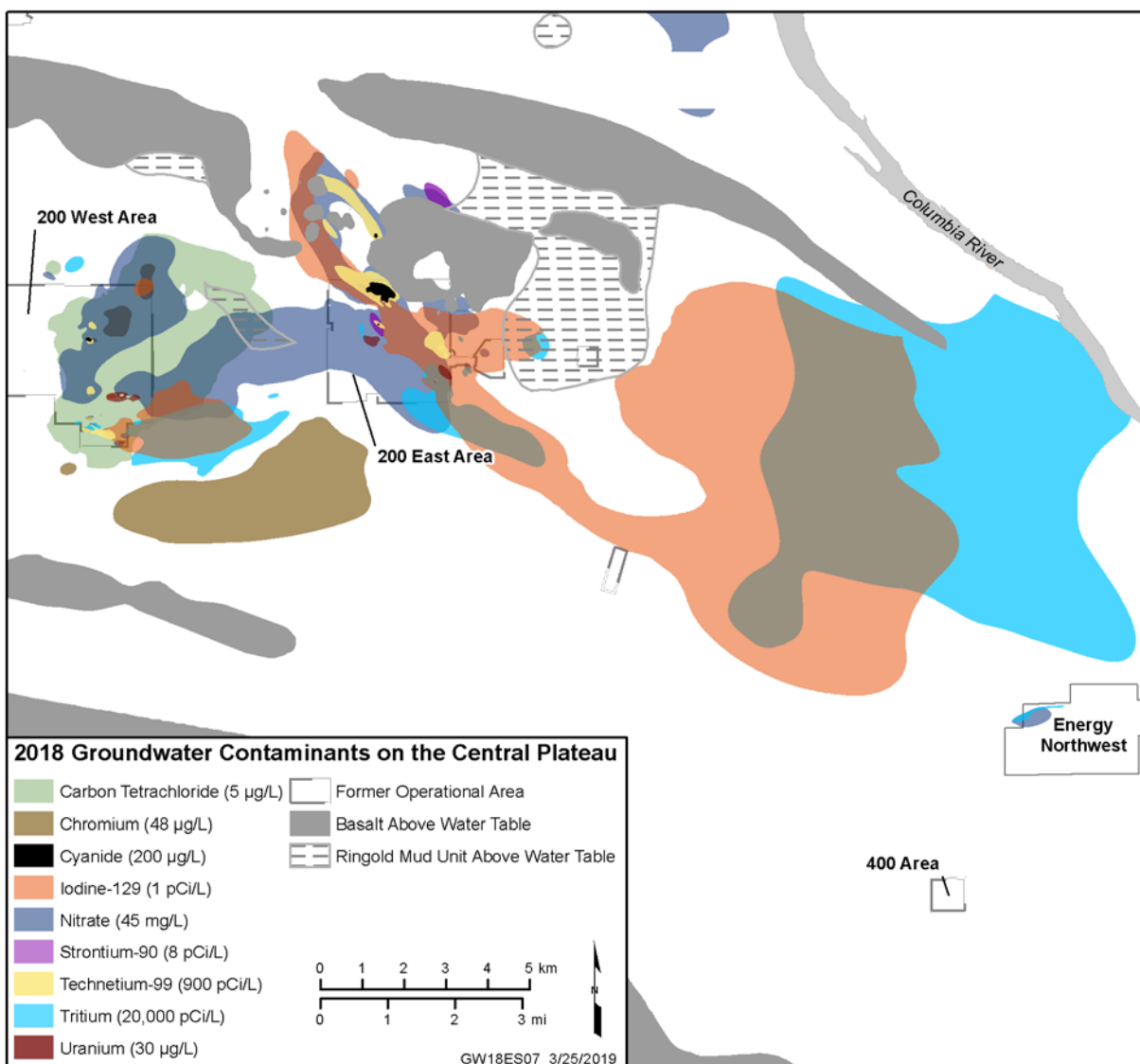


Figure 8-7. Groundwater Contaminant Plumes in the Central Plateau.

Table 8-4. Central Plateau Groundwater Contaminants, 2017 and 2018.

Ground-water Interest Area	Year	Maximum Concentrations							
		Carbon Tetra-chloride (µg/L)	Chromium (µg/L)	I-129 (pCi/L)	Nitrate (mg/L)	Sr-90 (pCi/L)	Tc-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)
200-BP	2018	0.80	39.0	9.87	1,060	602	29,100	33,700	1,100
	2017	N	37.5	9.67	1,590	511	36,000	53,700	2,970
200-PO	2018	N	130	13.1	159	14.8	4,850	365,000	71
	2017	N	110	10.9	120	13.3	5,360	311,000	63
200-UP	2018	428	373	23.0	270	23.5	30,900	187,000	3,520
	2017	412	224	22.8	221	19.1	13,700	218,000	5,000
200-ZP	2018	1,750	140	1.87	664	N	13,800	56,000	3.5
	2017	1,960	160	1.46	620	2.12	11,100	60,300	4.3
Regulatory standard		5	48	1	45	8	900	20,000	30
Half-life (years)		N/A	N/A	1.6E+07	N/A	28.8	212,000	12.3	>159,000
Mobility		Multi-phase	High to moderate	High	High	Slight	High	High	Moderate
Colors and listed values indicate maximum concentration, as follows:									
		<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 15px; background-color: #90EE90; border: 1px solid black; margin-right: 5px;"></div> > Standard and ≤10 × standard </div>							
		<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 15px; background-color: #FFFF00; border: 1px solid black; margin-right: 5px;"></div> >10 × standard and ≤100 × standard </div>							
		<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 15px; background-color: #FFA500; border: 1px solid black; margin-right: 5px;"></div> >100 × standard and ≤1,000 × standard </div>							
		N = not detected or not analyzed							
		N/A = not applicable							

Table 8-5. Summary of CERCLA Groundwater Remediation on the Central Plateau. (2 Pages)

Operable Unit	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern ^a	Current Groundwater Remediation	Mass Removed in 2018 (and Since Startup)
200-BP-5	Implemented action memorandum (2016); submitted draft RI report (2015) and FS (2018)	Cyanide, iodine-129, nitrate, strontium-90, technetium-99, tritium, uranium	Removal action: Groundwater extraction (2015–2018)	Cyanide: 62 kg (164 kg) Nitrate: 84,067 kg (171,328 kg) Technetium-99: 91.1 g (261 g) Uranium: 29.2 kg (166 kg)

Table 8-5. Summary of CERCLA Groundwater Remediation on the Central Plateau. (2 Pages)

Operable Unit	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern ^a	Current Groundwater Remediation	Mass Removed in 2018 (and Since Startup)
200-PO-1	Submitted RI report (2012) and RI addendum (2015) and FS (2018)	Iodine-129, tritium, nitrate, strontium-90, technetium-99, uranium	None required	Not applicable
200-UP-1	ROD for interim remedial action signed (2012); submitted remedial design investigation report for the southeast chromium plume (2018)	Technetium-99, uranium, carbon tetrachloride, hexavalent chromium, total chromium, iodine-129, nitrate, tritium, trichloroethene, chloroform, tetrachloroethene, strontium-90, and 1,4- dioxane	Interim actions: pump-and-treat near U-Plant (2015–2018) pump-and-treat at WMAS-SX (2012–2018) Hydraulic containment for iodine-129 (2015–2018) Monitored natural attenuation	Nitrate: 22,756 kg (202,278 kg ^b) Technetium-99: 27.4 g (378 g ^b) Uranium: 15.3 kg (953 kg ^b)
200-ZP-1	ROD for final remedial action signed (2008)	Carbon tetrachloride, hexavalent chromium, total chromium, iodine-129, nitrate, technetium-99, trichloroethene, tritium	pump-and-treat and monitored natural attenuation	Carbon tetrachloride: 2,231 kg (29,034 kg ^b) Chromium: 103 kg (437 kg) Nitrate: 415,533 kg (1,940,294 kg)
200-DV-1 ^c	Implemented action memorandum (2016); characterization of the deep vadose zone in progress	Nitrate, technetium-99, uranium, tritium, hexavalent chromium (perched water)	Removal action: Perched water extraction (2011–2018)	Nitrate: 1,608 kg (3,710 kg) Technetium-99: 2.9 g (8.0 g) Uranium: 74 kg (231 kg)

^a Contaminants of concern are listed for operable units with RODs for final action. The primary contaminants of potential concern are listed for the other operable units.

^b Totals includes mass from pump-and-treat system under earlier RODs for interim action and 200-DV-1 treatability test.

^c Deep vadose zone operable unit

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

FS = feasibility study

RI = remedial investigation

ROD = Record of Decision

WMA = waste management area

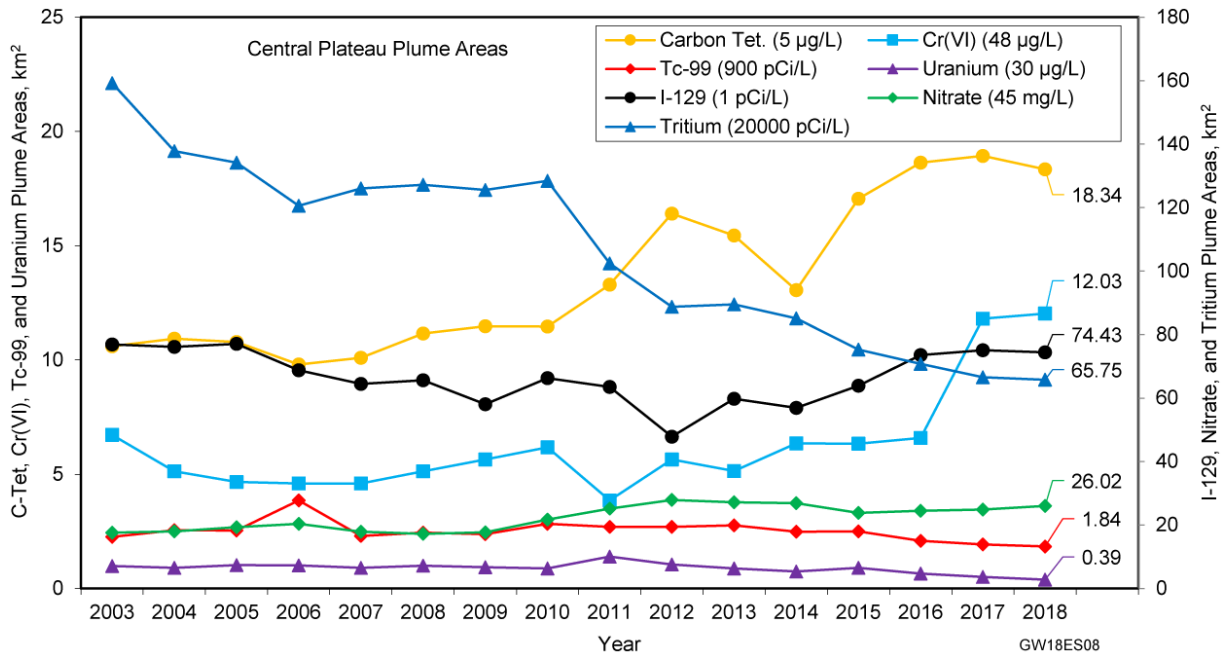


Figure 8-8. Central Plateau Plume Areas.

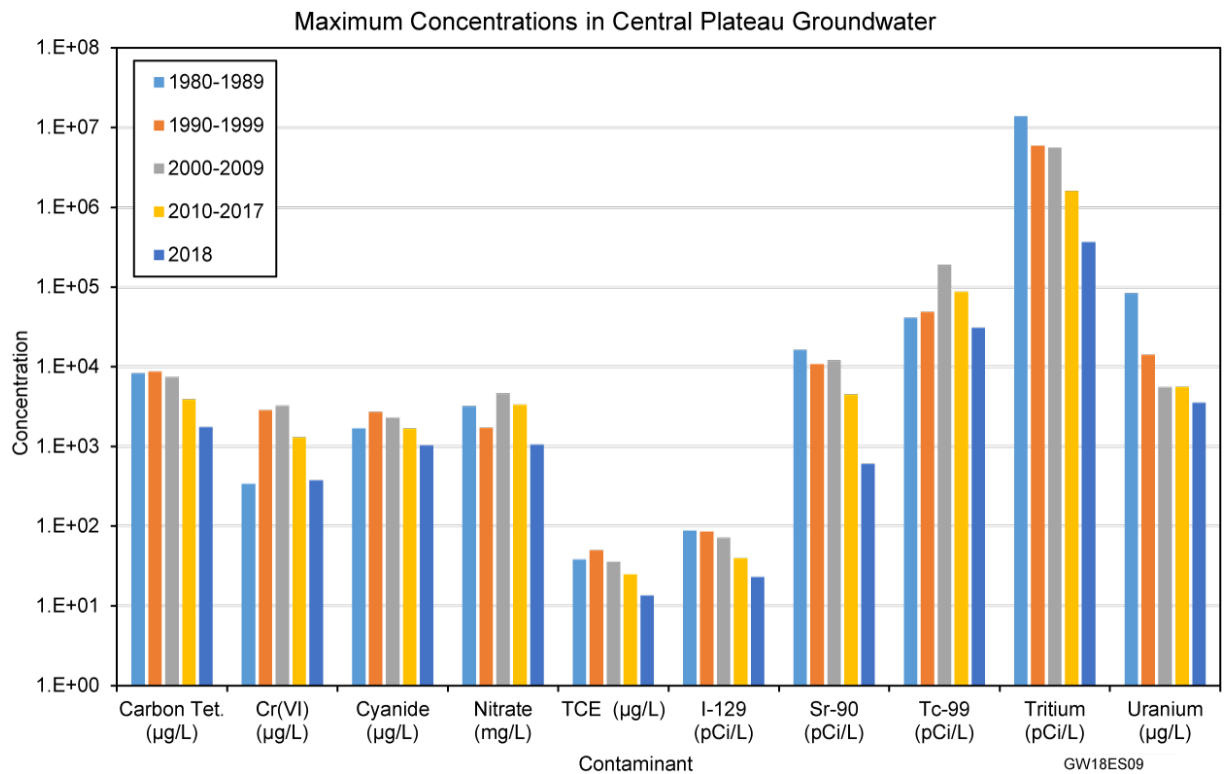


Figure 8-9. Maximum Concentrations of Central Plateau Contaminants over Time.

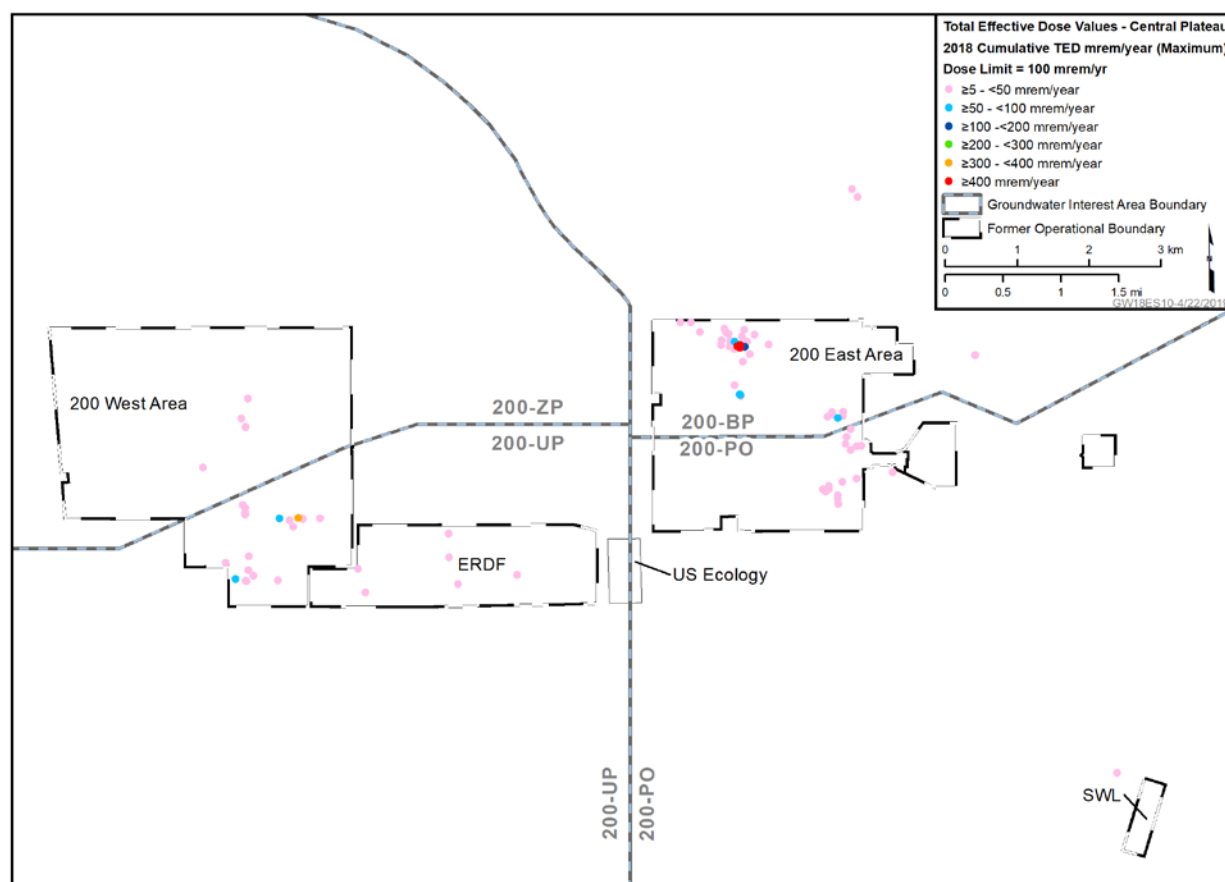


Figure 8-10. Groundwater Dose Calculation for the Central Plateau.

The following activities or changes occurred in the Central Plateau in 2018:

- **200-BP**
 - Groundwater extraction from well 299-E33-360 (in the B Complex area) continued in 2018. Concentrations of nitrate, technetium-99, uranium, and cyanide declined in nearby monitoring wells. DOE approved the design for a new extraction well (299-E33-361) in 2018.
- **200-PO**
 - The large tritium plume originating from sources in the 200-East Area continued to shrink in 2018 due to dispersion and radioactive decay.
- **200-UP**
 - Groundwater extraction and treatment for Waste Management Area S-SX and the U Plant area continued in 2018. Contaminant concentrations have declined in many monitoring wells in response to remediation.
 - In 2018, two new wells were installed to further characterize the nature and extent of the nitrate, iodine-129, and tritium plumes.

- **200-ZP**
 - As a result of remediation by the 200-West pump-and-treat, carbon tetrachloride concentrations are declining in locations where the highest levels were formerly present. The interpreted extent of the plume at lower concentrations (3.4 µg/L cleanup level) remained consistent between 2017 and 2018. The downgradient, lower concentration portion of the plume not captured by the pump-and-treat system will attenuate naturally over time, as described in the 200-ZP-1 Record of Decision (EPA et al. 2008).
 - Two new injection wells were installed for the pump-and-treat system and will begin operating in the near future.
- **200-DV-1:**
 - In 2018, 38 boreholes were drilled and sampled to determine potential risk to human health and the environment. The boreholes, ranging in depth from 1.9 to 79 m (6.3 to 260 ft), characterize vadose zone contamination beneath the Central Plateau.
- **RCRA**
 - RCRA groundwater monitoring continued at 20 dangerous waste management units on the Central Plateau in 2018.
- **New wells**
 - Table 8-6 lists wells installed or decommissioned at the Central Plateau in 2018.

Table 8-6. Summary of Central Plateau Wells or Boreholes Drilled or Decommissioned in 2018.

Groundwater Interest Area	Wells or Boreholes Drilled	Wells or Instrument Boreholes Completed	Wells or Boreholes Decommissioned	Comment
200-BP	12	0	12	200-DV-1 boreholes drilled and decommissioned.
200-PO	0	0	0	
200-UP	10	2	8	Two dual-purpose wells installed; eight 200 DV-1 boreholes drilled and decommissioned.
200-ZP	21	2	19	Two injection wells installed; 18 boreholes drilled and decommissioned in 200-DV-1; one monitoring well decommissioned.
Total	43	4	39	

8.3 References

Atomic Energy Act of 1954. 42 U.S.C. 2011 et seq. Online at <https://www.nrc.gov/docs/ML1327/ML13274A489.pdf>.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601 et seq., Public Law 107-377. Online at <https://www.govinfo.gov/content/pkg/USCODE-2017-title42/pdf/USCODE-2017-title42-chap103.pdf>.

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Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. Pub. L. 94-580, 90 Stat. 2795. Online at <https://elr.info/sites/default/files/docs/statutes/full/rcra.pdf>.

2018 Highlight

Routine Surveillance Soil Sampling

A total of 64 surface soil samples were collected on the Hanford Site in calendar year 2018. The concentrations of radionuclides at these locations are consistent with those seen in previous years.

Radiological Surveys

Radiological surveys performed near operational areas on the Hanford Site in CY 2018 identified 18 instances of radiological contamination in surface soil, resulting in 10 locations posted as contamination areas and eight locations cleaned up and the soil disposed of in licensed burial grounds.

9.0 Soil Monitoring

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Radiological monitoring of soil is conducted onsite near Hanford Site facilities and operations, as well as, onsite away from facilities and operations. Soil sampling is also performed offsite at perimeter and distant locations and in nearby communities. The environmental surveillance soil monitoring program complements Hanford Site emissions monitoring, including the Hanford Site ambient air monitoring network. Contaminant data collected are used to:

- Assess the impact of Hanford Site operations on the concentrations of manmade radionuclides in soil
- Determine the effectiveness of effluent monitoring and controls within facilities
- Confirm contaminant control measures at waste disposal sites during waste site remediation and at radioactive contamination areas
- Determine concentrations of naturally occurring radionuclides and those from fallout unrelated to Hanford Site activities
- Provide long-term radionuclide contamination trends in soil at undisturbed locations
- Detect and monitor unusual conditions associated with a potential release or spread of radioactive material.

Soil is an integrating sample medium that accounts for contaminants released to the atmosphere either directly (gaseous effluent), indirectly (re-suspension/deposition), or through liquid effluent waste streams that are subsequently used for irrigation.

Soil samples have been collected on and around the Hanford Site for more than 50 years; consequently, a significant data set exists that documents onsite and offsite levels of manmade radionuclides in and

around the Hanford Site. These data provide a baseline to which Hanford Site emissions and unplanned releases can be compared.

Soil samples from offsite locations are collected every 3 to 5 years and were last collected in 2015; sampling is currently on the schedule for summer 2019. Offsite soil sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in the U.S. Department of Energy (DOE) handbook DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

9.1 Hanford Site Soil Sampling

Surface soil sampling is required by the *Hanford Site Radioactive Air Emissions License #FF-01* (FF-01) (Section 5.1.2) as a qualitative indicator of the environmental monitoring program. It also is a recommended practice per DOE-HDBK-1216-2015.

Soil sampling data is used to evaluate long-term accumulation trends and provide baseline data to quantify short-term accumulations due to fugitive or accidental releases of Hanford Site radiological materials. Soil contamination can occur as the result of direct deposition from facility emissions, re-suspension and movement of contaminants from radioactively contaminated surface soil areas, or translocation of buried waste by biological intrusion.

Surface soil samples were collected on or adjacent to waste disposal sites, as well as from locations downwind, near, or within the boundaries of operating facilities and remedial action sites. The location and analyses of soil samples collected in calendar year (CY) 2018 are depicted in Table 9-1. The number of soil samples per operational area are summarized in Table 9-2.

Table 9-1. Hanford Site Soil Monitoring Locations and Sample Analyses. (2 Pages)

Soil Monitoring Location	EDP Codes ^a	Collection Period	Analyses
200-East Area	D054, D058 ^b , D060, D062, D064, D066, D072, D076, D078, D112 ^c	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA
Trench 94 (200-East Area)	D458, D460, D461	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA
200-West Area	D002, D004, D006, D012, D016, D020, D022, D024, D026, D028, D030, D036, D038, D046, D048 ^b , D050, D052, D142 ^c	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
Plutonium Finishing Plant (200-West Area)	D008, D010, D032, D034, D040, D044 ^b	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
ERDF at N482 (200-West Area)	D146	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA
300 Area	D120, D121, D123 ^b , D125, D126, D132 ^c , D140 ^c , D207	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA
400 Area	D130	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA

Table 9-1. Hanford Site Soil Monitoring Locations and Sample Analyses. (2 Pages)

Soil Monitoring Location	EDP Codes ^a	Collection Period	Analyses
600 Area	D080, D082, D084, D086, D088 ^b , D090, D092, D094, D096, D098, D100, D102, D104, D106, D108, D110, D114 ^c	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA
^a EDP Code=environmental data point code = sample location code ^b Collocated sampling location with WDOH ^c Quality assurance duplicate sample ERDF = Environmental Restoration Disposal Facility GEA = Gamma Energy Analysis ⁹⁰ Sr = Strontium-90 ²⁴¹ Am = Americium-241 Pu-iso = isotopic plutonium (²³⁸ Pu, ^{239/240} Pu) U-iso = isotopic uranium (²³⁴ U, ²³⁵ U, ²³⁸ U) WDOH = Washington State Department of Health			

Table 9-2. Number of Soil Samples per Operational Area.

Number of Samples	Operational Area (discrete samples analyzed)						
	200-East ^a	200-West ^a	Trench 94	ERDF	300 Area ^a	400 Area	600 Area ^a
64	10	24	3	1	8	1	17
^a Includes one or more duplicate samples. ERDF = Environmental Restoration Disposal Facility							

9.1.1 Sampling and Analysis

Samples were collected and analyzed according to DOE/RL-2013-53, *Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2018*. Onsite soil samples are collected annually and, as a cost-savings measure, collections in the 200 and 600 Areas are alternated between even and odd numbered years, aligning with even and odd numbered sample locations. Individual soil samples are approximately 2.2 lb (1.0 kg) and consist of five plugs of soil. The soil is sampled using a shallow (cookie cutter) coring device producing a core approximately 1 in. (2.5 cm) deep and 4.3 in. (11 cm) in diameter (RC-PRO-RC-60561). Five cores are combined to create one sample. Areas with heavy vegetation cover are avoided and any vegetation in the sample is removed. Soil samples are sieved in the field to remove potential sample intrusions (e.g., rocks and plant debris). The soil samples are packaged in two plastic bags (double bagged) and transported to an analytical laboratory. Samples are dried in the laboratory prior to analysis to remove residual moisture.

Soil samples were analyzed for strontium-90, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239/240, and gamma-emitting radionuclides. In support of the current deactivation and decommissioning (D&D) project at the Plutonium Finishing Plant (PFP) in the 200-West Area, and especially for monitoring during the demolition of the 242-Z Americium Recovery Facility, an americium-241 alpha energy analysis was added to the analyte list for all 200-West soil monitoring locations near the PFP complex.

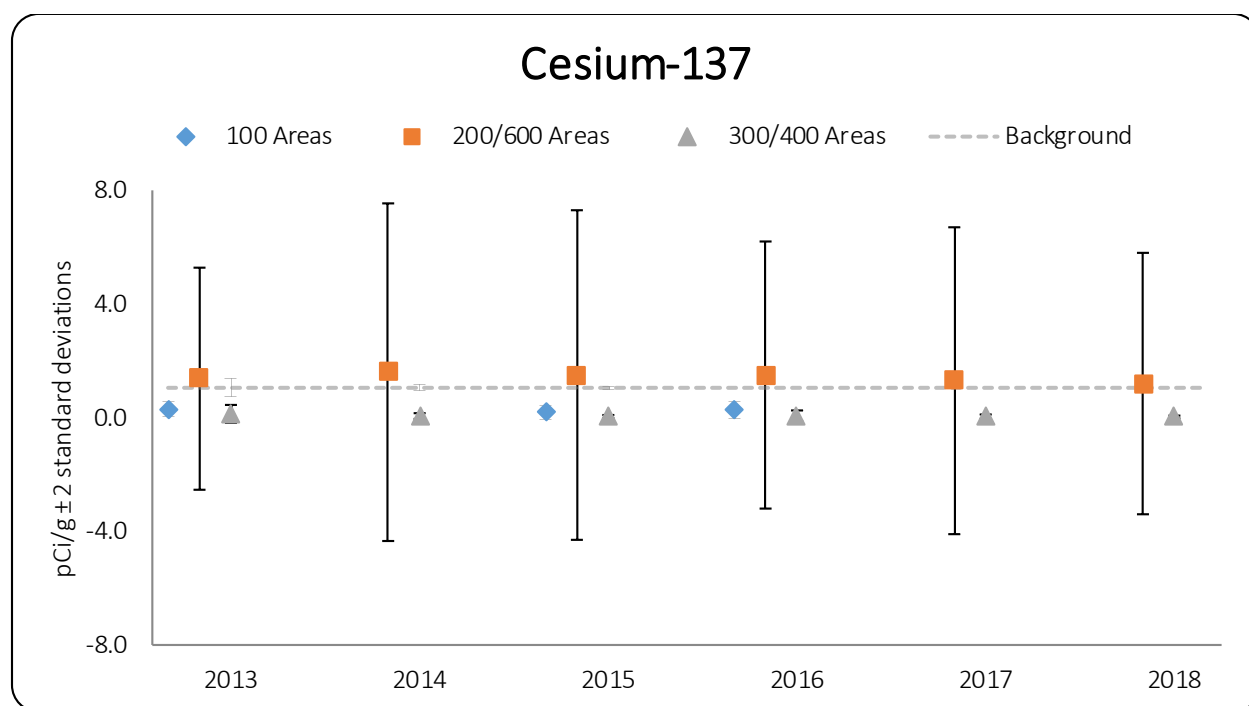
9.1.2 Soil Sampling Results

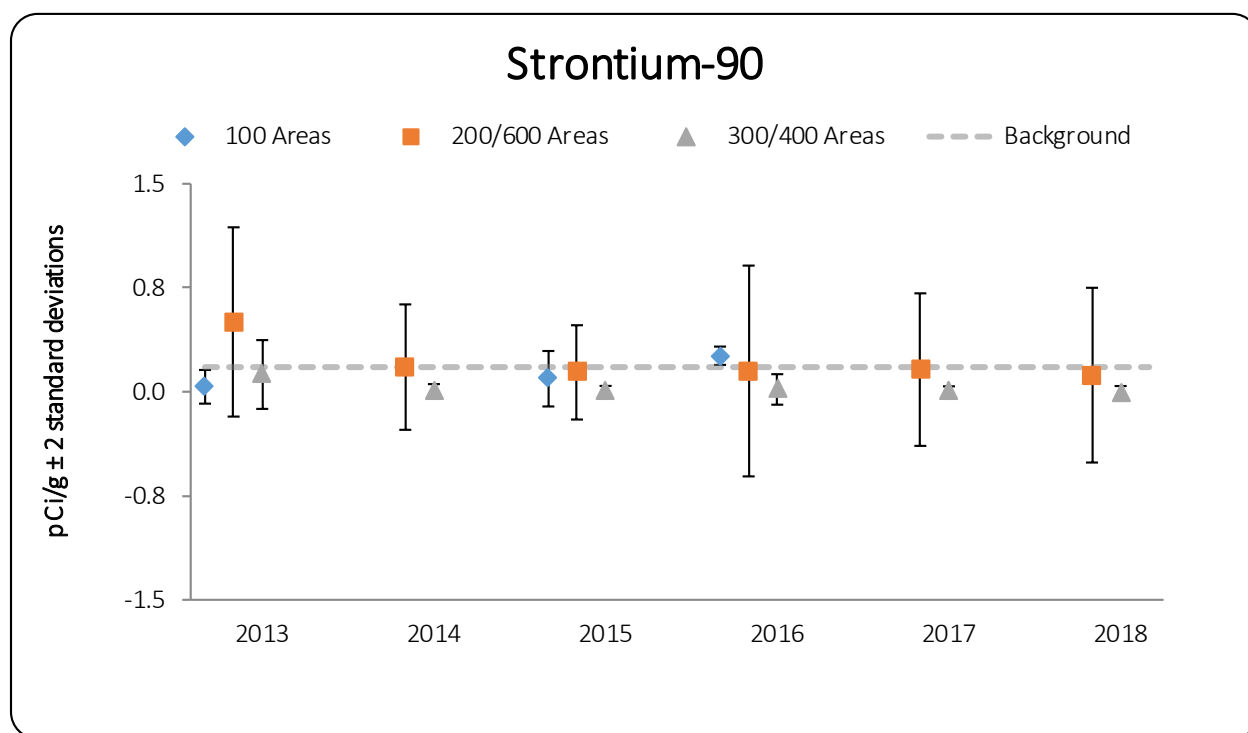
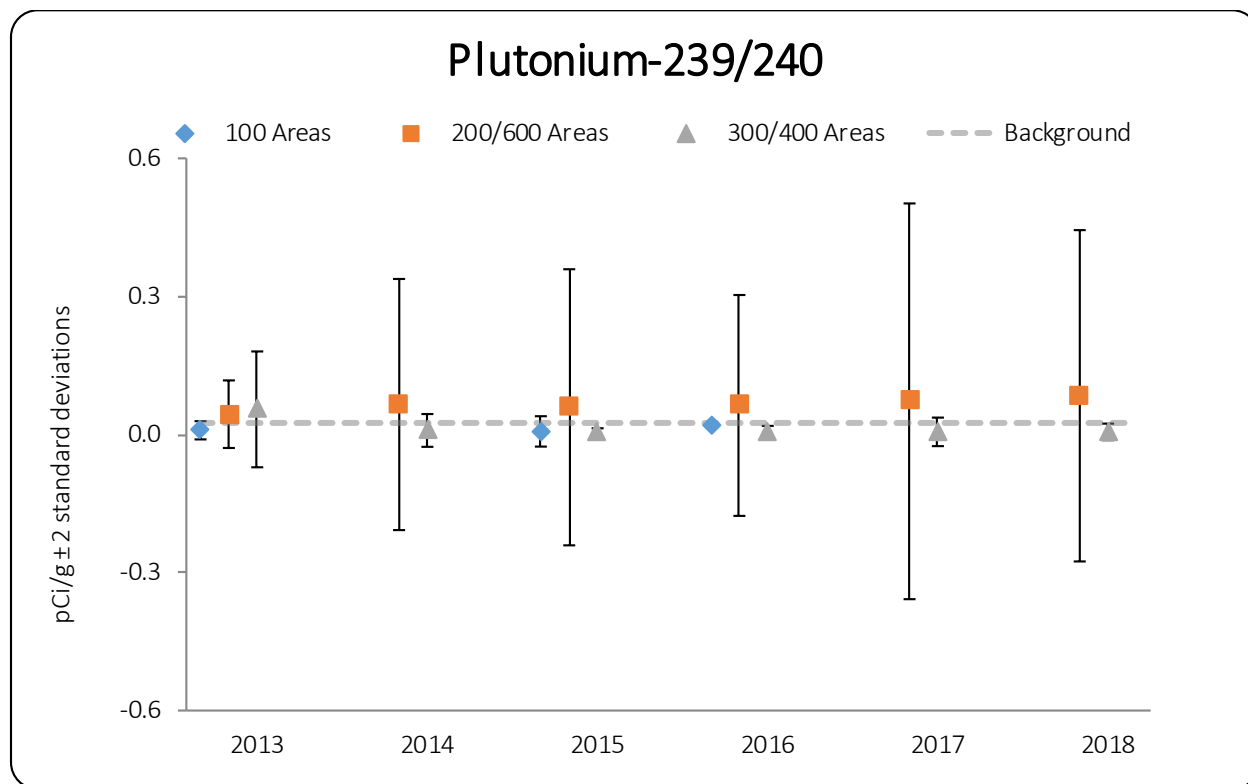
The analytical results from soil samples collected on the Hanford Site in CY 2018 are summarized in Appendix C, Table C-4. While there are no specific DOE limits for radionuclide concentrations in soil, the 2018 onsite soil sample results can be compared to other benchmarks including Hanford Site background concentrations (DOE/RL-96-12), radionuclide concentrations resulting from natural sources and worldwide fallout as observed in offsite soil samples, and dose-based limits for soil that have been developed for the Environmental Surveillance program to support calculation of a 1 mrem/yr dose threshold to an offsite member of the public (DOE/RL-91-50). More recently, soil radiological preliminary remediation goals (PRGs) have been developed for an outdoor worker exposure scenario for use in the Remedial Investigation/Feasibility Study reports for the Inner Area source operable units located within the Central Plateau of the Hanford Site (ECF-HANFORD-16-0133). These values may also be useful for comparison with onsite soil sample results. Values for these various soil benchmarks for key radionuclides are shown in Table 9-3. These levels are listed for comparison only and are not regulatory requirements. Generally, radionuclide concentrations in soil samples collected from the 200, 300, 400, and 600 Areas were near or below the Hanford Site background concentrations and below the dose-based reporting limits for an offsite member of the public and the PRGs for the outdoor worker exposure scenario. The average cesium-137 soil values in the 200 Areas were slightly above the Hanford Site background level but lower than the PRGs for the 200 Area outdoor worker exposure scenario. However, there was an elevated cesium-137 result in a sample collected from the 200-East Area that exceeded the PRGs for the 200 Area outdoor worker exposure scenario.

Table 9-3. Concentration Limits for Selected Radionuclides (pCi/g).

Isotope	Hanford Background (90 th Percentile) ^a	Environmental Surveillance Dose-based Reporting Limit for Offsite Exposure Scenarios ^b	Preliminary Remediation Goal for the Outdoor Worker Exposure Scenario ^c
Americium-241	N/A	20	613
Cesium-137	1.05	0.51	10.8
Plutonium-238	0.004	33	3,438
Plutonium-239/240	0.025	31	2,971
Strontium-90	0.178	55	1,190
Uranium-234	1.10	150	2,201
Uranium-235	0.109	2.3	36
Uranium-238	1.06	11	170
^a Values published in Hanford Site Background: Part 2, Soil Background for Radionuclides (DOE/RL-96-12). ^b Dose-based reporting limits established in reference to radionuclide contamination that could lead to an offsite public receptor dose of 1 mrem/yr if the condition persisted for an entire year. These limits are based on the inadvertent ingestion and external radiation exposure pathways as specified in Table 4-1 of the Hanford Site Environmental Monitoring Plan (DOE/RL-91-50, Rev. 7). ^c Soil radiological Preliminary Remediation Goals developed using U.S. Environmental Protection Agency guidance as specified in <i>Calculation of Soil Radiological Preliminary Remedial Goals for the Outdoor Worker Scenario</i> (ECF-HANFORD-16-0133) that correspond to a target cancer risk level of 1×10^{-4} that are protective of an outdoor worker based on direct contact (incidental soil ingestion and direct external gamma exposure) and the inhalation pathways. N/A = not available			

In general, radionuclide concentrations in soil samples collected in CY 2018 at locations in the 200-East, 200-West, 300, 400, and 600 Areas were comparable to those seen in previous years. Radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2018 were higher than the concentrations in samples collected further away. Historically, the predominant radionuclides detected are activation and fission products in the 100 Areas, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas. Consistent with historical detections, cesium-137, strontium-90, plutonium-239/240, uranium-234, and uranium-238 were detected in the 2018 soil samples. Figure 9-1 shows the annual average soil concentrations of selected radionuclides in the 100, 200, 300, 400, and 600 Areas. Appendix C, Table C-5 shows the annual average and maximum concentrations of radionuclides in surface soil samples by area during 2018 and for the preceding 5 years.





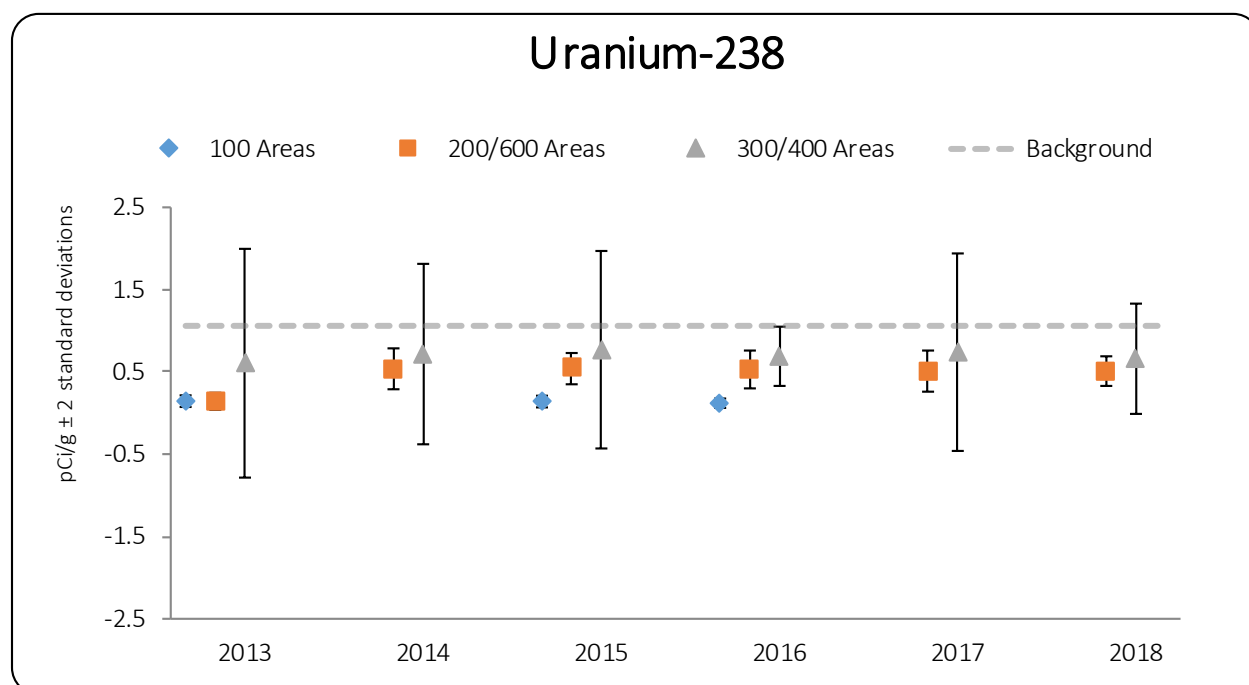
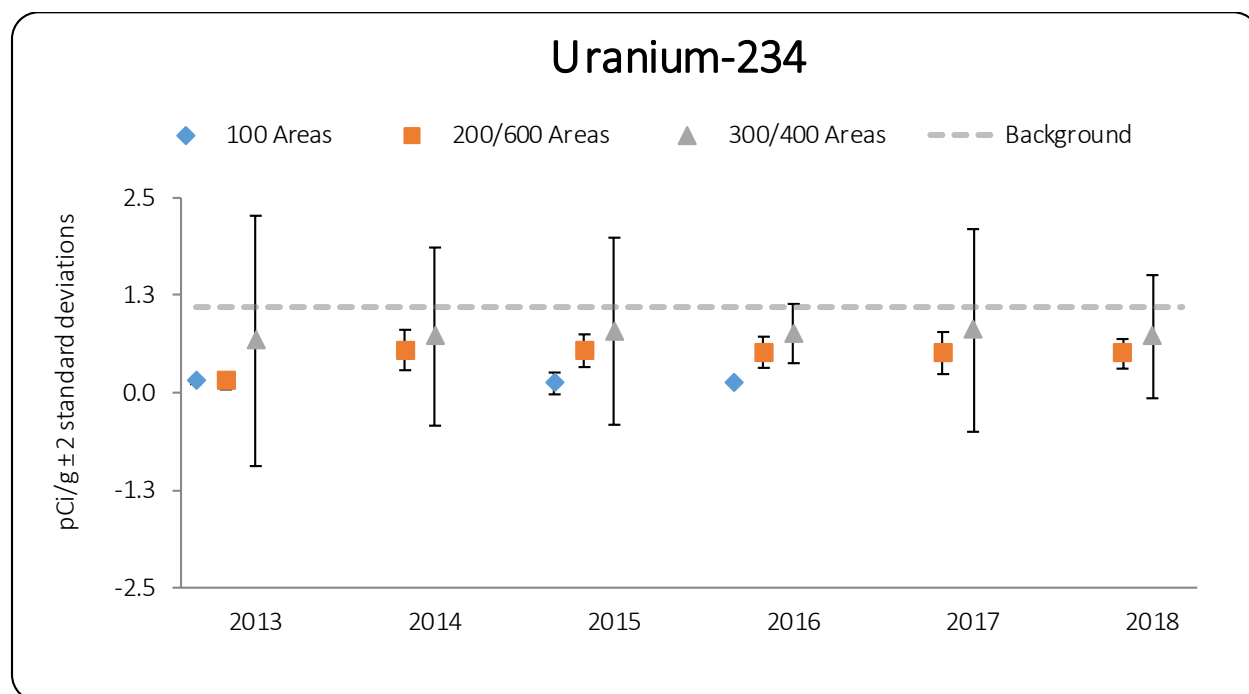


Figure 9.1. Average Concentrations of Select Radionuclides in Hanford Site Soil Samples, 2013–2018.
 (As a result of figure scale, some uncertainties [error bars] are concealed by the point symbol)

Soil sampling was conducted at 13 locations in the 200-East Area, including Trench 94 during CY 2018. Generally, radionuclide levels measured in the 2018 soil samples were similar to those measured in previous years. Cesium-137, strontium-90, uranium-234, and uranium-238 detection frequencies were also similar to those seen in previous years.

During CY 2018, routine soil sampling was conducted at 25 locations in the 200-West Area including the Environmental Restoration Disposal Facility (ERDF). Radionuclide levels measured were similar to previous years. Frequency of detection percentages for cesium-137, strontium-90, uranium-234, uranium-238, plutonium-239/240, and americium-241 were also similar to those seen in previous years.

Soil sampling was conducted at 17 locations in the 600 Area in CY 2018. Radionuclide levels measured in these samples were similar to those measured in previous years. Frequencies of detection for cesium-137, strontium-90, uranium-234, uranium-238, and plutonium-239/240 were also similar to those seen in previous years.

Soil samples were collected at eight locations in the 300 Area and one location in the 400 Area. These samples measured cesium-137, uranium-234, and uranium-238 at concentrations similar to those seen in previous years.

To comply with Washington State Department of Health Notice of Construction requirements, surface soil deposition sampling was conducted during CY 2018 around Trench 94 of the 218-E-12B waste site in the 200-East Area. Radionuclide levels measured in the 2018 soil samples were similar to those measured in previous years.

A soil sample is collected annually at the ERDF from a predominantly downwind sampling location. Radionuclide levels measured downwind of ERDF were comparable to previous years.

9.1.2.1 Uranium. Soil samples collected in the 300 Area showed concentrations of uranium-234 and uranium-238 that were comparable to historical data but remained slightly higher than those measured in the 200 Area. The higher uranium levels in the 300 Area were expected due to known uranium releases to the environment during historical fuel-fabrication operations and later remediation efforts.

9.1.2.2 Plutonium. Plutonium-239/240 was detected in approximately 70% of soil samples collected from the 200 and 600 Areas. Of the 35 detections, 22 were from locations in the 200-West Area. The concentrations measured were within historical ranges.

9.1.2.3 Strontium-90. Strontium-90 was detected in approximately 40% of the samples collected in the 200 and 600 Areas. The concentrations measured were within historical ranges.

9.1.2.4 Cesium-137. Cesium-137 was detected in over 90% of the soil samples collected from the 200, 300, 400, and 600 Areas at concentrations similar to those seen in previous years. However, cesium-137 concentrations in the 200 and 600 Areas are consistently higher than those measured in the 300 and 400 Areas, with a noticeable elevation in the cesium-137 concentration at location D054 in the 200-East Area.

9.1.2.5 Americium-241. Americium-241 analysis was performed on 24 samples in the 200-West Area in support of the current D&D project at the PFP. Americium-241 was detected at 13 of the 24 locations at concentrations similar to those seen in 2016 and 2017.

9.2 Radiological Contamination Surveys

Radiological surveys are performed in and near Hanford Site operational areas to monitor the presence or movement of radioactive materials or to verify radiological conditions at specific project sites. All sites are field surveyed for alpha and beta-gamma radiation.

Radiological surveys performed in CY 2018 identified 18 instances of radiological contamination in surface soil. Of the 18 soil contamination events reported, 10 were posted as contamination areas, and 8 were cleaned up with contaminated material disposed of onsite in licensed burial grounds. Table 9-4 summarizes the general locations of soil contamination incidents discovered during 2018 and Table 9-5 provides the number of contamination incidents from 2000 through 2018.

Table 9-4. Hanford Site Soil Contamination Incidents discovered in CY 2018.

Location	2018 Incidents
100 Area	0
200-East Area	
Tank farms	2
Burial grounds	1
Cribs, ponds, and ditches	7
Fence lines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	1
Liquid Effluent Treatment Facility/Effluent Treatment Facility	0
Miscellaneous	0
200-West Area	
Tank farms	2
Burial grounds	0
Cribs, ponds, and ditches	1
Fence lines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	1
Miscellaneous	1
Cross-site transfer line	0
200-BC cribs and trenches	0
200-North Area	0
300 Area	0
400 Area	0
600 Area	2
Total	18

Table 9-5. Hanford Site Soil Contamination Incidents from 2000 through 2018.

Year	Incidents
2000	25
2001	20
2002	22
2003	30
2004	19
2005	20
2006	25
2007	17
2008	16
2009	28
2010	22
2011	10
2012	10
2013	21
2014	22
2015	20
2016	17
2017	16
2018	18

9.3 References

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RC-PRO-RC-60561. *Environmental Soil Sampling*. Rev. 9. Mission Support Alliance, LLC, Richland, Washington.

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2018 Highlight

Routine Vegetation Sampling

A total of 45 vegetation samples were collected on the Hanford Site in 2018. Generally, the concentrations of radionuclides in these samples were consistent with those seen in previous years.

Food and Farm Products

In calendar year 2018, analytical concentrations of potential Hanford-Site produced contaminants and natural occurring radioactive elements were similar to results seen in the previous 5 to 10 years.

Wildlife Surveillance

Mission Support Alliance collects and analyzes wildlife samples that sportsmen or the general public may collect as foodstuff. In 2018, smallmouth bass, common carp, upland game birds, mule deer, and elk were collected and submitted to laboratories for radiological and metals analyses. A total of 50 animals were collected in 2018.

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, 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 (i.e., corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in calendar year (CY) 2018 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.

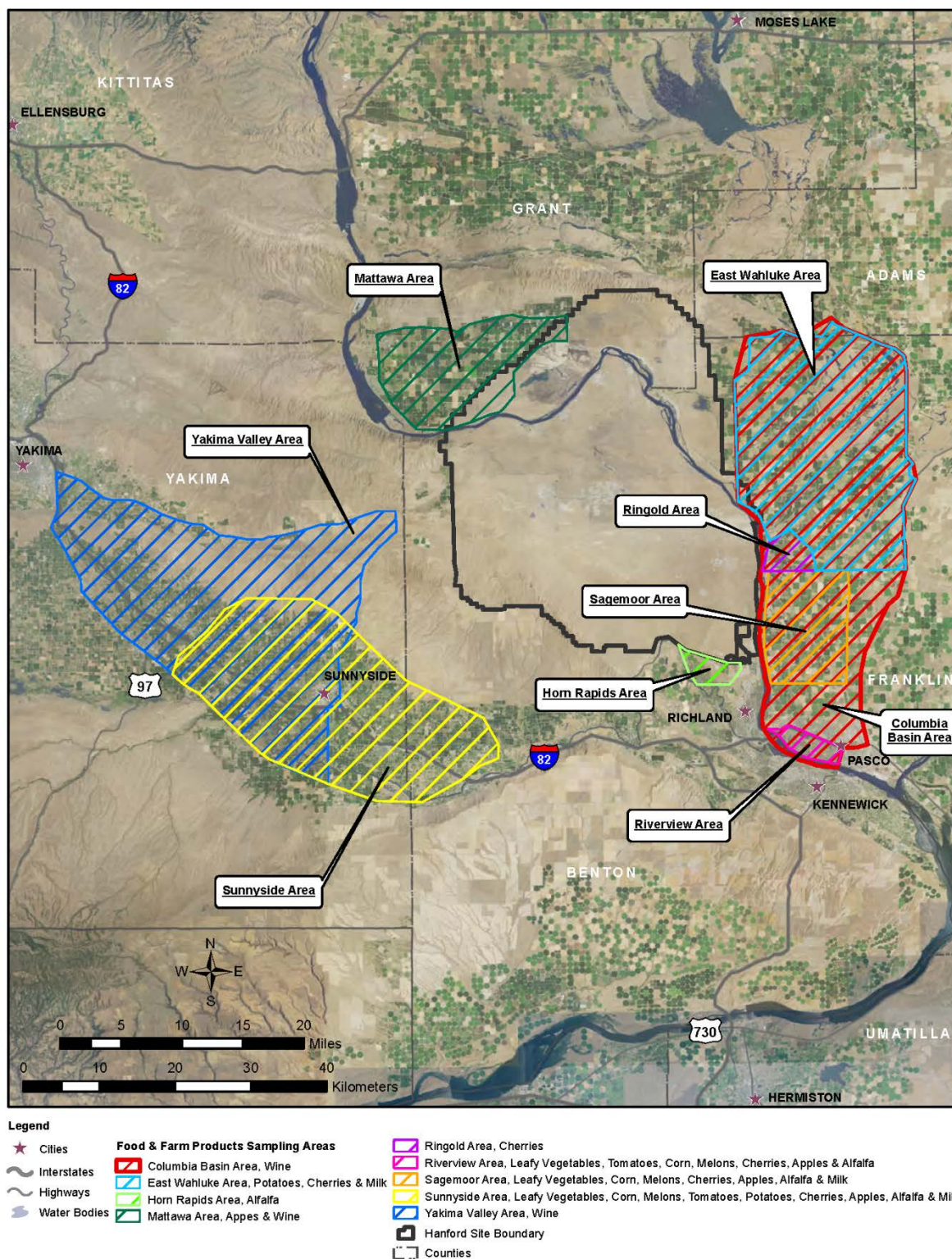
Sample analyses were used to assess the amounts of Hanford Site-origin contaminants in food and farm products by comparing the following:

- 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 CY 2018 were below the analytical laboratory detection levels; however, some potential Hanford Site-produced contaminants (e.g., carbon-14 and tritium) were found at low levels in some milk samples, leafy vegetable samples (strontium-90), and wine must (tritium). Data for potassium-40 and beryllium-7 were 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 were 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 CY 2018 are listed in Table 10-1 and are described in the following sections.

10.1.1 Milk

Milk samples were obtained quarterly in CY 2018 from several dairies in the East Wahluke and Sagemoor sampling areas. Milk was not obtained from a dairy in the Sunnyside area in 2018 due to closure of the dairy in late 2017. Surveillance personnel were attempting to locate a new Sunnyside-area dairy to sample at the time of this document.



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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
Corn	East Wahluke, Riverview, Sagemoor, and Sunnyside	¹⁴ C, Gamma, Sr-90
Leafy vegetables	East Wahluke, Riverview, Sagemoor, and Sunnyside	¹⁴ C, Gamma, Sr-90
Melons	East Wahluke, Riverview, Sagemoor, and Sunnyside	¹⁴ C, Gamma, Sr-90
Milk	East Wahluke and Sagemoor	¹⁴ C, Gamma, ¹²⁹ I, Sr-90, Tritium (Low level)
Potatoes	East Wahluke, Riverview, Sagemoor, and Sunnyside	¹⁴ C, Gamma, Sr-90
Tomatoes	Riverview and Sunnyside	¹⁴ C, Gamma, Sr-90, Tritium
Wine must	Columbia Basin, Mattawa, and Yakima Valley	¹⁴ C, Gamma, ¹²⁹ I, Tritium (Low level)

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 carbon-14, gamma-emitting radionuclides, strontium-90, and tritium. 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 were 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 but one milk sample collected in CY 2018. Overall concentrations of the eight detections ranged from a maximum of 33 pCi/L (1.2 Bq/L) in a Sagemoor area sample to a minimum of 10 pCi/L (0.37 Bq/L) in an East Wahluke area sample. Annual average concentrations for the two sampling areas were 20 pCi/L (0.74 Bq/L). Specific location average was 24 pCi/L (0.89 Bq/L) for Sagemoor (n = 4) and 16 pCi/L (0.59 Bq/L) for East Wahluke (n = 4). Overall averages were similar to historical concentrations in all areas.

10.1.1.2 Strontium-90. No detectable concentrations were found in CY 2018 milk samples.

10.1.1.3 Cesium-137. No synthetic gamma emitters were detected in milk samples collected and analyzed in 2018.

10.1.1.4 Potassium-40. Naturally occurring potassium-40 was detected in all milk samples collected in CY 2018. Concentrations ranged from a maximum of 1,580 pCi/L (58 Bq/L) in a Sagemoor area sample to a minimum of 1,440 pCi/L (53 Bq/L) in an East Wahluke sample.

10.1.2 Fruit, Vegetables, and Farm Products.

Apples, corn, leafy vegetable (e.g., lettuce), melon, potato, tomato, and wine must samples were collected from upwind and downwind sampling areas during the CY 2018 growing season (Figure 10-1; Table 10-1). All fruit and vegetable samples were analyzed for gamma-emitting radionuclides and strontium-90. All products were analyzed for carbon-14 to support Waste Treatment Plant monitoring

baseline data. Wine must was analyzed for gamma-emitting radionuclides and low-level tritium. Tomato samples were also monitored for strontium-90 and tritium (Table 10-1) but showed no detectable concentrations during 2018.

Three individual leafy vegetable samples (East Wahluke, Sagemoor, and Sunnyside) had detectable concentrations of beryllium-7; however, these concentrations were within historical range and follow typical result patterns. Three additional samples of leafy vegetables (East Wahluke [2] and Sunnyside [1]) had detections of strontium-90, but values reported were well below DOE project dose-based reporting limits and were within historical limits measured at these locations. No leafy vegetable samples were available for collection in the Sagemoor area. All remaining fruit and vegetable contaminant concentrations were reported as non-detects and were well within historical range.

All wine must samples collected in CY 2018 had detectable concentrations of tritium, were slightly higher than concentrations seen in CY 2017, but were within the historical range. Mattawa area wine had an average of 29.8 pCi/L (1.1 Bq/L) while the Columbia River Priest Rapids Dam fixed-station water average was 14.5 pCi/L (0.54 Bq/L). The Columbia Basin area winery had an annual tritium average of 71.9 pCi/L (2.7 Bq/L) while the Columbia River Richland Pumphouse fixed-station water had an annual average of 24.4 pCi/L (0.90 Bq/L). Irrigation results in the Riverview (14.3 pCi/L; 0.53 Bq/L) and Horn Rapids (16.0 pCi/L; 0.59 Bq/L) areas were similar to the Sagemoor (15.3 pCi/L; 0.57 Bq/L) area. These results were less than concentrations reported in wine and the fixed-station location in Richland, Washington. All wine must values for 2018 were well below the Washington State drinking water standard of 20,000 pCi/L (740 Bq/L).

All apple, corn, leafy vegetable, melon, potato, tomato, and wine must samples (red and white) had detectable concentration levels of naturally occurring potassium-40.

10.2 Fish and Wildlife Monitoring

JW Wilde

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during CY 2018 included smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), mule deer (*Odocoileus hemionus*), Rocky Mountain elk (*Cervus elaphus*), and upland game birds including California Quail (*Callipepla californica*) and Ring-necked Pheasant (*Phasianus colchicus*). 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 provides long term contamination trends to identify any threats to human health. These species and the sample locations were selected and monitored because they provide a potential pathway for offsite human consumption. Figure 10-2 shows the locations on and around the Hanford Site where fish and wildlife were collected in 2018. Samples of fish and wildlife were analyzed for selected (suspected or known to be present at the Hanford Site) radionuclides and metals (Table 10-2). In addition, samples were collected from locations distant from the Hanford Site to obtain reference (background) contaminant measurements. All fish and wildlife samples were monitored for strontium-90 contamination and analyzed by gamma spectrometry to detect a number of gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples.

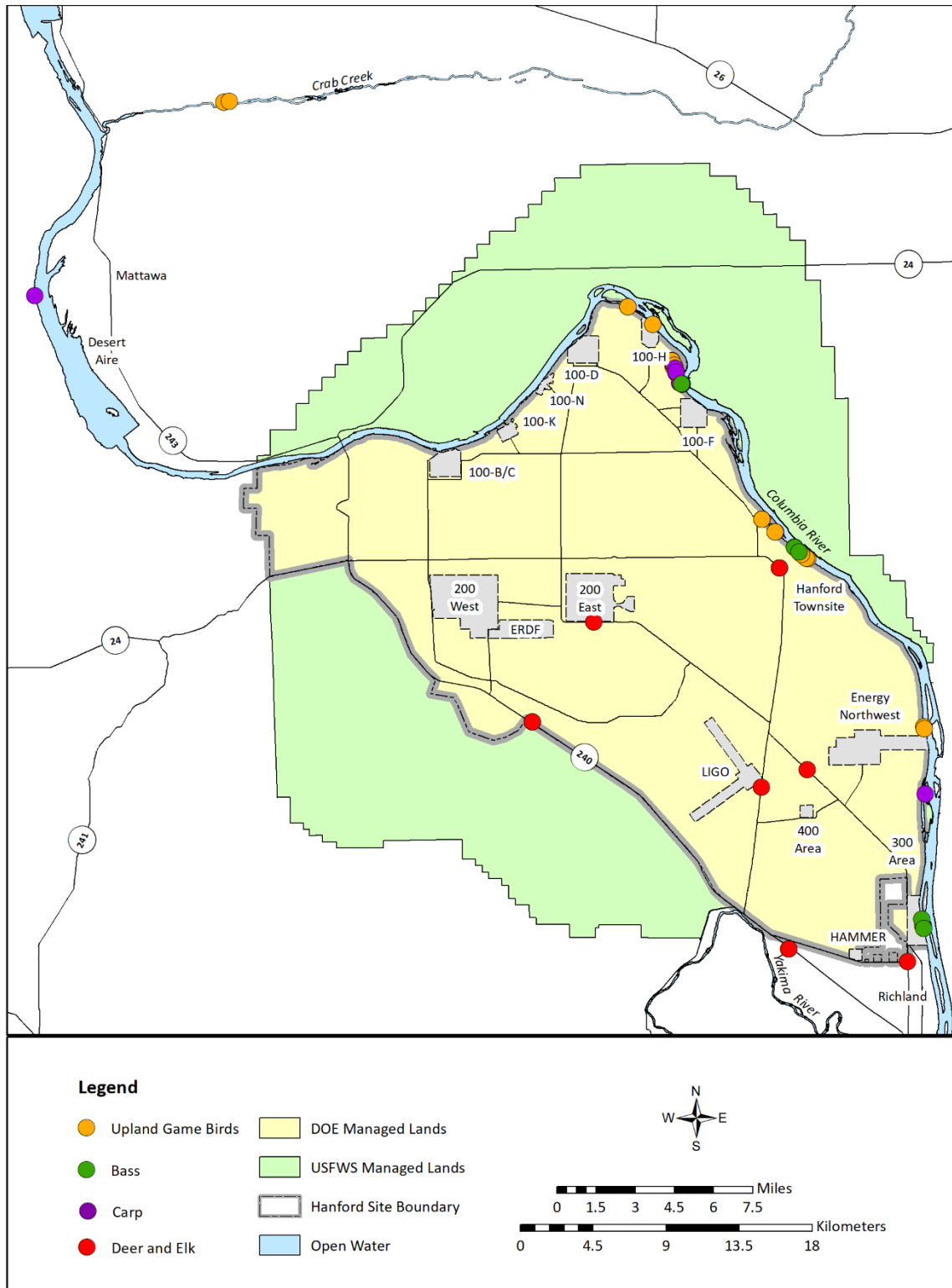


Figure 10-2. Locations of Wildlife Collections During Calendar Year 2018.

Table 10-2. Number of Wildlife Monitoring Samples Submitted for Analysis.

Biota	Offsite Sample Locations	Onsite Sample Locations	Gamma Samples	Strontium-90 Samples	Trace Metals Samples
Fish (smallmouth bass)	0	2	8	8	2
Fish (common carp)	1	2	9	12	9
Mammals (deer/elk)	0	9	16	12	7
Game birds (quail, pheasant)	1	2	8	8	0

Most fish and wildlife samples are collected on and around the Hanford Site and analyzed for human-pathway exposure every 2 to 3 years, with samples obtained at locations determined not to be affected by Hanford Site effluents and emissions at least every 3-5 years.

Strontium-90 is present in Hanford Site environments because of past Hanford Site operations, waste disposal practices and global nuclear fallout. 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).

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) from wildlife consumption.

Cesium-137 is present in Hanford Site environments because of past Hanford Site operations, waste disposal practices, and 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 operations) were released to the atmosphere. The fly ash contains trace metals and natural radionuclides that may have deposited on soil surfaces around the 100 Area reactors.

10.2.1 Smallmouth Bass

In 2018, smallmouth bass were sampled and analyzed for radiological contaminants, since bass are sometimes harvested for food along the Hanford Reach of the Columbia River, which could potentially contribute to human exposure through digestion. Smallmouth and largemouth bass are one of the most popular sportfish in the area.

Fourteen smallmouth bass were collected from two locations along the Hanford Reach (seven along the 100 Areas shoreline and seven from the shoreline from the Hanford town site down through the 300 Area). A total of 14 samples were comprised of the 14 collected fish. The following are the radiological and trace-metal results for the 14 smallmouth bass samples analyzed. Naturally-based isotopes, such as potassium-40, are not discussed here.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 were not detected above the reporting limit (0.03 pCi/g [0.001 Bq/g] wet weight) in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

Strontium-90. Strontium-90 was not detected above the reporting limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in any of the smallmouth bass samples analyzed. These results are consistent with those generally reported historically in the Columbia River near the Hanford Site.

Uranium. Uranium isotope uranium-235 was detected in two filet samples submitted. One sample was from near the 100 Areas and the other in the stretch of Columbia River between the Hanford Townsite and the 300 Area. Uranium-235 was reported at 9.9E-03 pCi/g in the 100 Area sample and 1.04E-02 pCi/g in the Townsite to 300 Area sample. Dose calculations for fish ingestion trigger reporting limits at 9.4E-02, a quantity 9 times greater than the maximum detected in any 2018 Hanford Site sample.

Trace Metals. Two smallmouth bass samples were analyzed for 18 different trace-metal concentrations. Only 6 of the 18 trace metals were detected in samples that were above the analytical detection limit at any location (Table 10-3). Surveillance data sets for trace-metal concentrations in fish both on and near the Hanford Site were relatively small with variable results. No established federal or state adverse-effects values (i.e., benchmark criteria) were available for trace-metal concentrations in fish tissue. Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about contribution effects were 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. The Washington State Department of Health (WDOH) provides lists of species retaining high concentrations of chemical contaminants and metals, and consumption guides for various water bodies throughout Washington State (<https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories>).

Table 10-3. Maximum Metal Concentrations (µg/kg) Detected in Wildlife Tissues Collected in 2018.

Species and Sample	Location	Metal	Maximum Concentration
Smallmouth Bass Filet	100 Areas	Ba	ND ^a
		Cu	299
		Mn	ND ^a
		Hg	125
		Se	1020
		Zn	6300
	Hanford Townsite to 300 Area	Ba	252
		Cu	763
		Mn	354
		Hg	155
		Se	1,160
		Zn	7,700
Common Carp Filet	100 Areas	Sb	ND ^a
		Cu	1,660
		Mn	488
		Hg	175
		Se	816
		U	3,650
		Zn	39,000
	Hanford Townsite to 300 Area	Sb	ND ^a
		Cu	ND ^a
		Mn	ND ^a
		Hg	86
		Se	ND
		U	2,470
		Zn	12,600
	Reference	Sb	471
		Cu	ND ^a
		Mn	ND ^a
		Hg	134
		Se	511
		U	4,630
		Zn	12,000
Deer/Elk Liver	Hanford and Adjacent Roadways	Al	11,300
		Sb	3,860
		Ba	325
		Cd	159
		Cr	678
		Cu	33,900
		Pb	668
		Mn	3,670
		Ni	516
		Se	1,260
		U	1,540
		Zn	42,900

10.2.2 Common Carp

In 2018, common carp were sampled and analyzed for radiological contaminants. 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.

Seven carp were collected from three locations along the Hanford Reach, including a Reference Area (five from waters adjacent to the 100 Areas, one fish from waters adjacent to the Hanford Townsite through the 300 Area, and one fish from Priest Rapids Lake above Priest Rapids Dam). Twelve samples were sent for laboratory analysis including duplicates. The following are the radiological results for the 12 carp samples analyzed. Naturally-based isotopes, such as potassium-40, are not discussed here.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 were not detected above the reporting limit (0.03 pCi/g [0.001 Bq/g] wet weight) in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

Strontium-90. Strontium-90 was not detected above the reporting limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in any of the carp smallmouth bass samples analyzed. These results are consistent with those generally reported historically in the Columbia River near the Hanford Site.

Uranium. Uranium isotopes (i.e., uranium-234, uranium-235, and uranium-238) were detected in four carp samples. All samples with uranium detections from the Hanford Reach were collected in waters adjacent to the 100 Areas. Uranium-234 maximum was reported at 2.28E-02 pCi/g (8.44E-04 Bq/g), uranium-235 maximum was reported at 1.93E-02 pCi/g (7.14E-04 Bq/g), and uranium-238 maximum was reported at 1.18E-02 pCi/g (4.37E-04 Bq/g). This is a higher number of detects and elevated results over recent carp collections. The values reported for uranium-234, uranium-235, and uranium-238 however, do not trip or even exceed 26% of the consumption-based dose limits provided in DOE/RL-91-50, Table 4-1.

Trace Metals. Six common carp samples were analyzed for 18 different trace-metal concentrations. Only seven trace metals were detected in samples that were above the analytical detection limit at any location. Table 10-3 provides a summary of the 2018 metal analyses for the carp samples. Uranium metal detections in these analyses were not radioactive isotopic analyses as described in the paragraph above. Surveillance data sets for trace-metal concentrations in fish both on and near the Hanford Site were relatively small with variable results. No established federal or state adverse-effects values (i.e., benchmark criteria) were available for trace-metal concentrations in fish tissue. Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about contribution effects were 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. The WDOH provides lists of species retaining high concentrations of chemical contaminants and metals, and consumption guides for various water bodies throughout Washington State. (<https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories>).

10.2.3 Deer and Elk

Deer and elk can be exposed to metals and persistent radionuclides when they forage on plants whose roots have access to contaminated groundwater or soil, drink contaminated water, or incidentally ingest contaminated soil. Deer and elk hunting is not allowed above the high-water mark on the Benton County side of the Columbia River (at the Hanford Site); however, the river is not a barrier to large mammal movements. In 2018, the Hanford Site Environmental Surveillance Program collected deer and elk killed due to road strikes rather than hunting animals onsite. Deer and elk are analyzed for public consumption as past animals that were captured and tagged at the Hanford Site have been legally killed by hunters on the Hanford Reach shoreline below the highwater mark and across the Columbia River in Franklin County. Harvesting deer and elk for food could potentially contribute to human exposure to contaminants. A total of five deer and three elk were collected from vehicle collisions with animals and a total of 25 samples, including duplicates, were submitted for analyses. All samples were collected when the location led investigators to believe the herd could contact Hanford environs. The following are the radiological results for the deer and elk samples analyzed. Naturally-based isotopes, such as potassium-40, are not discussed here.

Cesium-137. Cesium-137 was not detected in any of the nine 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 Site sample or a reference sample. These results are consistent with a decline in cesium-137 levels in wildlife examined from the preceding 10 years.

Strontium-90. Strontium-90 was detected in four of the nine bone samples analyzed during 2018. Strontium-90 was not detected in three liver samples analyzed for strontium. Concentrations of strontium-90 detected in bone samples collected ranged from 8.53E-02 pCi/g (3.16E-03 Bq/g) to 1.82E-01 pCi/g (6.73E-03 Bq/g). Bone is not usually considered an edible product. Historical strontium-90 values in deer and elk bone is displayed in Figure 10-3.

Trace Metals. Trace metals were analyzed in mule deer and elk liver samples collected from Hanford Site samples. Twelve of the 18 metals analyzed were found above analytical detection limits in 2018. The metals and the maximum detected concentration is found in Table 10-3.

10.2.4 Upland Game Birds

California quail and ring necked pheasants are some 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, and pheasants inhabit similar areas as well as the open steppe areas. Quail and pheasants forage for seeds, other plant parts, and grit in grassy and weedy places not far from cover. Ordinarily, upland game birds 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. Upland game birds 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 2018, 21 upland game birds were collected on the Hanford Site (8 quail and 1 pheasant from the 100 Area, 10 quail in the Hanford Townsite to 300 Area region, and 2 quail from a reference area near Crab Creek Wildlife Area). These birds were processed into 16 samples, including duplicates. All quail game birds were monitored for gamma emitting isotopes, such as cesium-137, in muscle and strontium-90 in bone. The following are the radiological results for the quail and pheasant samples analyzed. Naturally-based isotopes, such as potassium-40, are not discussed here and no metals analyses is performed on upland game birds.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 were not detected above the reporting limit (0.03 pCi/g [0.001 Bq/g] wet weight) in any of the upland game bird muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

Strontium-90. Strontium-90 was not detected above the reporting limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in any of the upland game bird bone samples analyzed.

10.3 Vegetation Monitoring

JE Cranna

Radiological monitoring of native vegetation is conducted from locations on or adjacent to waste disposal sites, as well as from locations downwind, near, or within the boundaries of operating facilities and remedial action sites. Vegetation sampling is also performed offsite at perimeter and distant locations, and in nearby communities. Contaminant data collected were used to:

- Determine the effectiveness of effluent monitoring and controls within facilities
- Assess the adequacy of contaminant containment at waste disposal sites, waste site remediation, and contamination areas
- Detect and monitor unusual conditions associated with a potential release or spread of radioactive material
- Provide long-term radionuclide contamination trends
- Provide complimentary monitoring to airborne sampling methods for atmospheric releases.

Vegetation is an integrating sample medium that accounts for contaminants released to the atmosphere either directly (gaseous effluent), indirectly (re-suspension/deposition), or through liquid effluent waste streams that are subsequently used for irrigation or from uptake of contaminants via their root system. Deep-rooted vegetation (e.g., tumbleweeds, sagebrush) growing over underground sources of radionuclides may selectively uptake contaminants (e.g., cesium, strontium) into their tissues. When radionuclides are transported from roots to above surface portions of the plant, surface contamination may result, which poses a potential risk of environmental/biological transport or human contact.

Vegetation samples have been collected on and around the Hanford Site for more than 50 years, and a significant data set exists that documents onsite and offsite levels of manmade radionuclides in and around the Hanford Site. These data provide a baseline to which unplanned releases are compared.

Vegetation samples from offsite locations are collected every 3 to 5 years and were last collected in 2015; sampling is currently on the schedule for summer 2019. Offsite vegetation sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

10.3.1 Hanford Site Vegetation Monitoring

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 location and analyses of vegetation samples collected in CY 2018 are depicted in Table 10-4. The number of vegetation samples per operational area are summarized in Table 10-5.

Table 10-4. Hanford Site Vegetation Monitoring Locations and Sample Analyses.

Location	EDP Codes ^a	Collection Period	Analyses
100-N Area	Y719, Y724	September	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
200-East Area	V054, V058 ^b , V060, V062, V064, V066, V076, V078	May-July	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
200-West Area	V004, V016, V020, V022, V024, V026, V046, V048 ^b , V050, V052	May-July	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
Plutonium Finishing Plant (200-West Area)	V006, V010, V012, V032 ^c , V034, V044 ^b , V112 ^c	May-July	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
300 Area ^(e)	V123 ^{b, c} , V132 ^c	May-July	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
400 Area	V130	May-July	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
600 Area	V080, V082, V086, V088 ^b , V090, V092, V094, V096 ^c , V098, V100, V102, V104, V106, V108, V114 ^c	May-July	⁹⁰ Sr, Pu-Iso, U-Iso, GEA

^a EDP Code=environmental data point code = sample location code
^b Collocated sampling location with WDOH
^c Quality assurance duplicate sample
 GEA = Gamma Energy Analysis
⁹⁰Sr = Strontium-90
²⁴¹Am = Americium-241
 Pu-iso = isotopic plutonium (²³⁸Pu, ^{239/240}Pu)
 U-iso = isotopic uranium (²³⁴U, ²³⁵U, ²³⁸U)
 WDOH == Washington State Department of Health

Table 10-5. Number of Vegetation Samples per Operational Area.

Number of Samples	Operational Area (discrete samples analyzed)					
	100-N	200-East	200-West ^a	300 Area ^a	400 Area	600 Area ^a
45	2	8	17	2	1	15

^a Includes one or more duplicate samples.

10.3.1.1 Sampling and Analysis. Samples were collected and analyzed according to DOE/RL-2013-53, *Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2018*. Onsite vegetation samples are collected annually. Collections in the 200 and 600 Areas are alternated between even and odd numbered years, aligning with even and odd numbered sample locations. Individual vegetation samples (approximately 17.6 oz [500 g]) consist 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 are dried prior to analyses and analytical results are reported on a dry weight basis.

Vegetation samples were analyzed for strontium-90, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239/240, and gamma-emitting radionuclides. In support of the current deactivation and decommissioning project at the Plutonium Finishing Plant (PFP) located in the 200-West Area, and especially for monitoring during the demolition of the Americium Recovery Facility, an americium-241 alpha energy analysis was added to the analyte list at six vegetation monitoring locations (V006, V010, V012, V032, V034, and V044) near the PFP complex.

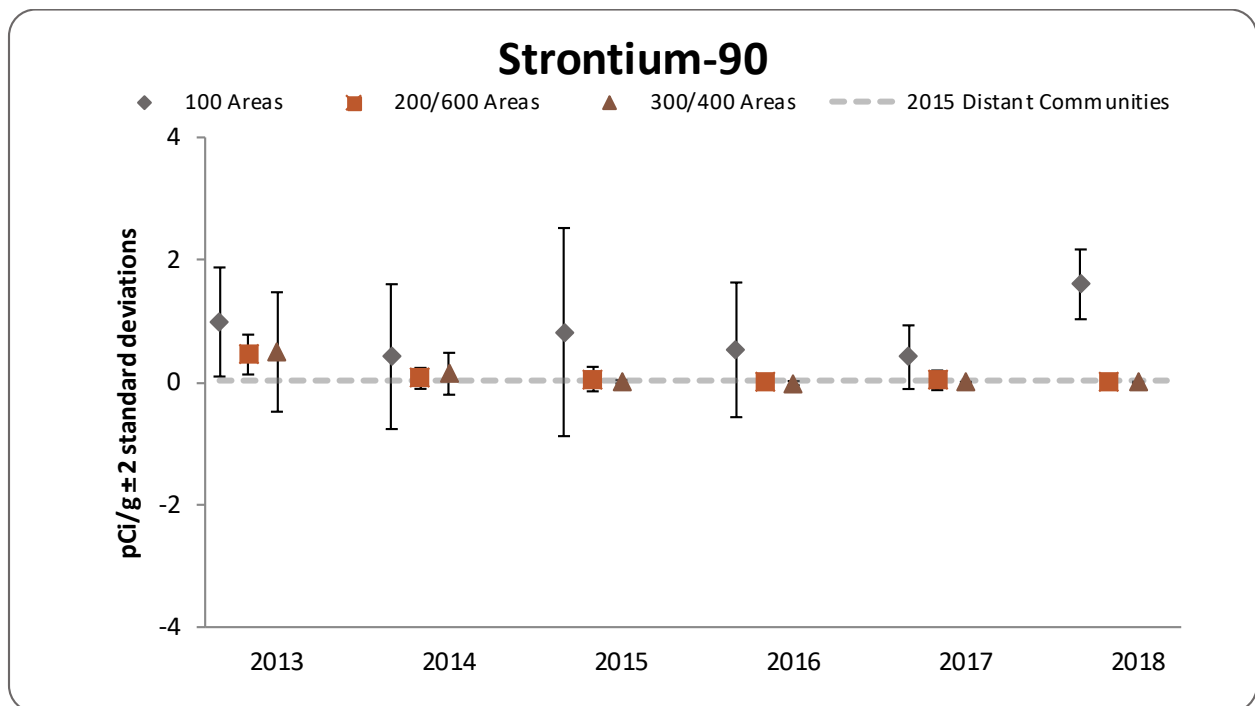
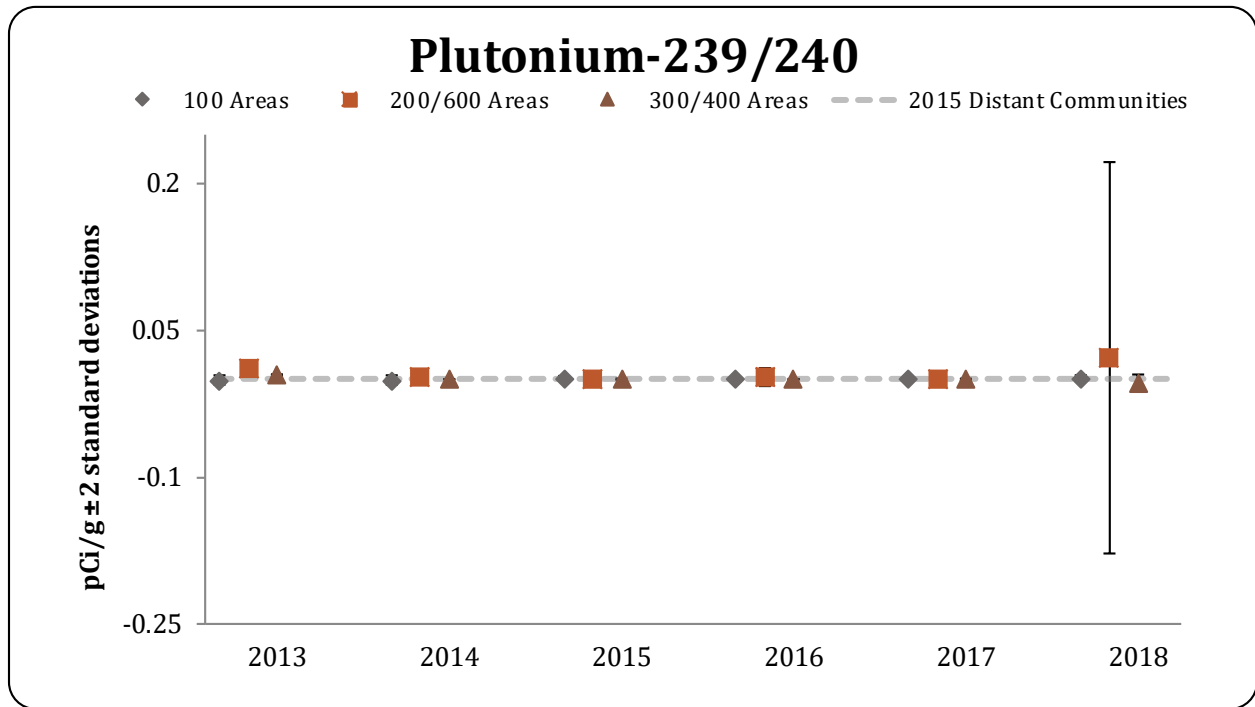
10.3.1.2 Vegetation Monitoring Results. The analytical results from Hanford Site vegetation samples collected in CY 2018 were compared with concentrations of radionuclides measured in samples collected offsite at various locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin Counties in 2015. These comparisons are used to differentiate concentrations of Hanford Site-produced contaminants from levels resulting from natural sources and worldwide fallout.

In general, radionuclide concentrations in vegetation samples collected from or adjacent to waste disposal facilities in 2018 were similar to or slightly higher than concentrations in samples collected further away, including concentrations measured offsite in 2015. Cesium-137, strontium-90, plutonium-239/240, uranium-234, and uranium-238 were detected in the 2018 vegetation samples at locations and concentrations consistent with previous years. Figure 10-3 shows the annual average vegetation concentrations of selected radionuclides in the 100, 200, 300, 400, and 600 Areas. Appendix C, Table C-18 shows the annual average and maximum concentrations of radionuclides in vegetation samples by area during 2018 and for the preceding 5 years.

Uranium. Uranium-234, uranium-235, and uranium-238 were detected in approximately 60% of the vegetation samples at concentrations that were consistent with historical concentrations. The uranium levels are a result of uranium releases to the environment during past fuel-fabrication operations in that area.

Plutonium. Plutonium-239/240 was detected in 35% of the vegetation samples collected in the 200 and 600 Areas, with the majority of these detections coming from the 200-West Area. Generally, the concentrations measured were within historical ranges, however, there was a slightly elevated plutonium-239/240 concentration measured at location V034 in the 200-West Area. This elevated result is higher than the 5-year maximum concentration for the 200-West Area, and may be attributed to PFP demolition activities that occurred in 2017.

Strontium-90. Strontium-90 was detected in both samples collected at 100-N and in approximately 18% of the samples in the 200 and 600 Areas. Concentrations of strontium-90 were within historical ranges.



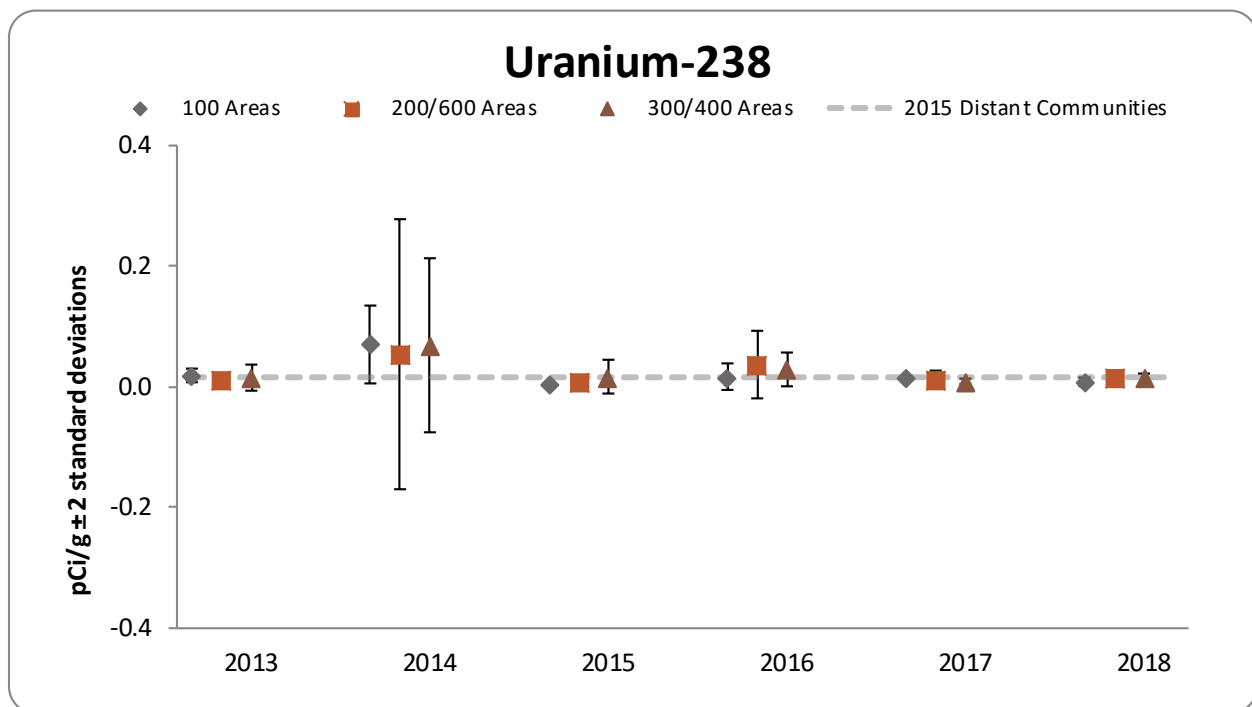
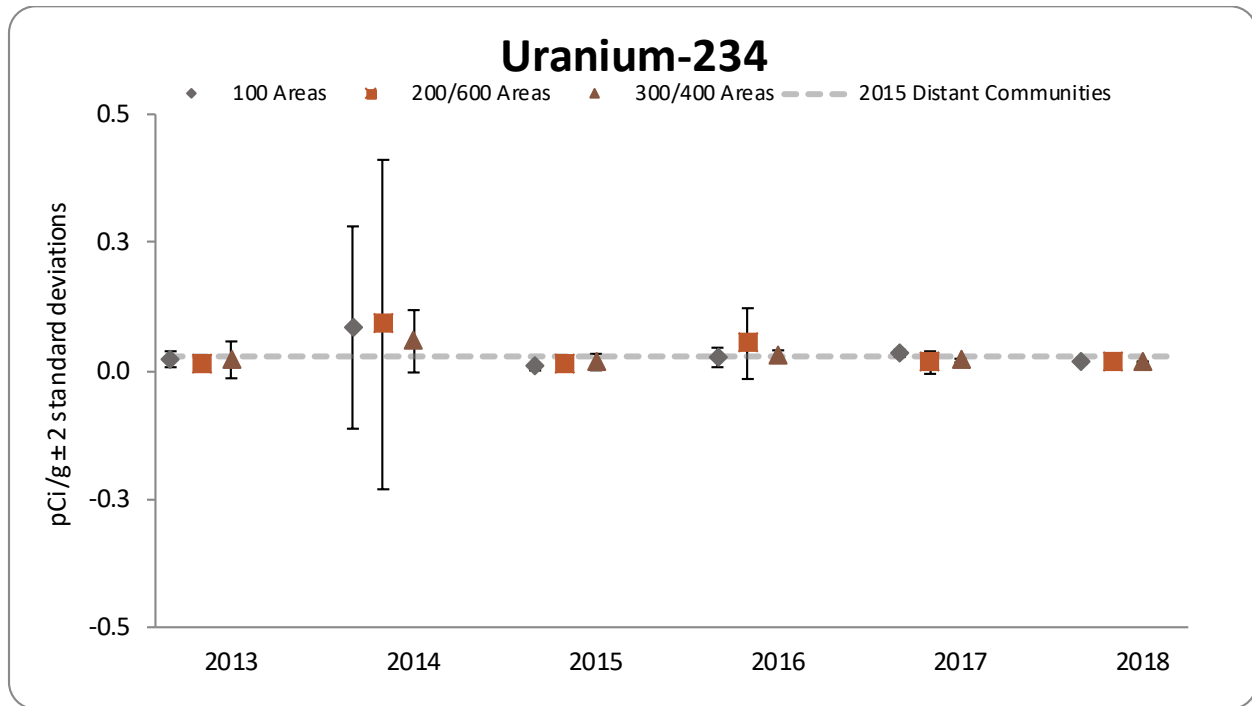


Figure 10-3. Hanford Site Vegetation Average Concentrations of Selected Radionuclides.

Cesium-137. Cesium-137 was detected in two samples in the 200 Areas. One of the samples had a slightly elevated cesium-137 concentration compared to historical data.

Americium-241. In support of the current deactivation and decommissioning project at the PFP, and especially for monitoring during the demolition of the Americium Recovery Facility, an americium-241 alpha energy analysis was added to the analyte list at six vegetation monitoring locations (V006, V010, V012, V032, V034, and V044) near the PFP complex. Americium-241 was detected in two of the seven samples analyzed for americium-241. The americium-241 concentration at location V034 in the 200-West Area was slightly elevated compared to what has been seen in the previous 2 years of analyzing for americium-241.

10.3.2 Radiological Contamination Surveys

Radiological surveys were performed in and near Hanford operational areas to monitor the presence or movement of radioactive materials or to verify radiological conditions at specific project sites.

Radiological surveys performed in CY 2018 identified 38 instances of radiological contamination in vegetation; 37 were Russian thistle (*Salsola tragus*) plants or fragments and 1 was gray rabbitbrush (*Ericameria nauseosa*). Of the 38 instances, 6 locations were posted as a contamination area and 32 were cleaned up and disposed of at a licensed facility.

Section 10.3.3 provides a discussion of the vegetation control on the Hanford Site. Table 10-6 summarizes the general locations of vegetation contamination incidents discovered in CY 2018. Table 10-7 provides the number of contamination incidents from 2000 to 2018.

Table 10-6. Hanford Site Vegetation Contamination Incidents Discovered in CY 2018. (2 Pages)

Location	2018 Incidents
100 Area	0
200-East Area	
Tank farms	8
Burial grounds	2
Cribs, ponds, and ditches	4
Fence lines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	1
Liquid Effluent Treatment Facility/Effluent Treatment Facility	7
Miscellaneous	0
200-West Area	
Tank farms	7
Burial grounds	3
Cribs, ponds, and ditches	5
Fence lines	0
Roads and railroads	0
Unplanned release sites	1
Underground pipelines	0
Miscellaneous	0

Table 10-6. Hanford Site Vegetation Contamination Incidents Discovered in CY 2018. (2 Pages)

Location	2018 Incidents
Cross-site transfer line	0
200-North Area	0
300 Area	0
400 Area	0
600 Area	0
Total	38

Table 10-7. Hanford Site Vegetation Contamination Incidents from 2000 through 2018.

Year	Incidents
2000	66
2001	20
2002	16
2003	32
2004	60
2005	66
2006	75
2007	62
2008	127
2009	109
2010	36
2011	10
2012	18
2013	35
2014	50
2015	48
2016	45
2017	23
2018	38

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 Hanford 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 5,170 ac (2,092 ha) were treated with herbicides in 2018 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 were included in the total treated acres; several areas received more than one herbicide application.

Noxious Weeds. Noxious weeds were 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, 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 39 ac (15.8 ha) of noxious weeds on the Hanford Site were treated with herbicides in 2018. These control measures were focused on revegetation and restoration sites including cleaned-up waste sites and revegetated mitigation sites. Noxious weed species that were controlled in 2018 included: diffuse knapweed (*Centaurea diffusa*), rush skeletonweed (*Chondrilla juncea*), Saltcedar (*Tamarix spp.*), Tackweed (*Tribulus terrestris*), and phragmites (*Phragmites spp.*).

10.4 Waste Site Remediation and Revegetation

RC Roos, JM Rodriguez

In 2018, 171 ac (69 ha) across the Hanford Site (100K – 100-K-95, 100-K-CTA, 128-K-2, 600-370, 600-301, 600-120, 600-100; 100 B/C – 116-C-5, 116-B/C-MISC, 100-B-14, 100-C-6; 100D – 128-D-2 East, 128-D-2 West, 118-D-2, 628-3 Inner, 628-3 Outer; 600A – 600-358, 600-566, 600-30) was planted with grass seed in an effort to restore native plant communities on revegetation and restoration sites including cleaned up waste sites and revegetated mitigation sites. In addition to planting grass seed, native shrub and forb seed was planted and nearly 2,000 shrub and forb seedlings were planted (DOE/RL-96-32).

10.5 References

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- PNL-9394. 1994. *Ecotoxicity Literature Review of Selected Hanford Site Contaminants*. Pacific Northwest Laboratory, Richland, Washington. Online at <http://www.osti.gov/bridge/servlets/purl/10136486-6slptz/native/10136486.pdf>.

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2018 Highlight

The peak annual Hanford Reach fall Chinook salmon redd count for 2018 (5,429) was the third lowest count (range: 4,018 – 20,678) in the past 20 years (1999 – 2018) and was far lower than the previous 10-year average (11,263).

Three successful Ferruginous Hawk nests occurred on the Hanford Site in 2018, producing two young per nest for a total of six young.

The 183-D Clearwell and the 183-F Clearwell continue to be used by Yuma myotis (bats) as maternity roosts. Peak counts at 183-D Clearwell decreased from 3,500 individuals in 2016 to 3,397 in 2018 while peak counts at 183-F Clearwell increased from 1,466 individuals in 2016 to 2,325 in 2018.

Fifty-one artificial nest burrows for Burrowing Owls were installed on the Hanford Site in 2018. Twenty-five of these newly installed artificial burrows replaced unused older artificial burrows and 26 of the artificial burrows were placed in new locations. The new designs are easier to monitor and maintain and have higher life expectancies.

The riparian vegetation along the Hanford Reach of the Columbia River from 100-B/C Area to the 100-H Area and the 100-F Area were mapped in 2018. The map and the accompanying report can be found on the Hanford Site's ecological monitoring website:
<https://www.hanford.gov/page.cfm/EcologicalMonitoring>.

Hanford Site archaeologists completed 94 National Historic Preservation Act Section 106 cultural resources reviews.

During 2018, 31 items were reviewed, cleared for public release, and /or transferred to the Hanford History Project repository for integration with the Hanford Collection. Fifteen artifacts and two linear feet of archival material were evaluated for inclusion in the Hanford Collection. These materials were delivered to the Hanford History Project repository at Washington State University, Tri-Cities leaving 26 (3.5%) of the 743 tagged artifacts onsite. They are scheduled for collection between 2018 and 2048.

11.0 Resource Protection

11.1 Ecological Protection

JW Wilde, KJ Cranna, JE Grzyb, ES Norris, 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* and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

The DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, (CLUP) 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 Hanford Site.

The DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*, (BRMP) 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]¹ 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 (i.e., 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*; *Bald and Golden Eagle Protection Act*; *Migratory Bird Treaty Act of 1918*; as well as compliance with executive orders, DOE Orders, and DOE resource management guidance
- Providing data for environmental impact and ecological risk assessments
- Providing information and maps of the distribution and condition of biological resources at the Hanford Site
- Supporting Hanford Site land-use planning and stewardship.

Hanford Site ecological monitoring activities provide information useful to the Hanford Site natural resource stakeholders and the public on the status of some of the Hanford 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.

¹The CLUP document uses a different acronym (BRMaP, in place of BRMP used here) for abbreviating the *Hanford Site Biological Resource Management Plan* document.

11.1.1 Fish and Wildlife Monitoring

JW Wilde

This section provides inventory, monitoring, and survey information for fish and wildlife evaluated at the Hanford Site during 2018. 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. Yearly monitoring provides occurrence and distribution data to ensure their protection from Hanford Site operations. Additional annual monitoring efforts include nesting ferruginous hawks 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 2018 monitoring also included burrowing owls and bats. The following sections provide summaries of the monitoring results; additional reports on these species can be found at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.1.1 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, as well as 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 (HNF-52190; HNF-54808; HNF-56707; HNF-58823; HNF-59813; MSA 2018). 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 is vitally important for the implementation of the Hanford Reach Fall Chinook Protection Program (ACE 2006). Prior to 2011, the Hanford Reach was divided into 16 areas that were maintained in the current monitoring campaign. In 2011, eight additional sub-areas (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 16 areas and the newer 8 areas are not mutually exclusive areas, they simply represent different divisions of the Hanford Reach.

In 2018, three surveys were completed along the Hanford Reach (October 22, November 5, and November 16). Table 11-1 summarizes the results of visual aerial surveys for fall Chinook salmon redds in the originally defined 16 areas. The results for the same surveys, organized into the eight operational areas, are shown in Table 11-2. The peak annual redd count for 2018 (5,429) was the third lowest count (range: 4,018 – 20,678) in the past 20 years (1999 – 2018) and was far lower than the previous 10-year average (11,263). The historical trend in redd counts since 1948 is shown in Figure 11-1.

An aerial photography flight was taken on November 17, 2018, and high quality photographs were captured for the entire Hanford Reach to enumerate all visible redds using a Geographic Information System. A detailed analysis of the photographs will be performed in 2019.

Table 11-1. Summary of Fall Chinook Salmon Redd Counts by Areas for the 2018 Aerial Surveys in the Hanford of the Columbia River.

Area	Description	10/22/2018	11/5/2018	11/16/2018	Maximum Count
0	Islands 17-21 (Richland)	0	0	0	0
1	Islands 11-16	0	4	88	88
1a	Savage Island/Hanford Slough	0	0	0	0
2	Islands 8-10	1	94	485	485
3	Near Island 7	3	22	350	350
4	Island 6 (lower half)	9	400	950	950
5	Island 4, 5, and upper 6	6	293	605	605
6	Near Island 3	0	125	310	310
7	Near Island 2	4	300	550	550
8	Near Island 1	0	70	170	170
8a	Upstream of Island 1 to Coyote Rapids	0	0	0	0
9	Near Coyote Rapids	0	40	51	51
9a	Upstream of Coyote Rapids to China Bar	0	0	0	0
China Bar	China Bar/Midway	0	9	25	25
10	Near Vernita Bar	15	1,120	1,840	1,840
11	Upstream of Vernita Bar to Priest Rapids Dam	0	4	5	5

Table 11-2. Summary of Fall Chinook Salmon Redd Counts by Sub-areas Adjacent to Hanford Site Operations for the 2018 Aerial Surveys in the Hanford Reach of the Columbia River.

Sub-area	10/22/2018	11/5/2018	11/16/2018	Maximum Count
300 Area	0	0	0	0
Dunes	0	0	0	0
100-F	3	22	350	350
100-H	6	293	605	605
100-D	0	70	170	170
100-N	0	0	0	0
100-K	0	0	0	0
100-BC	0	40	51	51

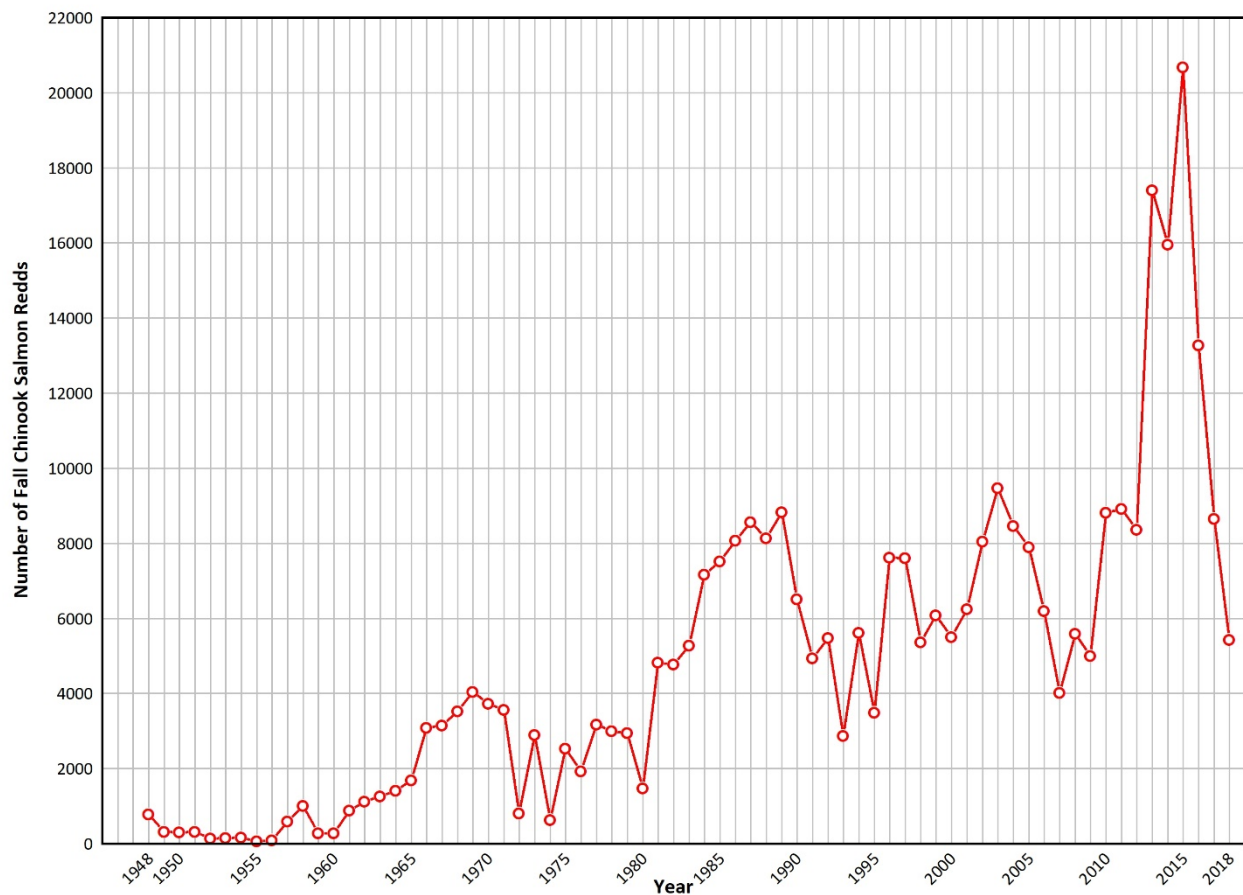


Figure 11-1. Visual Hanford Reach Fall Chinook Salmon Redd Counts 1948 to 2018.

11.1.1.2 Steelhead

JJ Nugent

Steelhead use the Hanford Reach for rearing as juveniles, as a migratory corridor for juveniles and adults, and for spawning as adults. Upper Columbia Summer-run Steelhead are currently listed as federally threatened under the *Endangered Species Act of 1973* in 16 USC 1531 and as a state candidate in Washington State (WDFW 2019). Because of their listing status and importance to recreational and Tribal fisheries, steelhead are monitored on the Hanford Reach.

Steelhead build nests termed “redds,” in gravel or cobble substrate and spawn in the spring; the steelhead fry emerge from the gravel later that same spring. Adult steelhead generally use smaller tributary habitat and substrate; however, adult steelhead will spawn in larger mainstream rivers with suitable habitat, such as the Columbia River. Suitable spawning conditions within the Hanford Reach occur between February and early June with peak spawning in mid-May (Watson 1973).

Aerial surveys for steelhead redds are conducted on the Hanford Reach in the spring of each year to identify potential spawning areas and timing as well as to provide an annual index of relative abundance among spawning areas. The surveys document any change in the status of steelhead spawning in the Hanford Reach and could help plan project activities to avoid redds, if any are identified. Similar to the methods used to document fall Chinook salmon spawning, the survey area is divided into 11 areas, with the number of redds being totaled by area. Eight additional sub-areas (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, Dunes, and 300 Area) were added to monitor the abundance and distribution of steelhead redds in areas of potential upwelling of contaminated groundwater. The original 11 areas and the newer 8 areas are not mutually exclusive areas, they simply represent different divisions of the Hanford Reach.

Information on the quantity and location of steelhead spawning is difficult to assess because aerial surveys of steelhead spawning are often hampered by high spring runoff that obscures visibility. Excessively high flows resulting from spring run-off flood areas typically characterized by terrestrial vegetation and lacking steelhead spawning habitat, and leave previously usable habitat with flows too swift for spawning and too deep to be observed from the air. Sustained flows in excess of 160 kcfs (4,531 m³/sec) are considered too high to survey.

In 2018, one steelhead redd survey was completed on the Hanford Reach (April 4). No steelhead redds were observed during the flight. In mid-April, Columbia River flows increased above 160 kcfs (4,531 m³/sec) and stayed high for the remainder of the steelhead spawning season (Figure 11-2). No other surveys were conducted in 2018.

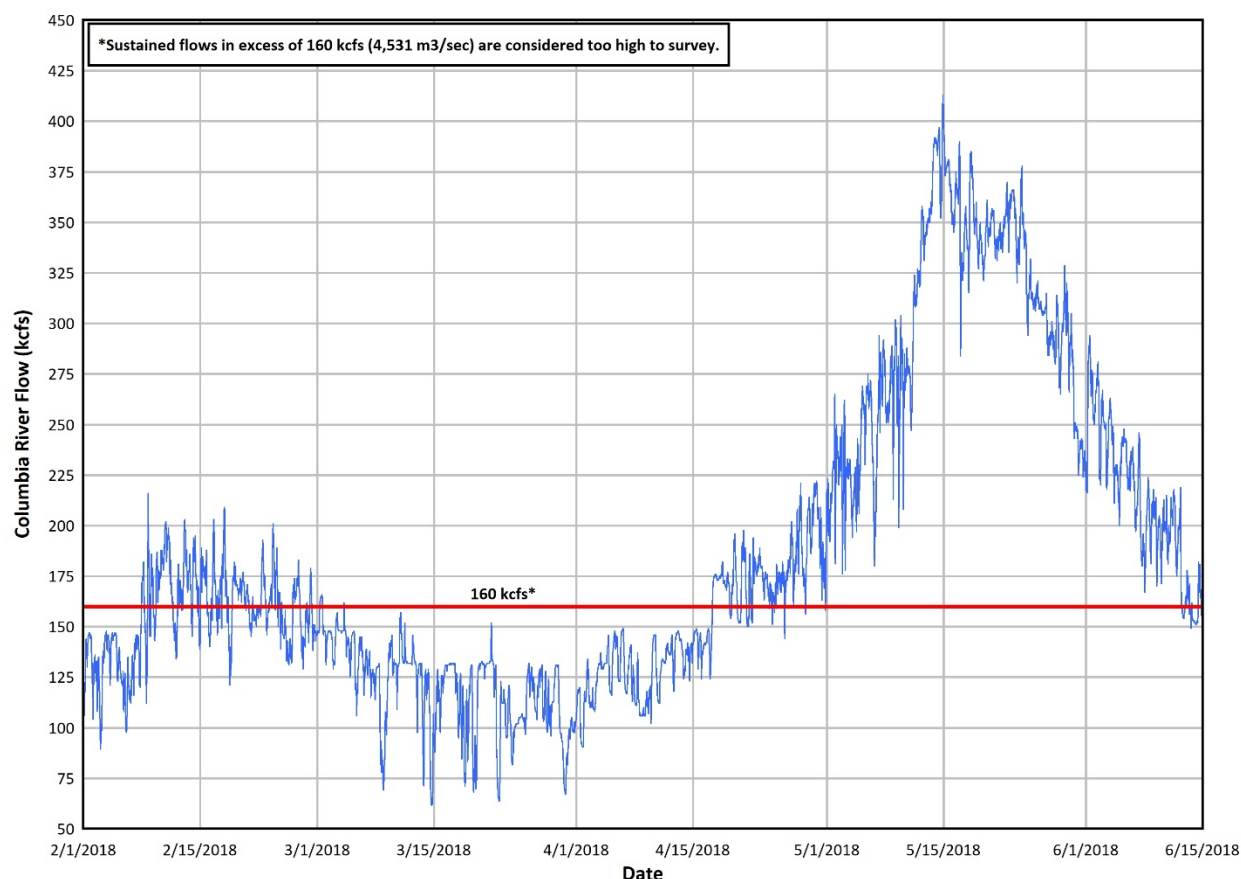


Figure 11-2. Columbia River Flows on the Hanford Reach during Late Winter and Spring 2018 (USGS 2018).

11.1.1.3 Bald Eagle

JW Wilde

The data and information displayed in this section is a modified reproduction from DOE/RL-2018-32, *Hanford Annual Site Environmental Report for Calendar Year 2017*. Bald eagle monitoring is initiated in the fall with roost monitoring and carries through to the summer months with nest monitoring. The roost data captured here occurred from November 2017 through March 2018 and includes the addendum of 2018 nest information not captured in the 2017 annual report. Roost monitoring for November 2018 through March 2019 will be reported in the 2019 Hanford Annual Site Environmental Report. 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 fiscal year 2018 season, 72 night roost surveys (9 locations on 8 nights) and 2 boat surveys were conducted. The Washington State 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” (Stinson et al. 2007). Night roost surveys were conducted at dusk from 15 minutes prior to sunset until dark. Night roost surveys were conducted biweekly at nine locations between November 13, 2017, and February 26, 2018.

The entire Hanford Reach was surveyed by boat two times during the 2018 fiscal year (December 11, 2017, and March 19, 2018). 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. During the third night roost survey on December 11, 2017, the single day maximum count on the Hanford Reach of 82 bald eagles was observed. This was less than the record maximum count of 141 documented during fiscal year (FY) 2015. However, it remains higher than the historic average maximum count of approximately 32 eagles (1961 to 2017). This was most likely a result of the high number of adult fall Chinook salmon spawning in the Hanford Reach in recent years, a primary food source for eagles.

Nest sites were monitored for nesting activities (e.g., a pair defending the nest from other eagles, nest tending, and pair bonding behaviors). Nesting attempts since 1991, although no active successful nest until 2013, on the Hanford Site are shown in Figure 11-3. In 2018, five nesting attempts were monitored during FY 2018 (marked as 2018 in Figure 11-3). Three of these five nests became active successful nests producing young birds in 2018. The nest on the White Bluffs peninsula (upstream of the boat launch) produced one juvenile eagle, Hanford townsite substation nest produced two juveniles, and the Benton Substation nest (same pair since 2013) produced 1 young bird. The nest across from the B Reactor and the second nest in the Hanford townsite were abandoned.

11.1.1.4 Ferruginous Hawk Nesting Territory Occupancy and Productivity Monitoring

JJ Nugent

The Ferruginous Hawk, a Washington State threatened species (WDFW 20198) and the largest of the North American Buteo species, inhabits grassland, shrub-steppe, and desert habitats of western North America from southern Canada to central Mexico. Generally, Ferruginous Hawks begin arriving in Washington State to nest in mid-February and begin laying eggs in mid-March. Most eggs hatch in May and most young fledge from late May through late July (WDFW 1996). Ferruginous Hawks build large stick nests. On the Hanford Site, Ferruginous Hawks have been found nesting on cliffs, rock outcrops, trees, and transmission towers.

Ferruginous Hawks are especially sensitive to human disturbance and incursion into their nesting areas. On the Hanford Site, nesting Ferruginous Hawks are protected using WDFW guidelines (WDFW 2004). Buffer zones of 3,281 ft (1,000 m) are established around active nests. Road closure signs are placed in the roads where they intersect with the 3,281-ft (1,000-m) buffers. Nest areas are protected from all human disturbance within 820 ft (250 m) between March 1 and May 31, and within 3,281 ft (1,000 m) for prolonged (greater than 0.5 hour) activities during the entire nesting and fledging season (March 1 to August 15). The identification of active nest sites during annual surveys allows for the protection of nesting Ferruginous Hawks.

Nesting Ferruginous Hawks were uncommon on the Hanford Site prior to 1987, with only one or two pairs nesting each year on basalt outcroppings on the side hills of Rattlesnake Mountain (Fitzner and Newell 1989). In 1987, four pairs of Ferruginous Hawks were observed nesting on the relatively new 230-kV transmission towers associated with the Washington Public Power Supply System reactors (now known as Energy Northwest). Construction of the transmission towers began in 1976 and lines were energized between December 1976 and July 1981. In 1988, seven Ferruginous Hawk nests were observed on 230-kV transmission towers and one in a tree. In 1991, 1992, and 1993, 11 active Ferruginous Hawk nests were reported each year on the entire Hanford Site (8 to 10 active nests on the

central Hanford Site) (WHC-EP-0513.; Nugent 1995). The majority of these nests were located on the newly built transmission towers. A decrease in the number of nesting Ferruginous Hawks on the Hanford Site has occurred since the 1990s. PNNL-SA-46396, *Breeding Population Status and Nest Site Characterization of Hawks (Buteo spp.) and Common Ravens (Corvus corax) on the Hanford Site, Southcentral Washington*, reported four nesting pairs on transmission towers in 2005 and WDFW (Livingston 2012) documented two nesting pairs on transmission towers in 2010. The number of occupied Ferruginous Hawk nests have remained stable on the Hanford Site since 2010 with two to four nests occurring each year (all on transmission towers) from 2012 to 2017 (HNF-53073; HNF-56769; HNF-58717; HNF-59755; HNF-60469). In 2016, a productivity survey found a total of six young were produced on the Hanford Site at three nest sites (two young at each nest site) (HNF-60469). In 2017, nest surveys located three occupied nesting territories but only two territories were successful. One young each was produced at two of the nests (MSA 2018).

Two surveys were conducted in 2018, one occupancy survey and one productivity survey. The occupancy survey took place May 22. Four occupied nests were identified, all of them were on 230-kV transmission towers (Figure 11-4). The productivity survey was performed on June 13. Productivity surveys are performed when most young are 2 to 5 weeks old but, ideally, when young are almost old enough to fly to consider the nest successful. One nest was reported down with no young. This nest had two small chicks at the time of the occupancy survey. The other three nests were found to each have two young for a total of six young.

11.1.1.5 Bat Monitoring

JE Grzyb

Under BRMP, bat roosts are classified as a Level 3 resource, which includes species recognized by Washington State as having conservation concern. The management goal for Level 3 resources is conservation with a compensatory mitigation action of habitat replacement. During Hanford Site remediation demolition efforts, a pallid bat maternity colonies was discovered to be utilizing the associated headhouses of the 183-D and 183-F water treatment plants. In order to mitigate the loss of habitat due to demolition of the facilities, one of the two clearwells at each location and its associated filter backwash flume and suction well at 183F were preserved for roosting habitat. These locations were fenced off and posted as a sensitive habitat area to limit human disturbance. Because it was unknown whether the clearwell would provide a suitable habitat replacement for the a colony of pallid bats, an additional structure known as the 114-D Bat Tower was constructed to provide mitigation habitat for the maternity colony in the head house. A similar decision was previously made to keep the 183-F Clearwell intact after a large Yuma myotis maternity colony was discovered in 2006.

While male Yuma myotis typically roost individually or in small numbers throughout the feeding season, mature females congregate in groups, sometimes consisting of many thousand individuals forming maternity colonies. In these maternity roosts, female bats will give birth to and raise their young until they can fend for themselves, a process that typically takes 2 to 3 months. Roost locations are occupied annually to complete the reproduction process. Yuma myotis select maternity roost locations based on a number of requirements. The habitat must maintain a balance of lighting, temperature, and humidity with food and water resources available in the approximate area (HNF-56359). Alterations to these habitat requirements can cause significant mortality to an entire generation, specifically when developing young are not volant; therefore, it is vital for the habitats to be identified and safeguarded in order for pregnant and lactating bats to birth and rear young successfully.

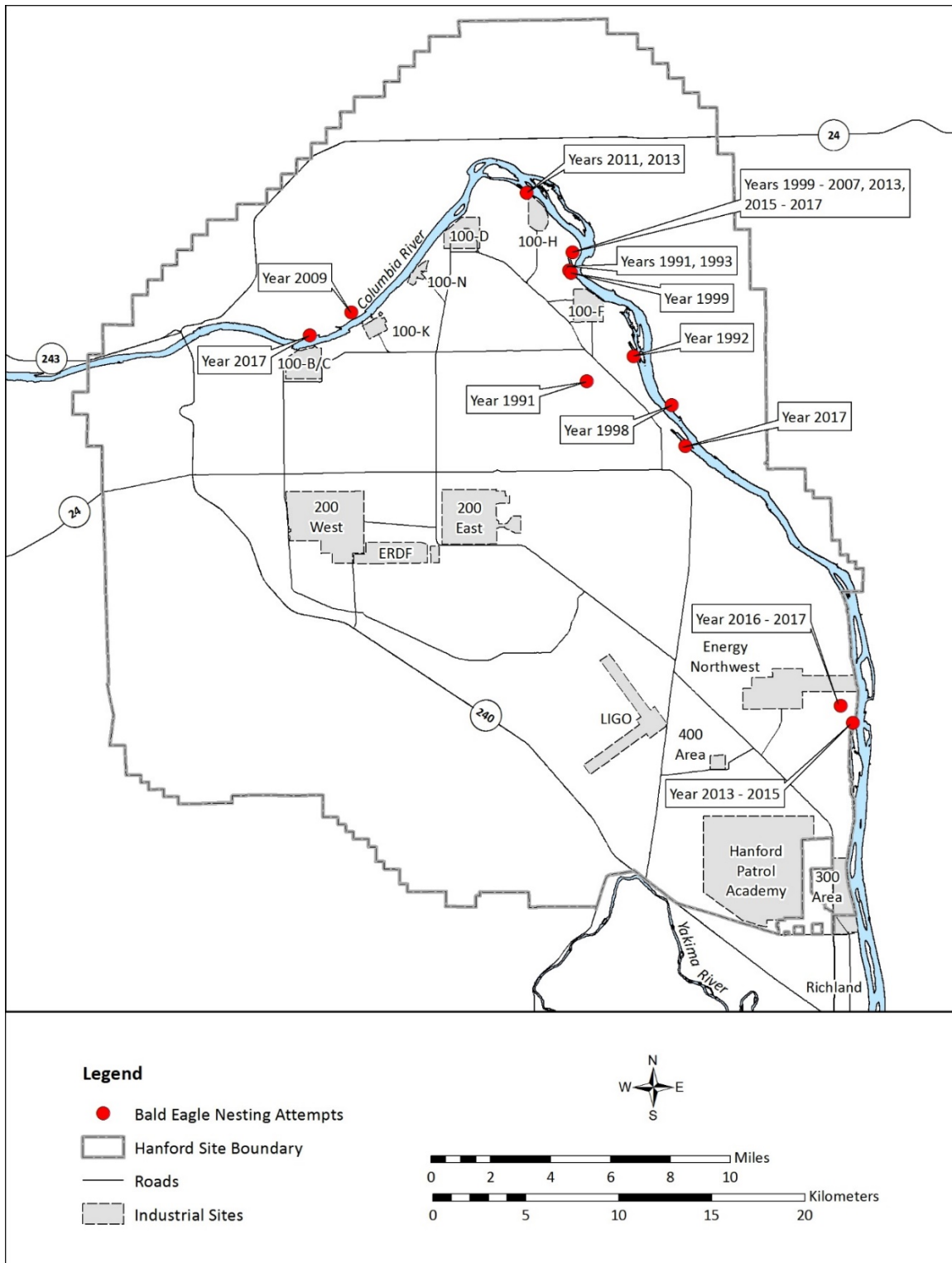


Figure 11-3. Location of Known Bald Eagle Nesting Attempts on the Hanford Site.

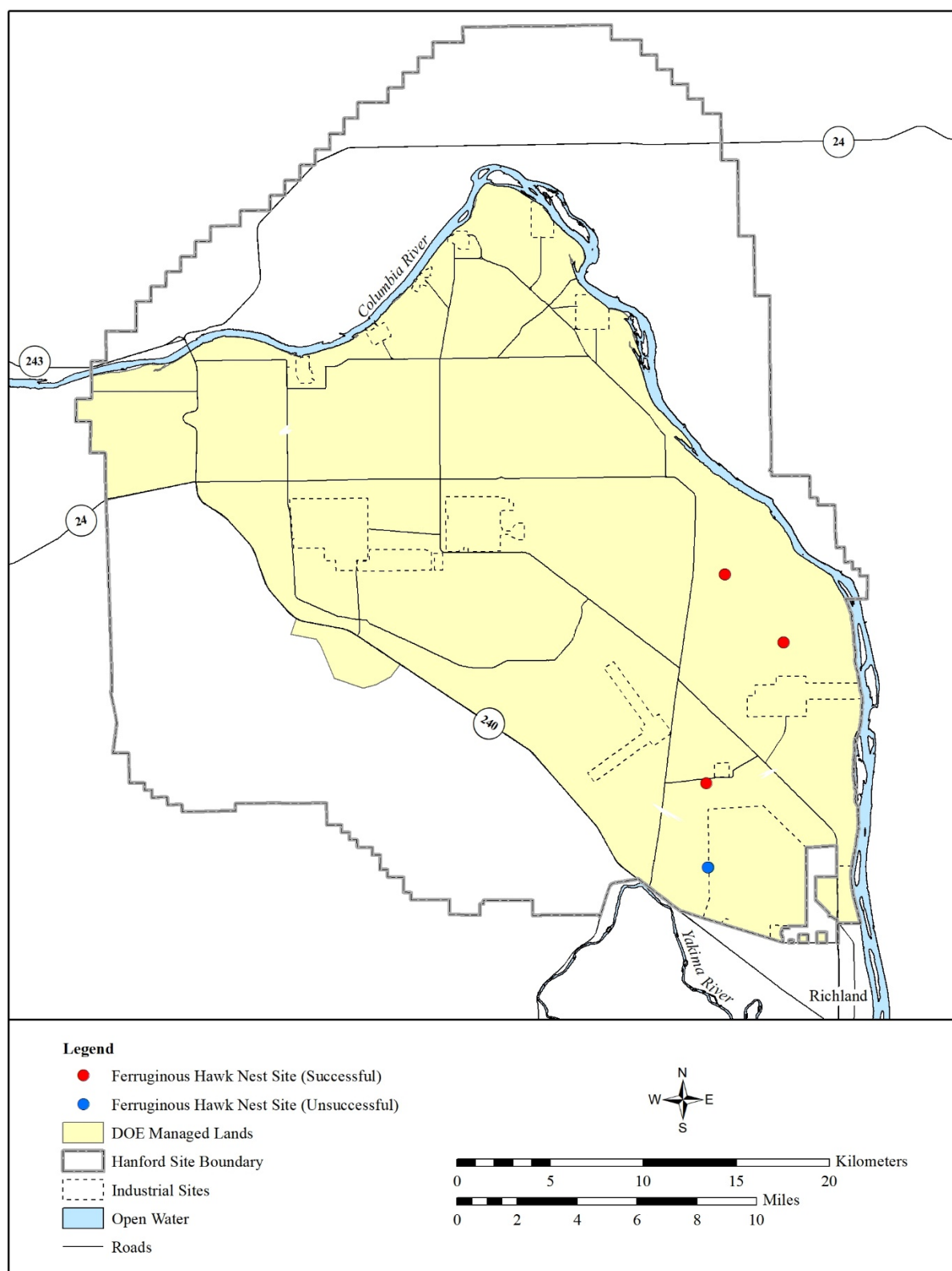


Figure 11-4. Active Ferruginous Hawk Nests Observed on DOE-RL Managed Lands of the Hanford Site in 2018.

Human disturbance is especially stressful to maternity roosts, females have been known to abandon the roost site all together following human disturbance, jeopardizing the survival of young (O'Shea et al. 1999). Anthropogenic noise, vibrations from human activity such as construction and mining, and recreational activities such as caving and rock climbing have all shown to disrupt roosting behavior (Hayes and Wiles 2013).

The 2018 bat surveys at the 183-F and 183-D Clearwells were conducted simultaneously by teams of two staff members at each location using the same survey method. Teams of two staff members at each location using the same survey method conducted the 2018 bat emergence surveys at the 183-F and 183-D Clearwells simultaneously. The counting method and restrictions followed a Bat colony emergence count protocol used developed by the WDFW Bat Colony Emergence Count Protocol. The initial two surveys were scheduled within 3 to 7 days of each other to minimize the possibility of short-term weather events or other environmental conditions influencing emergence counts. If environmental conditions were anticipated to affect the emergence, the survey was to be halted or canceled. These conditions included a temperature below 32 °F, heavy precipitation or fog, or steady winds above Beaufort scale 3 (13+ mph). Surveys began a half hour before sunset and ended when either it became too dark to observe bats, emergence slowed to a period of no bats observed exiting for 5 minutes, or when more bats were entering than exiting over a 5 minute period. Staff positioned themselves roughly 10 to 25 ft (3 to 8 m) from the ceiling hatch and counted bats exiting and entering the clearwell through the opening. In order to tally the two sets of counts, a manual hand counter was operated in each hand (one hand for exiting, the other hand for entering). During the survey, the two observers did not share their observations with each other in order to keep the survey unbiased. Emergence totals were calculated by using the formula:

$$\frac{(\text{Surveyor 1 Exiting Total} - \text{Entering Total}) + (\text{Surveyor 2 Exiting Total} - \text{Entering Total})}{2} = \text{Estimated Colony Emergence Total}$$

Both of these clearwell mitigation sites show a continued use for maternity roosting by Yuma myotis. At the time of these efforts, the 183-F Clearwell was recognized by WDFW as the largest maternal colony in Washington State (Hayes and Wiles 2013 and the 183-D Clearwell population is increasing in size. The high counts at the 183-F Clearwell peaked at 6,627 on July 24, 2012, and has not been observed greater than 3,500 since. This peak occurred the year before the 183-D Clearwell was first monitored during a pre-mitigation survey on July 24, 2013, when 11 bats were observed emerging from the clearwell. Colony emergence counts of Yuma myotis (*Myotis yumanensis*) in 2018 was estimated at 3397 bats for 183-F and 2325 bats for 183-D during the July surveys. These data shows that the 183-D Clearwell population has grown, while the 183-F population has remained similar to previous colony counts which have averaged approximately 3688 bats since 2008. The growth of the 183-D population may be due to a portion of the 183-F population immigrating to the 183-D Clearwell. There are known maternity colonies of Yuma myotis in the vicinity, located in the 190-D/DR water process tunnels (WCH-634), which may also be influencing the growth of the 183-D Clearwell population through immigration. As of 2018, the high count difference between the two clearwell populations is 1,072 bats (Figure 11-5). Figure 11-5 displays the counts and trends of the 183-F and 183-D colonies over recent years. While peak counts of 183-F in a 2012 July survey was 6627, where pup emergence was likely influencing the count, the 2018 results show similar overall numbers of Yuma myotis maternity colony size on the

Hanford Site. The continued stable counts at the 183-F Clearwell and the growing population of Yuma myotis at the 183-D Clearwell demonstrate that the collaborative input and final decisions made during the demolition process to keep these structures intact have proved to benefit Yuma myotis bats on Hanford. Continued annual monitoring will develop a valuable long-term timeline of bat numbers utilizing the two clearwells, better illustrating the carrying capacity of the locations. It is important to note that a number of factors can fluctuate the emergence observations including weather, phase of the moon, overall colony activity, and survey methods. Surveys conducted prior to 2018 relied on digital video recording while the 2018 surveys were based on real-time manual counting. Digital video recording was attempted during the 2018 manual counts but proved uninformative due to recording issues. Future surveys would benefit by using both survey methods with upgraded infrared recording equipment. These surveys should be conducted during both the pre and post-fledging seasons in order to more accurately assess the colonies reproductive success.

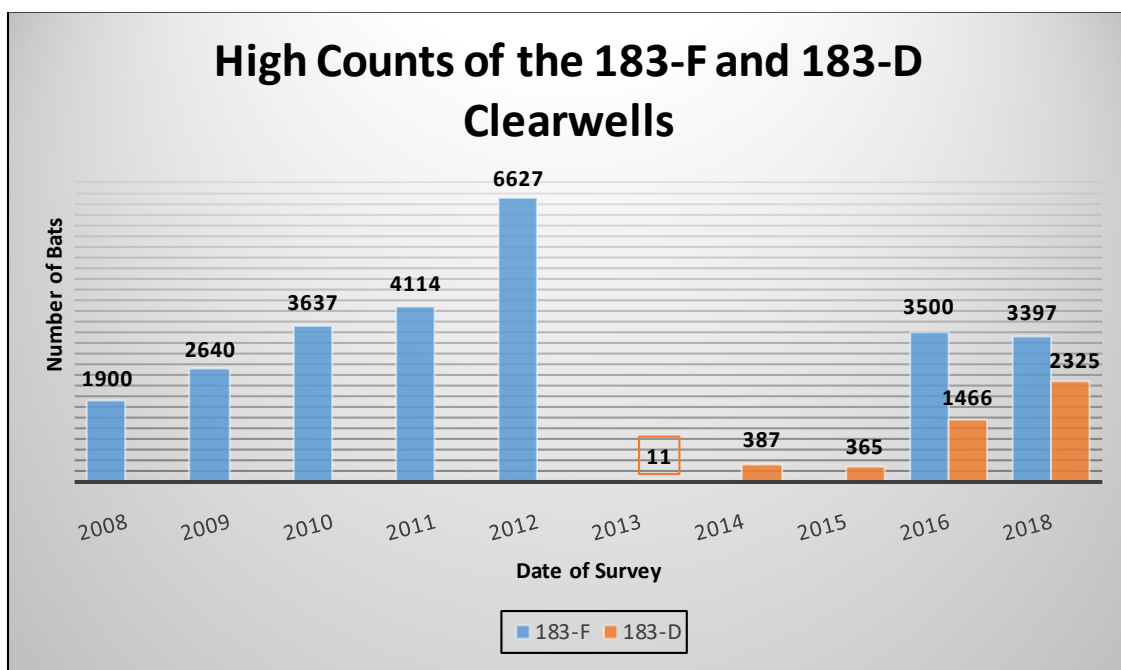


Figure 11-5. Comparison of the Yearly 183-F and 183-D Clearwell High Counts.

Annual emergence surveys should continue in order to track the population's health while keeping the sites protected; this will provide critical habitat for years to come. With the threat of white-nose syndrome spreading in Washington State, mist netting should continue to test for the disease under the guidance of WDFW (WNS 2016). Due to the size of these colonies, and the DNA matches relating the two, it is possible that they may share the same hibernation locations, increasing the possibility of the disease spreading to both the 183-F and 183-D maternity colonies. Future mist netting efforts should be conducted at both locations, providing a larger scope of the epidemic on the mating population as a whole.

Additional data was gathered throughout the 2018 summer roosting season to verify the habitability of the 114-D Bat Tower, built as mitigation for a pallid bat colony using the demolished 183-D Headhouse, to be based on the relationship between the exterior ambient temperature and the internal roosting

temperature. Data loggers were placed inside the structure at roosting height, recording temperature readings at 15-minute intervals from May through September. All ambient temperatures for comparison were taken from the Hanford Meteorological Station Number 13 at the 30 ft (9.1 m) level. Station 13 is located approximately 2,191.1 ft (667.9 m) southwest from the 114-D Bat Tower. Pallid bats will find new day roosting locations when the temperature reaches or exceeds 104 °F (Lewis 1996). Throughout the summer of 2018, the ambient temperature met or exceeded this 104 °F maximum threshold on three separate days (July 13, August 9, and August 10). The peak outdoor ambient temperatures were 104.10 °F, 105.90 °F, and 105.80 °F, respectively. The highest temperature recorded at the ceiling level in the interior on these days was 104.72 °F, 109.05 °F, and 105.34 °F, respectively (Table 11-3). The interior temperature of the tower met or exceeded the maximum temperature threshold on 12 days while the exterior ambient temperature maximum on those days remained below the threshold. The interior ceiling temperatures on these days ranged from 104.00 °F to 108.24 °F.

Table 11-3 Time Lapse between Peak External Ambient and Interior Ceiling Temperatures.

Date and Time	External Ambient Temperature (°F)	Date and Time	Interior Ceiling Temperature (°F)
7/13/18 15:30	104.10	7/13/18 15:26	99.81
7/13/18 19:45	91.30	7/13/18 19:41	104.72
Time Gap Between Peak Temperatures: 4 hours, 15 minutes			
8/9/18 17:15	105.90	8/9/18 17:20	104.31
8/9/18 21:00	84.80	8/9/18 21:05	109.05
Time Gap Between Peak Temperatures: 3 hours, 45 minutes			
8/10/18 15:45	105.80	8/10/18 15:50	100.76
8/10/18 19:15	89.10	8/10/18 19:20	105.34
Time Gap Between Peak Temperatures: 3 hours, 30 minutes			

The daily interior ceiling peak temperatures between May 22, 2018, and September 30, 2018, tend to be warmer than the exterior ambient peak temperatures. During this timeframe, 12,431 temperature readings were recorded. There is a small gap in the data between August 13, 2018, and August 15, 2018, due to weather station Number 13 being out of service for repairs. The next closest weather station to the 114-D Bat Tower is weather station Number 29, located between the 100-K and 100-N Reactors. The highest daily temperatures recorded during these days were 88.5 °F, 92.8 °F, and 97.0 °F, respectively.

The average temperatures for each month of this survey is provided in Table 11-4 and show that the interior ceiling average temperature peaks about 10 degrees warmer than the exterior ambient peak. Data from May through September 2018 show that the average temperature at the ceiling level of the 114-D Bat Tower is 10.76 °F greater than outdoor temperatures. This average is similar to the individual monthly averages compared to the monthly ambient. Between May and September, the interior ceiling temperature peaks after the ambient temperature has peaked and cooled. Table 11-5 compares the time of day when the exterior ambient temperature peaked with the interior ceiling temperature on the 3 days when the ambient surpassed the maximum temperature threshold. The data shows that on the hottest days of the summer in 2018, it took a minimum of 3.5 hours for the interior temperature to peak at ceiling level after the ambient temperature had peaked. The data gathered over the summer 2018 has provided valuable information verifying that the 114-D Bat Tower becomes too warm during the

summer months to act as a suitable long-term maternity roosting structure for pallid bats. Physical alterations to the 114-D Bat Tower are recommended to increase habitability of the structure and monitoring should be conducted to track results. Possible alterations that may aid in a lower internal temperature are repainting the structure a lighter color and/or the installation of a ceiling vent. The minimum monitoring methods after alterations are made should include continued deployment of ceiling level data loggers and the placement of acoustic monitoring equipment outside of the building exits during roosting season to identify the species of possible occupants. Visual surveys should be conducted inside of the tower during the day to inspect the ceiling for any day-roosting bats. These surveys should be conducted after parturition and before fledging (early May through mid-June). During any entrance into the 114-D Bat Tower, the floor should be inspected for guano and swept clean when leaving in order to assess new guano during any following tower inspections.

Table 11-4 Monthly Temperature Averages and Overall Average Difference.

Month (2018)	External Ambient Temperature (EAT) Average (°F)	Interior Ceiling Temperature (ICT) Average (°F)	Difference (°F) (ICT) - (EAT) = D
May	68.77	80.76	11.99
June	69.09	79.53	10.44
July	80.03	90.83	10.80
August	76.22	86.40	10.18
September	65.41	75.82	10.41
			Average Difference (°F) 10.76

Table 11-5 Time Lapse between Peak Exterior Ambient and Interior Ceiling Temperatures.

Date and Time	Exterior Ambient Temperature (°F)	Date and Time	Interior Ceiling Temperature (°F)
7/13/18 15:30	104.10	7/13/18 15:26	99.81
7/13/18 19:45	91.30	7/13/18 19:41	104.72
Time Gap Between Peak Temperatures: 4 hours, 15 minutes			
8/9/18 17:15	105.90	8/9/18 17:20	104.31
8/9/18 21:00	84.80	8/9/18 21:05	109.05
Time Gap Between Peak Temperatures: 3 hours, 45 minutes			
8/10/18 15:45	105.80	8/10/18 15:50	100.76
8/10/18 19:15	89.10	8/10/18 19:20	105.34
Time Gap Between Peak Temperatures: 3 hours, 30 minutes			

11.1.1.6 Roadside Bird Surveys

JW Wilde

Ecological monitoring staff conduct roadside bird counts 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 2018, roadside surveys were performed during breeding season (May and June). Three Hanford routes (Figure 11-6) were surveyed one time each in 2018. The Army Loop Rd route only was surveyed for points 12 through 25 during the U.S. Geological Survey Breeding Bird Survey route. Points 1

through 11 of Army Loop Rd were not surveyed. For the 2018 breeding season surveys, 1,149 individual birds were counted during surveys. Considering points 1 through 11 of the Army Loop Rd route were not surveyed, the total number of birds counted was similar to the 1,253 average number of individuals from 2013 through 2017. A total of 41 unique bird species were documented in the 2018 breeding season survey (Table 11-6), which was down from the 2013 through 2017 average of approximately 49 species.

The Old Fields survey route had the highest species diversity with 33 identified. The Army Loop Road survey route had the lowest species diversity at 10 species (Table 11-6). Caveated by the fact that only 14 of the 25 points were surveyed in 2018. The Cliff Swallow (*Petrochelidon pyrrhonota*) was the most abundant species documented in 2018. Surveys counted 255 individuals on two survey routes, 22.19% of the total number of individuals seen. This was due to a very high number of breeding swallows present around the reactor areas during the morning of the survey. The typically abundant steppe species were present in high numbers. The Horned Lark (*Eremophila alpestris*) had 228 individuals and the Western Meadowlark (*Sturnella neglecta*) had 174 individuals. These three species (Cliff Swallow, Horned Lark, and Western Meadowlark) accounted for 57.18% of the individuals documented.

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>.

11.1.1.7 Burrowing Owl Artificial Burrow Installation

JW Wilde

The Western Burrowing Owl (*Athene cunicularia*) is declining over much of its range. Range contractions have occurred in southern Canada, the northeast Great Plains, and parts of California and the Pacific Northwest. It is theorized Burrowing Owl declines in Washington State are due to loss of native grasslands and shrub steppe along with the decline of ground squirrels (*Spermophilus* spp.), yellow-bellied marmots (*Marmota flaviventris*), and American badgers (*Taxidea taxus*), which create natural soil burrows that the owls use for nests. The Hanford Site is situated at the center of the predicted distribution of Burrowing Owls in the Washington State (Washington Gap Analysis 1997) and is an important area for the conservation of Burrowing Owls. Natural soil burrows may have a limited lifespan of a few years and declining small mammal populations have led to a decrease in mammal digs. Effective restoration of Burrowing Owl nesting habitat can help prevent this decline.

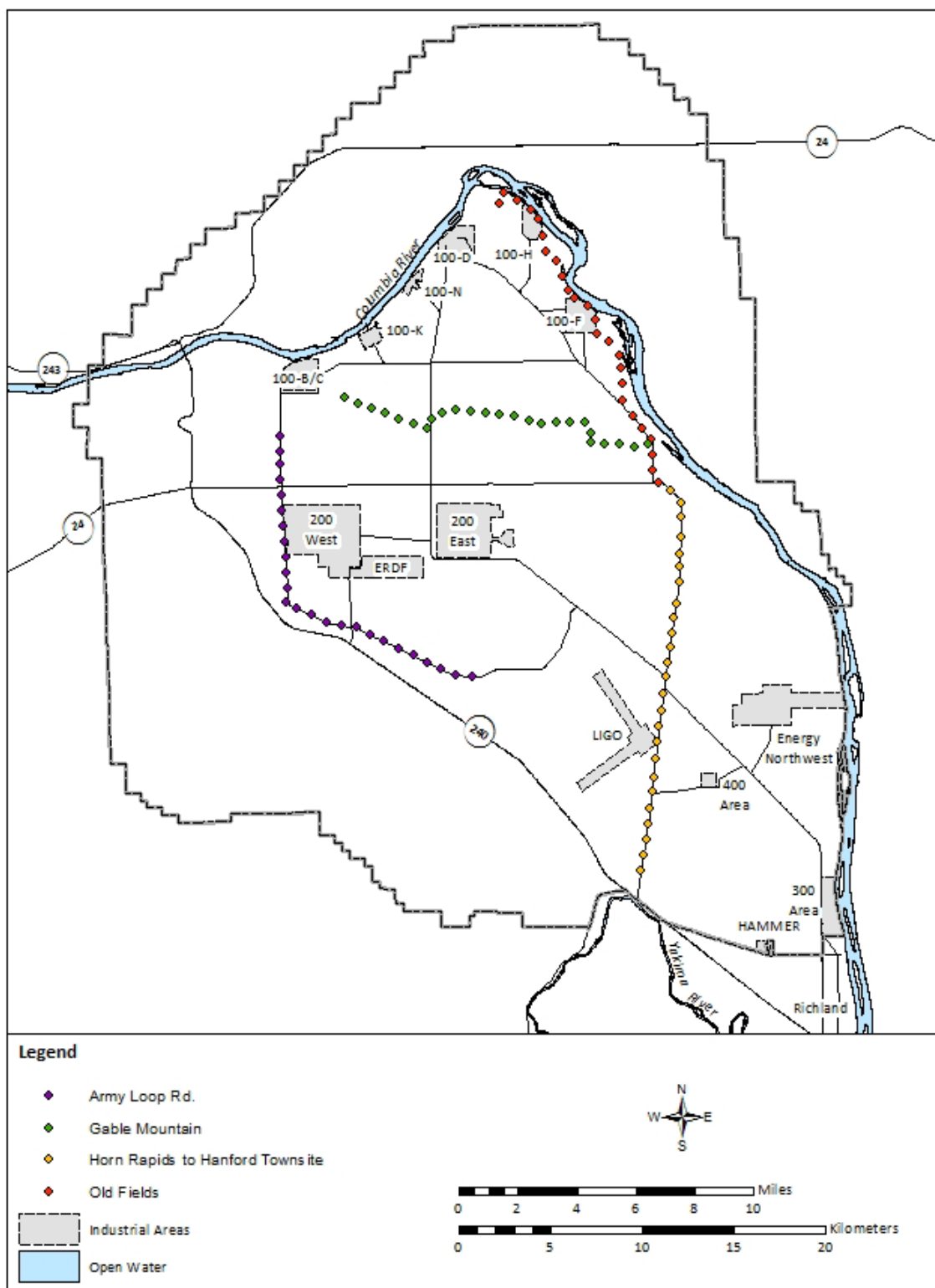


Figure 11-6. Roadside Bird Survey Routes Surveyed for Calendar Year 2018.

Table 11-6. Species Richness and Abundance Counted During the 2018 Breeding Season Roadside Bird Survey Routes on the Hanford Site Sorted by Route.

Route Name	Surveys Performed	Species Richness	Abundance
Army Loop Road	<1	10	103
Gable Mountain	1	14	162
Horn Rapids to Hanford Townsite	1	11	208
Old Fields	1	33	676
Total	3+	43 ^a	1,149
^a Unique species identified			

Historically, Burrowing Owls occupying the Hanford Site would nest in natural soil burrows. Today, the majority of Burrowing Owl nests on the Hanford Site are found in anthropogenic (i.e., old irrigation pipes) or artificial burrows installed by previous mitigation efforts. Previous artificial burrow installation efforts at the Hanford Site used an older design and had varying success. In 2018, Mission Support Alliance's Ecological Monitoring Program initiated an effort to replace many of the existing artificial burrows that were unusable or had been inactive for multiple years. The objective of this effort was to replace unused artificial burrows with new artificial burrows that had an improved design with the goal of creating more suitable Burrowing Owl nesting habitats and increasing Burrowing Owl population levels at the Hanford Site. The new artificial burrows provide more nesting space than the historic burrows and are made up of one half of a 55-gal (208 L) plastic drum with a 10-ft (3.05 m) length of 6-in. (15.24-cm) corrugated plastic tunnel access. These artificial burrow systems have an access port that sits just a few inches below grade so that staff can monitor and maintain the chambers in the future (Figure 11-7, 11-8). Use of this improved design in other areas of the Columbia Basin have proven successful in creating nesting habitat for Burrowing Owls (Johnson 2013). This improved design will extend the life of the burrows and allow for a level of monitoring not possible on past Hanford Site installations.

A total of 51 artificial burrows with the new design were installed at various locations throughout the Hanford Site. In addition to replacing 25 unused older artificial burrows with the new design, 26 new artificial burrows were installed in areas on the Hanford Site that had been identified as a historic or potential Burrowing Owl habitat (Figure 11-9). All artificial burrows installed in 2018 will be monitored annually for Burrowing Owl use starting in spring 2019. Routine maintenance will occur annually to ensure the artificial burrows are cleared of debris and suitable for inhabitation.



Figure 11-7. Burrowing Owl Artificial Burrow System Chamber Installed on the Hanford Site.



Figure 11-8. A Cluster of Three Artificial Burrow Systems Installed on the Hanford Site in Areas Inhabited by Burrowing Owls.

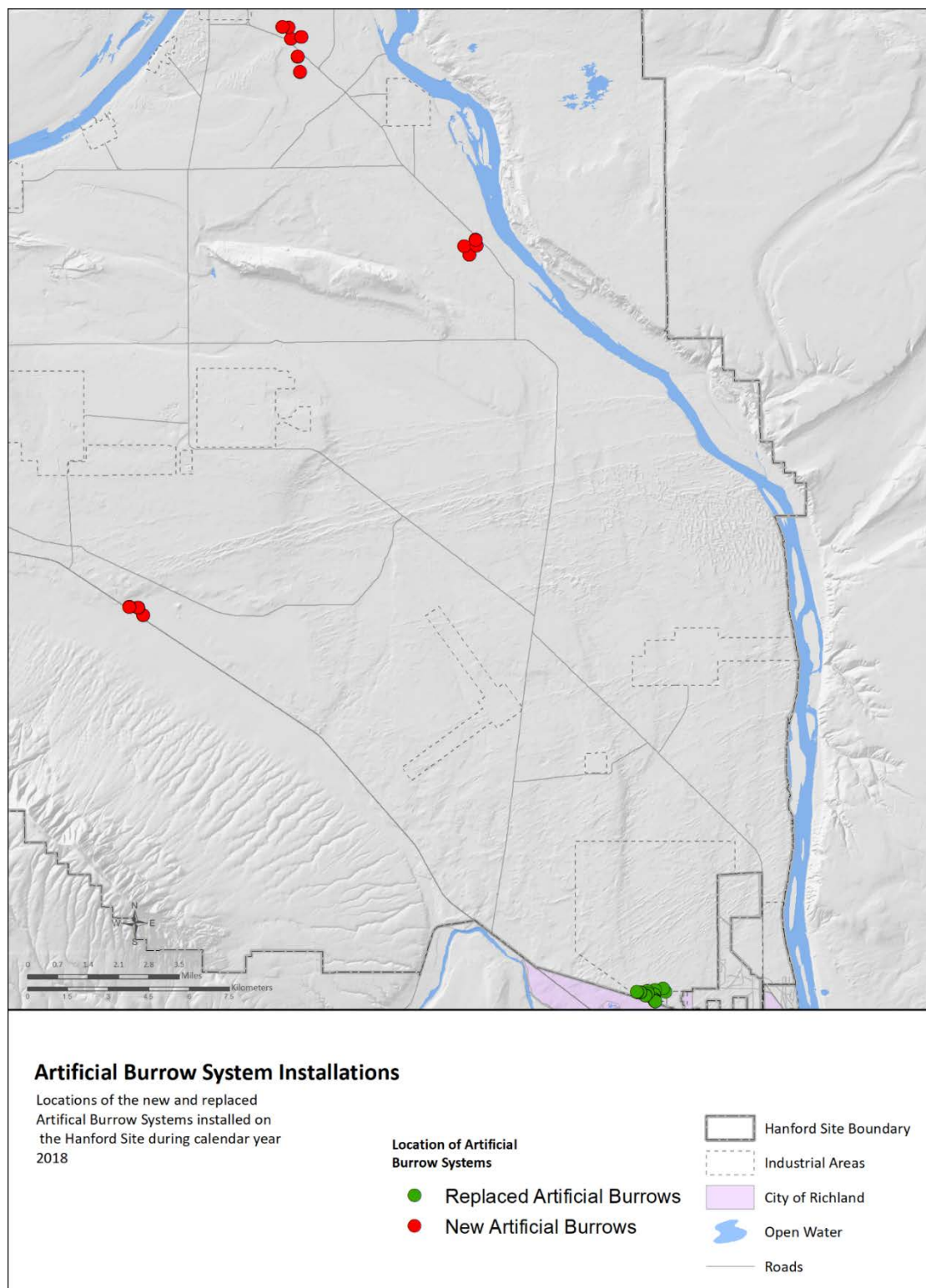


Figure 11-9. Locations of the New and Replaced Artificial Burrow Systems Installed on the Hanford Site During Calendar Year 2018.

11.1.2 Vegetation Monitoring

JA Pottmeyer

Riparian vegetation along the Hanford Reach of the Columbia River was mapped during the late summer and fall of 2018. This project focused on remapping the part of the Central Hanford in the area between and around 100-B/C Area to the 100-H Area, followed by the 100-F Area. The portion of the shoreline treated in this project is depicted in Figure 11-10.

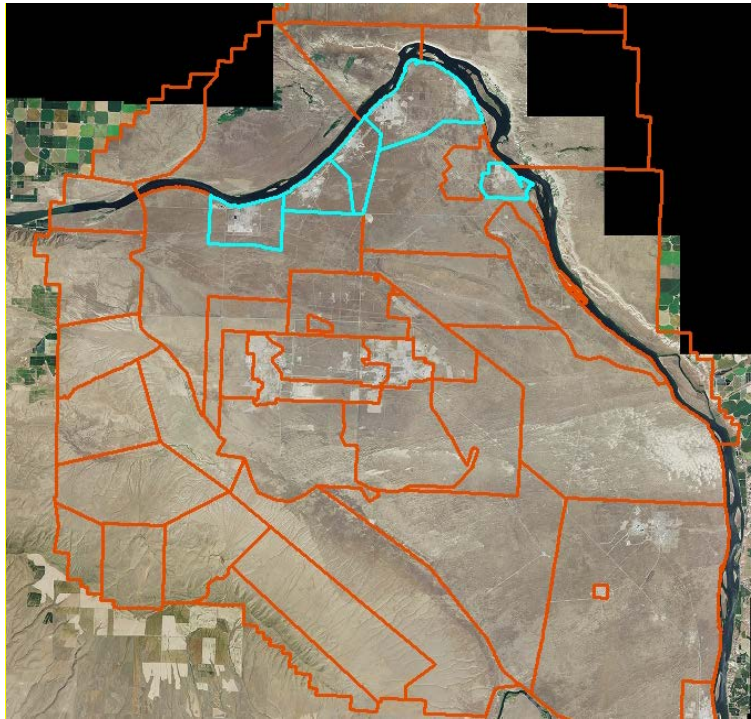


Figure 11-10. Hanford Site Management Units Mapped During 2018 (highlighted in blue).

Vegetation was assessed by traversing the study area and looking for shifts in composition. A total of 153 geo-referenced photo points were also placed at strategic points to depict changes in the dominant vegetation; the area was further characterized with 92 plots subjectively placed to characterize vegetative zones. Vegetative cover types were assigned according to the vegetation groupings shown in Table 11-7. The 2018 map and datasets were then compared with the 2004 map, with datasets from informal plots made during 1997, and with photos taken at geo-located sites during numerous projects between 2005 and 2018. In addition, rare plants were documented where found and many existing sites were revisited.

Table 11-7. Vegetation Cover Types (PNNL 2004).

Vegetation Cover Type	Cover Type Description
Bare bankslope	No vegetation
Bare silt	No vegetation
Cobble	Little to no vegetation
Low shrub-forb-cobble association	Vegetation band on unconsolidated cobble adjacent to the “low water mark” with low rhizomatous subshrubs, common dogbane (<i>Apocynum cannabinum</i>) and western goldenrod (<i>Euthamia occidentalis</i>) and scattered herbs.
Exotic weeds	Introduced weedy species such as knapweeds (<i>Centaurea diffusa</i> and <i>Rhaponticum repens</i>), Russian thistle (<i>Salsola tragus</i>), and cheatgrass (<i>Bromus tectorum</i>).
Horsetail association	Horsetails (<i>Equisetum</i> species) as the dominant cover occurring in topographic lows along the shoreline with silt embedded cobble or some siltation present.
Juniper	Characterized by widely spaced junipers (<i>Juniperus scopulorum</i>) at the transition between riparian and upland cover types.
Non-persistent emergent and emergent wetlands	Wetland areas of backwater and sloughs characterized by cattails (<i>Typha latifolia</i>), rushes (<i>Juncus</i> species and <i>Bolboschoenus maritimus</i>), and sedges (<i>Cyperus</i> species, <i>Eleocharis</i> species, and <i>Carex</i> species).
Reed canarygrass	Stands of reed canary grass (<i>Phalaris arundinaceae</i>).
Willow	Coyote willow (<i>Salix exigua</i>) patches and small groves scattered along the shore with occasional peach leaf willow (<i>Salix amygdaloides</i>)
Riparian mosaic	Patchy mosaic of riparian wheatgrass association, forb-cobble, willow, non-persistent emergent wetland, reed canary grass, wormwood/riparian wheatgrass, and exotic weed.
Rock/Road/Outflow	No vegetation
Tree association	Clumps or small stands of both native and non-native trees
Upland shrub-steppe	Upland areas including snow buckwheat (<i>Eriogonum niveum</i>)/ bunchgrass, sagebrush (<i>Artemisia tridentata</i>)/bunchgrass, rabbitbrush (<i>Chrysothamnus viscidiflorus</i> or <i>Ericameria nauseosa</i>)/bunchgrass, rabbitbrush/cheatgrass, and Antelope bitterbrush (<i>Purshia tridentata</i>)/ bunchgrass.
Riparian wheatgrass association	Riparian wheatgrass (<i>Elymus lanceolatus</i>) is the dominant species intermixed with other grasses and forbs.
Wormwood/forb	Low-lying areas, at or below the daily high water mark, with cobble/silty soil. The plant community is comprised of perennial <i>Artemisia</i> subshrubs with an understory hairy goldaster (<i>Heterotheca villosa</i>), western willow aster (<i>Symphotrichum lanceolatum</i>), Columbia tickseed (<i>Coreopsis tinctoria</i>), sneezeweed (<i>Helenium autumnale</i>), leafy beggar ticks (<i>Bidens frondosa</i>), and other riparian forbs.
Wormwood/perennial grass	Perennial <i>Artemisia</i> subshrub species including Pacific sage or field sagewort (<i>Artemisia campestris</i>), Columbia River wormwood or mugwort (<i>Artemisia lindleyana</i> ssp. <i>lindleyana</i>) and prairie or white sagebrush (<i>Artemisia lindleyana</i> ssp. <i>ludoviciana</i>).
Sand dropseed grass association	A subset of the wormwood/perennial grass category where the wormwood component is sparse or missing. [sand dropseed (<i>Sporobolus cryptandrus</i>)]
Wormwood/riparian wheatgrass	Perennial <i>Artemisia</i> subshrub species with riparian wheatgrass as the dominant understory grass.
Wild rye association	Great Basin wild rye (<i>Leymus cinereus</i>), a large perennial bunchgrass.
Open sand	Open sand beaches occur in small stretches.
Riparian shrub	Small patches of dense choke cherry (<i>Prunus virginiana</i>), currant (<i>Ribes</i> species) and/or Wood’s rose (<i>Rosa woodsii</i>), clematis (<i>Clematis ligusticifolia</i>) and various forbs or grasses may be present.

11.1.2.1 Changes in Riparian Vegetation Over Last 20 Years

Table 11-8 shows vegetation types and the area² of each type within the area mapped in 2018 and 2004. The difference in the total area between the two maps is mostly due to differing placement of the river and upland edges and a few connecting areas along the shoreline not included in the early map (e.g., areas with little habitat, facility concrete aprons). Some of the differences in areas of vegetation types between the two data sets are due to the higher level of detail in the 2018 map. In addition, some of the associations are very closely related and were distinguished by elements not emphasized during the 2018 update (mostly the presence or absence of wormwoods, *Artemisia* species).

Table 11-8. Vegetation Types in the Mapped Area of the Hanford Reach in 2004 and 2018.

Vegetation Type	2004		2018	
	Area (m ²)	% of Total	Area (m ²)	% of Total
Bare Bank Slope	245	<0.1	----	----
Bare Silt	1,085	<0.1	----	----
Cobble	62,834	2.4	322,456	11.4
Low Shrub-Forb-Cobble Association	718,838	27.4	320,992	11.4
Exotic Weed	62,854	2.4	79,420	2.8
Horsetail Association	115	<0.1	----	----
Juniper	6,290	0.2	3,977	0.1
Non-persistent Emergent and Emergent Wetlands	28,349	1.1	29,689	1.1
Reed Canarygrass	90,019	3.4	115,933	4.1
Reed Canarygrass / Willow	----	----	5,095	0.2
Willow	80,942	3.1	59,245	2.1
River and Riverine Wetland	21,831	0.8	----	----
Riparian Mosaic	----	----	13,265	0.5
Rock / Road / Outflow	15,011	0.6	62,447	2.2
Tree Association	15,918	0.6	72,334	2.6
Upland Shrub Steppe	20,159	0.8	39,816	1.4
Wormwood / Forb	3,871	<0.1	----	----
Wormwood / Perennial grass	276,856	10.6	1,124,006	39.8
Sand Dropseed Association	711,852	27.1	29,560	1.0
Wormwood / Riparian Wheatgrass	109,195	4.2	8,117	0.3
Riparian Wheatgrass Association	427,625	16.3	537,261	19.0
TOTAL	2,623,706		2,823,614	

11.1.2.2 Rare Plants

Known rare plant sites encountered during fieldwork were revisited. In addition, emergent muds that were encountered were targeted for further rare plant surveying; rare species in other habitats were

² One square meter is equivalent to 10.8 square feet.

documented as observed. Table 11-9 lists the rare riparian plants for which data were collected in 2018; occurrence forms will be submitted to the Washington State Natural Heritage Program.

Table 11-9. Rare Plant Species and Number of Points for which Information Gathered^a.

Species	Common Name	Status	Number of point locations
<i>Epilobium campestre</i>	Smooth willowherb	WA Review List 1	6
<i>Hypericum majus</i>	Canadian St. John's-wort	State Sensitive; Federal Strategic	5
<i>Lipocarpha aristulata</i>	Awned halfchaff sedge	State Threatened; Federal Sensitive	8
<i>Rorippa columbiae</i>	Columbia yellowcress	State Threatened; Federal Sensitive	12
<i>Rotala ramosior</i>	Lowland toothcup	State Sensitive; Federal Sensitive	49
<i>Sporobolus compositus</i> var. <i>compositus</i>	Composite dropseed	State Sensitive	11
^a Information was also gathered for <i>Rorippa curvipes</i> , which was Review Group 1 in fall 2018 (WNHP 2018b); since then, the species has been determined to be sufficiently widespread to be taken off that list.			

The final 2018 vegetation map and the accompanying report can be found on the Hanford Site's ecological monitoring website: <https://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.2 Endangered and Threatened Species

ES Norris

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 2019) maintains 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 *Endangered Species Act of 1973*. Washington State regulations also list species as endangered and threatened; however, 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 11-10 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 11-10. Federal and State Endangered, Threatened, Sensitive, and Candidate Species.
(2 Pages)

Species	Status ^a	
	Federal	State
Plants		
Annual sandwort (<i>Minuartia pusilla</i>)		Threatened
Awned halfchaff sedge (<i>Lipocarpa aristulata</i>)		Threatened
Beaked spike-rush (<i>Eleocharis rostellata</i>)		Sensitive
Canadian St. John's wort (<i>Hypericum majus</i>)		Sensitive
Columbia milkvetch (<i>Astragalus columbianus</i>)		Sensitive
Columbia yellowcress (<i>Rorippa columbiae</i>)		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>)		Threatened
Great Basin gilia (<i>Aliciella leptomeria</i>)		Threatened
Hairy bugseed (<i>Corispermum villosum</i>)		Sensitive
Hoover's desert parsley (<i>Lomatium tuberosum</i>)		Sensitive
Loeflingia (<i>Loeflingia squarrosa</i>)		Threatened
Lowland toothcup (<i>Rotala ramosior</i>)		Sensitive
Miner's candle (<i>Cryptantha scoparia</i>)		Sensitive
Rosy pussypaws (<i>Calyptidium 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
Ashy 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		Candidate
Steel head (upper Columbia River; <i>Oncorhynchus mykiss</i>)	Threatened	Candidate

Table 11-10. Federal and State Endangered, Threatened, Sensitive, and Candidate Species.
(2 Pages)

Species	Status ^a	
	Federal	State
Birds		
American white pelican (<i>Pelecanus erythrorhynchos</i>)		Threatened
Bald eagle (<i>Haliaeetus leucocephalus</i>)		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' woodpecker (<i>Melanerpes lewis</i>) ^c		Candidate
Loggerhead shrike (<i>Lanius ludovicianus</i>)		Candidate
Northern goshawk (<i>Accipiter gentilis</i>) ^c		Candidate
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>Anaxyrus 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 ^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, 13 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 15 sensitive plant species occurring or potentially occurring on the Hanford Site.

11.3 Cultural and Historic Resource Protection

CD Currie, AP Fergusson, KM Mendez, and M Petrich-Guy

Cultural and historic resources protection on the Hanford Site is conducted under the direction of the U.S. Department of Energy, Richland Operations Office (DOE-RL) Cultural and Historic Resources Program to ensure site compliance with federal cultural resources laws and regulations (Section 2.5). Program activities in 2018 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 and CERCLA with NHPA as an applicable or relevant and appropriate requirement
- Monitored site conditions to ensure important cultural resources were 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 were 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 2018 was performed by staff archaeologists from MSA.

The DOE-RL Cultural and Historic Resources Program also schedules weekly meetings with archaeological staff from MSA 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 in or eligible for inclusion in the National Register of Historic Places. 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 2018, Hanford Site archaeologists completed 94 NHPA Section 106 cultural resources reviews that included the following:

- Thirty-nine 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.
 - Twenty-eight were identified as No Historic Properties Affected.
 - Ten were determined to have No Adverse Effects to Historic Properties.
 - One was 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-four 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.
- Ten projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews (Previously Reviewed Project Analyses).
- Eleven projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration (Post Reviews) in accordance with Section 5.1.1 of DOE/RL-98-10, *Hanford Cultural Resources Management Plan*.

The following were completed as part of the reviews described above:

- A total of 1,163.35 ac (470.79 ha) of new ground was surveyed for cultural resources from NHPA Section 106 project-specific surveys
- Some undertakings required National Register of Historic Places (36 CFR 60) eligibility evaluations
- Most projects cleared under expedited reviews (Programmatic Agreement Exemptions and Previously Reviewed Project Analyses) occurred in the 200 Areas of the Hanford Site (Figure 11-11).

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³This number does not reflect all full cultural resources reviews initiated in 2018. Additional reviews were initiated in 2018 but completed in 2019 and are not included in this report.

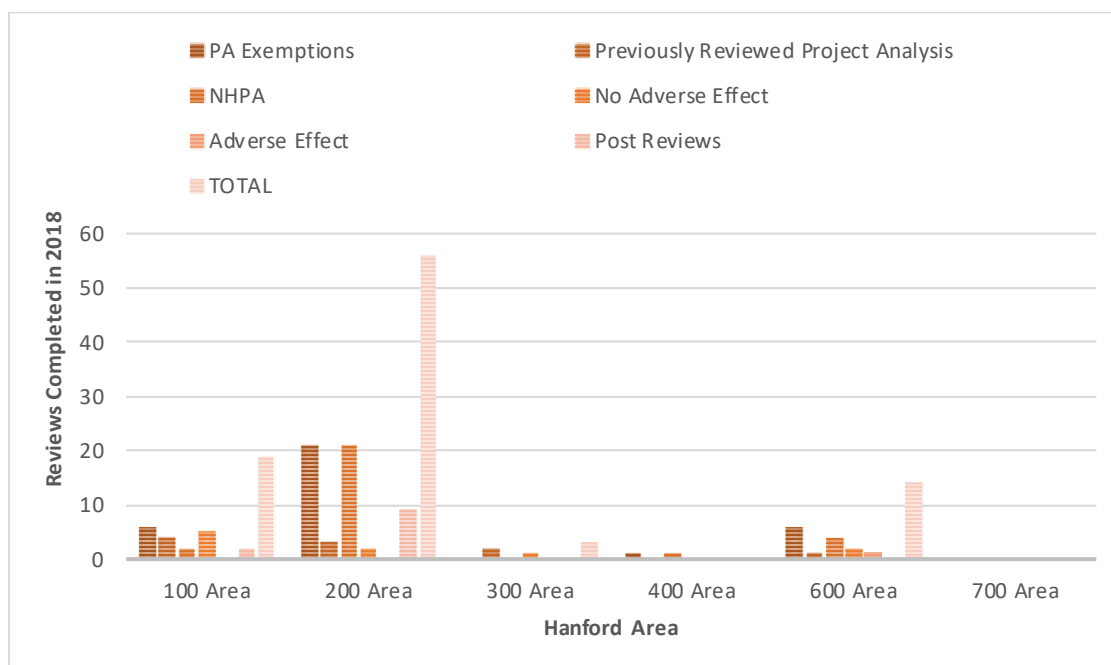


Figure 11-11. Hanford Site National Historic Preservation Act Section 106 Reviews by Area.

DOE conducted formal consultations with the Washington State Historic Preservation Officer within the Department of Archaeology and Historic Preservation, Native American Tribes, and other interested parties for cultural resources reviews to comply with NHPA Section 106 and *National Environmental Policy Act* (Section 2.1.4). DOE-RL consulted with the Washington State Historic Preservation Officer and Native American Tribes on all 39 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 2018 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 2018, proposed undertakings within traditional cultural property boundaries and view sheds, and approaches to protecting threatened archaeological sites and places containing Native American human remains.

11.3.2 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 and the *Archaeological Resources Protection Act*:

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 2018, 11 pre-contact and 2 historic archaeological sites were monitored under the Section 110 Site Conditions Monitoring program. As part of Section 110 block survey, one historic archaeological site was updated, one historic site, and two historic isolates were recorded. 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 2018, five new archaeological sites were recorded and three new isolated finds were located (Table 11-11). National Register evaluations were completed for three newly recorded and two previously recorded archaeological sites. Archaeological site forms for four previously recorded archaeological sites were updated. No Historic Property Inventory Forms were completed during the reporting period for components of the Hanford Site's built environment.

Table 11-11. Sites and Isolates Recorded or Updated.

2018	Eligible	Not Eligible	Unevaluated	Total
Site updates	1	1	2	4
New sites	0	3	2	5
New isolates	0	0	3	3
Historic Property Inventory Form	0	0	0	0
Total	1	4	7	12

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 2018. The Hanford Site Section 106 database tracks all cultural resources reviews conducted on the Hanford Site. The Section 106 database tracks dates, actions, letters, and results of the cultural resources 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 2018, 156 new projects were opened, with pertinent information entered as acquired into the Section 106 database. A total of 198⁴ projects were closed out after data entry was complete, with a digital copy of the project documentation added to the digital archive.

⁴This number is larger than the number of projects opened because projects from previous years were closed during 2018.

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 2018, a total of 20 polygons delineating completed archaeological surveys were added to the Hanford Site Survey Master shapefiles (map file) and 8 new archaeological sites/isolates, together with associated spatial and contextual information, were added to the GIS Archaeological Site and Isolate database. Spatial and contextual information for four archaeological sites/isolates were updated in this database based on information gathered during recent re-visits to these locations.

Largely due to excavations conducted as mitigation for adverse effects on archaeological sites, the Cultural and Historic Resources Program manages a collection of artifacts related 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. On behalf of DOE-RL, MSA's Cultural and Historic Resources Protection (CHRP) program manages a collection of archaeological artifacts. These artifacts were moved from within the Consolidated Information Center at the Washington State University, Tri-Cities Campus (WSU-TC) to the Wanapum Heritage Center (repository). The move is per the Memorandum of Understanding for Curatorial Services between DOE-RL and the Wanapum Heritage Center, which was signed November 5, 2018. The repository meets federal standards for archaeological collections storage. Depositing the collection at the new facility will help DOE-RL meet regulatory requirements outlined in 36 CFR 79, "Curation of Federally Owned and Administered Archaeological Collections."

CHRP accomplished the move of DOE-RL's Hanford Site archaeological collections (collection) in a three-part process including the inventory and sealing of boxes, followed by staging the collection, and, finally, moving of the collection to the repository. Each part of the process was conducted on the dates listed below.

- On December 26 through 27, 2018, CHRP inventoried and sealed the collection boxes.
- On January 2, 2019, CHRP oversaw MSA movers stage the collection in preparation for transportation.
- On January 3, 2019, CHRP oversaw MSA movers load the collection onto a covered truck, transport it to, and unload it at the repository.

Once unloaded, CHRP and Wanapum Heritage Center staff confirmed all boxes were accounted for and checked a random 10% of boxes for contents inventory and condition. All contents of the random sample were accounted for and in the same condition as prior to transport. The DOE-RL Cultural Resources Program Manager and the Wanapum participated in oversight of the move on January 3.

11.4 Collection Management and Curation

M Petrich-Guy and J Gardner-Andrews

DOE's National Park Program is responsible for management of the artifacts from the Hanford Site'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 HHP provides professional curatorial and archival services for the management, conservation, and public access of the Hanford Collection. The Hanford Collection consists of artifacts and multimedia relating to the Manhattan Project and Cold War Era (Figure 11-12). In addition to care, security, and public access to the collection the partnership provides research opportunities and use in academic programs for undergraduates. WSU-TC also 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.



Figure 11-12. Storage of Artifacts and Multimedia from the Manhattan Project and Cold War Era.

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. Transition of the bulk of the Hanford Collection to WSU-TC curation facility was previously

completed in 2016, with the exception of those materials requiring scarce historic media players for review.

Collection tasks for 2018 consisted of reviewing historic media items for public release and transfer to the HHP repository, artifact conservation, and archival processing. Of the materials scheduled for screening in 2018, 31 items were reviewed, cleared for public release, and /or transferred to the Hanford History Project repository for integration with the Hanford Collection (Figure 11-13). Fifteen artifacts and two linear feet of archival material were evaluated for inclusion in the Hanford Collection. These materials were delivered to the HHP repository at WSU-TC, leaving 26 (3.5%) of the 743 tagged artifacts scheduled for collection between 2018 and 2048.



Figure 11-13. Seismic Equipment Used on the Hanford Site, Transferred to the Hanford History Project Repository in 2018.

During 2018, the HHP processed and housed artifacts, multimedia were moved offsite and public access was facilitated to the Hanford Collection and Hanford Outreach Collection. During routine artifact and archival materials inventory of the 105-B Building (B Reactor National Historic Landmark), 551 new items were formally evaluated for inclusion in the Hanford Collection and/or transferred to the Hanford

History Project repository. Of these, 460 were designated by DOE-RL as eligible for inclusion in either the Hanford Collection or the Hanford Outreach Collection. These unique items were inventoried and tagged at their display locations within the B Reactor National Historic Landmark and will be added to the collections management database (Re:Discovery Proficio) for tracking and management. Artifacts continue to be indexed and added to the collections management database. An additional 31 historic items were catalogued during 2018; to date, approximately 437 (30%) of Hanford Collection and Hanford Outreach Collection items collected since 2011 and now housed by HHP have been fully catalogued.

Additionally, Pacific Northwest National Laboratory subject matter experts were consulted to ensure objects, documents, video, audio, and other forms of media are appropriately identified as export control items and actions identified to protect such items from unlawful access according to export control regulations. A review of property inventory was performed to determine export control status. A walkdown of the Hanford Collection materials was performed at the Hanford History Project Repository. Items were mapped to export control regulations and potential technology controls were identified. An export control technology guide was provided to include guidance on how export controls should be applied and managed and the minimum requirements for display and loans outlined.

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 outreach events that reached hundreds of members of the public in the Tri-Cities. Artifacts, multimedia, and information were supplied to several museums (e.g., Washington State Historical Society; The REACH Museum; Wanapum Heritage Center) as well as used for interpretation at the Manhattan Project National Historical Park's B Reactor. In October 2018, the first volume in the Hanford Histories Series was released through WSU Press. The book, *Nowhere to Remember: Hanford, White Bluffs, and Richland to 1943* (Bauman and Franklin 2018) documents the three agricultural communities that were located on what is now the Hanford Site until the Manhattan Project forced a permanent evacuation of the land.

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2018 Highlight

Quality Assurance and Quality Control Activities

Both field and laboratory quality assurance/quality control evaluations found no deficiencies in the sample collection, sample handling, analytical methods, or procedures employed to collect data for the Environmental Surveillance program.

Subcontracted laboratories used for this effort demonstrated acceptable analytical proficiency in independent quality control programs such as the Mixed Analyte Performance Evaluation Program and the U.S. Department of Energy Consolidated Audit Program.

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 independently conduct environmental monitoring and surveillance activities. Each of these groups are driven by different missions and regulatory requirements but with the same goal in mind. This section describes the Environmental Surveillance (ES) program managed by the Environmental Integration Services Group at Mission Support Alliance. The ES program includes environmental surveillance across multiple media types both on and off the Hanford Site. The data collected is used to evaluate the potential impact of current and historic site operations on the environment and to assess associated human health exposures to radionuclides and chemicals. This section provides information on specific measures taken in 2018 to ensure quality and defensibility in project management, sample collection, and analytical results.

NOTE: QA/QC specifications for groundwater sampling and program management are reported independently by the CH2M Hill Plateau Remediation Company in DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2018*, and are not discussed in this section. However, details of the groundwater monitoring program can be found in Section 8.0.

Quality assurances and QCs of the Hanford Site on and offsite surveillance programs are documented through QA program plans and describe applicable QA elements (e.g., MSC-23333). Sample analyses across all media types are performed by contracted laboratories, which are also required to meet plan specifications. To ensure the highest quality data are obtained, the accredited offsite laboratories 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 – DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document*
- *EPA Requirements for Quality Assurance Project Plans* (EPA 2001)
- Richland Requirements Document 008, Quality Assurance Program Requirements
- Project-specific QA plans and documentation are found in MSC-23333, *Environmental Quality Assurance Program Plan*, 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 is accomplished by establishing sitewide policies, procedures, and guidance through training programs. These training programs provide general and specialized training classes using hands-on training facilities dedicated to ensuring personnel are qualified and confident to perform their tasks safely.

The following principles and practices are highlighted in the training programs and 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

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

- Use a graded approach to develop training programs to ensure value and effectiveness
- Ensure that employee training records are current and complete.

12.2 Sample Collection Quality Assurance and Quality Control

Trained personnel collected environmental samples for air, surface water, biota (wildlife and food/farm products), soil, vegetation, and sediment in accordance with approved schedules, desk instructions, and procedures. Established sampling locations were identified with visible postings and/or global positioning system readings and documented to ensure data continuity. Samples collected in 2018 were analyzed by General Engineering Laboratories, LLC (GEL), TestAmerica Richland Laboratory (TARL), and ARS Aleut Analytical, LLC (ARS). (Table 12-1).

Table 12-1. Laboratories and Types of Environmental Surveillance Samples Analyzed.

Analytical Laboratory	Environmental Monitoring and Surveillance Samples			
	Air	Water	Biota	Other
General Engineering Laboratories, LLC	X	X	X	X
TestAmerica Richland Laboratory		X		
ARS Aleut Analytical, LLC		X		

12.3 Quality Control Samples

Multiple type QC samples are used by the ES program to evaluate the validity of sampling practices and laboratory results. The associated QC procedures followed in the field and in the laboratories ensure the highest quality data possible.

The potential for cross-contamination between samples is evaluated using trip blanks and equipment blanks. Field duplicates are collected to evaluate sample matrix heterogeneity and sample collection reproducibility. The precision and accuracy of laboratory data is evaluated using laboratory duplicates, matrix spikes, matrix spike duplicates, and method blanks. Table 12-2 summarizes the different types, characteristics, and frequencies of QC samples. A QC sample frequency goal of 5% (1 in 20 samples) is used for environmental surveillance activities when feasible.

Assessments of field sampling activities are routinely performed and documented by media task leads. In 2018, field duplicate samples were collected and analyzed for air, soil, Columbia River water, natural vegetation, farm products (e.g., milk, leafy vegetables, corn, apples, melons), wildlife, irrigation water, sediment, and seep samples. The accepted method of evaluating the precision or reproducibility of a duplicate sample pair is the calculation of the relative percent difference (RPD). RPDs are calculated for individual analytes. The generalized formula for calculating an RPD is as follows:

$$RPD = \left(\frac{|S - D|}{\frac{(S + D)}{2}} \right) \times 100$$

Where “S” and “D” are the sample and duplicate results, respectively.

Table 12-2. Field and Laboratory Quality Control Sample Types, Characteristics, and Frequency.

Sample Type	Primary Characteristics Evaluated	Frequency
Field QC Samples		
Trip blank	VOC cross-contamination during transportation	1 per field trip, if VOCs are collected
Equipment blank	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	
QA = quality assurance		
VOC = volatile organic compound		

For the 2018 Environmental Surveillance effort, field duplicate samples were collected at the locations indicated in Table 12-3. Sample duplicate pair results for non-detected analytes are considered acceptable. For detected analytes, the RPD of the duplicate sample pair must be less than 30% to be considered acceptable. Duplicate results for 2018 are shown in Table 12-4.

Table 12-3. 2018 Field Duplicate Samples.

Media	Location	Number of Duplicate Sample Pairs
Air	Various	54
Air - Tritium	Various	14
Soil	Various	4
Natural Vegetation	Various	3
Columbia River Water Transects	Various	4
Columbia River Sediment	100-D-Spring	1
Seeps	100-D Springs	2
Wildlife—Carp	Hanford Townsite 300 Area - 100 Area	1
Wildlife—Elk	Route 11 / Route 2	3
Wildlife - Quail	Various	2
Water - Irrigation	Riverview Canal	1
Apples	Sagemoore Area	1
Corn	Riverview Area	1
Melons	Riverview Area	1
Milk	East Wahluke Area	1

Table 12-4. 2018 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
Air	Alpha (gross)	42 of 54	75
	Beta (gross)	46 of 54	85
	Americium-241	4 of 4	100
	Antimony-125	6 of 6	100
	Cobalt-60	6 of 6	100
	Cesium-134	6 of 6	100
	Cesium-137	6 of 6	100
	Europium-152	6 of 6	100
	Europium-154	6 of 6	100
	Europium-155	6 of 6	100
	Hydrogen-3 (tritium)	14 of 14	100
	Plutonium-238	5 of 5	100
	Plutonium-239/240	6 of 6	100
	Potassium-40	6 of 6	100
	Ruthenium-106	6 of 6	100
	Strontium-90	6 of 6	100
	Uranium-234	6 of 6	100
	Uranium-235	6 of 6	100
	Uranium-238	6 of 6	100
Soil	Americium-241	1 of 1	100
	Antimony-125	5 of 5	100
	Cesium-134	2 of 2	100
	Cesium-137	4 of 5	80
	Cobalt-60	6 of 6	100
	Europium-152	5 of 5	100
	Europium-154	5 of 5	100
	Europium-155	4 of 4	100
	Plutonium-238	5 of 5	100
	Plutonium-239/240	4 of 5	80
	Potassium-40	5 of 5	100
	Ruthenium-106	5 of 5	100
	Strontium-90	6 of 6	100
	Uranium-234	4 of 5	80
	Uranium-235	4 of 5	80
	Uranium-238	3 of 5	60
Natural Vegetation	Americium-241	2 of 2	100
	Antimony-125	8 of 8	100
	Cesium-134	8 of 8	100
	Cesium-137	8 of 8	100
	Cobalt-60	8 of 8	100
	Europium-152	8 of 8	100
	Europium-154	8 of 8	100
	Europium-155	8 of 8	100
	Plutonium-238	8 of 8	100

Table 12-4. 2018 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Plutonium-239/240	8 of 8	100
	Potassium-40	7 of 8	87
	Ruthenium-106	8 of 8	100
	Strontium-90	8 of 8	100
	Uranium-234	7 of 8	87
	Uranium-235	7 of 7	100
	Uranium-238	8 of 8	100
Irrigation Water	Alpha (gross)	1 of 1	100%
	Beta (gross)	1 of 1	100%
	Strontium-90	1 of 1	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%
	Tecnetium-99	1 of 1	100%
	Tritium	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Cesium-134	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%
Columbia River Water Transects	Aluminum	4 of 4	100%
	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%
	Molybdenum	3 of 4	75%
	Nickel	4 of 4	100%
	Potassium	4 of 4	100%
	Silver	4 of 4	100%
	Strontium	4 of 4	100%
	Sodium	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	4 of 4	100%
	Cadmium	4 of 4	100%
	Cesium	4 of 4	100%
	Chromium	4 of 4	100%

Table 12-4. 2018 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Cobalt	4 of 4	100%
	Uranium	4 of 4	100%
	Vanadium	4 of 4	100%
	Zinc	4 of 4	100%
	Zirconium	4 of 4	100%
	Bismuth	4 of 4	100%
	Calcium	4 of 4	100%
	Phosphorus	4 of 4	100%
	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	2 of 2	100%
	Uranium-238	2 of 2	100%
Seep	Aluminum	1 of 2	50%
	Iron	1 of 2	50%
	Lead	2 of 2	100%
	Copper	0 of 2	0%
	Magnesium	2 of 2	100%
	Manganese	1 of 2	50%
	Molybdenum	2 of 2	100%
	Nickel	2 of 2	100%
	Potassium	2 of 2	100%
	Silver	2 of 2	100%
	Strontium	2 of 2	100%
	Strontium-90	1 of 1	100%
	Sodium	2 of 2	100%
	Thallium	2 of 2	100%
	Thorium	2 of 2	100%

Table 12-4. 2018 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	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%
	Cobalt	2 of 2	100%
	Uranium	2 of 2	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%
	Uranium-238	1 of 1	100%
	Vanadium	2 of 2	100%
	Zinc	1 of 2	50%
	Zirconium	2 of 2	100%
	Bismuth	2 of 2	100%
	Calcium	2 of 2	100%
	Phosphorus	1 of 2	50%
	Selenium	2 of 2	100%
	Tritium	2 of 2	100%
	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 Alkalinity	1 of 1	100%
	Nitrogen in Nitrate	2 of 2	100%
	Nitrogen in Nitrite	1 of 1	100%
	Lead	1 of 1	100%
	Copper	1 of 1	100%
	Mercury	0 of 1	0%
	Nickel	1 of 1	100%
	Silver	1 of 1	100%
	Strontium-90	1 of 1	100%
	Thallium	1 of 1	100%
	Antimony	1 of 1	100%
	Antimony-125	1 of 1	100%
	Arsenic	1 of 1	100%
	Beryllium	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cadmium	1 of 1	100%

Table 12-4. 2018 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Chromium	1 of 1	100%
	Hexavalent Chromium	0 of 1	0%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Uranium	1 of 1	100%
	Uranium-234	1 of 1	100%
	Uranium-235	0 of 1	0%
	Uranium-238	1 of 1	100%
	Potassium-40	1 of 1	100%
	Zinc	1 of 1	100%
	Plutonium-238	1 of 1	100%
	Plutonium-239/240	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Selenium	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%
	Nitrogen in Nitrate	1 of 1	100%
	Nitrogen in Nitrite	1 of 1	100%
Wildlife Carp	Aluminum	1 of 1	100%
	Lead	1 of 1	100%
	Copper	1 of 1	100%
	Manganese	1 of 1	100%
	Mercury	0 of 1	0%
	Nickel	1 of 1	100%
	Silver	1 of 1	100%
	Thallium	1 of 1	100%
	Thorium	1 of 1	100%
	Antimony	1 of 1	100%
	Arsenic	1 of 1	100%
	Barium	1 of 1	100%
	Beryllium	1 of 1	100%
	Cadmium	1 of 1	100%
	Chromium	1 of 1	100%
	Uranium	1 of 1	100%
	Zinc	1 of 1	100%
	Selenium	1 of 1	100%
	Cesium-137	3 of 3	100%
	Cesium-134	3 of 3	100%
	Cobalt-60	3 of 3	100%
	Potassium-40	3 of 3	100%

Table 12-4. 2018 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Berillium-7	3 of 3	100%
	Plutonium-238	1 of 1	100%
	Plutonium-239/240	1 of 1	100%
	Ruthenium-106	3 of 3	100%
	Antimony-125	3 of 3	100%
	Europium-152	3 of 3	100%
	Europium-154	3 of 3	100%
	Europium-155	3 of 3	100%
	Strontium-90	3 of 3	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%
	Uranium-238	1 of 1	100%
	Tritium	1 of 1	100%
Wildlife Elk	Cesium-137	3 of 3	100%
	Cesium-134	3 of 3	100%
	Cobalt-60	3 of 3	100%
	Potassium-40	3 of 3	100%
	Berillium-7	3 of 3	100%
	Ruthenium-106	3 of 3	100%
	Antimony-125	3 of 3	100%
	Europium-152	3 of 3	100%
	Europium-154	3 of 3	100%
	Europium-155	3 of 3	100%
Wildlife Quail	Strontium-90	3 of 3	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%
Corn	Europium-155	2 of 2	100%
	Strontium-90	2 of 2	100%
	Cesium-137	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cobalt-60	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%
Apples	Europium-155	1 of 1	100%
	Strontium-90	1 of 1	100%

Table 12-4. 2018 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	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%
	Tritium	2 of 2	100%
Melons	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%
Milk	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%
	Tritium	1 of 1	100%

^a Number of reported results within control limits are those with 1) Relative Percent Difference values less than 30% and 2) result greater than the minimum detectable activity or method detection limit.

12.4 Media Audits and Comparisons

Selected sediment, surface water, food and farm products, wildlife, soil, and vegetation samples were provided to the Washington State Department of Health (WDOH) for comparative analysis as part of the QA program (DOE/RL-91-50). The WDOH conducts the Hanford Environmental Radiation Oversight Program to independently verify the quality of U.S. Department of Energy, Richland Operations Office (DOE-RL) monitoring programs at the Hanford Site. Since 1985, WDOH and DOE-RL have collaboratively participated in the collection of environmental samples located on or in the surrounding areas of the Hanford Site (DOH 320-120, *Hanford Environmental Radiation Oversight Program: 2016 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 provided to the WDOH in 2018 included the following:

- Air filters from 15 locations
- Columbia River continuous water from one location
- Columbia River transects from six locations
- Columbia River shoreline springs (seeps) from seven locations
- Offsite irrigation water from two locations
- Columbia River Sediment from eight locations
- Melons from three locations
- Apples from three locations
- Leafy Vegetables from two locations
- Potatoes from four locations
- Corn from four locations
- Wine Must from three locations
- Upland Game Birds from two locations
- Bass from two locations
- Carp from one location
- Deer/Elk from one location
- Soil from three locations
- Vegetation from three locations.

No comparison data for 2018 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:

<https://www.doh.wa.gov/CommunityandEnvironment/Radiation/EnvironmentalSciences/HanfordEnvironmentalRadiationOversightProgram>.

12.5 Laboratory Quality Assurance Programs

Contracted analytical laboratories are required to participate in internal and independent QA and QC programs to ensure an appropriate level of performance.

Internal QC programs for contracted laboratories involve routine calibrations of counting instruments, yield determinations, radiochemical procedure reviews, radiation-source checks, background counts, replicate analyses, matrix spikes, reagent blanks, control charts, and other parameters that may identify potential analytical deficiencies.

Independent QA and QC programs are in part represented by the DOE Consolidated Audit Program (DOECAP) and the Mixed Analyte Performance Evaluation Program (MAPEP). DOECAP audits are conducted annually and MAPEP evaluations are conducted twice a year.

The DOECAP program audits laboratory operations by an extensive examination of licenses, procedures, practices, internal QA programs, and adherence to applicable regulation. In an ongoing process after each audit, a laboratory may receive direction to help improve laboratory operations. If needed, the laboratories submit plans to address deficiencies identified through the DOECAP process. The GEL, TARL, and ARS laboratories have all maintained a current and acceptable standing in the DOECAP program.

The MAPEP program evaluates laboratory performance by submitting standardized samples to participating laboratories for analysis. Analytical results from all participating laboratories are then compared to determine each laboratories performance, relative to the group, for each media and analyte tested.

In 2018, the GEL, TARL, and ARS laboratories participated in the MAPEP and DOECAP programs. All three of these laboratories had overall acceptable results under these programs.

Because the TARL and ARS laboratories only analyzed hexavalent chromium and low level tritium, respectively, for the ES program, and neither of these analytes were directly evaluated by MAPEP in 2018, the TARL and ARS MAPEP results are not presented here. The GEL MAPEP results are summarized in Table 12-5.

Table 12-5. 2018 DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC. (2 Pages)

Environmental Sample Media and Analytes Evaluated		MAPEP 38 Series June 2018 ^a	MAPEP 39 Series December 2018 ^a
Radionuclides			
Air Filters	Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, manganese-54, plutonium-238, plutonium-239/240, strontium-90, uranium-234/233, uranium-238, zinc-65	100% Acceptable	manganese-54 ^b
Water	Americium-241, cesium-134, cesium-137, cobalt-60, Hydrogen-3 (tritium), iron-55, manganese-54, Nickel-63, plutonium-238, plutonium-239/240, potassium-40, radium-226 technetium-99	100% Acceptable	Radium-226 ^b
Vegetation	Americium-241, cesium-134, cesium-137, cobalt 57, cobalt-60, manganese-54 plutonium-238, plutonium-239/240, strontium-90, uranium-234/233, uranium-238, zinc-65	100% Acceptable	100% Acceptable
Soil	Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, iron-55, manganese-54, nickel-63, plutonium-238, plutonium-239/240, potassium-40, strontium-90	100% Acceptable	100% Acceptable
Inorganic			
Air Filters	Uranium-235, Uranium-238, Uranium-total	100% Acceptable	100% Acceptable
Water	Antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium,	100% Acceptable	Technetium-99 ^b

Table 12-5. 2018 DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC. (2 Pages)

Environmental Sample Media and Analytes Evaluated		MAPEP 38 Series June 2018 ^a	MAPEP 39 Series December 2018 ^a
	technetium-99, thallium, Uranium-235, Uranium-238, Uranium-total, vanadium, zinc		
Vegetation	Uranium-235, Uranium-238, Uranium-total	100% Acceptable	100% Acceptable
Soil	Antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, technetium-99, thallium, Uranium-235, Uranium-238, Uranium-total, vanadium, zinc	100% Acceptable	Antimony ^b Technetium-99 ^b
^a Performance results 100% acceptable for all analytes reported 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			

12.5.1 Laboratory Performance Evaluation and Proficiency Testing

To demonstrate administrative and analytical proficiency all three laboratories (GEL, TARL, ARS) participate in independent QA and QC programs including the MAPEP and the DOECAP. For calendar year 2018, two full MAPEP evaluations were conducted (numbered 38 and 39), each of which included multiple studies of different types of media (e.g., soil, water, vegetation, air filters).

Participation of Hanford Site analytical laboratories in DOE and U.S. Environmental Protection Agency 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-RL laboratories and other federal, state, commercial, and international laboratories. MAPEP proficiency tests help to ensure the accuracy of analytical results reported to DOE-RL and other stakeholders while providing an efficient means for laboratories to demonstrate analytical proficiency. MAPEP reports can be found on the DOE's MAPEP webpage at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

MAPEP reports evaluate individual laboratory results against cumulative results from all of the participating laboratories for a standardized material by analyte. Where the individual results agree within 20% of the cumulative results an acceptable status is given. For individual results that differ from the cumulative result, in the range of 20 to 30%, an "acceptable with warning" status is given. For individual results that differ from the cumulative result by more than 30% an "unacceptable" result is given. Variability in the standardized material and analytical variability both play a role in determining these status rankings. It is not unusual, for a laboratory to receive "acceptable with warning" or "unacceptable" status rankings. Laboratories that repetitively receive other than "acceptable" results for the same analyte may receive technical assistance from the MAPEP team to resolve quality issues.

GEL is the primary laboratory for the ES program. GEL's 2018 MAPEP results were nearly all acceptable for all media and analytes. GEL received "acceptable with warning" status (bias in the range of 20 to

30%) for uranium-234/233, technetium-99, radium-226, manganese-54, and antimony. GEL did not receive any “unacceptable” results (bias greater than 30%). A summary of GEL’s 2018 MAPEP results is presented in Table 12-5.

Water samples collected for hexavalent chromium analysis were sent to TARL because of the proximity of the laboratory to the Hanford Site and the short holding time specified by the analytical method. This is the only analysis performed for the ES program by TARL. MAPEP does not specifically evaluate the analysis of hexavalent chromium in water. TARL’s MAPEP results for other radiological and chemical constituents are overall good, but there are multiple “acceptable with warning” (bias in the range of 20 to 30%) and several “unacceptable” (bias greater than 30%) ratings. Under the MAPEP program, these issues would be mitigated by future results and are not considered to be unrecoverable problems. However, it should be noted that the TARL stopped accepting samples in the first quarter of 2019 and will cease operations entirely by the end of the year.

Water samples collected for low-level tritium analysis by electrolytic enrichment were sub-contracted out to ARS. This is the only analytical method performed for the ES program by ARS. MAPEP does not specifically evaluate this method. ARS MAPEP program results for other radiological and chemical constituents were very good. Similar to the laboratories mentioned above, several analytes received “acceptable with warning” (bias in the range of 20 to 30%) and there were a few “unacceptable” (bias greater than 30%) ratings. Under the MAPEP program, these results will be mitigated by future results and are not considered unrecoverable.

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; 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.

12.7 References

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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 high *radiation* levels associated with waste for treatment or residuals which cannot be removed.

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 – 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 stream released from a facility.

emission – Gaseous stream released from a facility.

emission/effluent monitoring – Sampling or measuring specific streams for the presence of pollutants.

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 – For nuclides, 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 from 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. (Note: Ion exchange “resin” is frequently applied to inorganic materials {e.g., aluminosilicates and zeolites} which also exhibit ion exchange properties.)

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 – Nuclear waste that does not fit into the categorical definitions for high-level waste, spent nuclear fuel, transuranic waste, or certain byproduct materials such as uranium or thorium mill tailings.

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 discharges wastewater or other *effluent* to the environment (e.g., 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 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 nuclear 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 storage tanks used to hold wastes from nuclear fuel reprocessing activities at Hanford.

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 or concentrations determined using chemical analytical techniques .

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.

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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>.

Appendix B. Background Information

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B. 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 http://www.lib.washington.edu/gmm/collections/govpubs	Portland State University Government Information Branford Price Millar Library 1875 SW Park Ave Portland, OR 97207-1151 (503) 725-4542 https://library.pdx.edu/research/government-information-maps/
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 https://www.gonzaga.edu/academics/libraries/foley-library
Hanford Health Info Archive (through Washington State Archives): https://www.sos.wa.gov/archives/	

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	mm	millimeter (1×10^{-3} m)
gpm	gallon per minute	μm	micrometer (1×10^{-6} m)
mph	mile per hour	Area	
mR/hr	milliroentgen per hour	ha	hectare (1×10^4 m ²)
mrem/yr	millirem per year	km ²	square kilometer
Volume		mi ²	square mile
cm ³	cubic centimeter	ft ²	square foot
ft ³	cubic foot	Mass	
gal	gallon	g	gram
L	liter	kg	kilogram (1×10^3 g)
m ³	cubic meter	mg	milligram (1×10^{-3} g)
mL	milliliter (1×10^{-3} L)	μg	microgram (1×10^{-6} g)
yd ³	cubic yard	lb	pound

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

Multiply	By	To Obtain
rem	0.01	Sv
ppm	1,000	ppb
°C	$(^{\circ}\text{C} \times 9/5) + 32$	°F
oz	28.349	g
ton	0.9078	tonne

Multiply	By	To Obtain
Sv	100	rem
ppb	0.001	ppm
°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 bequerels.

Table B.3. Radioactivity Unit Conversions.

aCi	fCi	fCi	pCi	pCi	nCi	nCi	μCi	μCi	mCi	mCi	Ci	Ci	kCi
27	1	27	1	27	1	27	1	27	1	27	1	27	1
1	37	1	37	1	37	1	37	1	37	1	37	1	37
μBq	μBq	mBq	mBq	Bq	Bq	kBq	kBq	MBq	MBq	GBq	GBq	TBq	TBq

New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) (1 Ci = 3.7×10^{10} dps).
1 Becquerel = 1 disintegrations/sec (dps).

Table B-4. Radioactivity Units.

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel (2.7×10^{-11} Ci)
mCi	millicurie (1×10^{-3} Ci)	mBq	millibecquerel (1×10^{-3} Bq)
μCi	microcurie (1×10^{-6} Ci)	kBq	kilobecquerel (1×10^3 Bq)
nCi	nanocurie (1×10^{-9} Ci)	MBq	megabecquerel (1×10^6 Bq)
pCi	picocurie (1×10^{-12} Ci)	GBq	gigabecquerel (1×10^9 Bq)
fCi	femtocurie (1×10^{-15} Ci)	TBq	terabecquerel (1×10^{12} Bq)
aCi	attocurie (1×10^{-18} 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 (μSv) 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 μSv) 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 μSv] 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])
mrad	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
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 may be 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.

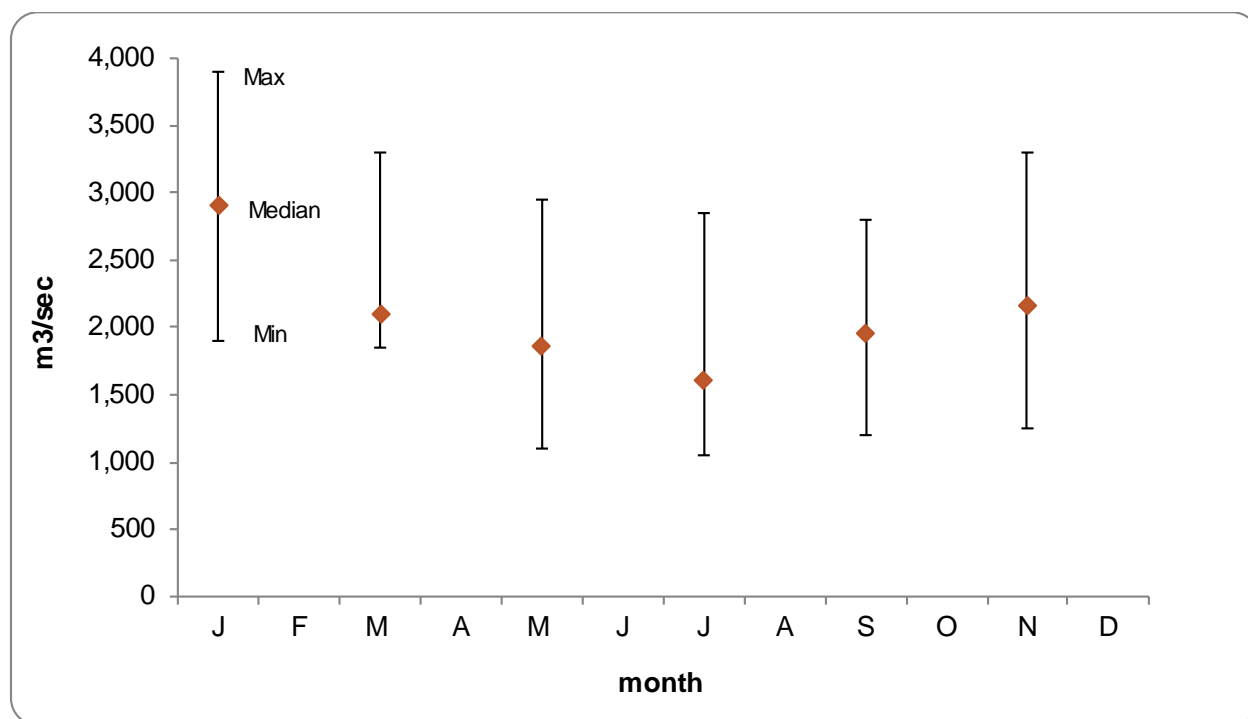


Figure B-1. Maximum, Median, and Minimum Values Graphical Representation.

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 during sample analysis. Backgrounds are determined with empty detectors and represent an average background decay rate. Because of the randomness of radioactive emissions (including backgrounds), the very low activities of some contaminants, it is possible that the average background value used is larger than the actual contaminant measurement result. 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.

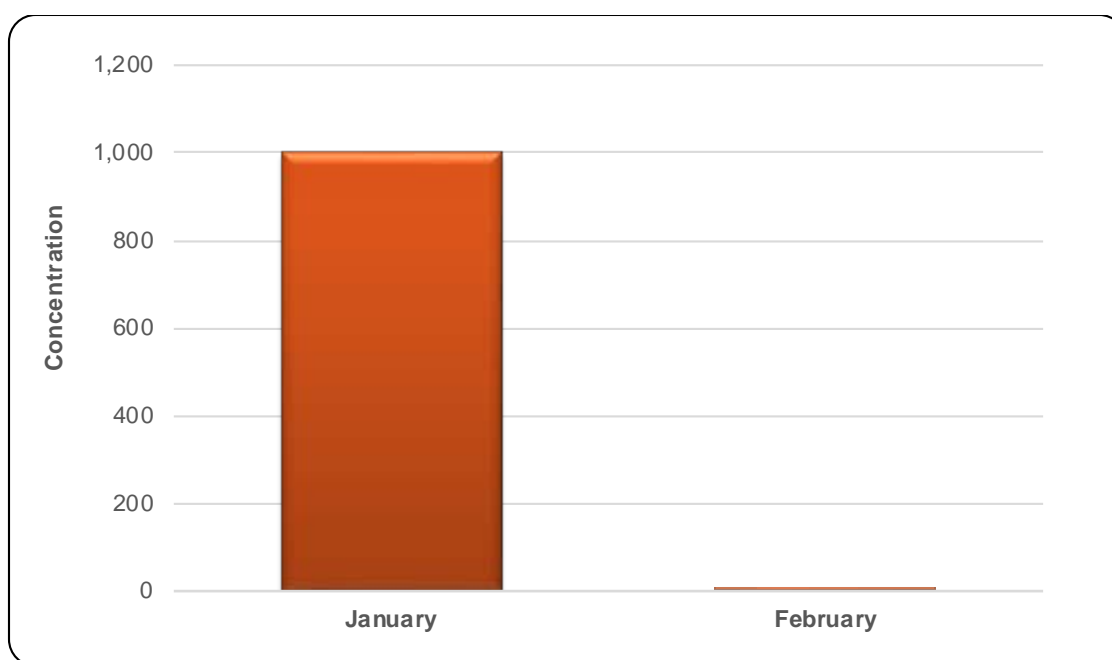


Figure B-2. Data Plotted Using a Linear Scale.

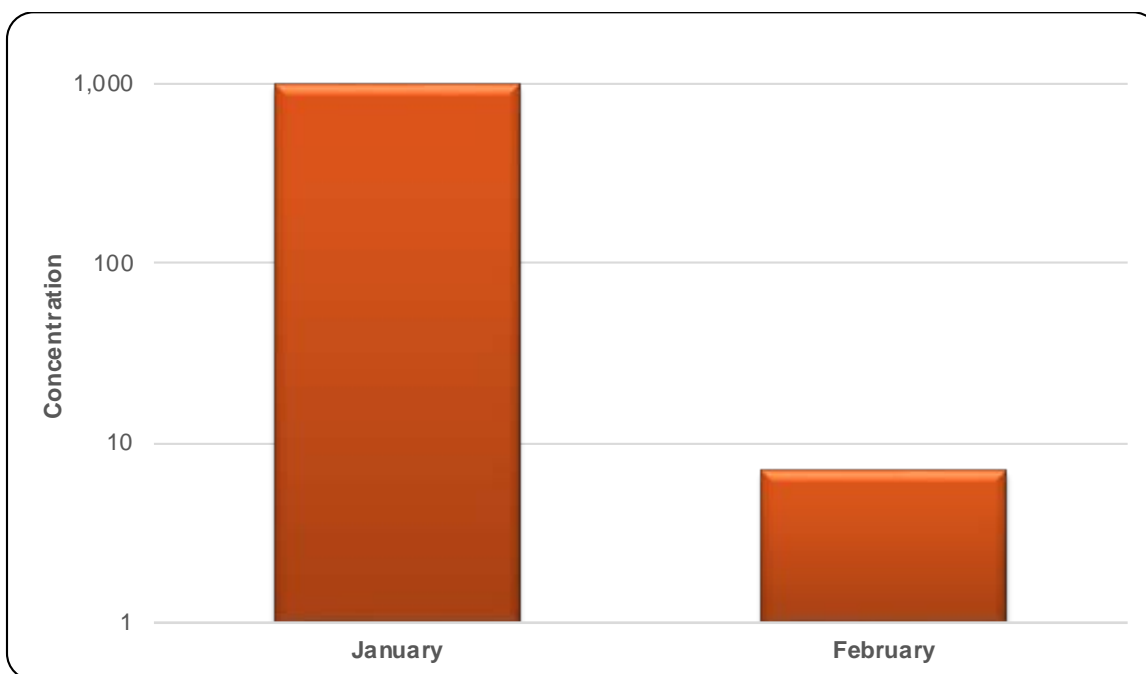


Figure B-3. Data Plotted Using a Logarithmic Scale.

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.

¹ Assuming the data are normally distributed.

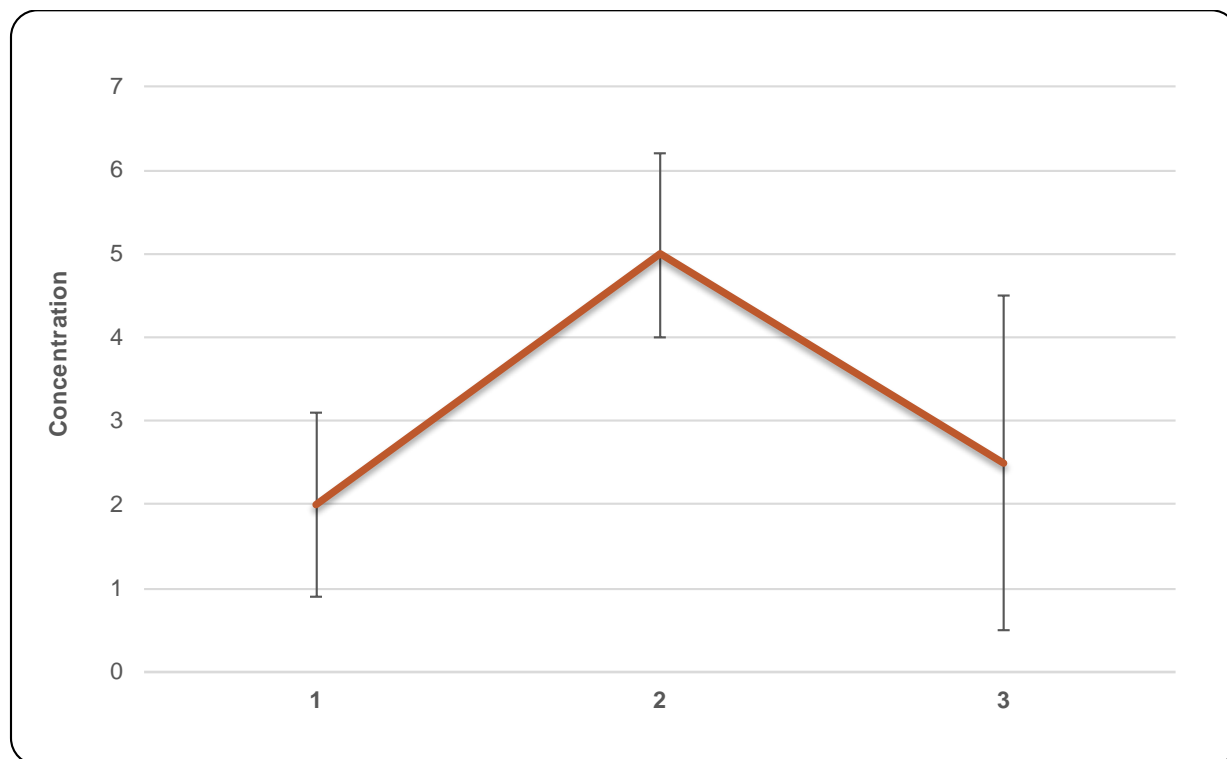


Figure B-4. Data with Error Bars Plotted Using a Linear Scale.

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.

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C.1 Onsite Pond

Table C-1. Selected Radionuclide Concentrations in West Lake Sediment.

Radionuclide	2018					2013-2017						
	No. of Samples	Concentration				No. of Samples	Concentration					
		Maximum ^a					Average ^b		Maximum ^a			
		pCi/g ^c		pCi/g ^c			pCi/g ^c		pCi/g ^c	pCi/g ^c		pCi/g ^c
Cesium-137	2	8.8E-01	±	7.7E-02		17	5.8E-01	±	7.3E-01	1.4E+00	±	1.3E-01
Gross Alpha ^d	2	7.5E+00	±	1.7E+00		17	9.4E+00	±	1.0E+01	2.3E+01	±	7.6E+00
Gross Beta	2	2.8E+01	±	2.6E+00		17	2.3E+01	±	9.4E+00	3.0E+01	±	2.4E+00
Strontium-90 ^d	2	3.5E-01	±	8.5E-02		17	1.4E-01	±	2.7E-01	4.4E-01	±	9.9E-02
Technetium-99 ^d	2	1.1E-01	±	3.7E-01		17	6.0E-02	±	4.6E-01	6.0E-01	±	2.8E-01
Uranium-234	2	4.7E+00	±	5.4E-01		17	3.0E+00	±	5.4E+00	9.6E+00	±	1.6E+00
Uranium-235 ^d	2	2.6E-01	±	7.9E-02		17	1.9E-01	±	3.1E-01	6.5E-01	±	1.6E-01
Uranium-238	2	4.7E+00	±	5.3E-01		17	2.8E+00	±	5.0E+00	9.3E+00	±	1.5E+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.

Table C-2. Radionuclide Concentrations in West Lake Surface Water.

Radionuclide	2018							2013-2017							DOE-Biota Concentration Guides ^c pCi/L
	No. of samples	Concentration						No. of samples	Concentration						
		Average ^a			Maximum ^b				Average ^a			Maximum ^b			
		pCi/L			pCi/L				pCi/L			pCi/L			
Technetium ^c	2	3.3E+02	±	6.4E+02	6.5E+02	±	9.8E+01	0	N/A			N/A			6.7E+05
Tritium ^d	2	1.3E+02	±	1.5E+02	2.0E+02	±	1.4E+02	19	7.6E+01	±	3.4E+02	6.9E+02	±	2.1E+02	2.7E+08
Uranium-234 ^d	2	4.0E+02	±	3.0E+02	5.5E+02	±	5.7E+01	18	1.3E+03	±	5.4E+03	1.1E+04	±	4.4E+03	2.0E+02
Uranium-235 ^d	2	1.8E+01	±	1.9E+01	2.8E+01	±	6.0E+00	18	1.1E+02	±	6.5E+02	1.4E+03	±	1.6E+03	2.2E+02
Uranium-238 ^d	2	3.6E+02	±	2.7E+02	5.0E+02	±	5.3E+01	18	1.4E+03	±	6.6E+03	1.4E+04	±	5.2E+03	2.2E+02

^a Averages are ±2 standard deviations of the mean.^b Maximum values are ± total propagated analytical uncertainty.^c Biota Concentration Guide value for Riparian Animal receptor (DOE/EH-0676)^d Biota Concentration Guide value for Aquatic Animal receptor (DOE/EH-0676)

C.2 Ambient Air

Table C-3. Concentrations of Select Radionuclides (pCi/m³)^a in Onsite Air Samples. (4 Pages)

Table C-3. Concentrations of Select Radionuclides (pCi/m³) ^a in Onsite Air Samples. (4 Pages)												
Radionuclide	Site	2018					2013 - 2017					EPA Table 2 ^e
		Number of		Average ^c	Maximum ^d	Sampler	Number of		Average ^c	Maximum ^d	Sampler	
		Samples	Detects ^b				Samples	Detects ^b				
gross α	100	163	162	1.6E-03 ± 2.1E-03	5.6E-03 ± 1.1E-03	N534	1100	1067	1.3E-03 ± 2.2E-03	9.3E-03 ± 6.6E-03	N106	
	200-E	717	687	1.5E-03 ± 1.9E-03	6.2E-03 ± 1.0E-03	N984	3380	3277	1.5E-03 ± 2.2E-03	1.0E-02 ± 2.4E-03	N581	
	200-W	677	672	1.7E-03 ± 2.3E-03	6.5E-03 ± 1.3E-03	N555	3444	3400	1.7E-03 ± 5.4E-03	8.4E-02 ± 7.7E-03	N956	
	300	208	188	1.0E-03 ± 1.5E-03	4.2E-03 ± 7.7E-04	N130	1005	907	1.0E-03 ± 1.6E-03	5.7E-03 ± 1.2E-03	N918	
	400	50	44	8.8E-04 ± 1.0E-03	2.1E-03 ± 5.4E-04	N911	259	233	9.5E-04 ± 1.6E-03	5.7E-03 ± 1.4E-03	N912	
	600	153	139	1.1E-03 ± 1.6E-03	3.9E-03 ± 8.1E-04	N587	1257	1186	1.2E-03 ± 2.5E-03	2.2E-02 ± 7.7E-03	N585	
	ERDF	130	130	1.5E-03 ± 1.8E-03	4.6E-03 ± 8.0E-04	N168	655	653	1.3E-03 ± 1.9E-03	9.3E-03 ± 1.3E-03	N963	
	WTP	282	261	1.3E-03 ± 1.9E-03	6.2E-03 ± 1.0E-03	N984	1156	1111	1.3E-03 ± 2.1E-03	8.2E-03 ± 1.6E-03	N985	
	Perimeter	293	266	8.4E-04 ± 9.4E-04	2.6E-03 ± 9.0E-04	N936	1423	1263	9.4E-04 ± 1.7E-03	7.7E-03 ± 1.2E-03	N934	
	Nearby Comm.	187	167	8.5E-04 ± 1.1E-03	3.8E-03 ± 1.1E-03	N946	700	617	9.1E-04 ± 1.5E-03	6.0E-03 ± 9.2E-04	N948	
	Dist Comm	26	24	7.9E-04 ± 8.5E-04	2.0E-03 ± 5.7E-04	N909	131	104	8.3E-04 ± 1.6E-03	4.2E-03 ± 8.5E-04	N909	
gross β	100	163	163	1.7E-02 ± 2.1E-02	5.9E-02 ± 5.7E-03	N534	1100	1100	1.8E-02 ± 2.6E-02	1.2E-01 ± 1.7E-02	N106	
	200-E	717	717	1.6E-02 ± 2.0E-02	5.9E-02 ± 4.9E-03	N929	3380	3379	1.8E-02 ± 2.6E-02	1.8E-01 ± 1.0E-02	N581	
	200-W	677	677	1.6E-02 ± 2.0E-02	5.8E-02 ± 8.4E-03	N482	3444	3444	1.6E-02 ± 2.2E-02	9.1E-02 ± 8.0E-03	N901	
	300	208	208	1.8E-02 ± 2.2E-02	6.2E-02 ± 6.0E-03	N905	1005	1005	2.0E-02 ± 2.6E-02	8.8E-02 ± 7.3E-03	N902	
	400	50	50	1.9E-02 ± 2.2E-02	5.1E-02 ± 4.1E-03	N912	259	259	2.0E-02 ± 2.8E-02	1.3E-01 ± 1.0E-02	N911	
	600	153	153	1.8E-02 ± 2.2E-02	6.2E-02 ± 5.0E-03	N981	1257	1257	1.9E-02 ± 2.7E-02	1.4E-01 ± 2.1E-02	N585	
	ERDF	130	130	1.6E-02 ± 2.1E-02	5.8E-02 ± 8.4E-03	N482	655	655	1.6E-02 ± 2.1E-02	7.6E-02 ± 5.8E-03	N963	
	WTP	282	282	1.7E-02 ± 2.1E-02	5.9E-02 ± 5.6E-03	N920	1156	1156	1.8E-02 ± 2.7E-02	1.8E-01 ± 1.3E-02	N158	
	Perimeter	293	293	1.8E-02 ± 2.3E-02	6.4E-02 ± 5.4E-03	N938	1423	1423	2.0E-02 ± 2.6E-02	9.5E-02 ± 8.8E-03	N937	
	Nearby Comm.	187	187	1.8E-02 ± 2.4E-02	5.8E-02 ± 5.4E-03	N945	904	904	2.0E-02 ± 2.7E-02	1.6E-01 ± 1.6E-02	N949	
	Dist Comm	26	26	1.7E-02 ± 2.0E-02	4.9E-02 ± 3.9E-03	N909	131	131	1.8E-02 ± 2.5E-02	9.5E-02 ± 7.4E-03	N909	
³ H	200-E	41	3	2.4E+00 ± 6.1E+00	1.2E+01 ± 5.5E+00	N584	130	28	4.8E+00 ± 2.5E+01	1.1E+02 ± 1.1E+01	N931	1.5E+03
	300	78	28	8.6E+00 ± 3.3E+01	1.4E+02 ± 3.0E+01	N130	347	187	9.7E+00 ± 2.3E+01	8.8E+01 ± 1.8E+01	N918	
	400	13	1	5.5E-01 ± 5.5E+00	7.3E+00 ± 3.2E+00	N912	66	19	5.2E+00 ± 1.3E+01	4.1E+01 ± 8.3E+00	N912	
	WTP	41	4	2.6E+00 ± 8.0E+00	1.5E+01 ± 4.7E+00	N934	129	33	4.4E+00 ± 1.7E+01	8.1E+01 ± 7.6E+00	N920	
	Perimeter	97	9	3.0E+00 ± 7.4E+00	1.5E+01 ± 4.7E+00	P934	454	135	5.2E+00 ± 1.9E+01	9.4E+01 ± 8.9E+00	P941	
	Nearby Comm.	28	1	3.0E+00 ± 5.3E+00	1.0E+01 ± 3.9E+00	P944	130	40	7.1E+00 ± 5.7E+01	3.2E+02 ± 6.4E+01	P944	
	Dist Comm	13	1	2.9E+00 ± 9.2E+00	1.8E+01 ± 6.3E+00	P909	65	11	3.0E+00 ± 1.1E+01	2.9E+01 ± 6.5E+00	P909	
⁶⁰ Co	100	14	1	5.6E-04 ± 4.2E-03	8.1E-03 ± 3.1E-03	N588	85	0	4.1E-06 ± 9.1E-04	3.0E-03 ± 7.7E-03	N102	1.7E-02
	200-E	93	0	-5.8E-06 ± 3.0E-04	3.9E-04 ± 4.1E-04	N985	263	0	8.7E-06 ± 3.1E-04	3.7E-04 ± 3.9E-04	N920	
	200-W	49	0	3.0E-05 ± 3.3E-04	3.1E-04 ± 3.7E-04	N901	267	0	-2.8E-06 ± 3.1E-04	6.6E-04 ± 6.1E-04	N975	

Table C-3. Concentrations of Select Radionuclides (pCi/m³)^a in Onsite Air Samples. (4 Pages)

Radionuclide	Site	2018					2013 - 2017					EPA Table 2 ^e
		Number of		Average ^c	Maximum ^d	Sampler	Number of		Average ^c	Maximum ^d	Sampler	
		Samples	Detects ^b				Samples	Detects ^b				
	300	14	0	-1.4E-05 ± 2.5E-04	2.0E-04 ± 3.2E-04	N902	70	1	8.7E-05 ± 1.8E-03	7.6E-03 ± 2.5E-03	N905	
	400	4	0	9.0E-05 ± 5.0E-04	3.7E-04 ± 3.8E-04	N911	20	0	4.7E-05 ± 4.1E-04	4.3E-04 ± 4.4E-04	N912	
	600	12	0	6.1E-05 ± 2.5E-04	2.9E-04 ± 2.9E-04	N930	98	0	3.8E-05 ± 2.9E-04	5.3E-04 ± 4.1E-04	N906	
	ERDF	10	0	-1.7E-05 ± 3.3E-04	1.9E-04 ± 1.9E-04	N963	50	0	-1.2E-05 ± 239E-04	2.0E-04 ± 2.0E-04	N517	
	Perimeter	26	0	-1.8E-06 ± 2.4E-04	2.7E-04 ± 2.6E-04	N933	110	1	2.4E-05 ± 8.0E-04	3.1E-03 ± 1.1E-03	N934	
	Nearby Comm.	14	0	1.3E-05 ± 3.8E-04	3.3E-04 ± 3.4E-04	N945	70	0	7.9E-05 ± 1.5E-03	6.1E-03 ± 2.1E-03	N945	
	Dist Comm	2	0	4.1E-05 ± 2.2E-04	1.5E-04 ± 3.5E-04	N909	10	0	9.3E-05 ± 3.6E-04	4.3E-04 ± 5.4E-04	N909	
⁹⁰ Sr	100	14	0	-2.7E-05 ± 7.3E-04	5.3E-04 ± 4.8E-04	N476	85	5	1.1E-04 ± 1.2E-03	4.3E-03 ± 6.0E-03	N106	1.9E-02
	200-E	55	0	3.0E-05 ± 4.7E-04	8.5E-04 ± 6.9E-04	N582	252	20	9.5E-05 ± 1.3E-03	5.8E-03 ± 2.2E-03	N581	
	200-W	47	0	1.4E-05 ± 4.9E-04	7.8E-04 ± 7.2E-04	N956	257	17	1.2E-05 ± 4.6E-04	6.8E-04 ± 5.2E-04	N517	
	300	14	0	-4.0E-05 ± 4.7E-04	3.1E-04 ± 3.5E-04	N902	70	2	8.7E-06 ± 5.1E-04	1.0E-03 ± 8.3E-04	N557	
	400	4	0	-7.6E-05 ± 5.9E-04	2.1E-04 ± 6.5E-04	N911	20	0	1.6E-06 ± 4.7E-04	6.2E-04 ± 4.9E-04	N911	
	600	10	0	7.7E-06 ± 4.9E-04	4.9E-04 ± 4.2E-04	N981	86	5	7.1E-05 ± 6.1E-04	1.7E-03 ± 7.4E-04	N549	
	ERDF	10	0	-1.5E-05 ± 3.5E-04	2.4E-04 ± 5.0E-04	N168	50	3	8.7E-05 ± 4.7E-04	6.8E-04 ± 5.2E-04	N517	
	WTP	22	0	-2.8E-05 ± 4.1E-04	5.2E-04 ± 4.4E-04	N984	79	7	9.6E-05 ± 1.3E-03	5.2E-03 ± 2.1E-03	N158	
	Perimeter	18	0	-3.6E-05 ± 4.1E-04	2.9E-04 ± 2.7E-04	N935	90	0	-1.3E-05 ± 4.7E-04	7.8E-04 ± 6.6E-04	N941	
	Nearby Comm.	6	0	4.3E-05 ± 4.0E-04	4.8E-04 ± 5.1E-04	N946	32	0	-5.7E-06 ± 2.8E-04	4.0E-04 ± 5.0E-04	N945	
	Dist Comm	2	0	-1.3E-05 ± 1.0E-04	3.7E-05 ± 1.8E-04	N909	10	0	3.6E-05 ± 2.6E-04	2.8E-04 ± 2.5E-04	N909	
¹³⁷ Cs	100	14	0	6.8E-05 ± 2.7E-04	4.9E-04 ± 9.2E-04	N588	85	0	1.8E-05 ± 1.4E-03	3.8E-03 ± 8.2E-03	N102	1.9E-02
	200-E	88	0	2.6E-05 ± 3.0E-04	4.0E-04 ± 4.5E-04	N532	262	14	3.3E-04 ± 3.3E-03	1.9E-02 ± 6.2E-03	N984	
	200-W	48	0	1.1E-05 ± 2.7E-04	3.3E-04 ± 4.4E-04	N555	264	1	3.9E-05 ± 3.5E-04	6.1E-04 ± 3.8E-04	N966	
	300	14	0	6.3E-05 ± 2.7E-04	2.7E-04 ± 3.0E-04	N919	70	1	6.6E-05 ± 3.5E-04	6.5E-04 ± 5.1E-04	N904	
	400	4	0	-1.7E-04 ± 6.1E-04	4.9E-05 ± 2.3E-04	N912	20	0	5.3E-05 ± 2.6E-04	3.2E-04 ± 4.6E-04	N911	
	600	12	0	1.4E-04 ± 4.6E-04	6.4E-04 ± 3.9E-04	N906	98	0	7.3E-06 ± 3.3E-04	6.0E-04 ± 6.3E-04	N907	
	ERDF	10	0	2.0E-05 ± 1.8E-04	2.3E-04 ± 3.2E-04	N168	50	0	2.5E-05 ± 2.7E-04	4.0E-04 ± 4.5E-04	N168	
	WTP	63	0	8.0E-06 ± 2.8E-04	3.4E-04 ± 3.6E-04	N499	89	4	3.6E-04 ± 4.1E-03	1.9E-02 ± 6.2E-03	N984	
	Perimeter	26	0	4.8E-05 ± 2.1E-04	3.5E-04 ± 4.1E-04	N938	110	0	3.2E-05 ± 3.8E-04	6.0E-04 ± 6.3E-04	N907	
	Nearby Comm.	14	0	2.4E-06 ± 3.0E-04	3.0E-04 ± 3.0E-04	N943	70	0	4.2E-05 ± 3.1E-04	3.8E-04 ± 5.2E-04	N947	
	Dist Comm	2	0	5.4E-05 ± 1.8E-04	1.4E-04 ± 2.6E-04	N909	10	0	3.1E-05 ± 2.6E-04	3.0E-04 ± 3.0E-04	N909	
²³⁸ Pu	100	14	0	3.8E-07 ± 2.6E-05	1.5E-05 ± 2.2E-05	N927	77	0	-1.3E-06 ± 1.4E-05	8.8E-06 ± 1.2E-05	N574	2.1E-03
	200-E	55	2	3.3E-05 ± 4.1E-04	1.6E-03 ± 5.1E-04	N583	243	2	4.7E-07 ± 1.8E-05	1.2E-04 ± 3.4E-05	N924	
	200-W	49	1	2.4E-06 ± 1.3E-05	1.7E-05 ± 1.4E-05	N975	245	9	4.9E-06 ± 5.9E-05	3.7E-04 ± 1.5E-04	N901	
	300	14	0	-9.0E-08 ± 1.8E-05	1.9E-05 ± 4.4E-05	N904	66	0	7.5E-07 ± 1.3E-05	1.7E-05 ± 3.4E-05	N902	
	400	4	0	-5.7E-06 ± 3.2E-05	2.0E-05 ± 3.6E-05	N912	15	0	-1.4E-06 ± 5.0E-06	2.4E-06 ± 2.4E-05	N912	
	600	11	0	-3.0E-06 ± 1.7E-05	7.7E-06 ± 4.0E-05	N906	94	0	2.2E-06 ± 1.3E-05	2.4E-05 ± 2.9E-05	N580	
	ERDF	10	0	4.3E-06 ± 7.0E-06	8.7E-06 ± 1.0E-05	N168	49	0	1.6E-06 ± 9.8E-06	2.0E-05 ± 3.1E-05	N482	

Table C-3. Concentrations of Select Radionuclides (pCi/m³)^a in Onsite Air Samples. (4 Pages)

Radionuclide	Site	2018					2013 - 2017					EPA Table 2 ^e
		Number of		Average ^c	Maximum ^d	Sampler	Number of		Average ^c	Maximum ^d	Sampler	
		Samples	Detects ^b				Samples	Detects ^b				
	WTP	22	2	7.9E-05 ± 6.4E-04	1.6E-03 ± 5.1E-04	N583	82	2	1.7E-06 ± 2.7E-05	1.2E-04 ± 3.4E-05	N924	
	Perimeter	18	0	2.7E-06 ± 2.8E-05	3.5E-05 ± 3.7E-05	N940	80	0	-5.9E-09 ± 9.3E-06	2.0E-05 ± 2.5E-05	N933	
	Nearby Comm.	8	0	8.6E-06 ± 2.4E-05	3.7E-05 ± 5.6E-05	N943	40	2	-7.8E-07 ± 2.5E-05	5.9E-05 ± 2.8E-05	N944	
	Dist Comm	2	0	9.6E-07 ± 5.5E-06	3.7E-06 ± 1.2E-05	N909	8	0	-1.2E-06 ± 6.6E-06	3.8E-06 ± 1.4E-05	N909	
	100	14	0	-2.3E-06 ± 2.3E-05	6.3E-06 ± 9.1E-06	N576	76	2	6.8E-06 ± 7.6E-05	2.4E-04 ± 6.0E-04	N106	2.0E-03
^{239/240} Pu	200-E	55	0	6.3E-07 ± 2.2E-05	3.0E-05 ± 4.2E-05	N583	251	9	1.6E-06 ± 2.7E-05	1.6E-04 ± 5.2E-05	N924	
	200-W	49	8	9.7E-06 ± 3.8E-05	9.1E-05 ± 5.1E-05	N966	259	45	6.1E-05 ± 6.3E-04	3.2E-03 ± 1.0E-03	N155	
	300	13	0	-6.5E-07 ± 1.7E-05	1.5E-05 ± 2.5E-05	N902	68	0	-1.5E-06 ± 1.1E-05	8.4E-06 ± 1.5E-05	N557	
	400	4	0	-7.2E-06 ± 1.4E-05	3.8E-06 ± 1.9E-05	N912	17	0	-7.7E-07 ± 1.1E-05	8.4E-06 ± 4.7E-05	N911	
	600	12	0	-6.6E-07 ± 1.6E-05	1.8E-05 ± 2.1E-05	N930	97	18	1.9E-05 ± 1.1E-04	4.6E-04 ± 1.7E-04	N548	
	ERDF	10	0	2.0E-06 ± 5.1E-06	6.8E-06 ± 8.0E-06	N168	48	8	1.0E-05 ± 4.4E-04	1.2E-04 ± 7.4E-05	N518	
	WTP	22	0	-1.3E-06 ± 1.8E-05	3.0E-05 ± 4.2E-05	N583	83	4	1.6E-06 ± 3.7E-05	1.6E-04 ± 5.2E-05	N924	
	Perimeter	18	0	-2.5E-06 ± 1.2E-05	1.5E-05 ± 3.7E-05	N941	87	1	-1.7E-07 ± 1.2E-05	1.8E-05 ± 1.9E-05	N938	
	Nearby Comm.	8	0	3.1E-06 ± 1.0E-05	1.4E-05 ± 3.8E-05	N943	41	2	-2.1E-06 ± 2.1E-05	1.5E-05 ± 2.1E-05	N946	
	Dist Comm	2	0	-4.2E-07 ± 5.2E-06	2.2E-06 ± 1.2E-05	N909	10	0	4.5E-07 ± 9.2E-06	1.2E-05 ± 4.7E-05	N909	
	²³⁴ U	100	12	2	1.2E-05 ± 1.7E-05	3.3E-05 ± 2.1E-05	N588	65	30	5.2E-06 ± 1.3E-04	1.5E-04 ± 5.0E-04	N102
200-E		55	25	3.8E-05 ± 7.4E-05	1.7E-04 ± 6.6E-05	N924	263	106	2.0E-05 ± 4.7E-05	1.7E-04 ± 2.0E-04	N581	
200-W		46	11	1.4E-05 ± 3.2E-05	6.3E-05 ± 4.7E-05	N901	265	79	1.3E-05 ± 3.2E-05	9.9E-05 ± 7.9E-05	N901	
300		14	10	4.7E-05 ± 4.1E-05	7.8E-05 ± 5.4E-05	N918	70	48	4.5E-05 ± 5.6E-05	1.2E-04 ± 7.6E-05	N919	
600		10	6	3.0E-05 ± 5.2E-05	6.4E-05 ± 4.8E-05	N906	77	33	2.0E-05 ± 4.5E-05	1.3E-04 ± 8.9E-05	N906	
ERDF		7	4	1.0E-05 ± 1.3E-05	1.8E-05 ± 1.3E-05	N963	49	14	9.8E-06 ± 1.7E-05	3.3E-05 ± 3.6E-05	N482	
WTP		22	19	6.1E-05 ± 8.6E-05	1.7E-04 ± 6.6E-05	N924	89	46	2.6E-05 ± 5.0E-05	1.3E-04 ± 7.6E-05	N920	
Perimeter		8	5	5.8E-05 ± 5.2E-05	1.0E-04 ± 4.1E-05	N934	40	37	5.8E-05 ± 5.7E-05	1.6E-04 ± 1.1E-04	N937	
Nearby Comm.		10	7	5.8E-05 ± 3.7E-05	9.6E-05 ± 6.0E-05	N943	52	43	5.9E-05 ± 4.6E-05	1.5E-04 ± 1.4E-04	N943	
Dist Comm		2	1	3.1E-05 ± 3.6E-05	4.9E-05 ± 4.1E-05	N909	10	8	4.7E-05 ± 3.5E-05	8.8E-05 ± 5.6E-05	N909	
²³⁵ U	100	11	1	4.9E-06 ± 8.7E-06	1.2E-05 ± 1.2E-05	N576	59	2	9.3E-06 ± 6.7E-05	2.5E-04 ± 5.0E-04	N102	7.1E-03
	200-E	51	3	9.0E-06 ± 1.9E-05	4.0E-05 ± 5.6E-05	N969	238	9	4.9E-06 ± 2.5E-05	1.4E-04 ± 2.0E-04	N581	
	200-W	45	2	6.5E-06 ± 1.6E-05	3.4E-05 ± 4.9E-05	N966	236	10	4.5E-06 ± 1.7E-05	6.9E-05 ± 5.0E-05	N161	
	300	14	2	1.8E-05 ± 3.5E-05	6.2E-05 ± 5.3E-05	N902	64	4	9.0E-06 ± 2.6E-05	6.7E-05 ± 6.2E-05	N919	
	600	10	3	2.9E-05 ± 3.6E-05	6.5E-05 ± 4.7E-05	N928	64	2	3.9E-06 ± 1.4E-05	2.8E-05 ± 5.5E-05	N930	
	ERDF	7	1	4.1E-06 ± 9.8E-06	1.4E-05 ± 1.1E-05	N963	43	2	2.1E-06 ± 6.3E-06	1.3E-05 ± 2.8E-05	N517	
	WTP	21	3	7.1E-06 ± 1.0E-05	1.6E-05 ± 1.3E-05	N984	85	4	5.1E-06 ± 1.6E-05	2.9E-05 ± 3.4E-05	N934	
	Perimeter	8	0	3.4E-06 ± 1.7E-05	1.5E-05 ± 2.4E-05	N935	40	7	1.1E-05 ± 3.3E-05	8.4E-05 ± 8.0E-05	N937	
	Nearby Comm.	10	3	2.2E-05 ± 4.0E-05	5.4E-05 ± 4.4E-05	N946	52	7	1.1E-05 ± 3.8E-05	8.9E-05 ± 9.2E-05	N944	
	Dist Comm	2	0	1.2E-05 ± 3.1E-05	2.7E-05 ± 3.3E-05	N909	9	1	1.0E-05 ± 2.2E-05	3.3E-05 ± 3.0E-05	N909	

Table C-3. Concentrations of Select Radionuclides (pCi/m³)^a in Onsite Air Samples. (4 Pages)

Radionuclide	Site	2018					2013 - 2017					EPA Table 2 ^e
		Number of		Average ^c	Maximum ^d	Sampler	Number of		Average ^c	Maximum ^d	Sampler	
		Samples	Detects ^b				Samples	Detects ^b				
²³⁸ U	100	12	4	1.3E-05 ± 2.4E-05	4.2E-05 ± 2.3E-05	N588	65	20	1.8E-05 ± 1.7E-04	6.5E-04 ± 1.2E-03	N106	8.3E-03
	200-E	55	27	3.7E-05 ± 7.4E-05	1.6E-04 ± 6.0E-05	N984	262	97	1.4E-05 ± 3.5E-05	1.5E-04 ± 1.8E-04	N581	
	200-W	49	14	1.3E-05 ± 2.2E-05	4.7E-05 ± 4.2E-05	N965	264	80	8.6E-06 ± 2.0E-05	6.6E-05 ± 6.1E-05	N901	
	300	14	9	4.2E-05 ± 5.0E-05	1.0E-04 ± 6.5E-05	N902	70	48	3.7E-05 ± 4.2E-05	9.3E-05 ± 6.5E-05	N919	
	600	10	4	2.8E-05 ± 3.3E-05	5.4E-05 ± 3.8E-05	N928	77	42	4.5E-05 ± 2.2E-04	7.6E-04 ± 2.6E-04	N548	
	ERDF	10	4	9.6E-06 ± 1.5E-05	2.6E-05 ± 3.1E-05	N517	49	16	1.0E-05 ± 2.1E-05	5.3E-05 ± 7.9E-05	N518	
	WTP	22	19	6.2E-05 ± 8.4E-05	1.6E-04 ± 6.0E-05	N984	89	42	1.9E-05 ± 3.6E-05	6.8E-05 ± 4.6E-05	N920	
	Perimeter	8	6	5.6E-05 ± 5.0E-05	9.7E-05 ± 5.4E-05	N935	40	34	5.1E-05 ± 4.6E-05	1.7E-04 ± 1.0E-04	N935	
	Nearby Comm.	10	9	7.1E-05 ± 6.9E-05	1.5E-04 ± 8.1E-05	N945	52	44	5.1E-05 ± 3.6E-05	1.0E-04 ± 9.7E-05	N944	
	Dist Comm	2	1	3.5E-05 ± 3.1E-05	5.1E-05 ± 4.0E-05	N909	10	7	3.3E-05 ± 2.2E-05	5.6E-05 ± 2.5E-05	N909	
²⁴¹ Am	100	11	0	1.4E-06 ± 4.7E-06	4.2E-06 ± 8.4E-06	N535	81	0	-3.6E-05 ± 8.8E-04	1.4E-03 ± 1.9E-03	N921	1.9E-03
	200-E	25	0	2.5E-06 ± 7.3E-06	1.3E-05 ± 2.7E-05	N584	225	0	2.8E-05 ± 1.6E-03	4.0E-03 ± 3.2E-03	N920	
	200-W	24	3	3.7E-06 ± 1.1E-05	2.1E-05 ± 1.5E-05	N964	193	20	-6.8E-05 ± 1.5E-03	2.7E-03 ± 4.7E-03	N200	
	600	6	0	2.6E-06 ± 1.2E-05	1.1E-05 ± 3.1E-05	N906	96	13	-3.5E-05 ± 1.6E-03	2.6E-03 ± 3.5E-03	N922	
	WTP	22	0	3.9E-06 ± 1.1E-05	2.4E-05 ± 2.7E-05	N934	77	0	-6.3E-05 ± 1.9E-03	4.0E-03 ± 3.2E-03	N920	
	Perimeter	19	0	1.8E-06 ± 1.7E-05	2.4E-05 ± 2.7E-05	N934	110	0	-1.8E-05 ± 1.6E-03	2.1E-03 ± 2.1E-03	N937	
	Nearby Comm.	12	0	2.2E-06 ± 1.0E-05	1.3E-05 ± 2.3E-05	N947	70	0	-1.8E-06 ± 1.3E-03	2.8E-03 ± 2.1E-03	N949	
	Dist Comm	2	0	-7.0E-07 ± 7.9E-06	3.2E-06 ± 1.2E-05	N909	10	0	2.5E-04 ± 1.2E-03	1.8E-03 ± 2.1E-03	N909	
²⁴¹ Pu	100	10	0	3.3E-04 ± 7.5E-04	9.9E-04 ± 1.1E-03	N575	50	0	-3.9E-06 ± 1.0E-03	2.7E-03 ± 3.3E-03	N534	1.0E-01
	200-E	4	0	1.0E-04 ± 8.1E-04	6.2E-04 ± 9.7E-04	N481	20	0	-1.2E-04 ± 9.8E-04	7.7E-04 ± 1.1E-03	N481	
	200-W	22	0	1.1E-05 ± 9.6E-04	1.8E-03 ± 1.3E-03	N956	38	5	3.6E-04 ± 2.2E-03	4.3E-03 ± 1.8E-03	N975	
	600	2	0	6.8E-05 ± 7.5E-04	4.4E-04 ± 8.5E-04	N587	0	0				

^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 EPA values are based on an effective dose equivalent of 10 mrem/yr (40 CFR 61, Appendix E, Table 2)

ERDF = Environmental Restoration Disposal Facility

WTP = Waste Treatment Plant

C.3 Surface Soil

Table C-4. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Soil Samples. (2 Pages)

Radionuclide	Hanford Area	2018									2013 - 2017								
		Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location	Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location
		Samples	Detects ^b								Samples	Detects ^b							
²⁴¹ Am	200-W	24	13	3.5E-02	±	1.0E-01	2.3E-01	±	3.7E-02	D032	30	25	3.9E-02	±	9.9E-02	2.5E-01	±	8.3E-02	D032
¹³⁷ Cs	200-E	14	14	2.6E+00	±	9.2E+00	1.8E+01	±	1.5E+00	D054	82	81	2.9E+00	±	8.4E+00	1.6E+01	±	7.4E-01	D143
	200-W	25	24	1.1E+00	±	2.5E+00	5.0E+00	±	4.4E-01	D030	116	111	1.2E+00	±	2.6E+00	7.8E+00	±	6.3E-01	D030
	300	8	4	2.3E-02	±	4.8E-02	6.5E-02	±	1.8E-02	D121	40	22	5.6E-02	±	1.6E-01	4.1E-01	±	6.9E-02	D121
	400	1	1	1.7E-02 ^e			1.7E-02	±	1.1E-02	D130	5	5	3.9E-02	±	1.7E-02	5.3E-02	±	1.5E-02	D130
	600	16	16	4.4E-01	±	7.9E-01	1.4E+00	±	1.2E-01	D104	62	61	4.4E-01	±	8.4E-01	2.5E+00	±	2.9E-01	D091
²³⁸ Pu	200-E	14	1	2.9E-03	±	1.2E-02	1.1E-02	±	9.9E-03	D461	80	18	9.1E-04	±	4.2E-03	1.0E-02	±	1.1E-02	D078
	200-W	25	8	1.4E-02	±	2.0E-02	4.4E-02	±	2.3E-02	D038	116	52	7.1E-03	±	3.7E-02	1.4E-01	±	2.3E-02	D039
	300	8	1	5.3E-03	±	1.1E-02	1.2E-02	±	7.6E-03	D126	40	6	1.2E-03	±	4.0E-03	5.3E-03	±	2.5E-03	D132
	400	1	0	4.0E-03 ^e			4.0E-03	±	7.3E-03	D130	5	1	1.6E-03	±	6.8E-03	8.0E-03	±	2.8E-03	D130
	600	16	0	4.6E-03	±	1.0E-02	1.3E-02	±	1.2E-02	D106	59	17	1.6E-03	±	8.9E-03	2.4E-02	±	1.8E-02	D107
^{239/240} Pu	200-E	13	5	2.1E-02	±	4.2E-02	8.4E-02	±	2.0E-02	D078	82	57	1.3E-02	±	3.0E-02	6.4E-02	±	1.6E-02	D053
	200-W	25	22	1.4E-01	±	4.9E-01	1.1E+00	±	1.3E-01	D032	117	104	9.8E-02	±	3.1E-01	8.3E-01	±	9.1E-02	D032
	300	7	2	6.1E-03	±	1.8E-02	2.1E-02	±	1.1E-02	D121	40	19	8.4E-03	±	3.7E-02	9.9E-02	±	3.1E-02	D121
	400	1	0	8.1E-04 ^e			8.1E-04	±	6.1E-03	D130	5	2	1.8E-03	±	6.6E-04	2.1E-03	±	7.8E-04	D130
	600	15	8	2.9E-02	±	7.1E-02	1.4E-01	±	3.5E-02	D108	62	48	6.8E-02	±	4.5E-01	1.6E+00	±	1.8E-01	D107
⁹⁰ Sr	200-E	14	8	2.8E-01	±	1.1E+00	2.2E+00	±	4.2E-01	D064	82	56	3.0E-01	±	9.2E-01	2.2E+00	±	4.1E-01	D457
	200-W	25	9	6.8E-02	±	2.4E-01	5.1E-01	±	1.1E-01	D032	98	64	1.7E-01	±	4.0E-01	1.1E+00	±	2.6E-01	D321
	300	8	0	-2.8E-03	±	4.4E-02	2.6E-02	±	2.1E-02	D132	40	1	3.8E-02	±	1.5E-01	2.5E-01	±	1.8E-01	D121
	400	1	0	2.6E-03 ^e			2.6E-03	±	1.8E-02	D130	5	0	-1.6E-02	±	2.4E-02	-1.6E-03	±	1.6E-01	D130
	600	16	5	5.1E-02	±	1.3E-01	2.0E-01	±	5.7E-02	D114	62	26	9.3E-02	±	3.1E-01	1.0E+00	±	2.0E-01	D091
²³⁴ U	200-E	14	14	4.8E-01	±	9.1E-02	5.4E-01	±	1.1E-01	D078	82	82	5.1E-01	±	3.3E-01	1.1E+00	±	1.9E-01	D060
	200-W	25	25	5.1E-01	±	2.2E-01	7.1E-01	±	1.1E-01	D024	98	98	4.6E-01	±	2.9E-01	7.5E-01	±	1.2E-01	D306
	300	8	8	7.5E-01	±	7.5E-01	1.5E+00	±	2.0E-01	D121	40	40	7.8E-01	±	1.1E+00	2.3E+00	±	3.7E-01	D126
	400	1	1	4.5E-01 ^e			4.5E-01	±	9.8E-02	D130	5	5	4.0E-01	±	3.2E-01	5.8E-01	±	1.1E-01	D130
	600	16	16	5.0E-01	±	1.8E-01	7.0E-01	±	1.2E-01	D108	62	62	5.0E-01	±	3.3E-01	9.3E-01	±	1.6E-01	D091
²³⁵ U	200-E	14	13	7.4E-02	±	7.7E-02	1.8E-01	±	8.9E-02	D460	81	67	5.1E-02	±	5.9E-02	1.1E-01	±	5.0E-02	D059
	200-W	25	21	5.9E-02	±	4.5E-02	1.0E-01	±	4.2E-02	D026	98	74	4.4E-02	±	4.6E-02	1.1E-01	±	4.8E-02	D026
	300	8	6	8.3E-02	±	8.3E-02	1.6E-01	±	6.8E-02	D126	40	38	6.6E-02	±	9.6E-02	1.9E-01	±	5.7E-02	D126
	400	1	1	5.1E-02 ^e			5.1E-02	±	3.5E-02	D130	5	5	3.9E-02	±	4.4E-02	7.7E-02	±	4.1E-02	D130
	600	16	13	6.5E-02	±	6.2E-02	1.2E-01	±	5.3E-02	D094	62	47	5.0E-02	±	5.2E-02	1.1E-01	±	4.9E-02	D094
²³⁸ U	200-E	14	14	5.1E-01	±	2.2E-01	8.4E-01	±	1.3E-01	D112	82	82	5.0E-01	±	3.2E-01	1.1E+00	±	1.9E-01	D060
	200-W	25	25	5.2E-01	±	1.6E-01	7.0E-01	±	1.3E-01	D010	98	98	4.6E-01	±	2.8E-01	6.6E-01	±	1.0E-01	D306
	300	8	8	6.7E-01	±	6.4E-01	1.4E+00	±	1.9E-01	D121	40	40	7.4E-01	±	1.1E+00	2.2E+00	±	3.5E-01	D126
	400	1	1	5.3E-01 ^e			5.3E-01	±	1.0E-01	D130	5	5	3.7E-01	±	2.7E-01	4.8E-01	±	9.1E-02	D130

Table C-4. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Soil Samples. (2 Pages)

Radionuclide	Hanford Area	2018									2013 - 2017								
		Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location	Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location
		Samples	Detects ^b								Samples	Detects ^b							
	600	16	16	5.1E-01	±	1.5E-01	7.4E-01	±	1.3E-01	D114	62	62	5.2E-01	±	3.4E-01	9.7E-01	±	1.5E-01	D094
^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 Standard deviation cannot be calculated for one sample.																			

C.4 Columbia River Water

Table C-5. Radionuclide Concentrations in Columbia River Water (Richland, Washington).

Radionuclide ^b		2018				2013-2017				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		13	0	4.4E-02 ± 3.1E-02	1.6E-02 ± 2.7E-02	52	0	5.6E-02 ±3.7E-02	8.0E-03 ±4.8E-02	8
Tritium		13	13	4.5E+01 ± 1.4E+01	2.4E+01 ± 2.0E+01	51	51	6.3E+01 ±9.7E+00	2.7E+01 ±2.2E+01	20000
Technetium-99		13	2	1.1E+00 ± 5.7E-01	3.3E-01± 1.0E+00	52	0	6.2E-01 ±4.5E-01	5.4E-02 ±4.6E-01	900
Uranium-234		13	13	4.1E-01 ± 8.0E-02	3.0E-01 ± 9.7E-02	52	52	3.4E-01 ±7.2E-02	2.8E-01 ±9.8E-02	--
Uranium-235		13	7	7.9E-02 ± 3.0E-02	2.7E-02± 3.9E-02	52	12	5.3E-02 ±3.1E-02	1.6E-02 ±2.4E-02	--
Uranium-238		13	13	3.0E-01 ± 8.2E-02	2.5E-01 ± 6.1E-02	52	51	2.8E-01 ±6.3E-02	2.2E-01 ±7.6E-02	--
Continuous System										
Cesium-137	D ^b	6	0	1.3E-03 ±2.3E-03	5.1E-04 ±1.3E-03	54	0	2.4E-03 ± 2.3E-03	-3.0E-05 ± 2.3E-03	200
	P ^b	6	0	1.4E-03 ±3.2E-03	-1.3E-05 ±2.5E-03	54	0	6.9E-03 ± 6.6E-03	4.7E-04 ± 4.8E-03	
Plutonium-238	D ^b	6	0	7.0E-05 ±7.3E-05	-3.0E-06 ±8.1E-05	38	0	8.7E-05 ± 7.4E-05	3.7E-06 ± 6.3E-05	600
	P ^b	6	0	1.7E-04 ±1.6E-04	5.9E-06 ±1.6E-04	38	2	7.9E-04 ± 3.1E-04	3.8E-05 ± 2.7E-04	
Plutonium-239/240	D ^b	6	0	4.4E-05 ±5.7E-05	-3.6E-05 ±1.2E-04	38	0	9.7E-05 ± 1.9E-04	1.4E-05 ± 6.4E-05	--
	P ^b	6	0	3.4E-05 ±7.5E-05	1.3E-05 ±4.3E-05	38	1	1.8E-04 ± 1.6E-04	1.5E-05 ± 1.6E-04	
^a Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±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 The continuous system was inoperable for half of 2018 at RPH so no filter or resin data is available for this time.										
Note: Dashes indicate no concentration guides available.										
WA = Washington State.										

Table C-6. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, Washington).

Radionuclide ^b		2018								2013-2017								WA Ambient Surface Water Quality Standard ^d
		Number of Samples Detects	Concentration ^a						Number of Samples Detects	Concentration ^a								
			Maximum			Average				Maximum			Average					
			<i>(pCi/L)</i> ^c			<i>(pCi/L)</i> ^c				<i>(pCi/L)</i> ^c			<i>(pCi/L)</i> ^c					
Composite System																		
Strontium-90		13	0	3.5E-02	±	3.6E-02	6.1E-03	±	4.5E-02	59	0	5.4E-02	±	3.7E-02	9.5E-03	±	4.5E-02	
Tritium		13	13	2.1E+01	±	7.3E+00	1.4E+01	±	8.8E+00	59	57	2.7E+01	±	7.3E+00	1.6E+01	±	8.6E+00	
Technetium-99		13	0	1.5E+00	±	1.0E+00	3.3E-01	±	1.2E+00	59	0	1.5E+00	±	1.0E+00	9.2E-02	±	6.9E-01	
Uranium-234		13	13	4.4E-01	±	8.7E-02	2.7E-01	±	1.3E-01	59	59	3.4E-01	±	6.5E-02	2.5E-01	±	9.2E-02	
Uranium-235		13	7	6.5E-02	±	3.2E-02	3.0E-02	±	2.8E-02	59	18	7.4E-02	±	3.3E-02	1.8E-02	±	3.3E-02	
Uranium-238		13	13	2.9E-01	±	5.9E-02	2.1E-01	±	6.1E-02	59	59	2.7E-01	±	1.0E-01	2.0E-01	±	6.5E-02	
Continuous System																		
Cesium-137	D ^b	13	0	1.3E-03	±	1.7E-03	-1.9E-04	±	1.9E-03	64	0	4.4E-03	±	2.1E-03	2.7E-04	±	1.8E-03	200
	P ^b	13	0	3.9E-03	±	4.5E-03	9.6E-04	±	3.0E-03	64	0	5.1E-03	±	4.5E-03	9.0E-04	±	4.0E-03	
Plutonium-238	D ^b	13	0	2.3E-04	±	1.7E-04	3.4E-05	±	1.4E-04	47	0	5.4E-05	±	7.0E-05	-3.0E-06	±	4.6E-05	600
	P ^b	13	0	3.8E-05	±	7.4E-05	7.3E-06	±	6.2E-05	44	3	5.2E-04	±	1.7E-04	2.2E-05	±	2.6E-04	
Plutonium-239/240	D ^b	13	0	4.7E-05	±	8.1E-05	-8.3E-06	±	8.7E-05	47	0	9.9E-05	±	7.8E-05	2.7E-06	±	5.4E-05	--
	P ^b	13	1	2.1E-04	±	1.3E-04	3.9E-05	±	1.3E-04	44	1	2.4E-04	±	2.4E-04	2.6E-05	±	1.2E-04	
^a Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±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. Note: Dashes indicate no concentration guides available. WA = Washington State.																		

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Table C-7. Radionuclide Concentrations in Columbia River Transect Water Samples. (2 Pages)

Transect/Radionuclide	No. of Samples	No. of Detections	Concentration ^a					
			Maximum			Average		
			pCi/L ^b			pCi/L ^b		
Vernita Bridge (HRM 0.3)								
Strontium-90 ^c	0	8	3.98E-02	±	3.55E-02	1.24E-02	±	2.59E-02
Technetium-99 ^c	0	8	3.91E-01	±	7.50E-01	1.75E-02	±	5.39E-01
Tritium	8	8	1.74E+01	±	6.41E+00	1.49E+01	±	5.12E+00
Uranium-234	8	8	2.86E-01	±	4.52E-02	2.43E-01	±	5.46E-02
Uranium-235	5	8	2.63E-02	±	1.52E-02	1.83E-02	±	7.02E-03
Uranium-238	8	8	2.50E-01	±	4.44E-02	2.00E-01	±	5.13E-02
100H Area (HRM 15.3)								
Strontium-90 ^c	0	5	3.80E-02	±	3.58E-02	6.34E-03	±	5.04E-02
Tritium	5	5	2.62E+01	±	9.20E+00	1.85E+01	±	9.00E+00
Uranium-234	5	5	2.77E-01	±	6.09E-02	2.39E-01	±	6.28E-02
Uranium-235 ^d	1	5	2.45E-02	±	2.26E-02	1.73E-02	±	1.17E-02
Uranium-238	5	5	2.01E-01	±	5.07E-02	1.73E-01	±	3.45E-02
100N Area (HRM 9.5)								
Strontium-90 ^c	0	5	4.26E-02	±	3.65E-02	1.91E-02	±	4.42E-02
Tritium	5	5	1.99E+01	±	7.04E+00	1.74E+01	±	3.38E+00
Uranium-234	5	5	2.60E-01	±	4.61E-02	2.35E-01	±	3.89E-02
Uranium-235	3	5	3.59E-02	±	1.71E-02	2.24E-02	±	1.85E-02
Uranium-238	5	5	2.09E-01	±	4.35E-02	1.98E-01	±	1.88E-02
Hanford Townsite (HRM 28.7)								
Strontium-90 ^c	0	6	5.54E-02	±	3.75E-02	3.47E-02	±	3.12E-02
Tritium	6	6	1.03E+03	±	2.32E+02	3.43E+02	±	9.22E+02
Uranium-234	6	6	3.06E-01	±	6.91E-02	2.63E-01	±	6.15E-02
Uranium-235	1	6	3.02E-02	±	2.36E-02	2.10E-02	±	1.22E-02
Uranium-238	6	6	2.36E-01	±	5.86E-02	1.93E-01	±	5.69E-02
300 Area (HRM 43.1)								
Strontium-90 ^c	0	5	2.19E-02	±	3.40E-02	-6.08E-05	±	2.88E-02
Tritium	5	5	5.56E+01	±	1.70E+01	2.74E+01	±	2.84E+01
Uranium-234	5	5	4.78E-01	±	7.77E-02	3.07E-01	±	1.87E-01
Uranium-235	2	5	2.55E-02	±	1.88E-02	1.20E-02	±	2.26E-02
Uranium-238	5	5	3.61E-01	±	6.39E-02	2.52E-01	±	1.35E-01
Richland (HRM 46.4)								
Strontium-90 ^c	0	11	3.50E-02	±	3.15E-02	1.56E-02	±	3.57E-02
Technetium-99	0	11	5.30E-01	±	6.83E-01	-1.87E-01	±	6.24E-01
Tritium	11	11	1.92E+01	±	7.14E+00	1.46E+01	±	7.38E+00
Uranium-234	11	11	3.25E-01	±	5.13E-02	2.83E-01	±	5.51E-02
Uranium-235	10	11	4.68E-02	±	2.66E-02	2.73E-02	±	2.13E-02
Uranium-238	11	11	2.51E-01	±	5.75E-02	2.28E-01	±	3.29E-02

Table C-7. Radionuclide Concentrations in Columbia River Transect Water Samples. (2 Pages)^a Maximum values \pm total propagated analytical uncertainty; Average values \pm 2stdv.^b 1 pCi = 0.037 Bq.^c All value(s) reported are non-detects.^d Maximum value reported in a non-detect

HRM = Hanford river marker.

Table C-8. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (4 Pages)

Metal	No. of Samples	No. of Detections	Maximum ($\mu\text{g/L}$) ^a	Minimum ($\mu\text{g/L}$) ^a	Average ($\mu\text{g/L}$) ^{a,b}	Minimum Detectable Concentrations ($\mu\text{g/L}$)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
Vernita Bridge							
Antimony	9	0	—	—	—	1	N/A
Arsenic	9	9	2.45	2.09	2.29	2	190
Beryllium	9	0	—	—	—	0.2	N/A
Cadmium	9	0	—	—	—	0.3	N/A
Chromium	9	0	—	—	—	3	10
Copper	9	9	0.99	0.46	0.64	0.3	6
Hexavalent Chromium	9	0	—	—	—	1.5	10
Lead	9	0	—	—	—	0.5	1.1
Nickel	9	0	—	—	—	0.6	83
Selenium	9	0	—	—	—	2	5
Silver	9	0	—	—	—	0.3	N/A
Thallium	9	0	—	—	—	0.6	N/A
Uranium	9	9	0.66	0.51	0.58	0.067	30 ^d
Zinc	9	7	5.66	3.30	4.07	3.3	55
100-N Area							
Antimony	5	0	—	—	—	1	N/A
Arsenic	5	3	2.23	2.12	2.18	2	190
Beryllium	5	0	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3	10
Copper	5	5	0.81	0.65	0.70	0.3	6
Hexavalent Chromium	5	0	—	—	—	1.5	10
Lead	5	0	—	—	—	0.5	1.1
Nickel	5	0	—	—	—	0.6	83
Selenium	5	0	—	—	—	2	5
Silver	5	0	—	—	—	0.3	N/A

**Table C-8. Dissolved Metal Concentrations in Columbia River Transect
Water Near Hanford Site. (4 Pages)**

Metal	No. of Samples	No. of Detections	Maximum ($\mu\text{g/L}$) ^a	Minimum ($\mu\text{g/L}$) ^a	Average ($\mu\text{g/L}$) ^{a,b}	Minimum Detectable Concentrations ($\mu\text{g/L}$)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
Thallium	5	0	—	—	—	0.6	N/A
Uranium	5	5	0.54	0.48	0.52	0.067	30 ^d
Zinc	5	4	4.69	3.78	4.32	3.3	55
100-H Area							
Antimony	5	0	—	—	—	1	N/A
Arsenic	5	5	2.34	2.22	2.26	2	190
Beryllium	5	0	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3	10
Copper	5	5	0.64	0.56	0.61	0.3	6
Hexavalent Chromium	5	0	—	—	—	1.5	10
Lead	5	0	—	—	—	0.5	1.1
Nickel	5	0	—	—	—	0.6	83
Selenium	5	0	—	—	—	2	5
Silver	5	0	—	—	—	0.3	N/A
Thallium	5	0	—	—	—	0.6	N/A
Uranium	5	5	0.54	0.52	0.53	0.067	30 ^d
Zinc	5	3	5.11	3.54	4.31	3.3	55
Hanford Townsite							
Antimony	6	0	—	—	—	1	N/A
Arsenic	6	5	2.22	2.02	2.11	2	190
Beryllium	6	0	—	—	—	0.2	N/A
Cadmium	6	0	—	—	—	0.3	N/A
Chromium	6	0	—	—	—	3	10
Copper	6	6	0.77	0.61	0.67	0.3	6
Hexavalent Chromium	6	0	—	—	—	1.5	10
Lead	6	0	—	—	—	0.5	1.1
Nickel	6	0	—	—	—	0.6	83
Selenium	6	0	—	—	—	2	5
Silver	6	0	—	—	—	0.3	N/A
Thallium	6	0	—	—	—	0.6	N/A
Uranium	6	6	0.62	0.51	0.55	0.067	30 ^d
Zinc	6	2	4.46	3.34	3.90	3.3	55

**Table C-8. Dissolved Metal Concentrations in Columbia River Transect
Water Near Hanford Site. (4 Pages)**

Metal	No. of Samples	No. of Detections	Maximum ($\mu\text{g/L}$) ^a	Minimum ($\mu\text{g/L}$) ^a	Average ($\mu\text{g/L}$) ^{a,b}	Minimum Detectable Concentrations ($\mu\text{g/L}$)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
300 Area							
Antimony	5	0	—	—	—	1	N/A
Arsenic	5	5	2.35	2.17	2.25	2	190
Beryllium	5	0	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3	10
Copper	5	5	1.65	0.62	0.87	0.3	6
Hexavalent Chromium	5	0	—	—	—	1.5	10
Lead	5	0	—	—	—	0.5	1.1
Nickel	5	0	—	—	—	0.6	83
Selenium	5	0	—	—	—	2	5
Silver	5	0	—	—	—	0.3	N/A
Thallium	5	0	—	—	—	0.6	N/A
Uranium	5	5	1.12	0.55	0.70	0.067	30 ^d
Zinc	5	2	8.03	5.61	6.82	3.3	55
Richland							
Antimony	11	0	—	—	—	1	N/A
Arsenic	11	10	2.25	2.00	2.14	2	190
Beryllium	11	0	—	—	—	0.2	N/A
Cadmium	11	0	—	—	—	0.3	N/A
Chromium	11	0	—	—	—	3	10
Copper	11	11	1.91	0.49	0.75	0.3	6
Hexavalent Chromium	11	0	—	—	—	1.5	10
Lead	11	0	—	—	—	0.5	1.1
Nickel	11	0	—	—	—	0.6	83
Selenium	11	0	—	—	—	2	5
Silver	11	0	—	—	—	0.3	N/A
Thallium	11	0	—	—	—	0.6	N/A
Uranium	11	11	0.70	0.52	0.62	0.067	30 ^d
Zinc	11	5	5.86	3.73	4.71	3.3	55

Table C-8. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (4 Pages)

Metal	No. of Samples	No. of Detections	Maximum (µg/L) ^a	Minimum (µg/L) ^a	Average (µg/L) ^{a,b}	Minimum Detectable Concentrations (µg/L)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
^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 CaCO ₃ /L, for 1992 through 2000 water samples collected near Vernita Bridge by the U.S. Geological Survey was used. Parts per million (ppm) values are equivalent to the reported micrograms per liter (µg/L) concentrations shown. ^c Average calculated using reporting limit values for all results at or below minimum detectable concentrations. ^d EPA drinking water standard applied.							

Table C-9. Columbia River Organic Concentrations in Transect Water.

Location	No. of Samples	Trichloroethene	cis-1,2-Dichloroethene	Regulatory Standard ^a
		(mg/L) ^b	(mg/L) ^b	(mg/L)
Richland Pumphouse-1 HRM 46.4	3	0.003	0.003	0.005
Richland Pumphouse-3 HRM 46.4	2	0.003	0.003	0.005
Richland Pumphouse-5 HRM 46.4	2	0.003	0.003	0.005
Richland Pumphouse-7 HRM 46.4	2	0.003	0.003	0.005
Richland Pumphouse-9 HRM 46.4	2	0.003	0.003	0.005
300 Area-1 HRM 43.1	1	0.003	0.003	0.005
300 Area-3 HRM 43.1	1	0.003	0.003	0.005
300 Area-5 HRM 43.1	1	0.003	0.003	0.005
300 Area-7 HRM 43.1	1	0.003	0.003	0.005
300 Area-9 HRM 43.1	1	0.003	0.003	0.005
Vernita-1 HRM 0.3	2	0.003	0.003	0.005
Vernita-2 HRM 0.3	2	0.003	0.003	0.005
Vernita-3 HRM 0.3	2	0.003	0.003	0.005
Vernita-4 HRM 0.3	2	0.003	0.003	0.005
^a EPA Drinking Water Regulation Standard = 0.005 mg/L (both constituents)				
^b Maximum concentration reported was a non-detect.				

C.5 Shoreline Seep Water

Table C-10. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/Radionuclide	2017		Concentration pCi/L ^(a) Maximum ^(c)			2012-2016		Concentration pCi/L ^(a) Average ^(d)			Washington State Ambient Surface Water Quality Standard pCi/L ^(a, b)
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				
100-B Area (100-B Spring 38-3 and 100B Spring 39-2)											
Strontium-90	2	1	7.8E-01	±	1.5E-01	9	4	7.1E-01	±	2.8E+00	8
Tritium	2	2	1.5E+03	±	3.4E+02	9	8	1.2E+03	±	1.3E+03	20,000
100-D Area (Spring 110-1)											
Alpha (gross) ^e	2	0	2.0E+00	±	2.3E+00	5	1	2.4E+00	±	2.4E+00	15
Beta (gross)	2	2	5.6E+00	±	2.4E+00	5	5	8.6E+00	±	8.4E+00	50
Strontium-90	2	2	2.1E+00	±	3.5E-01	5	4	1.8E+00	±	2.4E+00	8
Technetium-99 ^e	2	0	-7.4E-02	±	5.9E-01	5	0	-5.6E-01	±	3.8E+00	900
Tritium	2	2	2.6E+03	±	5.6E+02	5	5	1.9E+03	±	1.8E+03	20,000
Uranium-234	2	2	1.0E+00	±	1.9E-01	5	5	9.5E-01	±	6.6E-01	—
Uranium-235	2	2	5.2E-02	±	3.5E-02	5	4	6.7E-02	±	5.8E-02	—
Uranium-238	2	2	8.1E-01	±	1.6E-01	5	5	8.8E-01	±	8.0E-01	—
100-F Area (100-F Spring 207-1 and 100F Spring 211-1)											
Strontium-90 ^e	1	0	-1.1E-02	±	3.2E-02	13	0	-8.5E-02	±	5.9E-01	8
Tritium	1	0	3.0E+01	±	1.3E+02	13	9	3.1E+02	±	3.0E+02	900
100-H Area (100-H Spring 145-1 and 100-H Spring 152-2)											
Strontium-90	1	1	7.4E-01	±	1.3E-01	3	2	3.0E+00	±	4.5E+00	8
Tritium ^e	1	0	-2.2E+01	±	1.3E+02	4	1	2.5E+02	±	3.6E+02	900
100K Area (Spring 63-1)											
Alpha (gross) ^e	1	0	2.8E-01	±	1.5E+00	5	1	1.6E+00	±	2.6E+00	15
Beta (gross)	1	1	5.3E+00	±	2.0E+00	5	5	7.7E+00	±	1.2E+01	50

Table C-10. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/Radionuclide	2017		Concentration pCi/L ^(a) Maximum ^(c)			2012-2016		Concentration pCi/L ^(a) Average ^(d)			Washington State Ambient Surface Water Quality Standard pCi/L ^(a, b)
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				
Carbon-14	1	1	1.3E+02	±	2.8E+01	12	10	3.2E+02	±	1.1E+03	2,000
Strontium-90 ^e	1	0	-1.5E-03	±	3.2E-02	5	0	-1.7E-01	±	6.8E-01	8
Technetium-99	1	1	4.9E+00	±	9.1E-01	5	4	7.3E+00	±	1.4E+01	—
Tritium ^e	1	0	9.0E+01	±	1.7E+02	5	1	2.6E+02	±	6.9E+02	20,000
100-N Area (Spring 8-13)											
Alpha (gross) ^e	1	0	-6.1E-01	±	9.7E-01	5	0	9.7E-01	±	1.9E+00	15
Beta (gross) ^e	1	0	1.1E+00	±	1.5E+00	5	3	3.5E+00	±	2.6E+00	50
Strontium-90 ^e	1	0	-1.7E-03	±	3.1E-02	5	0	-1.2E-01	±	5.6E-01	8
Tritium	1	1	2.7E+03	±	5.5E+02	5	5	4.1E+03	±	1.9E+03	20,000
100-N Area (Spring 89-1)											
Strontium-90	1	1	8.0E+01	±	1.4E+01	5	5	2.9E+01	±	3.1E+01	8
Tritium	1	1	2.0E+03	±	4.4E+02	5	3	6.8E+02	±	1.3E+03	20,000
Hanford Townsite (Hanford Spring 25-4)											
Alpha (gross) ^e	1	0	3.3E-01	±	1.5E+00	4	0	3.9E-01	±	9.8E-01	15
Beta (gross) ^e	1	0	-4.7E-01	±	1.9E+00	4	1	3.2E+00	±	3.6E+00	50
Strontium-90 ^e	1	0	5.5E-03	±	2.7E-02	4	0	-6.4E-02	±	1.8E-01	8
Technetium-99 ^e	1	0	-3.9E-01	±	3.5E-01	4	0	4.6E-01	±	3.2E-01	—
Tritium ^e	1	0	2.0E+02	±	1.5E+02	4	0	-3.5E+01	±	1.0E+02	20,000
Hanford Townsite (Hanford Spring 28-2)											
Alpha (gross) ^e	1	0	9.8E-01	±	1.8E+00	5	3	3.7E+00	±	3.4E+00	15
Beta (gross)	1	1	2.5E+01	±	4.2E+00	5	5	3.4E+01	±	2.4E+01	50
Tritium	1	1	2.3E+04	±	4.4E+03	5	5	1.7E+04	±	1.2E+04	20,000
Iodine ^e	1	0	2.0E-01	±	5.3E-01	5	0	3.4E-02	±	4.7E-01	—

Table C-10. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/Radionuclide	2017		Concentration pCi/L ^(a) Maximum ^(c)			2012-2016		Concentration pCi/L ^(a) Average ^(d)			Washington State Ambient Surface Water Quality Standard pCi/L ^(a, b)
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				
300 Area (300 Area Spring 42-2 and 300 Area Spring DR 42-2)											
Alpha (gross)	2	2	2.5E+01	±	5.8E+00	12	12	3.7E+01	±	4.8E+01	15
Beta (gross)	2	2	2.1E+01	±	3.7E+00	12	12	2.2E+01	±	1.8E+01	50
Tritium	2	2	2.8E+03	±	5.9E+02	12	12	4.2E+03	±	1.2E+03	20,000
Uranium-234	2	2	1.7E+01	±	1.7E+00	12	12	2.2E+01	±	2.5E+01	—
Uranium-235	2	2	1.1E+00	±	1.6E-01	12	12	1.8E+00	±	2.0E+00	—
Uranium-236	2	1	3.4E-01	±	7.0E-02	2	1	4.0E-01	±	1.1E-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. ^f Maximum value reported for 2018 is a non-detect. Note: Dashes indicate no concentration guides available.											

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c (µg/L)
100B (39-2 and 38-3)	Metals								
	Antimony	2	0	Filtered	1.00E+00			µg/L	12
		2	0	Unfiltered					
	Arsenic	2	1	Filtered	2.00E+00	-	2.08E+00	µg/L	10
		2	1	Unfiltered	2.00E+00	-	4.01E+00		
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59
		2	0	Unfiltered					

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c (µg/L)	
	Chromium	2	2	Filtered	4.99E+00	-	9.81E+00	µg/L	10 ^e	
		2	2	Unfiltered	1.02E+01	-	4.37E+01		96 ^f	
	Copper	2	2	Filtered	3.70E-01	-	6.95E-01	µg/L	1300	
		2	2	Unfiltered	1.34E+00	-	1.03E+01			
	Hexavalent Chromium	2	2	Filtered	3.40E+00	-	1.10E+01	µg/L	10	
		2	1	Unfiltered	1.50E+00	-	8.70E+00			
	Lead	2	0	Filtered	5.00E-01			µg/L	1.1	
		2	2	Unfiltered	1.14E+00	-	5.93E+00			
	Nickel	2	1	Filtered	6.00E-01	-	9.08E-01	µg/L	150	
		2	2	Unfiltered	9.06E-01	-	1.73E+01			
	Selenium	2	0	Filtered	2.00E+00			µg/L	120	
		2	0	Unfiltered						
	Thallium	2	0	Filtered	6.00E-01			µg/L	0.24	
		2	0	Unfiltered						
	Zinc	2	2	Filtered	7.83E+00	-	4.00E+01	µg/L	2,300	
		2	2	Unfiltered	1.59E+01	-	1.95E+02			
	Anions									
		Nitrate	2	2	Unfiltered	3.58E+03	-	3.78E+03	µg/L	10 ^g
100D (110-1)	Metals									
	Antimony	2	0	Filtered	1.00E+00			µg/L	12	
		2	0	Unfiltered						
	Arsenic	2	2	Filtered	2.44E+00	-	2.75E+00	µg/L	10	
		2	2	Unfiltered	2.16E+00	-	2.49E+00			
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59	
		2	0	Unfiltered						
	Chromium	2	2	Filtered	1.15E+01			µg/L	10 ^e	
2		2	Unfiltered	1.16E+01					-	1.19E+01

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c (µg/L)	
	Copper	2	2	Filtered	4.62E-01	-	1.02E+00	µg/L	1300	
		2	1	Unfiltered	3.33E-01					
	Hexavalent Chromium	2	2	Filtered	1.10E+01			µg/L	10	
		2	2	Unfiltered	1.10E+01	-	1.20E+01			
	Lead	2	0	Filtered	5.00E-01			µg/L	1.1	
		2	0	Unfiltered						
	Nickel	2	2	Filtered	6.87E-01	-	1.22E+00	µg/L	150	
		2	2	Unfiltered	7.19E-01	-	9.84E-01			
	Selenium	2	2	Filtered	2.14E+00	-	2.16E+00	µg/L	120	
		2	0	Unfiltered	2.00E+00					
	Thallium	2	0	Filtered	6.00E-01			µg/L	0.24	
		2	0	Unfiltered						
	Zinc	2	2	Filtered	8.08E+00	-	9.48E+00	µg/L	2,300	
		2	2	Unfiltered	9.47E+00	-	9.79E+00			
	Anions									
		Nitrate	2	2	Unfiltered	2.13E+04	-	2.15E+04	µg/L	10 ^g
100F (207-1, 211-1)	Metals									
	Antimony	1	0	Filtered	1.00E+00			µg/L	12	
		1	0	Unfiltered						
	Arsenic	1	1	Filtered	2.29E+00			µg/L	10	
		1	1	Unfiltered	8.60E+00					
	Cadmium	1	1	Filtered	4.77E-01			µg/L	0.59	
		1	1	Unfiltered	1.08E+00					
	Chromium	1	0	Filtered	3.00E+00			µg/L	10 ^e	
		1	1	Unfiltered	8.97E+00				96 ^f	
	Copper	1	1	Filtered	1.84E+00			µg/L	1300	
		1	1	Unfiltered	1.59E+01					

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b	Unit	Regulatory limit ^c (µg/L)	
	Hexavalent Chromium	1	0	Filtered	1.50E+00	µg/L	10	
		1	0	Unfiltered				
	Lead	1	1	Filtered	1.91E+00	µg/L	1.1	
		1	1	Unfiltered	3.37E+01			
	Nickel	1	1	Filtered	1.22E+00	µg/L	150	
		1	1	Unfiltered	6.58E+00			
	Selenium	1	0	Filtered	2.00E+00	µg/L	120	
		1	0	Unfiltered				
	Thallium	1	0	Filtered	6.00E-01	µg/L	0.24	
		1	0	Unfiltered				
	Zinc	1	1	Filtered	2.56E+01	µg/L	2,300	
		1	1	Unfiltered	1.36E+02			
	Anions							
		Nitrate	1	1	Unfiltered	1.96E+03	µg/L	10 ^g
100H (152-2)	Metals							
	Antimony	1	0	Filtered	1.00E+00	µg/L	12	
		1	0	Unfiltered				
	Arsenic	1	1	Filtered	2.58E+00	µg/L	10	
		1	1	Unfiltered	2.37E+00			
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59	
		1	0	Unfiltered				
	Chromium	1	0	Filtered	3.00E+00	µg/L	10 ^e	
		1	0	Unfiltered			96 ^f	
	Copper	1	1	Filtered	7.39E-01	µg/L	1300	
		1	1	Unfiltered	9.18E-01			
	Hexavalent Chromium	1	1	Filtered	1.80E+00	µg/L	10	
		1	1	Unfiltered	2.10E+00			

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b	Unit	Regulatory limit ^c (µg/L)
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
		1	0	Unfiltered			
	Nickel	1	0	Filtered	6.00E-01	µg/L	150
		1	0	Unfiltered			
	Selenium	1	0	Filtered	2.00E+00	µg/L	120
		1	0	Unfiltered			
	Thallium	1	0	Filtered	6.00E-01	µg/L	0.24
		1	0	Unfiltered			
	Zinc	1	1	Filtered	8.42E+00	µg/L	2,300
		1	1	Unfiltered	9.54E+00		
	Anions						
	Nitrate	1	1	Unfiltered	2.24E+03	µg/L	10 ^g
100K (63-1)	Metals						
	Antimony	1	0	Filtered	1.00E+00	µg/L	12
		1	0	Unfiltered			
	Arsenic	1	1	Filtered	2.49E+00	µg/L	10
		1	1	Unfiltered	2.67E+00		
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59
		1	0	Unfiltered			
	Chromium	1	0	Filtered	3.00E+00	µg/L	10 ^e
		1	0	Unfiltered			96 ^f
	Copper	1	1	Filtered	5.44E-01	µg/L	1300
		1	1	Unfiltered	2.66E+00		
	Hexavalent Chromium	1	1	Filtered	1.60E+00	µg/L	10
		1	0	Unfiltered	1.50E+00		
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
		1	0	Unfiltered			

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c (µg/L)	
	Nickel	1	0	Filtered	6.00E-01			µg/L	150	
		1	1	Unfiltered	7.79E-01					
	Selenium	1	0	Filtered	2.00E+00			µg/L	120	
		1	0	Unfiltered						
	Thallium	1	0	Filtered	6.00E-01			µg/L	0.24	
		1	0	Unfiltered						
	Zinc	1	1	Filtered	8.63E+00			µg/L	2,300	
		1	1	Unfiltered	1.31E+01					
	Anions									
		Nitrate	1	1	Unfiltered	3.95E+03			µg/L	10 ^g
100N ^h (8-13, 89-1)	Metals									
	Antimony	2	0	Filtered	1.00E+00			µg/L	12	
		2	0	Unfiltered						
	Arsenic	2	2	Filtered	2.71E+00	-	8.86E+00	µg/L	10	
		2	2	Unfiltered	3.34E+00	-	9.24E+00			
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59	
		2	0	Unfiltered						
	Chromium	2	1	Filtered	4.27E+00			µg/L	10 ^e	
		2	1	Unfiltered	6.04E+00				96 ^f	
		Copper	2	2	Filtered	5.84E-01	-	1.94E+00	µg/L	1300
2			2	Unfiltered	5.96E-01	-	2.01E+00			
	Hexavalent Chromium	2	1	Filtered	4.20E+00			µg/L	10	
		2	1	Unfiltered	2.20E+00					
	Lead	2	0	Filtered	5.00E-01			µg/L	1.1	
		2	1	Unfiltered	1.82E+00					
	Nickel	2	1	Filtered	9.35E-01			µg/L	150	
		2	2	Unfiltered	8.17E-01	-	1.96E+00			

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c (µg/L)
	Selenium	2	0	Filtered	2.00E+00			µg/L	120
		2	0	Unfiltered					
	Thallium	2	0	Filtered	6.00E-01			µg/L	0.24
		2	0	Unfiltered					
	Zinc	2	2	Filtered	8.60E+00	-	9.66E+00	µg/L	2,300
		2	2	Unfiltered	9.25E+00	-	2.67E+01		
	Anions								
	Nitrate	2	2	Unfiltered	1.85E+04	-	3.52E+04	µg/L	10 ^g
Hanford Townsite (25-4)	Metals								
	Antimony	1	0	Filtered	1.00E+00			µg/L	12
		1	0	Unfiltered					
	Arsenic	1	1	Filtered	2.07E+00			µg/L	10
		1	1	Unfiltered	2.12E+00				
	Cadmium	1	0	Filtered	3.00E-01			µg/L	0.59
		1	0	Unfiltered					
	Chromium	1	0	Filtered	3.00E+00			µg/L	10 ^e
		1	0	Unfiltered					96 ^f
	Copper	1	1	Filtered	4.92E-01			µg/L	1300
		1	1	Unfiltered	5.24E-01				
	Hexavalent Chromium	1	0	Filtered	1.50E+00			µg/L	10
		1	0	Unfiltered					
	Lead	1	0	Filtered	5.00E-01			µg/L	1.1
		1	0	Unfiltered					
	Nickel	1	0	Filtered	6.00E-01			µg/L	150
		1	0	Unfiltered					
	Selenium	1	0	Filtered	2.00E+00			µg/L	120
		1	0	Unfiltered					

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c (µg/L)
	Thallium	1	0	Filtered	6.00E-01			µg/L	0.24
		1	0	Unfiltered					
	Zinc	1	1	Filtered	5.69E+00			µg/L	2,300
		1	1	Unfiltered	6.96E+00				
	Anions								
	Nitrate	1	1	Unfiltered	2.74E+03			µg/L	10 ^g
Hanford Spring ^d (28-2)	Hexavalent Chromium	1	0	Filtered	1.50E+00			µg/L	10
	Hexavalent Chromium	1	1	Unfiltered	2.00E+00			µg/L	10
	Anions								
	Nitrate	1	1	Unfiltered	2.13E+04			µg/L	10 ^g
100D (110-1)	Metals								
	Antimony	2	0	Filtered	1.00E+00			µg/L	12
		2	0	Unfiltered					
	Arsenic	2	2	Filtered	2.37E+00	-	3.51E+00	µg/L	10
		2	2	Unfiltered	2.79E+00	-	4.05E+00		
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59
		2	1	Unfiltered	4.78E-01				
	Chromium	2	0	Filtered	3.00E+00			µg/L	10 ^e
		2	0	Unfiltered					96 ^f
	Copper	2	2	Filtered	4.85E-01	-	1.02E+00	µg/L	1300
		2	2	Unfiltered	2.07E+00	-	4.50E+00		
	Hexavalent Chromium	2	0	Filtered	1.50E+00			µg/L	10
		2	0	Unfiltered					
	Lead	2	0	Filtered	5.00E-01			µg/L	1.1
		2	2	Unfiltered	1.84E+00	-	2.53E+00		
	Nickel	2	2	Filtered	1.75E+00	-	2.39E+00	µg/L	150

Table C-11. Metals and Anions in Columbia River Water Shoreline Seep Water. (9 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a		Range (min-max) ^b			Unit	Regulatory limit ^c (µg/L)
		2	2	Unfiltered		1.12E+00	-	2.14E+00		
	Selenium	2	0	Filtered		2.00E+00			µg/L	120
		2	0	Unfiltered						
	Thallium	2	0	Filtered		6.00E-01			µg/L	0.24
		2	0	Unfiltered						
	Zinc	2	2	Filtered		8.17E+00	-	4.52E+01	µg/L	2,300
		2	2	Unfiltered		1.81E+01	-	5.16E+01		
	<i>Anions</i>									
	Nitrate	2	2	Unfiltered		2.23E+03	-	1.35E+04	µg/L	10 ^g

^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 Hanford Spring 28-2 analyses performed during 2018 included anions and hexavalent chromium only.

^e Value for hexavalent chromium.

^f Value for trivalent chromium.

^g Washington State drinking water standard utilized ([WAC 246-290](#)).

^h Exceeded analytical laboratory hold times for hexavalent chromium.

Table C-12. Columbia River Organic Concentrations in Shoreline Seep Water.

Location	No. of Samples	Trichloroethene	cis-1,2-Dichloroethene	Regulatory Standard ^a
		(mg/L) ^b	(mg/L) ^c	(mg/L)
300 Area Spring DR 42-2	1	0.003	0.003	0.005
300 Area Spring 42-2	1	0.003	0.003	0.005
Hanford Townsite 25-4	1	0.003	0.003	0.005
100F Spring 107-1	1	0.003	0.003	0.005
100K Spring 63-1	1	0.003	0.003	0.005
100B Spring 39-2	1	0.003	0.003	0.005
100B Spring 38-3	1	0.003	0.003	0.005
^a EPA Drinking Water Regulation Standard = 0.005 mg/L (both constituents) ^b Maximum concentration reported was a non-detect. ^c Maximum concentration reported was a non-detect.				

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Table C-13. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site) (2013-2018). (2 Pages)

Sediment Location	Radionuclide	2018					2013-2017				
		No. of Samples	No. of Detects	Maximum Concentration ^a <i>pCi/g</i>			No. of Samples	No. of Detects	Average Concentration ^a <i>pCi/g</i>		
Adjacent to Locke Island	Cesium-137 ^b	2	0	6.56E-03	±	1.82E-02	5	0	1.02E-02	±	1.55E-02
	Plutonium-239/240 ^b	2	0	-1.08E-03	±	6.99E-03	5	0	2.20E-04	±	4.88E-03
	Uranium-234	2	2	1.26E+00	±	1.75E-01	5	5	1.30E+00	±	2.45E-01
	Uranium-235	2	2	1.87E-01	±	6.09E-02	5	5	9.67E-02	±	1.71E-02
	Uranium-238	2	2	1.15E+00	±	1.62E-01	5	5	1.25E+00	±	1.71E-02
Adjacent to Savage Island	Cesium-137	1	1	4.96E-02	±	3.28E-02	5	5	4.08E-02	±	1.62E-02
	Plutonium-239/240 ^b	1	0	-1.18E-03	±	7.67E-03	5	0	1.10E-04	±	7.83E-03
	Uranium-234	1	1	8.43E-01	±	1.24E-01	5	5	7.60E-01	±	2.99E-01
	Uranium-235	1	1	1.40E-01	±	4.67E-02	5	5	6.88E-02	±	3.17E-02
	Uranium-238	1	1	8.97E-01	±	1.29E-01	5	5	7.18E-01	±	2.08E-01
100-D Spring 102-1	Cesium-137	1	1	9.48E-02	±	4.49E-02	9	9	1.09E-01	±	2.08E-02
	Plutonium-239/240 ^b	1	0	5.41E-03	±	5.60E-03	9	3	2.85E-03	±	9.64E-03
	Uranium-234	1	1	5.32E-01	±	9.67E-02	9	9	5.06E-01	±	1.30E-01
	Uranium-235	1	1	4.81E-02	±	3.19E-02	9	9	5.19E-02	±	4.05E-02
	Uranium-238	1	1	4.91E-01	±	8.82E-02	9	9	4.94E-01	±	8.73E-02
100F Slough	Cesium-137	1	1	1.50E-01	±	2.79E-02	6	6	1.90E-01	±	4.88E-02
	Plutonium-239/240 ^b	1	0	3.29E-03	±	1.08E-02	6	2	1.31E-03	±	3.61E-03
	Uranium-234	1	1	5.54E-01	±	1.04E-01	6	6	5.74E-01	±	1.83E-01
	Uranium-235	1	1	5.80E-02	±	3.64E-02	6	6	5.76E-02	±	2.34E-02
	Uranium-238	1	1	4.51E-01	±	9.18E-02	6	6	5.31E-01	±	1.62E-01
100-H Spring 145-1	Cesium-137	1	1	1.98E-01	±	4.34E-02	3	3	1.36E-01	±	6.48E-02
	Plutonium-239/240 ^b	1	0	3.77E-03	±	1.04E-02	3	0	3.51E-03	±	2.47E-03
	Uranium-234	1	1	9.04E-01	±	1.57E-01	3	3	7.64E-01	±	2.19E-01
	Uranium-235	1	1	5.91E-02	±	4.38E-02	3	3	6.23E-02	±	5.22E-02
	Uranium-238	1	1	7.95E-01	±	1.43E-01	3	3	6.87E-01	±	1.98E-02

Table C-13. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site) (2013-2018). (2 Pages)

Sediment Location	Radionuclide	2018					2013-2017				
		No. of Samples	No. of Detects	Maximum Concentration ^a <i>pCi/g</i>			No. of Samples	No. of Detects	Average Concentration ^a <i>pCi/g</i>		
100-K Spring 63-1	Cesium-137	1	1	1.02E-01	±	3.11E-02	4	4	9.37E-02	±	5.34E-02
	Plutonium-239/240 ^b	1	0	-4.99E-03	±	7.23E-03	4	1	4.15E-03	±	5.09E-03
	Uranium-234	1	1	1.10E+00	±	1.59E-01	4	4	1.15E+00	±	2.18E-01
	Uranium-235	1	1	9.94E-02	±	4.30E-02	4	3	6.07E-02	±	2.55E-02
	Uranium-238	1	1	1.06E+00	±	1.51E-01	4	4	1.03E+00	±	2.52E-01
Hanford Slough	Cesium-137	1	1	2.45E-01	±	3.86E-02	7	7	2.37E-01	±	4.28E-02
	Plutonium-239/240	1	1	1.21E-02	±	7.96E-03	7	3	2.12E-03	±	4.61E-03
	Uranium-234	1	1	6.15E-01	±	1.12E-01	7	7	1.19E+00	±	2.37E+00
	Uranium-235	1	1	6.26E-02	±	3.42E-02	7	6	9.10E-02	±	1.55E-01
	Uranium-238	1	1	6.99E-01	±	1.18E-01	7	7	7.37E-01	±	3.42E-01
McNary Dam	Cesium-137	2	2	2.04E-01	±	3.62E-02	10	10	2.27E-01	±	5.50E-02
	Plutonium-239/240 ^b	2	0	-3.78E-03	±	9.08E-03	10	5	8.56E-03	±	5.02E-03
	Uranium-234	2	2	1.77E+00	±	2.46E-01	10	10	1.20E+00	±	1.62E-01
	Uranium-235	2	2	1.13E-01	±	4.93E-02	10	10	1.04E-01	±	6.60E-02
	Uranium-238	2	2	1.33E+00	±	1.99E-01	10	10	1.20E+00	±	1.62E-01
Priest Rapids Dam	Cesium-137	2	2	2.38E-01	±	5.89E-02	10	10	2.47E-01	±	5.61E-02
	Plutonium-239/240 ^b	2	0	9.56E-03	±	1.12E-02	10	9	1.08E-02	±	3.62E-03
	Uranium-234	2	2	1.39E+00	±	1.86E-01	10	10	1.28E+00	±	3.23E-01
	Uranium-235	2	2	1.33E-01	±	5.32E-02	10	10	9.85E-02	±	3.41E-02
	Uranium-238	2	2	1.16E+00	±	1.64E-01	10	10	1.14E+00	±	2.52E-01
White Bluffs Slough	Cesium-137	1	1	2.51E-01	±	4.32E-02	5	5	3.30E-01	±	1.05E-01
	Plutonium-239/240 ^b	1	0	3.22E-03	±	6.97E-03	5	2	4.21E-03	±	4.89E-03
	Uranium-234	1	1	9.01E-01	±	1.58E-01	5	5	9.66E-01	±	3.27E-01
	Uranium-235	1	1	1.36E-01	±	6.29E-02	5	5	8.44E-02	±	6.63E-02
	Uranium-238	1	1	8.39E-01	±	1.48E-01	5	5	9.06E-01	±	3.19E-01

^a Maximum Concentrations ± Analytical Uncertainty; Average Concentrations ± 2stdv.
^b Maximum value reported as a non-detect.

Table C-14. 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	4.71 - 4.81	0.508 - 5.65	3.69 - 4.28
Arsenic	6.18 - 8.36	2.89 - 13.5	7.37 - 8.34
Beryllium	0.601 - 0.647	0.16 - 1.59	1.69 - 2.08
Cadmium	3.07 - 6.43	0.148 - 1.47	1.30 - 1.46
Chromium	39.2 - 42.3	14.9 - 40.5	29.6 - 32.3
Copper	44.0 - 48.2	9.63 - 34.4	30.3 - 38.5
Lead	37.2 - 39.7	8.71 - 81.8	26.2 - 26.9
Mercury	0.114 - 0.132	0.005 - 0.047	0.089 - 0.092
Nickel	37.5 - 42.2	9.73 - 22.2	30.9 - 34.1
Selenium	3.51 - 4.07	0.503 - 2.29	1.12 - 1.30
Silver	0.285 - 0.292	0.127 - 0.385	0.224 - 0.588
Thallium	1.43 - 1.57	0.671 - 5.03	1.12 - 1.30
Zinc	343 - 471	70.9 - 438	235 - 258
No. of Samples	2	10	2
^a 100-F Slough (n=1), Hanford Slough (n=1), White Bluffs Slough (n=1), Adjacent to Locke Island (n=2), Adjacent to Savage Island (n=1), 100-H 145-1 (n=1), 100-D Spring 102-1 (n=1), 100-K 63-1 (n=1), 300 Area (n=1); where n = number of samples.			

Table C-15. Columbia River Hexavalent Chromium in Sediment Samples.

Location	No. of Samples	No. of Detects	2018 Max Concentration (ug/Kg)	No. of Samples	No. of Detects	2013-2017 Max Concentration (ug/Kg)
300 Area Spring DR 42-2 (shoreline)	1	1	4420	3	0	211
Adjacent to Savage Island (shoreline)	1	0	142	5	1	772
Hanford Slough	1	0	174	7	4	530
White Bluffs Slough	1	0	266	5	3	1700
100F Slough	1	0	122	6	3	461
100H Spring 145-1 (shoreline)	1	0	150	3	1	611
Adjacent to Locke Island (shoreline)	2	0	248	5	2	643
100D 102-1	1	1	591	9	9	5850
100K Spring 63-1 (shoreline)	1	1	144	4	3	2430
Priest Rapids Dam (Grant Side)	1	1	2670	5	1	2010
Priest Rapids Dam (Yakima Side)	1	0	2700	5	1	2870
McNary Dam (WA Side)	1	1	125000	5	1	1250
McNary Dam (OR Side)	1	1	88200	5	1	2470

Table C-16. Total Organic Carbon in Columbia River Sediment.

Sediment Location	2018				2013-2017		
	No. of Samples	Concentration ^a			No. of Samples	Concentration ^a	
		Minimum mg/kg	Maximum mg/kg			Minimum mg/kg	Maximum mg/kg
Adjacent to Locke Island ^{b,c}	0	N/A			1	1.17E+03	
Adjacent to Savage Island ^{b,c}	0	N/A			1	2.24E+03	
100-D Spring 102-1 ^c	1	3.95E+03			9	1.59E+03	4.35E+03
100-F Slough ^c	1	6.59E+03			6	1.43E+03	2.61E+03
100-H Spring 145-1 ^c	1	1.59E+04			3	7.25E+03	8.72E+03
100-K Spring 63-1 ^c	1	1.50E+04			4	1.40E+03	1.81E+04
300 Area DR 42-2 ^c	1	5.33E+03			3	1.77E+03	7.78E+03
Hanford Slough ^c	1	9.53E+03			7	5.29E+03	1.48E+04
McNary Dam	2	1.25E+04	1.85E+04		10	4.45E+03	2.52E+04
Priest Rapids Dam	2	1.86E+04			10	1.47E+04	3.95E+04
White Bluffs Slough ^c	1	1.14E+04			5	6.30E+03	1.68E+04
^a 1 mg/kg = ug/kg divided by 1000							
^b Adjacent to Locke and Savage Island sediment was analyzed for TOC in 2013 only.							
^c Only one sample was collected so minimum and maximum values are equivalent.							

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Table C-17. Irrigation Water Sample Results.																	
Radionuclide	2018									2013-2017							
	Number of		Average ^a (pCi/L)			Maximum ^b (pCi/L)				Number of		Average ^a (pCi/L)			Maximum ^b (pCi/L)		
	Samples	Detects								Samples	Detects						
Antimony-125	10	0	-1.6E-01	±	3.8E+00	2.2E+00	±	4.4E+00		34	0	5.4E-01	±	5.6E+00	8.0E+00	±	1.1E+01
Cesium-134	10	0	1.3E-01	±	3.1E+00	4.1E+00	±	2.7E+00		34	0	9.1E-02	±	2.5E+00	2.6E+00	±	2.6E+00
Cesium-137	10	0	5.6E-01	±	9.1E-01	1.4E+00	±	2.4E+00		34	0	1.8E-01	±	2.3E+00	2.5E+00	±	1.8E+00
Cobalt-60	10	0	6.2E-01	±	1.8E+00	2.4E+00	±	2.1E+00		34	0	6.5E-02	±	2.3E+00	3.9E+00	±	3.2E+00
Europium-152	10	0	-7.3E-01	±	4.6E+00	3.5E+00	±	5.1E+00		34	0	9.6E-02	±	5.9E+00	5.1E+00	±	6.9E+00
Europium-154	10	0	4.2E-02	±	3.6E+00	3.1E+00	±	4.1E+00		34	0	-1.2E-01	±	6.0E+00	4.0E+00	±	7.1E+00
Europium-155	10	0	3.6E+00	±	7.7E+00	9.2E+00	±	8.6E+00		34	0	5.3E-01	±	7.7E+00	8.1E+00	±	8.0E+00
Ruthenium-106	10	0	8.9E-01	±	1.9E+01	2.0E+01	±	2.0E+01		34	0	-1.6E+00	±	1.9E+01	1.7E+01	±	1.9E+01
Strontium-90	10	0	6.8E-03	±	3.2E-02	3.1E-02	±	2.7E-02		34	0	8.3E-03	±	4.5E-02	4.8E-02	±	3.7E-02
Tritium	10	5	1.5E+01	±	6.1E+00	2.0E+01	±	7.3E+00		34	33	2.6E+01	±	7.3E+01	2.3E+02	±	1.3E+02
^a Averages are ±2 standard deviations.																	
^b Maximum values are ± analytical uncertainty.																	

C.6 Vegetation Monitoring

Table C-18. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Vegetation Samples. (2 Pages)

Radionuclide	Hanford Area	2018								2013 - 2017							
		Number of		Average ^c (pCi/g)		Maximum ^d (pCi/g)		Location		Number of		Average ^c (pCi/g)		Maximum ^d (pCi/g)		Location	
		Samples	Detects ^b							Samples	Detects ^b						
²⁴¹ Am	200-W	7	2	2.2E-02	± 7.0E-02	1.1E-01	± 2.5E-02	V034		5	0	5.3E-03	± 6.6E-03	9.1E-03	± 7.9E-03	V007	
¹³⁷ Cs	100	2	0	1.6E-02	± 1.0E-02	2.1E-02	± 2.3E-02	Y724		12	0	6.4E-03	± 3.4E-02	3.4E-02	± 3.7E-02	Y724	
	200-E	7	0	1.9E-02	± 1.8E-02	3.7E-02	± 5.0E-02	V066		44	14	5.6E-02	± 2.4E-01	8.0E-01	± 5.9E-02	V076	
	200-W	16	0	1.1E-02	± 2.2E-02	3.7E-02	± 3.2E-02	V050		71	10	2.1E-02	± 4.8E-02	1.3E-01	± 3.4E-02	V301	
	300	2	0	2.4E-02	± 4.0E-02	4.4E-02	± 4.7E-02	V132		7	1	1.8E-02	± 3.6E-02	4.3E-02	± 4.8E-02	V132	
	400	1	0	9.0E-03 ^e		9.0E-03	± 2.0E-02	V130		5	0	1.1E-02	± 6.7E-02	7.7E-02	± 5.9E-02	V130	
	600	14	2	1.7E-02	± 3.1E-02	4.4E-02	± 3.0E-02	V090		54	4	1.5E-02	± 4.8E-02	1.3E-01	± 3.5E-02	V086	
²³⁸ Pu	100	2	0	-1.4E-10	± 3.3E-11	-1.2E-10	± 1.2E-09	Y719		10	0	-5.5E-04	± 2.0E-03	7.9E-04	± 6.7E-04	Y724	
	200-E	9	1	5.6E-03	± 8.6E-03	1.1E-02	± 8.1E-03	V060		41	1	2.3E-04	± 1.9E-03	3.3E-03	± 5.8E-03	V314	
	200-W	16	3	8.8E-03	± 2.0E-02	4.5E-02	± 1.4E-02	V034		70	5	1.5E-04	± 1.3E-03	3.6E-03	± 2.5E-03	V139	
	300	2	0	8.7E-04	± 1.7E-03	1.7E-03	± 6.4E-03	V132		7	0	3.2E-04	± 8.2E-04	1.1E-03	± 3.9E-03	V123	
	400	1	0	4.9E-03 ^e		4.9E-03	± 7.8E-03	V130		4	0	-1.6E-04	± 9.2E-04	2.8E-04	± 3.5E-04	V130	
	600	14	0	2.1E-03	± 8.3E-03	8.8E-03	± 1.2E-02	V092		53	0	-8.4E-06	± 1.7E-03	2.6E-03	± 2.6E-02	V083	
^{239/240} Pu	100	2	0	1.1E-03	± 2.2E-03	2.2E-03	± 3.8E-03	Y719		9	1	3.0E-04	± 2.3E-03	2.1E-03	± 1.0E-03	Y719	
	200-E	9	1	3.8E-03	± 7.6E-03	9.9E-03	± 8.5E-03	V060		43	9	7.7E-04	± 2.1E-03	5.2E-03	± 5.2E-02	V310	
	200-W	17	6	4.9E-02	± 2.9E-01	6.3E-01	± 7.8E-02	V034		72	50	2.9E-03	± 8.5E-03	2.1E-02	± 2.0E-03	V048	
	300	2	0	-3.5E-03	± 6.9E-03	6.2E-10	± 6.2E-09	V123		7	0	6.6E-04	± 3.1E-03	4.4E-03	± 5.5E-03	V123	
	400	1	0	-9.9E-04 ^e		-9.9E-04	± 8.0E-03	V130		5	0	8.7E-04	± 2.9E-03	3.7E-03	± 4.3E-03	V130	
	600	14	0	2.1E-03	± 1.0E-02	9.7E-03	± 9.0E-03	V098		54	12	3.8E-04	± 2.1E-03	3.0E-03	± 3.0E-02	V319	
⁹⁰ Sr	100	2	2	1.6E+00	± 3.6E-01	1.8E+00	± 3.4E-01	Y724		12	11	6.0E-01	± 1.0E+00	1.4E+00	± 2.8E-01	Y724	
	200-E	9	1	2.5E-02	± 1.1E-01	1.8E-01	± 4.5E-02	V064		44	20	1.4E-01	± 3.9E-01	8.2E-01	± 1.8E-01	V063	
	200-W	17	1	8.6E-03	± 4.5E-02	7.8E-02	± 3.7E-02	V044		72	11	4.6E-02	± 2.0E-01	5.3E-01	± 2.0E-01	V302	
	300	2	0	-9.0E-03	± 4.4E-03	-6.9E-03	± 2.6E-02	V132		7	2	1.5E-01	± 5.9E-01	8.4E-01	± 1.9E-01	V123	
	400	1	0	3.1E-03 ^e		3.1E-03	± 1.5E-02	V130		5	0	3.2E-02	± 1.2E-01	1.5E-01	± 1.7E-01	V130	
	600	14	0	3.2E-03	± 2.8E-02	3.0E-02	± 2.0E-02	V094		55	8	3.7E-02	± 1.8E-01	4.2E-01	± 1.8E-01	V081	
²³⁴ U	100	2	1	1.4E-02	± 1.0E-03	1.5E-02	± 8.1E-03	Y719		12	8	3.8E-02	± 9.8E-02	1.8E-01	± 1.4E-01	Y724	
	200-E	9	6	2.0E-02	± 1.5E-02	3.2E-02	± 1.8E-02	V060		44	34	5.6E-02	± 1.7E-01	3.6E-01	± 1.8E-01	V315	
	200-W	17	10	1.4E-02	± 1.4E-02	2.8E-02	± 1.3E-02	V004		72	48	3.0E-02	± 1.3E-01	3.4E-01	± 1.7E-01	V305	
	300	2	1	1.6E-02	± 1.1E-02	2.1E-02	± 1.1E-02	V123		7	6	3.5E-02	± 3.8E-02	7.9E-02	± 9.5E-02	V123	
	400	1	1	2.1E-02 ^e		2.1E-02	± 1.3E-02	V130		5	4	2.0E-02	± 2.0E-02	3.6E-02	± 1.2E-01	V130	
	600	14	9	1.8E-02	± 1.4E-02	2.6E-02	± 1.4E-02	V102		55	40	2.7E-02	± 9.1E-02	1.4E-01	± 4.7E-02	V108	
²³⁵ U	100	2	2	9.7E-03	± 4.7E-03	1.2E-02	± 7.4E-03	Y724		12	3	1.4E-02	± 2.2E-02	4.4E-02	± 1.1E-01	Y724	
	200-E	9	2	7.5E-03	± 1.3E-02	2.0E-02	± 1.4E-02	V060		44	26	2.7E-02	± 8.2E-02	1.6E-01	± 1.3E-01	V062	

Table C-18. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Vegetation Samples. (2 Pages)

Radionuclide	Hanford Area	2018									2013 - 2017								
		Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location	Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location
		Samples	Detects ^b								Samples	Detects ^b							
²³⁸ U	200-W	17	6	9.4E-03	±	8.9E-03	2.1E-02	±	1.0E-02	V004	66	21	1.1E-02	±	9.8E-02	1.6E-01	±	1.2E-01	V304
	300	2	2	1.0E-02	±	1.8E-03	1.1E-02	±	7.0E-03	V132	7	2	5.1E-03	±	2.9E-02	2.3E-02	±	1.2E-02	V123
	400	1	0	8.4E-03 ^e			8.4E-03	±	1.0E-02	V130	5	1	2.3E-02	±	6.6E-02	8.9E-02	±	1.1E-01	V130
	600	14	13	1.5E-02	±	1.0E-02	2.4E-02	±	1.3E-02	V094	54	20	9.8E-03	±	6.7E-02	7.7E-02	±	3.9E-02	V108
	100	2	1	8.6E-03	±	5.3E-03	1.1E-02	±	7.5E-03	Y724	12	7	2.8E-02	±	5.9E-02	1.0E-01	±	1.2E-01	Y724
	200-E	9	6	1.6E-02	±	1.3E-02	3.0E-02	±	1.7E-02	V054	44	29	3.6E-02	±	7.2E-02	1.4E-01	±	1.3E-01	V312
²³⁸ U	200-W	16	8	1.4E-02	±	1.2E-02	2.7E-02	±	1.1E-02	V004	72	43	1.8E-02	±	7.1E-02	1.4E-01	±	1.1E-01	V304
	300	2	2	1.6E-02	±	7.1E-03	1.9E-02	±	9.3E-03	V123	7	7	3.8E-02	±	6.9E-02	1.2E-01	±	1.1E-01	V123
	400	1	0	1.2E-02 ^e			1.2E-02	±	1.1E-02	V130	5	2	9.9E-03	±	8.2E-03	1.8E-02	±	7.9E-02	V130
	600	14	12	1.6E-02	±	1.1E-02	2.4E-02	±	1.3E-02	V094	54	34	1.9E-02	±	9.8E-02	1.6E-01	±	2.5E-01	V308
^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 Standard deviation cannot be calculated for one sample.																			

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C.7 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.

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>.

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Appendix D. Dose Calculations

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D.0 Dose Calculations

AG Fleury, R Perona, C Schaupp

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 2018 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.28 mrem (2.8 μ Sv). This dose is 0.28% of the 100 mrem (1000 μ Sv)/yr 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 2018 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)¹ 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 years) internal exposure from radionuclides absorbed into the body during the current year. The committed effective dose equivalent is the sum of individual committed (50 years) organ doses multiplied by tissue weighting factors (ICRP 1991) that represent the contribution of each organ or tissue to a person's internal radiation dose. Internal organs also may be irradiated from external sources of radiation. The external exposure received during the current year is added to the committed internal dose to obtain the total effective dose.

Releases of radionuclides from Hanford Site facilities are frequently too small for their concentrations to be accurately measured in many of the offsite environmental media of interest. Even when present in measurable 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

¹ 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

radionuclide concentrations were estimated from stack effluent measurements (air pathway doses) or river water measurements (water pathway doses) by using environmental transport models. The air dose calculations employ environmental transport modeling based on measurements made at the points of release (stacks and vents). The water pathway dose calculations are based on the difference in measurements of radionuclide concentrations in the Columbia River upstream and downstream of the Hanford Site.

The transport of radionuclides in the environment to points of exposure is predicted using mathematical models of the physical processes underlying the various exposure pathways. 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 2.10.2* (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 2.10.2 was used for the 2018 dose calculations. 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* 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-220 and radon-222) 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 and off DOE sites
 - 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/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 (e.g., 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 2018 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 air emissions sources), Sagemoor (300 Area air emissions sources), Horn Rapids Road (300 Area air emissions sources, plus drinking water pathway dose), and Riverview (300 Area air emissions sources, plus drinking water pathway dose).

For 2018, air pathway radiological dose calculations conducted using CAP-88PC in support of the *Clean Air Act* requirements and GENII Version 2.10.2 have identified 638 Horn Rapids Road (with CAP-88PC, the nearby the Pacific Northwest National Laboratory [PNNL] Laboratory Support Warehouse) 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 2018 are not very different (0.24 mrem/yr at Sagemoor and 0.28 mrem/yr at Horn Rapids Road). Unlike the Sagemoor receptor, the MEI at Horn Rapids Road receives additional dose from the drinking water pathway, although this pathway contributed only 0.01 mrem to the total. A comparison of Sagemoor and Horn Rapids Road MEI GENII results are shown in Section 4.0, Figure 4.4.

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 Area: 7.92 km Easting, -7.92 km Northing

D.1.1.2 Water and Air Release Inputs Used In GENII Version 2.10.2. As discussed in Section 4.2, the environmental data needed to perform the GENII Version 2.10.2 dose calculations for the water pathway are the measured upstream and downstream radionuclide concentrations in the Columbia River. As discussed below, radionuclide releases to the Columbia River that are calculated as the difference between annual-average downstream and upstream concentrations. 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 2018. 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 (samples collected at the Richland Pumphouse, sampling location label RICH.PMPHS HRM46.4) and upstream of the Hanford Site (samples collected at a location below the Priest Rapids Dam, sampling location label PRIEST RAPIDS-RIVER). Radionuclides are measured in both filtered samples (in solution) and in samples that capture suspended particulates (adhered to a resin). These data for dissolved and particle-bound radionuclides were evaluated both separately and summed.

The river water samples used in the GENII dose assessment are based on continuous sampling of river water. A continuous sampler collects 55-mL water samples at 1-hr intervals. These samples are composited bimonthly and then combined for a single monthly composite that is submitted for laboratory analysis (DOE/RL-2017-24). As discussed in Section 4.2.1.1, the Richland Pumphouse sampling station continuous water sampler failed in August 2017 and a new continuous sampler was not put online until July 2018. Water samples for the period of January through June 2018 were instead collected as 0.5-gal (2-L) grab samples. Because the continuous sampler provides a more representative measure of river concentrations over time than a single grab sample, there is a higher degree of uncertainty in the representativeness of the 2018 Richland Pumphouse sampling station water data than would be the case if all samples had been acquired with the continuous sampler.

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 uranium-238 as potential Hanford-related contaminants to include in the 2018 water pathway dose assessment using a p-value of 0.05. Statistical tests could not be reliably conducted for gamma-emitting radionuclides and isotopic plutonium, analytes that are commonly present in forms that are relatively insoluble (antimony-125, beryllium-7, cesium-134, cesium-137, cobalt-60, isotopic europium, isotopic plutonium, potassium-40, and ruthenium-106). With the continuous flow sampler, these radionuclides are sampled by passing water through a filter to trap particulates and subsequently through a resin column to trap radionuclides in solution. The minimum detectable activity of these analytes in the grab samples was considerably larger than was the case for the continuous samples. In 2018, none of these insoluble radionuclides were detected in any grab sample, and only potassium-40 was detected in any of the downstream Richland Pumphouse samples. Potassium-40 is a primordial radionuclide (half-life of approximately 1.25×10^9 years) that is naturally occurring and has no known Hanford-related sources. Therefore, although the use of grab samples resulted in a reduced ability to detect low concentrations of these radionuclides for part of 2018, review of the 2018 continuous water sample data indicates that these radionuclides were not present at concentrations between the detectable activities of the two sample methods.

Table D-1 summarizes the mean annual differences in downstream and upstream concentrations, and calculated annual releases for the 2018 GENII water pathway dose calculations.

Table D-1. 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	2.7E+01	1.2E+01
Uranium-234	2.7E-01	3.1E-01	4.0E-02
Uranium-238	2.1E-01	2.5E-01	4.0E-02
<i>Calculated Radionuclide Releases (Ci/year)^b</i>			
Tritium	NA ^c	NA ^c	1.46E+03
Uranium-234	NA ^c	NA ^c	3.8E+00
Uranium-238	NA ^c	NA ^c	4.4E+00
^a 1 pCi=0.037 Bq ^b Calculated as the product of the difference in downstream and upstream radionuclide concentrations and the 2018 annual-average river flow rate of 3,755 m ³ /sec at Priest Rapids Dam. ^c Radionuclide releases calculated based on difference between annual-average downstream and upstream concentrations. NA = not applicable			

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 were also made on emissions from each operating area. Following the precedent of DOE/RL-2018-05, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2017*, 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 were 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-2. 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 ^a	NA ^a	82.5	NA ^a
Hydrogen-3 (tritiated water vapor)	NA ^a	NA ^a	252	0.016
Carbon-14	NA ^a	NA ^a	1.1E-04	NA ^a
Sodium-22	NA ^a	NA ^a	NA ^a	2.1E-10
Cobalt-60	NA ^a	NA ^a	7.7E-08	NA ^a
Krypton-85	NA ^a	NA ^a	1.1E-06	NA ^a
Stontium-90	1.8E-05	7.8E-06	1.8E-07	NA ^a
Yttrium-90 ^a	2.7E-06	1.2E-06	2.7E-08	--
Technetium-99	NA ^a	NA ^a	4.2E-06	NA ^a
Ruthenium-106	NA ^a	NA ^a	3.0E-09	NA ^a
Iodine-129	NA ^a	1.3E-03	NA ^a	NA ^a
Cesium-137 ^b	6.1E-05	3.3E-05	5.0E-06	3.1E-06
Barium-137m ^{b, c}	6.1E-05	3.3E-05	5.0E-06	3.1E-06
Europium-152	NA ^a	NA ^a	2.0E-09	NA ^a
Europium-154	NA ^a	NA ^a	2.2E-08	NA ^a
Europium-155	NA ^a	NA ^a	NA ^a	NA ^a
Gadolinium-153	NA ^a	NA ^a	3.7E-10	NA ^a
Radon-219	NA ^a	NA ^a	559	NA ^a
Lead-211 ^c	--	--	1.0	--
Bismuth-211 ^c	--	--	0.17	--
Thallium-207 ^c	--	--	7.8E-03	--
Radon-220	NA ^a	NA ^a	885	NA ^a
Lead-212 ^c	--	--	1.3	--
Bismuth-212 ^c	--	--	1.1	--
Radon-222	NA ^a	NA ^a	NA ^a	NA ^a

Table D-2. Air Pathway Radionuclide Stack Emissions for GENII Modeling. (2 Pages)

Radionuclide	100 Area	200 Areas	300 Area	400 Area
	(Curies)			
Polonium-218 ^c	--	--	--	--
Lead-214 ^c	--	--	--	--
Bismuth-214 ^c	--	--	--	--
Radium-226	NA ^a	NA ^a	3.6E-10	NA ^a
Actinium-227	NA ^a	NA ^a	2.1E-10	NA ^a
Uranium-232	NA ^a	NA ^a	8.5E-09	NA ^a
Uranium-233	NA ^a	NA ^a	1.9E-08	NA ^a
Neptunium-237	NA ^a	NA ^a	1.4E-08	NA ^a
Plutonium-238	1.1E-06	5.0E-08	3.7E-08	NA ^a
Plutonium-239/240 ^e	3.1E-05	6.5E-06	1.6E-07	5.6E-07
Plutonium-241	2.8E-05	NA ^a	3.8E-07	NA ^a
Americium-241	8.3E-06	8.0E-07	2.2E-09	NA ^a
Americium-243	NA ^a	NA ^a	1.6E-07	NA ^a
Neptunium-239 ^e	--	--	2.7E-08	--
Curium-243/244	NA ^a	NA ^a	NA ^a	NA ^a
(gross alpha)	2.4E-05	4.8E-06	1.5E-07	5.6E-07
(gross beta)	5.0E-05	2.9E-05	4.9E-06	3.1E-06

^a No stack emissions reported for this radionuclide.
^b Values include the addition of gross beta activity.
^c These short-lived radionuclides will ingrow during air dispersion to offsite locations and contribute to inhalation dose. Values are the highest activity calculated within an upper bound 15-hr dispersion time period to any exposure point within a 50-mi (80-km) distance.
^d Separate stack emission estimates were not reported for this short-lived radionuclide.
^e Values include the addition of gross alpha activity.
-- = Separate stack emission measurements are not made for this short-lived radionuclide.
NA = Not available or not detected.

D.1.1.3 Exposure Parameter Values Used in GENII Version 2.10.2. GENII Version 2.10.2 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 2.10.2. GENII Version 2.10.2 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 2018 meteorological data used in the GENII air dispersion modeling were gathered at monitoring stations in the 100 Area (station 29 100-K), 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 200 Areas, where some active stacks are 200 ft (61 m) in height, the meteorological data used were collected at 200 ft (61 m).

Hourly meteorological data from the monitoring stations described above were formatted for use in the GENII computer code. Four meteorological files were created, one for each of the Hanford Site operating areas and stations described above. 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 in Section D.1.1.1. 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 conform to DOE environmental protection policies and to 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.

Table D-3. Agricultural Pathway Parameters for Hanford Site Dose Calculations.

Medium	Vegetables		Fruit s	Cereal s	Eggs	Poultr y	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	NA ^c	NA	NA	NA	NA	103	103	NA ^c
Irrigation period; month	6	6	6	NA ^c	NA	NA	NA	NA	6	6	NA ^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 surface water. ^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-4. 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 hours 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.
MEI = maximally exposed individual

Table D-5. 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 (groundshine)	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 hours is protectively assumed for ingrowth of short-lived progeny during transport (50 mi [80 km]) population dose radius and 4.9 ft/sec (1.5 m/sec) wind speed.

Table D-6. 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 hours 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.

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 Cities² 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.

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)/yr. 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:

$$\text{Population dose (person-rem)} = \text{MEI dose (mrem)} \times 0.001 \text{ rem/mrem} \times (\text{annual catch [kg/yr]}/\text{IR_fish [kg/yr/person]}), \text{ where MEI dose=fish ingestion dose for the MEI; annual catch=15,000 kg fish/yr; IR_fish=individual fish ingestion rate used in the MEI calculation (40 kg/yr/person)}$$

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 (PNNL-20631). 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 4 cardinal, 4 ordinal, and 8 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 (1.6, 3.2, 4.8, 6.4, 8, 16, 32.1, 48.2, 64.3 and 80.4 km). These radii correspond to the downwind distances specified in the GENII Chronic Plume Air Module. Population files

² The Cities of Pasco, Kennewick, and Richland—known as the Tri Cities—are located in southeastern Washington State. Population estimates are based on the 2010 census, from <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.

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 2018 radionuclide concentrations in water, sediment, soil, and tissues to see if they exceeded the established biota concentration guides. Biota concentration guides (BCGs) 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/day for aquatic biota or 0.1 rad/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-7. Biota Concentration Guides and Sediment to Water Distribution Coefficients.

Radionuclide	Water (pCi/L) ^a	Limiting Organism	Sediment (pCi/g) ^a	Limiting Organism	Default K _d (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 K_d=Sediment to Water Distribution Coefficients (mL/g) from RESRAD-BIOTA v1.8.
 RESRAD = RESidual RADioactivity

Table D-8. 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 the following:

- 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 Townsite (sediments from Hanford slough, Savage Island, and Locke Island; river water; and seep water from Hanford Spring)
- The 300 Area (river water and springs)
- Downstream (sediments from McNary Dam and river water from the Richland Pump house station).

Table D-9. Maximum Detected Concentrations Evaluated for Aquatic Biota Dose Assessment. (2 Pages)

Location Group	Radionuclide	Maximum Sediment (pCi/g) ^a	Maximum Water (pCi/L) ^a
Upstream	Hydrogen-3	—	17.353
	Cesium-137	0.238	—
	Plutonium-239/240	—	—
	Uranium-234	1.39	0.286

Table D-9. Maximum Detected Concentrations Evaluated for Aquatic Biota Dose Assessment. (2 Pages)

100 Area	Uranium-235	0.133	0.0263
	Uranium-238	1.16	0.25
	Hydrogen-3	—	2650
	Carbon-14	—	130
	Strontium-90	—	80.2
	Technetium-99	—	4.9
	Cesium-137	0.251	—
	Plutonium-238	—	—
	Plutonium-239/240	—	—
	Uranium-234	1.1	1.04
	Uranium-235	0.136	0.0523
	Uranium-238	1.06	0.813
Hanford Townsite	Hydrogen-3	—	22700
	Cesium-137	0.245	—
	Plutonium-238	0.0141	—
	Uranium-234	1.26	0.306
	Uranium-235	0.187	0.0208
	Uranium-238	1.15	0.0586
300 Area	Hydrogen-3	—	2790
	Cesium-137	0.0974	—
	Uranium-234	1.16	17.1
	Uranium-235	0.0624	1.475 ^b
	Uranium-238	1.01	16.4
Downstream	Hydrogen-3	—	19.213
	Cesium-137	0.204	—
	Uranium-234	1.77	0.325
	Uranium-235	0.113	0.0468
	Uranium-238	1.33	0.251

^a 1 pCi = 0.037 Bq

^b Uranium-236 was added to the uranium-235 value due to the lack of available BCGs for uranium-236 in RESRAD-BIOTA v1.8. These radionuclides have similar K_d values and emissions and thus would have similar calculated BCGs.

— = Not detected or not measured

K_d = Water to Sediment Distribution Coefficients (mL/g) from RESRAD-BIOTA v1.8

BCG = Biota Concentration Guide

RESRAD = RESidual RADioactivity

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-10. West Lake 2018 Water and Sediment Samples.

Radionuclide	Water Concentration (pCi/L) ^a		Sediment Concentration (pCi/g) ^a	
	Maximum	Average	Maximum	Average
Hydrogen-3	—	—	—	—
Strontium-90	—	8.55	0.352	0.257
Cesium-137	650	650	—	3.25
Uranium-234	—	1.581	0.877	0.791
Uranium-235	546	398	4.74	2.88
Uranium-238	27.6	17.9	0.259	0.163
^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 a highly protective generic factor for estimating accumulation in biota. The isotopic ratios of uranium indicate a natural source and no uranium-236 was detected, albeit some minor amounts of depleted uranium may be present (PNL-7662). 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 most 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 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 in annual reports since that date. 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-11. 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 BCG = Biota Concentration Guide RESRAD = RESidual RADioactivity				

Dose to terrestrial biota were evaluated using the onsite soil sample results. Note that offsite soil samples are collected every 3 to 5 years and are scheduled for collection in 2019. Table D-12 lists the maximum concentrations of strontium-90, cesium-137, plutonium-238, plutonium-239/240, uranium-234, uranium-235, uranium-238, and americium-241. 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-12. Maximum Detected Concentrations Evaluated in 2018 for the Terrestrial Biota Dose Assessment.

Location Group	Radionuclide	Maximum Soil Concentration (pCi/g) ^a
Onsite	Strontium-90	2.21
	Cesium-137	17.7
	Uranium-234	1.450
	Uranium-235	0.162
	Uranium-238	1.350
	Plutonium-238	0.029
	Plutonium-239/240	1.140
	Americium-241	0.240
^a 1 pCi=0.037 Bq.		

D.3 References

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