Mission Support Alliance
Post Office Box 650
Richland, Washington 99352

September 22, 2020

MSA-2003252
CONTRACT NO. DE-AC06-09RL14728

Mr. Timothy E. Corbett, Contracting Officer
U.S. Department of Energy
Richland Operations Office
Procurement Division
Post Office Box 550
Richland, Washington 99352

Dear Mr. Corbett:

RL APPROVAL - CONTRACT DELIVERABLE CD0063, "HANFORD ANNUAL SITE ENVIRONMENTAL REPORT"

In accordance with MSC Section C.2.1.8.3, "Environmental Surveillance," attached is contract deliverable CD0063, "Hanford Annual Site Environmental Report." As required by DOE Order 231.1B, the Annual Site Environmental Report (ASER) for calendar year (CY) 2019 must be submitted to Mr. G. S. Podonsky, Chief Health, Safety and Security Officer, Office of Health, Safety and Security, and made available to the public by October 1, 2020. The report is available to the public on the MSA external web page at http://msa.hanford.gov/page.cfm/EnvironmentalReports2011-latest.

MSA prepared the *Hanford Site Environmental Report for Calendar Year 2019* (DOE/RL-2019-33) in accordance with DOE O 231.1B, *Environment, Safety and Health Reporting*. The 2019 report includes contributions from RL; DOE Office of River Protection; Bechtel National, Inc.; CH2M HILL Plateau Remediation Company; MSA; Pacific Northwest National Laboratory; and Washington River Protection Solutions, LLC. The report is the principal document for reporting annual site environmental and operating performance information that demonstrates the Hanford Site's compliance with DOE O 458.1, Change 3, *Radiation Protection of the Public and the Environment,* requirements for CY 2019. The report is also a DOE resource for communicating environmental protection performance information to the public, regulators, stakeholders, and other interested parties living near the Hanford Site.

Approval of CD0063, "Hanford Annual Site Environmental Report," is requested within 90 days of receipt of this letter, in accordance with MSC Section J-11.1.

Technical questions should be directed to M. B. Wilson at 376-1667, and contractual questions should be directed to me at 376-0381.

Sincerely,

Robert H. Miller, Director
Prime Contracts and Program Controls

jmk:ljm

Attachment

RL –	K. C. Barott-Wolff	ORP –	L. A. Huffman
	S. R. Einan		
	T. W. Ferns	BNI –	R. D. Haggard
	J. R. Franco		
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Electronically Approved by:

UserName: SKELTON MARY (h0096083)
Title:
Date: Tuesday, 22 September 2020, 03:58 PM Pacific Daylight Time
Meaning: Signed per Direction of the MSC President's Office
==========

MSA-2003252
CONTRACT NO. DE-AC06-09RL14728

ATTACHMENT

Contract Deliverable CD0063
September 2020

HANFORD ANNUAL SITE ENVIRONMENTAL REPORT
DOE/RL-2020-26, Revision 0

Consisting of 523 pages,
including this cover page

DOE/RL-2020-26
REV 0

Hanford Annual Site Environmental Report For Calendar Year 2019

Prepared for the U.S. Department of Energy

Springtime vegetation on Umtanum Ridge, overlooking the Hanford Site. The rocky basalt provides unique habitat for wildlife and a number of rare plant species.

DOE/RL-2020-26, Rev. 0

Hanford Annual Site Environmental Report for Calendar Year 2019

September 2020

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

APPROVED
By Lynn M. Ayers at 6:11 am, Sep 16, 2020

Release Approval/Date

Approved for Public Release
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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 2019* 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 of 1954* (AEA). In some cases, other federal agencies such as the Council on Environmental Quality, U.S. Environmental Protection Agency (EPA), and U. S. Fish and Wildlife Service have authority to regulate activities pursuant to the *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 (Ecology) and Washington State Department of Health (WDOH) 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 mi^2 (1,505 km^2) 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.

The primary mission of the Hanford Site shifted from production to cleanup with the signing of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement [TPA]) in 1989 (Ecology et al. 1989) by the Ecology, EPA, and DOE (collectively, TPA agencies). 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 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 mi^2 (777 km^2) 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 manages programs, goals, and objectives at the Hanford Site. DOE chartered the Pacific Northwest Site Office 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 one of ten DOE national laboratories in the Office of Science.

From 1989 through 2019, a total of 1,349 TPA milestones were completed and 343 target dates were met. During 2019, 25 specific cleanup milestones were scheduled for completion; of those, 2 milestones were deleted, 18 milestones were completed on time, 5 milestones were being disputed, and zero milestones were in negotiation. In addition, two target dates were met, zero target dates were deleted or disputed, and there were no target dates were in negotiation.

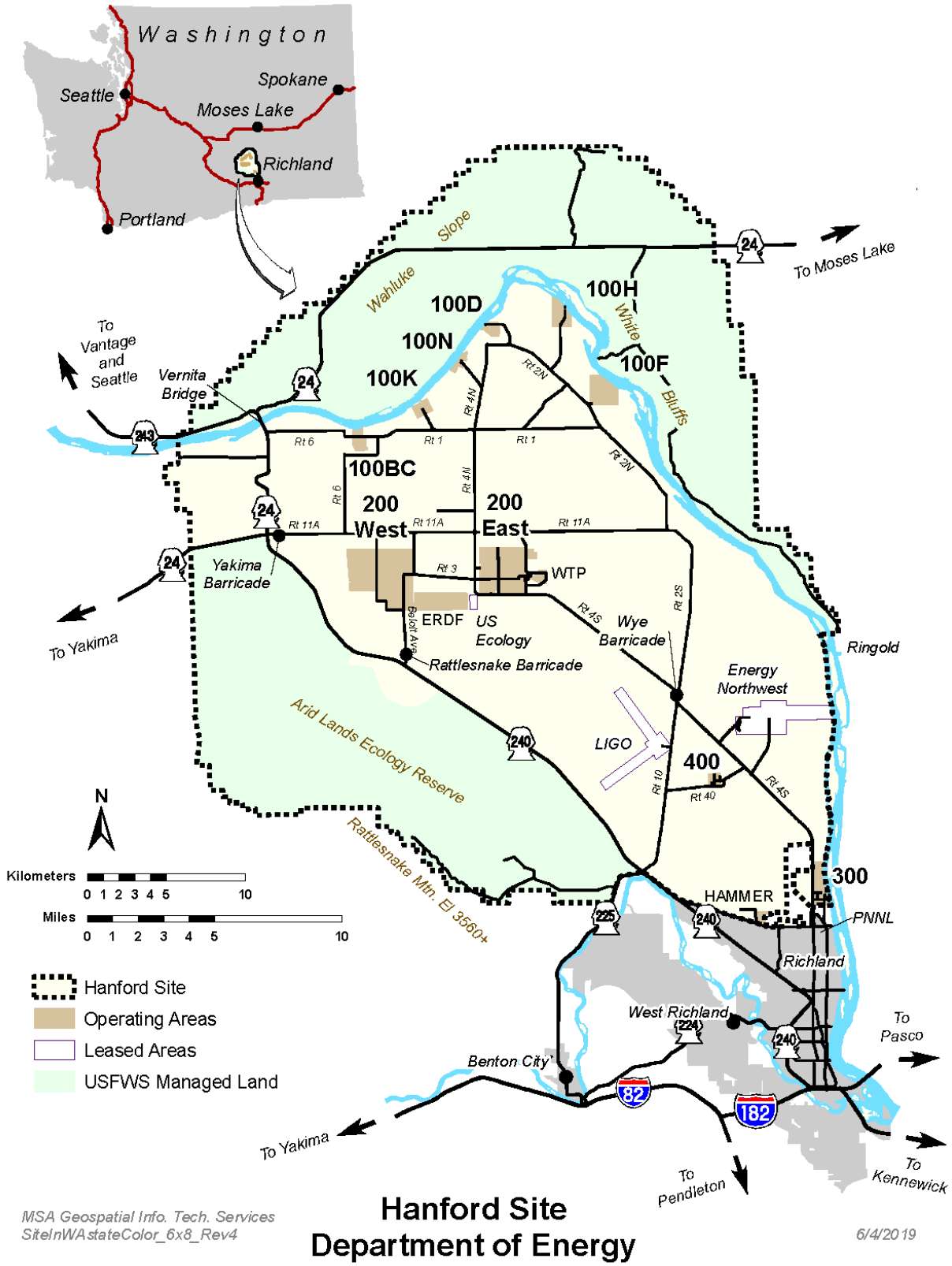

Figure ES-1. Location of the Hanford Site.

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, WDOH, City of Richland, and the Benton Clean Air Agency. The EPA and Ecology are the two main agencies who oversee Hanford Site cleanup as part of the TPA. In addition, the Defense Nuclear Facilities Safety Board provides oversight of DOE work. Congress created the Defense Nuclear Facilities Safety Board 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.

Hazardous Material and Waste Management

During fiscal year (FY) 2019, 90 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. The General -Inspections were conducted by Hanford Site contractors with DOE oversight. Agency inspections at Hanford are occasionally conducted jointly between multiple agencies.

The Ecology inspections focused on treatment, storage, and disposal (TSD) unit compliance with the *Hanford Facility Dangerous Waste Permit* (Ecology 1994) and WAC 173-303, "Dangerous Waste Regulations." Generator activities, waste accumulation, and universal waste management areas were also inspected. During 2019, permit modifications were processed to change requirements for TSD units pursuant to WAC 173-303-830, "Permit Changes."

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.

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.

National Environmental Policy Act of 1969

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 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. Proposed actions are evaluated to determine whether an Environmental Impact Statement (EIS) or Environmental Assessment is required, or the proposed action is categorically excluded (CX) from preparation of an EIS or Environmental Assessment.

During CY 2019, there were no EISs completed or underway. The EA for rebuild of the Benton-Othello switching station 115-kV transmission line on the Hanford Site was completed and a Finding of No Significant Impact was issued; therefore, an EIS is not required. A total of 49 CXs were approved by the DOE NEPA Compliance Officer. These included 36 annual CXs for recurring maintenance activities and 13 activity-specific CXs for non-routine construction projects.

Radiation Protection Statues, Regulations, and Directives

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, at 0.16 mrem during 2019. 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.

Air Quality Statutes and Regulations

In 2019, 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 2019, regulatory agencies conducted 44 *Clean Air Act* inspections on the Hanford Site.

Water Quality Permits, Statutes, and Regulations

The Ecology state waste discharge permits, all held by DOE, were in effect during 2019: 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 2019: WAG-50-5180 and WAG-50-5181.

Natural and Cultural Resources

There were 100 ecological compliance reviews requested during FY 2019 from 17 functional departments on the Hanford Site. Of the 17 functional departments, those with a significant number of requests include Soil and Groundwater (16), Reliability Services (12), Remediation (10), Water and Sewer Utilities (10), and Electrical Utilities (6).

Sustainability

The Hanford Site maintains a pollution prevention and waste minimization program that contributes to the achievement of sustainability goals. The Hanford Site continued diversion of non-hazardous solid waste. In 2019, a total of 1,125 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 gas emissions. There was a 39% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2019 from the FY 2008 baseline; emissions in FY 2019 were 25,234.2 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.

Occurrence Reporting and Processing of Operations Information

Per DOE O 232.2A, *Occurrence Reporting and Processing of Operations Information*, and associated Supplemented Contractor 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 2019, there were 29 documented occurrences of legacy contamination.

Environmental Permits

During 2019, permit modifications were processed to change requirements for TSD units pursuant to WAC 173-303-830, "Permit Changes."

Environmental Enforcement Actions

During 2019 there were 10 regulatory agency compliance actions filed against the DOE and its contractors for alleged violations of regulatory requirements or other enforceable agreements. Ten compliance actions were issued by Ecology. Nine compliance actions resulted from regulatory agency inspections of DOE facilities on the Hanford Site (Section 2.1.2.2). The inspection reports also contained 24 concerns.

During CY 2019, there were 18 non-compliances reported to regulatory agencies for wastewater permit deviations. Two of the events involved Large Onsite Sewage System permits and 16 involved State Waste Discharge Permits. In all cases, action was taken to repair and correct the non-compliant conditions; regulatory notifications were made in accordance with permit requirements.

ES.3 Section 3, Environmental Management System

Environmental management performance measure objectives for 2019 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, and sanitary waste reduction. The targets for renewable electric energy, sanitary waste reduction, and alternative fuel vehicle acquisitions were not met in 2019. The target objectives for potable and non-potable water, facility fuel, facility energy, and Electronic Product Environmental Assessment Tool acquisitions were met in FY 2019.

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 2019 monitoring efforts are provided below.

External Radiation Monitoring

External radiation fields were monitored in 2019 at 122 locations on and off the Hanford Site. 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 2019 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 2019.

Personal Property. An estimated 37,000 items of personal property were surveyed for residual radioactivity during 2019. 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 2019.

Granular Activated Carbon for Offsite Shipment and Regeneration. Four containers, approximately 80,000 lb (36,300 kg) of granular-activated carbon, were shipped offsite in 2019 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 2019 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 2019 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 2019 from Hanford Site operations was 0.16 mrem (1.6 µSv), which is 0.16% of the 100 mrem (1,000 µSv) 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 1.4 person-rem (0.014 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. An onsite annual dose of up to 0.074 mrem (0.74 µSv) was calculated for ingestion of Hanford Site drinking water based on samples from the 400 Area, where water is supplied by groundwater wells. Onsite annual doses were also calculated for workers and visitors to the Manhattan Project National Historical Park, including B Reactor, Hanford Townsite and White Bluffs Bank tour locations. Up to 0.036 mrem (0.36 µSv) could be received at B Reactor. Like the offsite MEI dose, these calculated doses were far below the public dose limit. Due to a lack of site-related radionuclides detected at levels greater than analytical minimum detectable activities in muscle tissue samples of game animals and fillet samples of fish, there was no basis for a quantitative dose screening of the outdoor recreationalist based on the 2019 wildlife data collected from the Hanford Site.

To place this information into perspective, Hanford-related 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 µSv), 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 2019 cleanup and remediation activities at the Hanford Site.

River Corridor Closure

Hanford's River Corridor, which borders the Columbia River, includes the 100 Area, 300 Area and 400 Area. The majority of waste sites in the River Corridor have been remediated, and the majority of lands within the River Corridor have now been transitioned to MSA's Long-Term Stewardship (LTS) Program Exceptions include the 105-K East and West Reactors, and the 105-K West Spent Fuel Storage Basins under CH2M Plateau Remediation Contractor (CHPRC) management, portions of the 300 Area (including the 325 Building, 331 Building under PNNL management and the 324 Building under CHPRC Management), and portions of the 400 Area (including the Fast-Flux Test Facility under CHPRC management).

The 100-K Area completed transfer of sludge from 105-KW Basin engineered containers into 20 sludge transfer and storage containers, which were transported to T-Plant for storage. The 105-KW Basin floor sample analysis was conducted to help assess the transuranic/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. A treatability test to flush the residual contamination in the vadose zone to the groundwater was conducted at 100-K West. Removal of asbestos from the 165-KW Building was completed in preparation for demolition. Removal began of the 166-KE fuel oil bunker; the bunker supplied fuel oil to the boilers located in 165-KE Power Control Building. Removal of the fuel oil bunker will continue into 2020. Demolition of 1724, 1724-KA, and 167-K Buildings was completed. Waste sites 100-K-50:2 and 100-K-94 are interim closed and backfilled. Excavation and load out of contaminated material for the 100-K-99 waste site was completed. Verification samples have been collected and are waiting on results.

Central Plateau

The Central Plateau includes a rectangular area of about 20 mi^2 (52 km^2) in the center of the Central Plateau that is designated in the DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, and the 64 FR 61615, "Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement," 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 (Figure ES-2).

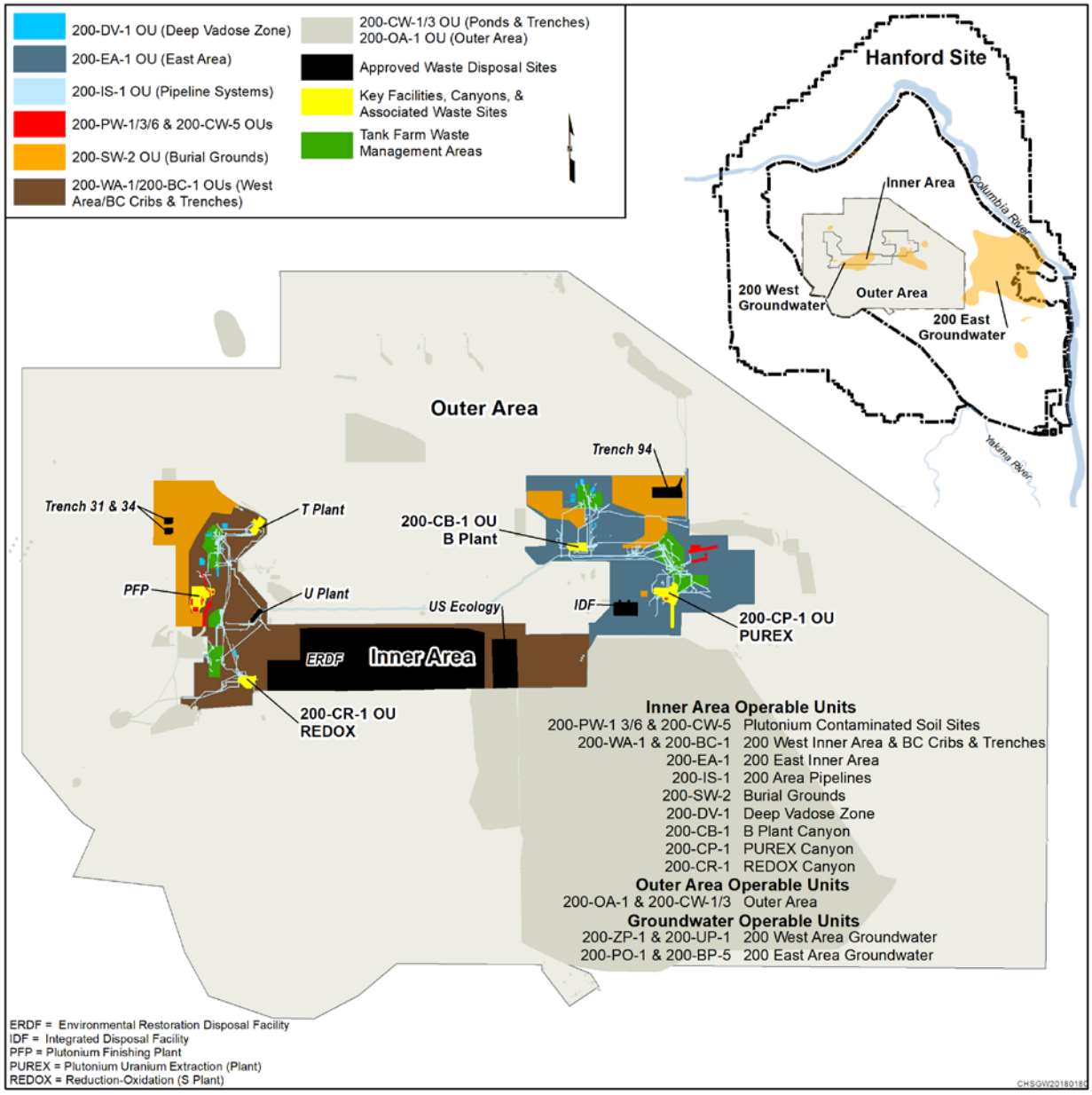

Figure ES-2. Overview of the Central Plateau.

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, or low-level waste (LLW) under the AEA. Wastes that contain constituents regulated under both WAC 173-303 and the AEA are classified as mixed wastes.

Radioactive and/or mixed wastes are managed in several ways. high-level waste is stored in large underground single-shell and double-shell tanks. LLW typically is stored in tanks or containers. The method used to store LLW depends on the source, composition, and waste concentration. Transuranic waste is stored in vaults, in storage buildings, on aboveground storage pads, and retrievably buried cribs

and vaults. 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.

As of December 31, 2019, 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 ES-1 and ES-2. Quantities of dangerous waste shipped offsite as tracked by the database are shown in Table ES-3. All data is current as of December 31, 2019.

Table ES-1. Solid Waste[a] Quantities Generated on the Hanford Site.

Waste Category		2014	2015	2016	2017	2018	2019
Mixed	Tons	140	657	609	452	523	571
	Metric tons	127	596	552	410	474	518
Radioactive	Tons	572	1550	665	828	2680	658
	Metric tons	519	1408	603	751	2434	597

[a] Solid waste includes containerized liquid waste.

Table ES-2. Solid Waste[a] Quantities Received on the Hanford Site from Offsite Sources.

Waste Category[b]		2014	2015	2016	2017	2018	2019
Mixed	Tons	38.4	97.9	105	83.3	118	120
	Metric tons	35	88.9	95.3	76	107	109
Radioactive	Tons	57	91.4	113	133	130	187
	Metric tons	52	82.9	102	121	118	170

[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 ES-3. Dangerous Waste[a] Quantities Shipped Off the Hanford Site.

Waste Category		2014	2015	2016	2017	2018	2019
Containerized (DW Only)	Tons	103	76.8	69.4	68.5	84.5	67.9
	Metric tons	93.4[b]	69.7[b]	63.0[b]	62	76.6	61.6
Containerized (MW Only)	Tons	33.7	65.7	69.7	90.4	56.9	36.6
	Metric tons	30.6[c]	59.6[c]	63.2[c]	82	51.6	33.2
Bulk Solids (DW Only)	Tons	22.1	—		0	0	0
	Metric tons	20.1	—		0	0	0
Bulk Solids (Non-Rad/Non-DW)	Tons	—	—		0	0	0
	Metric tons	—	—		0	0	0
Bulk Liquids (DW Only)	Tons	22	—	1	0	0	0
	Metric tons	20	—	1.36	0	0	0
Bulk Liquids (Non-Rad/Non-DW)	Tons	—	—		0	0	0
	Metric tons	—	—		0	0	0
Totals	**Tons**	**181**	**142**	**140**	**158.9**	**141.4**	**104.5**
	Metric tons	**164**	**129**	**127**	**144**	**128.2**	**94.8**

[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

Groundwater Remediation

Candidate remediation technologies were evaluated in support of the 200-UP-1 Operable Unit record of decision-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 proceeding with a technical impracticability waiver application for the iodine-129 plume in the 200-UP-1 Operable Unit. A technical basis for a Technical Impracticability waiver for iodine-129 was provided by PNNL. Relevant parameters and information were 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.

Online decision-support tools (SOCRATES) were created to meet DOE needs for groundwater assessments, real-time remedy support, and pump-and-treat exit strategies. 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.

Long-Term Stewardship

The Hanford Site's LTS Program has responsibilities within the 220 mi^2 (570 km^2) 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 waste sites and six Manhattan Project Era production reactors that have been placed in interim safe storage (i.e., cocooned reactors). In 2019, the LTS Program completed annual inspections of 38 accepted and active Waste Information Data System sites, as required, to confirm their current status; assessed 221 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 11 underground-injection-control wells; and continued to manage the LTS library, which now contains over 25,000 documents associated with LTS-managed lands.

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 to assess the effectiveness of emission control equipment. 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 impact from 2019 emissions were well below DOE O 458.1 and federal and state limits. Non-radioactive air pollutant emissions are estimated via sampling or chemical and material use. Pollutant emissions from all sources in 2019 were similar to emissions in 2018.

Onsite Air Monitoring

A network of continuously operating samplers at 78 locations across the Hanford Site was used during 2019 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 2019 by 19 continuously operating samplers in the vicinity of the Hanford Site. Generally, the 2019 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 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 µSv)/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.

Sample results from the first half of 2019 at a station near the 200 Area Liquid Effluent Retention Facility in the 200-East Area showed an elevated cesium-137 concentration. As this facility is not a source of cesium-137 and this was a lone occurrence, no additional actions were taken. Future sampling results in this vicinity will be closely monitored.

ES.7 Section 7, Water Monitoring

In 2019, 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 2019. 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 2019 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 those measured 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 2019 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 trichloroethane and dichloroethane, attributable to past Hanford Site 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 2019 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 2019 concentrations were similar to previous years with the exception of technetium-99 as those increased when compared to 2018 West Lake water results. However, overall concentrations of technetium-99 were well below DOE derived guidelines for riparian receptors.

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 2019 were at similar levels shown in Columbia River transect water samples collected upstream of the Hanford Site.

Liquid Effluent Monitoring

Liquid effluent discharges to the environment are governed by federal and state regulations, discharge permits, and DOE Orders. In CY 2019 there were no liquid effluent discharges to the Columbia River and two permitted liquid effluent point sources discharged to the ground. Samples collected, analyzed, and reported monitor pollutants of concern. Permit required discharge monitoring reports with sample data are submitted to Ecology. Discharges to the ground in CY 2019 were similar to previous years.

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-2019-66, *Hanford Site Groundwater Monitoring Report for 2019*, 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 collected in 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 2019 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 2019 onsite soil sample results were 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, 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 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 preliminary remediation goals for the outdoor worker exposure scenario.

Radionuclide concentrations in soil samples collected in CY 2019 at offsite locations were compared to results from 2001, 2004, 2008, and 2015. In 2019, the observed average concentrations in soil samples for all isotopes were generally similar to their respective averages from 2001, 2004, 2008, and 2015. The Hanford sitewide average soil concentrations in 2019 were higher than at site perimeter and distant locations for the radionuclides measured (Appendix C, Table C-6). This was consistent with historical data and reflected the higher sitewide soil concentrations associated with years of nuclear materials production.

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., alfalfa, apricots, corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in 2019 at locations near the Hanford Site. Radionuclide concentrations in most food and farm product samples in 2019 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 the CY 2019 included mountain whitefish (*Prosopium williamsoni*), walleye (*Prosopium williamsoni*), and Canada goose (*Branta canadensis*). Monitoring fish and wildlife for uptake and exposure to Hanford Site operations-produced contaminants ensures that consumption of fish and wildlife obtained from Hanford Site environs does not pose a threat to human health and provides long-term contamination trends. These species were selected and analyzed because they provide a potential pathway for offsite human consumption. 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. Analytical results for vegetation samples collected in CY 2019 at locations in the 200-East, 200-West, 100-N, 300, 400, and 600 Areas were consistent with those seen in previous years.

Vegetation samples from offsite locations are collected every 3 to 5 years and were most recently collected in the summer of 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*.

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 2019 identified 29 instances of radiologically contaminated vegetation. All 29 were Russian thistle (Salsola tragus) plants or fragments.

Vegetation Control. Approximately 4,868 ac (1,898 ha) were treated with herbicides in 2019 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 2019, 125 ac (51 ha) across the Hanford Site were revegetated in an effort to restore native plant communities on revegetation and restoration sites including cleaned-up waste sites and revegetated mitigation sites.

ES.11 Section 11, Resource Protection

DOE is responsible for managing and protecting biological and cultural resources on the Hanford Site. Ecological and cultural resource monitoring are conducted to collect and track data needed to ensure compliance with applicable laws, regulations, and policies (including management plans) governing DOE activities.

Ecological Protection

Ecological monitoring data provide baseline information about the plants, animals, and habitats under DOE stewardship at the Hanford Site that is required to make cleanup decisions. During 2019, 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 vernal pools, ferruginous hawk nest monitoring, roadside bird surveys, burrowing owls, bats, pollinators, and riparian vegetation and rare plant species. Additionally, in 2019 DOE conducted a Conservation Habitat Assessment and Mitigation Prioritization study (HNF-64135) using ecological data to identify the high priority conservation and mitigation areas on the Hanford Site (HNF-64135).

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 Hanford 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, 16 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 12 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 2019, Hanford Site archaeologists completed 71 *National Historic Preservation Act of 1966* (NHPA) Section 106 cultural resources reviews. Twenty-six undertakings had the potential to affect cultural resources. Twenty 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. Eighteen projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews. Six projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration. A total of 915.1 ac

(370.3 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 2019, 20 items were reviewed, cleared for public release, and /or transferred to the Hanford History Project repository for integration with the Hanford Collection. Nineteeen artifacts and one linear foot of archival material were evaluated for inclusion in the Hanford Collection. These materials were determined to meet the collections criteria and delivered to the Hanford History Project repository at WSU-TC for curation, leaving 20 (2.7%) of 744 tagged artifacts scheduled for collection between 2020 and 2048. Having transitioned the bulk of the Hanford Collection to the WSU-TC facility in 2016, tasks during 2020 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. Multiple 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 Eurofins TestAmerica St Louis Laboratory (TASL). 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.

ES.13 References

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Table of Contents

1.0 INTRODUCTION 1-1
1.1 Hanford Site Location 1-2
1.2 Hanford Site History and Mission 1-5
1.3 Primary Operations and Activities 1-6
1.3.1 100 Area 1-6
1.3.2 200 Areas 1-7
1.3.3 300 Area 1-9
1.3.4 400 Area 1-9
1.3.5 600 Area 1-9
1.3.6 1100 Area 1-10
1.3.7 3000 Area 1-10
1.3.8 Richland North Area (Offsite) 1-10
1.3.9 700 Area (Offsite) 1-10
1.3.10 Volpentest Hazardous Materials Management and Emergency Response Federal Training Center 1-10
1.3.11 Hanford Tank Waste Treatment and Immobilization Plant 1-11
1.3.12 Non-DOE Operations and Activities on Hanford Site-Leased Land 1-12
1.3.13 Non-DOE Nuclear Operations 1-12
1.3.14 Hanford Reach National Monument 1-12
1.3.15 Manhattan Project National Historical Park 1-13
1.4 Hanford Site Management 1-13
1.5 Fire Protection and Management 1-15
1.6 Climate and Meteorology 1-16
1.6.1 Historical Climatological Information 1-18
1.6.2 Meteorological Monitoring 1-18
1.7 Stakeholder Involvement 1-19
1.7.1 Role of Native American Tribes 1-19
1.7.2 Cultural and Historic Resource Consultations 1-22
1.7.3 Hanford Natural Resource Trustee Council 1-22
1.7.4 Public Involvement in Hanford Site Decisions 1-24
1.7.5 State of Oregon 1-26
1.7.6 Hanford Advisory Board 1-26
1.8 Hanford Site Regulatory Oversight 1-26
1.8.1 Hanford Federal Facility Agreement and Consent Order 1-27
1.8.2 Defense Nuclear Facility Safety Board 1-28
1.9 References 1-28

2.0 COMPLIANCE SUMMARY 2-1
2.1 Hazardous Materials and Waste Management 2-2

2.1.1 Federal Facility Compliance Act of 1992 2-2
2.1.2 Resource Conservation and Recovery Act of 1976....2-2
2.1.3 Comprehensive Environmental Response, Compensation, and Liability Act....2-5
2.1.4 Emergency Planning and Community Right-to-Know Act of 1986 2-9
2.1.5 Environmental Release Reporting....2-12
2.1.6 Toxic Substances Control Act 2-12
2.1.7 Federal Insecticide, Fungicide, and Rodenticide Act....2-14
2.2 National Environmental Policy Act of 1969....2-14
2.2.1 Hanford Site Environmental Impact Statements....2-14
2.2.2 Hanford Site Environmental Assessments. 2-14
2.2.3 Hanford Site Categorical Exclusions....2-15
2.3 Radiation Protection Statutes, Regulations, and Directives....2-15
2.3.1 Atomic Energy Act of 1954 2-16
2.3.2 DOE O 458.1, Radiation Protection of the Public and the Environment....2-16
2.3.3 DOE O 435.1, Radioactive Waste Management....2-18
2.4 Air Quality Statutes and Regulations 2-19
2.4.1 Clean Air Act 2-19
2.4.2 Air Permits Required by Regulations....2-19
2.5 Water Quality Permits, Statutes, and Regulations 2-20
2.5.1 Federal Permit – Discharges to Columbia River....2-20
2.5.2 State Waste Discharge Permit – Discharges to the Soil Column/Groundwater 2-21
2.5.3 Local Discharge Permit – Discharges to the City of Richland Sewer 2-21
2.5.4 Safe Drinking Water Act of 1974....2-21
2.5.5 Surface Water Standards....2-23
2.6 Natural and Cultural Resources....2-23
2.6.1 Ecological Compliance 2-23
2.6.2 Cultural Resource Compliance....2-25
2.7 Sustainability....2-26
2.7.1 Chemical Management Systems....2-26
2.7.2 Pollution Prevention Program....2-26
2.7.3 DOE O 436.1, Departmental Sustainability....2-28
2.8 Occurrence Reporting and Processing of Operations Information....2-29
2.8.1 High-Level Report 2-29
2.8.2 Low-Level Report....2-29
2.8.3 Informational Level Report....2-29
2.9 Environmental Permits....2-30
2.10 Environmental Enforcement Actions....2-32
2.10.1 Enforcement Actions by Regulatory Program Area....2-33
2.10.2 Wastewater Permit Deviations....2-35

2.11 References 2-37

3.0 ENVIRONMENTAL MANAGEMENT SYSTEM 3-1

3.1 Environmental Performance Measures 3-3
3.1.1 Fleet Management 3-4
3.1.2 Alternative Fuel Use 3-4
3.1.3 Potable and Non-potable Water Use 3-5
3.1.4 Electricity Use 3-5
3.1.5 Facility Fuel Use 3-5
3.1.6 Facility Energy Use 3-7
3.1.7 Electronic Product Environmental Assessment Tool 3-7
3.1.8 Sanitary Waste Reduction 3-7
3.1.9 Regulated Waste Reduction 3-8
3.2 Hanford Site Awards and Recognition 3-9
3.2.1 HPMC Occupational Medical Services 3-9
3.2.2 CH2M Plateau Remediation Company 3-10
3.2.3 Mission Support Alliance, LLC 3-10
3.2.4 Washington River Protection Solutions, LLC 3-10
3.2.5 Veolia Nuclear Solutions Federal Services 3-11
3.3 References 3-11

4.0 RADIOLOGICAL PROTECTION AND DOSES 4-1

4.1 External Radiation Monitoring 4-1
4.1.1 External Radiation Measurements 4-2
4.1.2 Waste Disposal Sites Radiological Surveys 4-5
4.2 Potential Radiological Doses 4-6
4.2.1 Maximally Exposed Individual Dose (Offsite Resident) 4-8
4.2.2 Collective Dose 4-15
4.2.3 Compliance with *Clean Air Act* Standards 4-18
4.2.4 Special Case Dose Estimates 4-20
4.2.5 Doses from Non-U.S. Department of Energy Sources 4-23
4.2.6 Dose to Non-Human Biota 4-23
4.2.7 Radiological Dose in Perspective 4-27
4.3 Radiological Clearance of Hanford Site Property 4-30
4.3.1 Personal Property 4-31
4.3.2 Real Property 4-32
4.3.3 Granular-Activated Carbon for Offsite Shipment and Regeneration 4-32
4.4 References 4-33

5.0 ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT 5-3

5.1 Site Remediation 5-3
5.1.1 River Corridor 5-3

5.1.2 Central Plateau....5-9
5.1.3 Groundwater Remediation Support....5-18
5.2 Waste Management Activities....5-21
5.2.1 Tank Farms....5-24
5.2.2 Single-Shell Tank Closure and Interim Measures Program....5-33
5.2.3 Central Waste Complex....5-35
5.2.4 Waste Receiving and Processing Facility....5-36
5.2.5 T-Plant Complex....5-37
5.2.6 Canister Storage Building....5-38
5.2.7 Low-level Burial Grounds....5-38
5.2.8 Waste Encapsulation and Storage Facility....5-40
5.2.9 Integrated Disposal Facility....5-41
5.2.10 Environmental Restoration Disposal Facility....5-42
5.2.11 200 Area Effluent Treatment Facility....5-43
5.2.12 Liquid Effluent Retention Facility....5-44
5.2.13 200 Area Treated Effluent Disposal Facility....5-45
5.2.14 242-A Evaporator....5-46
5.2.15 Hanford Tank Waste Treatment and Immobilization Plant....5-47
5.3 Long-Term Stewardship....5-48
5.4 References....5-52

6.0 AIR MONITORING....6-1
6.1 Air Effluent Monitoring....6-1
6.1.1 Radioactive Airborne Emissions....6-1
6.1.2 Criteria Air Pollutants....6-4
6.1.3 Hazardous and Toxic Air Pollutants....6-5
6.1.4 Reporting....6-6
6.2 Radioactive Air Monitoring....6-8
6.2.1 Hanford Site Air Monitoring....6-9
6.2.2 Perimeter and Offsite Air Monitoring....6-15
6.3 References....6-19

7.0 WATER MONITORING....7-1
7.1 Drinking Water Systems....7-1
7.1.1 Drinking Water Treatment Facilities....7-2
7.1.2 Monitoring....7-2
7.1.3 Radiological Results....7-4
7.2 Columbia River Surface Water....7-7
7.2.1 Monitoring....7-11
7.2.2 Radiological Results....7-13
7.2.3 Inorganic and Organic Chemical Results....7-17
7.3 Columbia River Sediment....7-19

7.3.1 Monitoring 7-20
7.3.2 Radiological Results 7-21
7.3.3 Chemical Results 7-23
7.4 Columbia River Seep Water 7-24
7.4.1 Seep Water Monitoring 7-25
7.4.2 Monitoring Results 7-26
7.4.3 Sediment Monitoring 7-28
7.5 Pond Water and Sediment 7-30
7.5.1 West Lake Water 7-30
7.5.2 West Lake Sediment 7-30
7.6 Offsite Irrigation Water 7-33
7.6.1 Offsite Irrigation Water Monitoring 7-33
7.6.2 Sample Results 7-33
7.7 Liquid Effluent 7-34
7.7.1 Point Source Discharges 7-34
7.7.2 Nonpoint Source Discharges 7-37
7.8 References 7-40

8.0 GROUNDWATER MONITORING 8-1
8.1 River Corridor 8-2
8.2 Central Plateau 8-10
8.3 References 8-17

9.0 SOIL MONITORING 9-1
9.1 Hanford Site Soil Sampling 9-2
9.2 Offsite Soil Sampling 9-9
9.3 Radiological Contamination Surveys 9-10
9.4 References 9-12

10.0 BIOTA MONITORING 10-1
10.1 Agricultural Monitoring 10-1
10.1.1 Milk 10-4
10.1.2 Fruit, Vegetables, and Farm Products 10-5
10.2 Fish and Wildlife Monitoring 10-5
10.2.1 Mountain Whitefish 10-8
10.2.2 Walleye 10-9
10.2.3 Waterfowl 10-11
10.3 Vegetation Monitoring 10-12
10.3.1 Hanford Site Vegetation Monitoring 10-12
10.3.2 Offsite Vegetation Sampling 10-17
10.3.3 Radiological Contamination Surveys 10-18
10.3.4 Vegetation Control 10-19

10.4 Waste Site Remediation and Revegetation 10-20
10.5 References 10-20

11.0 RESOURCE PROTECTION 11-2
11.1 Ecological Protection 11-2
11.1.1 Conservation Habitat Assessment and Mitigation Prioritization 11-3
11.1.2 Fish and Wildlife Monitoring 11-15
11.1.3 Vegetation and Habitat Monitoring 11-46
11.2 Endangered and Threatened Species 11-51
11.3 Cultural and Historic Resource Protection 11-54
11.3.1 Cultural Resources Reviews 11-54
11.3.2 Cultural Resources Protections and Section 110 Activities 11-56
11.4 Collection Management and Curation 11-58
11.5 References 11-61

12.0 QUALITY ASSURANCE 12-1
12.1 Program Management 12-1
12.1.1 Personnel Training and Qualifications 12-2
12.2 Sample Collection Quality Assurance and Quality Control 12-3
12.3 Quality Control Samples 12-3
12.4 Media Audits and Comparisons 12-11
12.5 Laboratory Quality Assurance Programs 12-12
12.5.1 Laboratory Performance Evaluation and Proficiency Testing 12-14
12.6 Data Recording and Data Management 12-15
12.7 References 12-15

Appendices

A GLOSSARY A-1
B BACKGROUND INFORMATION B-1
C ADDITIONAL MONITORING RESULTS C-1
D RADIATION DOSE CALCULATIONS D-1

Figures

Figure 1-1. Location of the Hanford Site 1-3
Figure 1-2. Detailed Geography of the Hanford Site, Hanford Reach National Monument, and U.S. Department of Energy Portions of the Hanford Site. 1-4
Figure 1-3. The Frank Hensley Apple Ranch (circa 1913) 1-5
Figure 1-4. Aerial View of 100-H Reactor. 1-6
Figure 1-5. Firefighters Practice Skills They Will Use On and Off the Hanford Site 1-11

Figure 1-6. Meteorological Monitoring Network Wind Roses from 2019. 1-17

Figure 2-1. Alleged Environmental Noncompliance Violations, Concerns, and Associated Fines Summary. 2-35

Figure 3-1. Fleet Management – Acquisitions Fiscal Years 2005 through 2019. NOTE: AFV stands for alternative fuel vehicle. 3-4
Figure 3-2. Vehicle Fuel Use – Fiscal Years 2005 through 2019. 3-5
Figure 3-3. Water Use – Fiscal Years 2007 through 2019. 3-6
Figure 3-4. Electricity Use – Fiscal Years 2016 through 2019 with Target Objectives through 2025. 3-6
Figure 3-5. Facility Fuel Use – Fiscal Years 2003 through 2019. NOTE: KBTU stands for one thousand British thermal units 3-7
Figure 3-6. Facility Energy Use – Fiscal Years 2015 through 2019 with Target Objectives through 2025. 3-8
Figure 3-7. Electronic Product Environmental Assessment Tool Standards Compliance. 3-8
Figure 3-8. Sanitary Waste Reduction. 3-9
Figure 3-9. Onsite Waste Disposal – Fiscal Years 2008 through 2019 at the Environmental Restoration Disposal Facility. 3-9

Figure 4-1. Average Thermoluminescent Dosimeter Results (mrem/year) in Selected Operational Areas. 4-3
Figure 4-2. Locations Evaluated for Onsite and Offsite Receptors. 4-10
Figure 4-3. Conceptual Site Model of Exposure Pathways Evaluated in Dose Calculations (Horn Rapids Road Maximally Exposed Individual). 4-11
Figure 4-4. Total Dose for the Hypothetical Maximally Exposed Individual Over Time. 4-13
Figure 4-5. Comparison of Measured and Modeled Tritium Air Concentrations Near the 300 Area. 4-14
Figure 4-6. Collective Total Dose within a 50-mi (80-km) Radius. 4-18
Figure 4-7. U.S. Annual Average Radiological Doses from Various Sources 4-29
Figure 4-8. Radiological Doses from Hanford Site Operations Compared to Annual Average from Natural Sources. 4-30

Figure 5-1. Aerial View of 100-K Area Looking North showing the site as it looked in 2010 on the left compared to 2019 view on the right. 5-4
Figure 5-2. The 116-KE-2 Excavation Site. 105-KE Reactor Building is in the Background. 5-6
Figure 5-3. Aerial View of the Fast Flux Test Facility. 5-9
Figure 5-4. December 2019 Aerial View of the Plutonium Finishing Plant. 5-13
Figure 5-5. Aerial Over of the 200 Areas Tank Farms. 5-25
Figure 5-6. AX-Farm (Aerial Photograph, January 2020). 5-26
Figure 5-7. A-Farm Ventilation System (Aerial Photograph, January 2020). 5-26
Figure 5-8. Composite AX-102 In-Tank View during Retrieval. 5-27

Figure 5-9. Photographs of the 2019 Model of the RAVIS Air-Slot Non-Destructive Evaluation Sensor.. 5-30
Figure 5-10. Photographs of the RAVIS Robotic System During 2019 Testing.. 5-31
Figure 5-11. Aerial View of the Central Waste Complex..... 5-36
Figure 5-12. A worker loads 65 drums of mixed low-level waste debris for shipment from the Waste Receiving and Processing Facility to Perma Fix Northwest. 5-37
Figure 5-13. Aerial View of the T-Plant Complex..... 5-38
Figure 5-14. Trenches 31 (Bottom Trench) and 34 (Top Trench) are Used to Store and Dispose of Low-Level Waste and Mixed Low-Level Waste from Hanford Site Work. 5-40
Figure 5-15. Aerial View of the Integrated Disposal Facility..... 5-41
Figure 5-16. Aerial View of the Environmental Restoration Disposal Facility. 5-42
Figure 5-17. The Effluent Treatment Facility Receives Liquids from the Liquid Effluent Retention Facility..... 5-44
Figure 5-18. The Liquid Effluent Retention Facility is Located in the Central Part of the Hanford Site. 5-45
Figure 5-19. 200 Area Treated Effluent Disposal Facility Ponds A and B..... 5-46
Figure 5-20. Land Areas Managed by the Long-Term Stewardship Program as of 2019. 5-50

Figure 6-1. Sources Contributing to Volatile Organic Compounds and Ammonia Effluents. 6-7
Figure 6-2. Sources Contributing to Carbon Monoxide Effluents. 6-8
Figure 6-3. 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..... 6-14
Figure 6-4. Offsite Air Sampling Locations for Calendar Year 2019. 6-16
Figure 6-5. Radionuclide Concentrations in Air Samples (1 pCi = 0.037 Bq)..... 6-19

Figure 7-1. Drinking Water Treatment Facilities. 7-3
Figure 7-2. 400 Area Tritium Concentrations in Drinking Water (2014-2019) 7-6
Figure 7-3. Surface Water and Sediment Sampling Locations. 7-8
Figure 7-4. Columbia River Flow Rates at Priest Rapids Dam..... 7-12
Figure 7-5. 2019 Annual Tritium Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site. 7-14
Figure 7-6. 2019 Annual Strontium-90 Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site 7-15
Figure 7-7. 2019 Annual Uranium Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site..... 7-15
Figure 7-8. 2019 Tritium Concentrations in Cross-River Transect Water Samples 7-17
Figure 7-9. 2019 Selected Anion Concentrations in Columbia River Transect Samples..... 7-19
Figure 7-10. Cesium-137 Average, Maximum (top), and Minimum (bottom) Concentrations Measured in Columbia River Sediment 7-22
Figure 7-11. Plutonium-239/240 Average, Maximum (top), and Minimum (bottom) Concentrations Measured in Columbia River Sediment..... 7-22

Figure 7-12. Uranium Average, Maximum (top), and Minimum (bottom) Concentrations Measured in Columbia River Sediment. 7-23
Figure 7-13. Selected Metals Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (Washington and Oregon), 2019..... 7-24
Figure 7-14. Sediment Collections Sampling Locations Collected in Fiscal Year 2019..... 7-31
Figure 7-15. 2014 Through 2019 West Lake Uranium-234 Water Results..... 7-32
Figure 7-16. Location of Effluent Treatment Facility and State-Approved Land Disposal Site..... 7-35
Figure 7-17. Location of the Treated Effluent Disposal Facility..... 7-37
Figure 7-18. Location of the Evaporative Sewage Treatment Lagoon..... 7-39

Figure 8-1. Regions of the Hanford Site and Most Extensive Contaminant Plumes.....8-3
Figure 8-2. Hanford Site Plume Areas.....8-4
Figure 8-3. Groundwater Contaminant Plumes in the River Corridor.....8-5
Figure 8-4. River Corridor Plume Areas.....8-8
Figure 8-5. Maximum Concentrations of River Corridor Contaminants Over Time.....8-8
Figure 8-6. Groundwater Dose Calculation for the River Corridor. 8-9
Figure 8-7. Groundwater Contaminant Plumes in the Central Plateau..... 8-13
Figure 8-8. Central Plateau Plume Areas..... 8-16
Figure 8-9. Maximum Concentrations of Central Plateau Contaminants over Time..... 8-16
Figure 8-10. Groundwater Dose Calculation for the Central Plateau..... 8-17

Figure 9.1. Average Concentrations of Select Radionuclides in Hanford Site Soil Samples, 2014–2019.....9-7

Figure 10-1. Agricultural Monitoring Locations. NOTE: Duplicate information may or may not be included in this data. 10-5
Figure 10-2. Animal Monitoring Locations..... 10-8
Figure 10-3. Strontium-90 Concentrations in Canada Goose Bone Samples..... 10-13
Figure 10-3. Hanford Site Vegetation Average Concentrations of Selected Radionuclides..... 10-18

Figure 11-1. Best Solution Determined by Marxan Assessment for Conservation Areas on the DOE-RL-managed Portion of Hanford Site..... 11-8
Figure 11-2. Irreplaceability vs Vulnerability Plot..... 11-9
Figure 11-3. Potential Conservation Action Map for the DOE-RL-Managed Portion Hanford Site Overlain with the CHAMP Best Solution..... 11-10
Figure 11-4. The Hanford Site Comprehensive Land-Use Planning Map Overlain with the CHAMP Best Solution..... 11-12
Figure 11-5. The Hanford Site Biological Resources Management Plan Resources Levels Map Overlain with the CHAMP Best Solution..... 11-14
Figure 11-6. Visual Hanford Reach Fall Chinook Salmon Redd Counts 1948 to 2019..... 11-18
Figure 11-7. Columbia River Flows on the Hanford Reach during Late Winter and Spring 2019. 11-19

Figure 11-8. Hanford Bald Eagle Night Roost Buffers..... 11-21
Figure 11-9. Age Class of Bald Eagles Counted During Roost Surveys..... 11-23
Figure 11-10. Active Ferruginous Hawk Nests Observed on DOE-RL-Managed Lands of the Hanford Site in 2019..... 11-26
Figure 11-11. Burrowing Owl Artificial Burrow System Chamber Installed on the Hanford Site..... 11-28
Figure 11-12. Locations of the New and Replaced Artificial Burrow Systems Installed on the Hanford Site During Calendar Year 2018..... 11-29
Figure 11-13. Burrow 49, Located Along Highway 240, Contained Nine Eggs and Three Newly Hatched Young..... 11-30
Figure 11-14. Burrow 39, Located Near the HAMMER EVOC Facility Contained Five Hatch Year Owls..... 11-30
Figure 11-15. Newly Banded Hatch Year Owl Being Returned to Burrow..... 11-31
Figure 11-16. Roadside Bird Survey Routes Surveyed for Calendar Year 2019..... 11-32
Figure 11-17. Apodemus Infrared Camera Bat Counters Placed on the 183-F Clearwell Opening..... 11-34
Figure 11-18. Maximum Emergence Counts from the 183-F and 183-D Clearwells Since 2008..... 11-35
Figure 11-19. Infrared Bat Counter Ins and Outs from June Roost Survey Displayed in Chart View..... 11-36
Figure 11-20. Northern and Southern Region Driving Routes used for FY 2019 Hanford Site Mule Deer Surveys..... 11-38
Figure 11-21. Average Number of Deer Observed in Both Regions FY 1995 to FY 2019..... 11-41
Figure 11-22. Distribution of Observed Mule Deer and Incidental Elk Herds During FY 2019..... 11-42
Figure 11-23. Ratio of Fawns to Does in each Region from FY 1995 to FY 2019..... 11-43
Figure 11-24. Percentage of Bucks with Abnormal Antler Growth, FY 1995 through FY 2019..... 11-43
Figure 11-25. Bee Next Boxes: Design A (Left) and Design B (Right), Not to Scale..... 11-45
Figure 11-26. The Occupied Bee Nest Boxes in December 2019..... 11-46
Figure 11-27. Area Monitored in 2019 Riparian Vegetation Mapping Surveys..... 11-47
Figure 11-28. Boundaries of the Gable Mountain Pools in 2019 Compared to 2017 Boundaries..... 11-50
Figure 11-29. Hanford Site National Historic Preservation Act Section 106 Reviews by Area..... 11-56
Figure 11-30. Storage of Artifacts and Multimedia from the Manhattan Project and Cold War Era..... 11-59
Figure 11-31. Ground Penetrating Radar Equipment Used on the Hanford Site, Transferred to the Hanford History Project Repository in 2019..... 11-59
Figure 11-32. Communication Panels from 105-B Reactor, Transferred to the Hanford History Project Repository in 2019..... 11-60

Tables

Table 1-1. Hanford Meteorological Station Climatological Information for 1945 through 2019..... 1-18
Table 1-2. Meteorology Station[a] Monthly and Annual Climatological Data 2019..... 1-20

Table 2-1. Emergency Planning and Community Right-to-Know Act Requirements Summary..... 2-10

Table 2-2. Emergency Planning and Community Right-to-Know Compliance Reporting..... 2-11
Table 2-3. Average Quantity of the 10 Hazardous Chemicals Stored in Greatest Quantities..... 2-11
Table 2-4. Toxic Chemicals Exceeding Reporting Thresholds. 2-12
Table 2-5. Radiation Protection Standards for the Public and the Environment from All Routine DOE Operations. 2-17
Table 2-6. Selected Drinking Water Standards. 2-22
Table 2-7. Recycle Quantities. 2-27
Table 2-8. Environmental Permits. 2-30
Table 2-9. Alleged Environmental Noncompliance Summary by Program Area, 2014 through 2019. 2-34
Table 2-10. Summary of Alleged Environmental Noncompliances for Calendar Year 2019. 2-34
Table 2-11. CY 2019 Wastewater Permit Deviations. 2-35

Table 3-1. DOE Contract Actions and Contractor Implementation..... 3-2
Table 3-2. Hanford Site Environmental Management System Internet Links..... 3-3

Table 4-1. Thermoluminescent Dosimeter Locations and Results (mrem/yr)[a] in 2018 and 2019. 4-2
Table 4-2. Pathway Doses for the Hypothetical Maximally Exposed Individual Residing at Horn Rapids Road..... 4-12
Table 4-3. Collective Pathway Doses within a 50-mi (80-km) Radius. 4-17
Table 4-4. Annual Doses for a Hypothetical Individual at National Historic Park Locations (2019). 4-23
Table 4-5. Estimated Sum of Fractions to Biota Associated with Columbia River Sediment and Water. 4-26
Table 4-6. Estimated Sum of Fractions to Biota Associated with West Lake[a]. 4-26
Table 4-7. Estimated Sum of Fractions to Terrestrial Biota Associated with On- and Offsite Soil. 4-27
Table 4-8. Estimated Risk from Various Activities and Exposures. 4-30
Table 4-9. Dose Constraints for Release and Clearance of Property, DOE O 458.1. 4-31
Table 4-10. Authorized Limits for Offsite Shipment and Regeneration of Granular-Activated Carbon. 4-33

Table 5-1. Central Plateau Operable Unit Structure. 5-10
Table 5-2. Solid Waste[a] Quantities Generated on the Hanford Site. 5-22
Table 5-3. Solid Waste[a] Quantities Received on the Hanford Site from Offsite Sources. 5-22
Table 5-4. Dangerous Waste[a] Quantities Shipped Off the Hanford Site. 5-23
Table 5-5. Tank Farm System Quantities of Waste Retrieved and Stored. 5-28

Table 6-1. Hanford Site Stack Locations and Sample Analyses. 6-2
Table 6-2. Hanford Site Radioactive Airborne Emissions in Calendar Year 2019..... 6-4
Table 6-3. Calendar Year 2019 Hanford Site Air Emissions Inventory. 6-8
Table 6-4. Hanford Site Monitoring Locations and Analyses for Air Monitoring Samples. 6-9

Table 7-1. Drinking Water Systems. 7-2

Table 7-2. Drinking Water Annual Average Concentrations of Selected Radiological Constituents. 7-5
Table 7-3. Tritium Concentrations in Hanford Site 400 Area Drinking Water Wells. 7-7
Table 7-4. Surface Water Surveillance. 7-9
Table 7-5. Columbia River Sediment. 7-10
Table 7-6. Columbia River Seep Monitoring. 7-25
Table 7-7. Sediment Samples at Riverbank Seep Locations. 7-29
Table 7-8. Calendar Year 2019 Tritium Discharges to the State-Approved Land Disposal Site. 7-36

Table 8-1. River Corridor Groundwater Contaminants, 2018 and 2019. 8-5
Table 8-2. Summary of CERCLA Groundwater Remediation in the River Corridor. 8-7
Table 8-3. Central Plateau Groundwater Contaminants, 2018 and 2019. 8-14
Table 8-4. Summary of CERCLA Groundwater Remediation on the Central Plateau. 8-14

Table 9-1. Hanford Site Soil Monitoring Locations and Sample Analyses. 9-2
Table 9-2. Number of Soil Samples per Operational Area. 9-3
Table 9-3. Concentration Limits for Selected Radionuclides (pCi/g). 9-4
Table 9-4. Offsite Soil Monitoring Locations and Sample Analyses. 9-9
Table 9-5. Hanford Site Soil Contamination Occurrences discovered in CY 2019. 9-10
Table 9-6. Hanford Site Soil Contamination Occurrences from 2000 through 2019. 9-11

Table 10-1. Agricultural Monitoring Location. 10-4
Table 10-2. Wildlife Monitoring Analysis. 10-8
Table 10-3. Metals Analyses for the Mountain Whitefish Samples. 10-9
Table 10-4. Metals Analyses for the Walleye Samples. 10-10
Table 10-5. Hanford Site Vegetation Monitoring Locations and Sample Analyses. 10-13
Table 10-6. Number of Vegetation Samples per Operational Area. 10-13
Table 10-7. Offsite Vegetation Monitoring Locations and Sample Analyses. 10-17
Table 10-8. Hanford Site Vegetation Contamination Occurrences Discovered in Calendar Year 2019. 10-18
Table 10-9. Hanford Site Vegetation Contamination Occurrences from 2000 through 2019. 10-19

Table 11-1. Summary of the Focal Habitats or Species Key Ecological Attributes and their Indicators. 11-4
Table 11-2. Area of the DOE-RL-Managed Portion of Hanford Site and the Marxan Best Solution Covered by Each Hanford Site Comprehensive Land-Use Planning Designations. 11-13
Table 11-3. Area of the DOE-RL-Managed Portion of Hanford Site and the Marxan Best Solution Covered by Each Biological Resources Management Plan Resource Level of Concern. 11-15
Table 11-4. Summary of Fall Chinook Salmon Redd Counts by Areas for the 2019 Aerial Surveys in the Hanford of the Columbia River. 11-17

Table 11-5. Summary of Fall Chinook Salmon Redd Counts by Sub-areas Adjacent to Hanford Site Operations for the 2019 Aerial Surveys in the Hanford Reach of the Columbia River. 11-17
Table 11-6. Bald Eagle Night Roost Monitoring Data for FY 2019. 11-22
Table 11-7. Species Richness and Abundance Counted During the 2018 Breeding Season Roadside Bird Survey Routes on the Hanford Site Sorted by Route. 11-33
Table 11-8. Mule Deer Survey Results for FY 2019. 11-39
Table 11-9. Vegetation Cover Types 11-47
Table 11-10. Rare Plant Data During Riparian Monitoring 2019. 11-49
Table 11-11. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. 11-51
Table 11-12. Sites and Isolates Recorded or Updated. 11-57

Table 12-1. Laboratories and Types of Environmental Surveillance Samples Analyzed. 12-3
Table 12-2. Field and Laboratory Quality Control Sample Types, Characteristics, and Frequency. 12-4
Table 12-3. 2019 Field Duplicate Samples. 12-4
Table 12-4. 2019 Field Duplicate Sample Results. 12-5
Table 12-5. 2019 DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC. 12-13
Table 12-6. MAPEP Relative Performance Status Ratings. 12-14

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Abbreviations and Acronyms

µS	microsiemens
µSv	microsievert
AEA	*Atomic Energy Act of 1954*
AEI	Air Emissions Inventory
AERR	Air Emissions Reporting Rule
ALARA	as low as reasonably achievable
ALI	Arid Lands Initiative
AOP	Air Operating Permit
ASCX	activity-specific categorical exclusion
BLM	Boundary Length Modifier
BNI	Bechtel National, Inc.
BOF	Balance of Facilities
BPA	Bonneville Power Administration
BRMP	Hanford Site Biological Resources Management Plan
C&D	construction and demolition
CAA	*Clean Air Act*
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CGS	Columbia Generating Station
CHAMP	Conservation Habitat Assessment and Mitigation Prioritization
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	categorical exclusion
DFLAW	Direct Feed Low-Activity Waste
DMM	dimethyl mercury

DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOECAP	DOE Consolidated Audit Program
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
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
ERT	Electrical Resistivity Tomography
ES	Environmental Surveillance
ESA	*Endangered Species Act of 1973*
ETF	Effluent Treatment Facility
EVOC	Emergency Vehicle Operations Course
FFTF	Fast Flux Test Facility
FMEF	Fuels and Materials Examination Facility
FS	feasibility study
FY	fiscal year
GAC	granular-activated carbon
GIS	Geographic Information System
HAB	Hanford Advisory Board
HAMMER	Hazardous Materials Management and Emergency Response
HAP	hazardous air pollutant
HDPE	high-density polyethylene
HFFACO	Hanford Federal Facility Agreement and Consent Order
HHP	Hanford History Project

HLW	high-level waste
HPMC-OMS	HPMC Occupational Medical Services
HRM	Hanford River Mile
HSTGWG	Hanford State and Tribal Government Working Group
HTO	tritiated water vapor
IC	institutional control
ICRP	International Convention on Radiological Protection
IDF	Integrated Disposal Facility
ISMS	Integrated Safety Management System
KEA	key ecological attribute
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
MASF	Maintenance and Storage Facility
MBTA	*Migratory Bird Treaty Act of 1918*
MCO	Multi-Canister Overpacks
MEI	maximally exposed individual
MLLW	mixed low-level waste
MOA	Memorandum of Agreement
MSA	Mission Support Alliance
MSDS	Material Safety Data Sheet
NCO	NEPA Compliance Officer
NEPA	*National Environmental Policy Act of 1969*
NFFS	Nuclear Fuel Fragment Specimens
NFPA	National Fire Protection Association
NHPA	*National Historic Preservation Act of 1966*
NLOP	North Load-Out Pit
NOC	notice of construction

NRC	U.S. Nuclear Regulatory Commission
NRDA	Natural Resource Damage Assessment
NRDWL	Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill
P&T	pump-and-treat
PCB	polychlorinated biphenyl
PEP	Project Execution Plan
PFP	Plutonium Finishing Plant
PHOENIX	PNNL-Hanford Online Environmental Information Exchange
PNNL	Pacific Northwest National Laboratory
PRG	preliminary remediation goal
PUREX	Plutonium Uranium Extraction Facility
QA	quality assurance
QC	quality control
RAVIS	robotic air-slot volumetric inspection system
RBDA	risk-based disposal approvals
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-oxidation
RESRAD	RESidual RADioactivity
RI	remedial investigation
ROD	Record of Decision
RPD	Relative Percent Difference
RPH	Richland Pumphouse
S&M	surveillance and maintenance
SALDS	State-Approved Land Disposal Site
SARA	Superfund Amendments and Reauthorization Act
SDS	Safety Data Sheet
SDWA	*Safe Drinking Water Act of 1974*
SPF	Species Penalty Factor
SSE	safe storage enclosure
SST	single-shell tank
STOMP-WAE	Subsurface Transport Over Multiple Phases – Water-Air-Energy
STSC	sludge transfer and storage containers
SVE	soil vapor extraction

SWL	Solid Waste Landfill
TAP	toxic air pollutant
TBI	Test Bed Initiative
TCE	trichloroethene
TEDF	Treated Effluent Disposal Facility
TLD	thermoluminescent dosimeter
TPA	Tri-Party Agreement
Tri-Cities	cities of Kennewick, Pasco, and Richland
TRU	transuranic
TSCA	*Toxic Substances Control Act*
TSD	treatment, storage, and disposal
UIC	underground injection control
USFWS	U.S. Fish and Wildlife Service
VNSFS	Veolia Nuclear Solutions – Federal Services
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
WHCWG	Wildlife Habitat Connectivity Working Group
WIDS	Waste Information Data System
WIPP	Waste Isolation Pilot Plant
WIR	Waste Incidental to Reprocessing
WMA	waste management area
WNS	White Nose Syndrome
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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2019 Highlight

The Hanford Site is located in south-central Washington State and encompasses approximately 581 mi^2 (1,505 km^2) in Benton, Franklin, Adams, and Grant Counties.

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 average temperature for 2019 was below normal with 6 months showing warmer temperatures and 4 months showing cooler temperatures. Precipitation and snowfall for 2019 were 130% and 199% above normal, respectively.

In August 2019 U.S. Department of Energy established the Hanford State and Tribal Government Working Group. This group is focused on Hanford Site cleanup, Long-Term Stewardship activities, and Tribal program activities.

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. The report has continued to be published annually, previous years are available at http://msa.hanford.gov/page.cfm/enviroreports. The calendar year 2019 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. 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 2019 monitoring efforts and 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 Site regulatory oversight.

1.1 Hanford Site Location

The Hanford Site encompasses approximately 581 mi^2 (1,505 km^2) 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 former 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, Umtanum Ridge, Rattlesnake Hills (including Rattlesnake Mountain), 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.

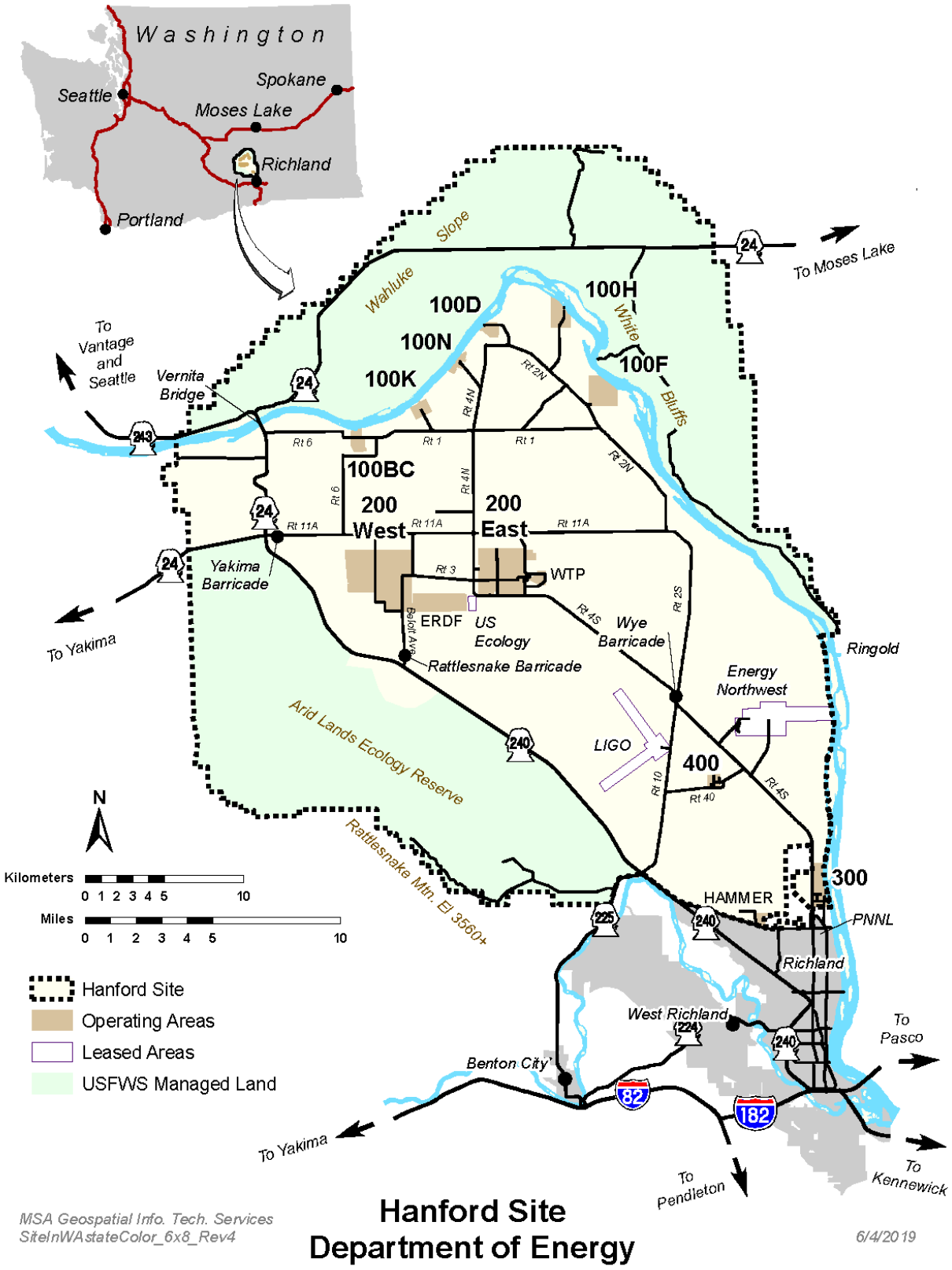

Figure 1-1. Location of the Hanford Site.

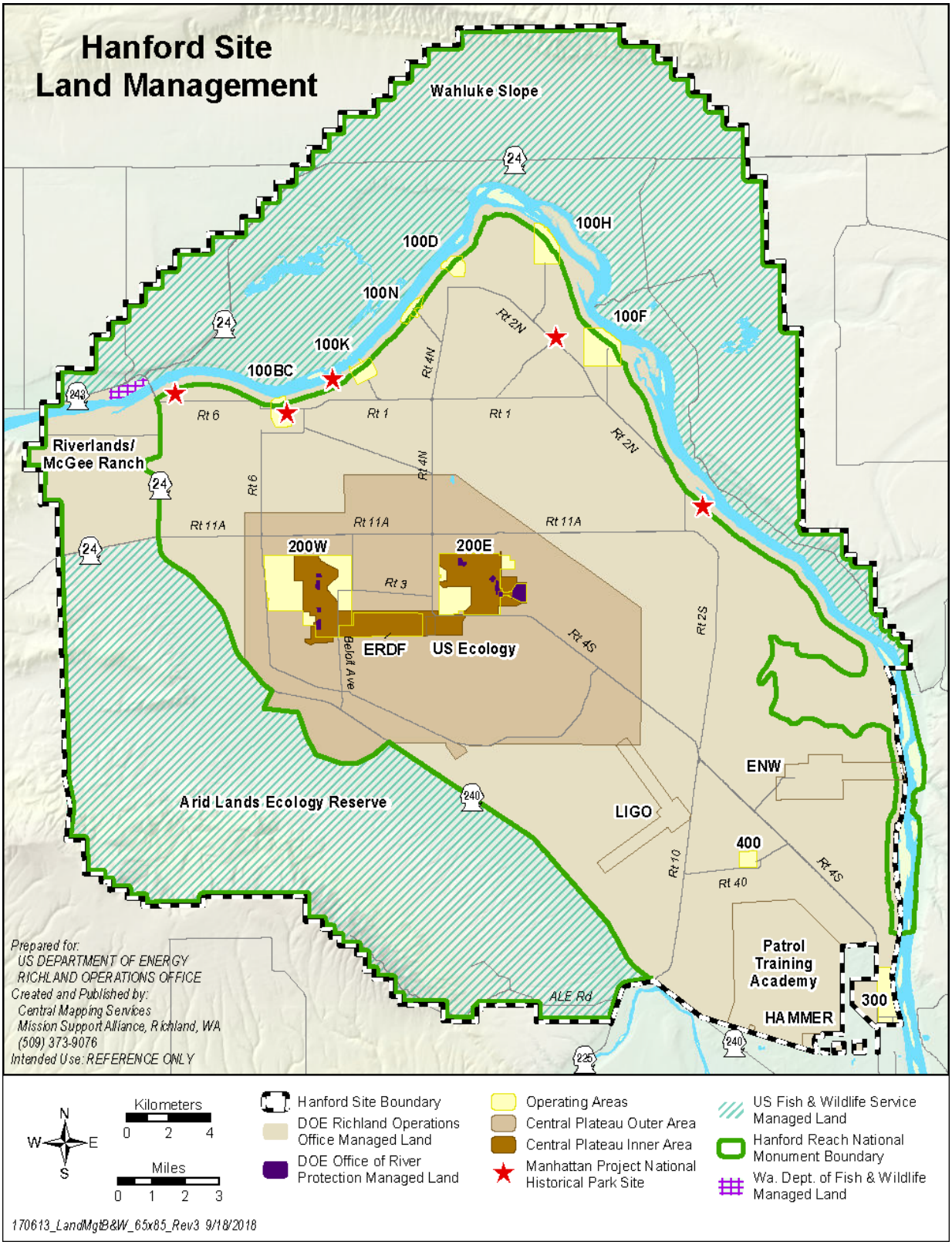

Figure 1-2. Detailed Geography of the Hanford Site, Hanford Reach National Monument, and U.S. Department of Energy Portions of the Hanford Site.

1.2 Hanford Site History and Mission

In February 1943, the federal government, under the authority of the *War Powers Act*, acquired 625 mi^2 (1,689 km^2) 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 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. The Hanford Site manufactured the uranium metal fuel for the nuclear reactors onsite. Five chemical process plants in the center of the Hanford Site processed 110,000 tons (100,000 metric tons) of irradiated fuel from the reactors, discharging an estimated 450 billion gal (1.7 trillion L) of liquids to soil disposal sites and 54.1 million gal (204.8 million L) of radioactive waste to 177 large underground tanks.

Figure 1-3. The Frank Hensley Apple Ranch (circa 1913).

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 activities to environmental remediation. At Hanford, 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), related scientific and environmental research, and development of waste management technologies. In addition, the 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. Aerial View of 100-H Reactor. The 100-H Reactor was the first reactor to be built on the Hanford Site after World War II. It became operational in 1949 and ran until 1965.

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 mi^2 (11 km^2) 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 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 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 9 reactors in Hanford's 100 Area will be cocooned. Reactors C, D, DR, F, H, and N are already cocooned, with K-East and K-West Reactors next in line to be cocooned. B Reactor 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 2015 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. Every 10 years, Hanford Site crews enter the cocooned reactors (also termed Safe Storage Enclosures) to ensure they are maintained in a safe, environmentally secure, and cost-effective manner until subsequent closure during the final disposition phase of decommissioning. The next series of inspections are planned for the year 2025. These Safe Storage Enclosures will remain in place for approximately 75 years.

DOE operates five pump-and-treat facilities along the River Corridor to intercept and treat contaminated plumes before they enter the river. 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 up to 330 gal/min (1,249 L/min). The third and newest system (KX) began operation in February 2009 and treats up to 900 gal/min (3,407 L/min). The KX system is used primarily to treat hexavalent chromium in groundwater in KE and 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 in the HR Operable Unit. 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 up to 900 gal/min (3,407 L/min) each. Details of the operations and results for these pump-and-treat facilities can be found in DOE/RL-2018-67, *Calendar Year 2018 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 mi^2 (194 km^2) 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 the 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 plays many roles that 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 mixed 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 processed water is sent to other facilities for treatment and safe disposal.

The Canister Storage Building (CSB) is a large 42,000-ft^2 (3,902-m^2) 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 removed for shipment to and permanent placement in the 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 will also be 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 mi^2 (1.5 km^2). 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 mi^2 (0.61 km^2). 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 remainder of the Hanford Site and includes the 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 received wastes that were generated by activities in the 300 Area of the Hanford Site. The 300 Area included

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 included remediating more than 2,200 drums, debris, and 94 buried vertical pipe units (VPU) that contain radioactive and chemical waste. The VPUs were either 55-gal (208-L) steel drums welded together end-to-end to form a pipe, or corrugated steel pipes. 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 of the 618-11 Burial Ground was completed in 2011.

1.3.6 1100 Area

The former 1100 Area is located between the 300 Area and Richland, covering 1.2 mi^2 (3.1 km^2). 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. While this area is no longer part of the Hanford Site, 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 research and development 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

The Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Federal Training Center 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-mi^2 (0.31-km^2) main site and a 15.6-mi^2 (40.4-km^2) 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. Firefighters Practice Skills They Will Use On and Off the Hanford Site.

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 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) of 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 mergers of 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 as well as other facilities across the United States. 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-mi^2 (36.4-km^2) 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-mi^2 (101-km^2) area in Benton, Franklin, and Grant counties also includes the 9.9-mi^2 (25.6-km^2) Hanford Site dunes north of the CGS.

1.3.15 Manhattan Project National Historical Park

Established in November 2015, The Manhattan Project National Historic Park 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:

- Bruggemann's Agricultural Warehouse Complex (existed since circa 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.

- MSA 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.

- 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, Effluent Treatment Facility/Liquid Effluent Treatment Facility, 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 2019 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 2019 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.

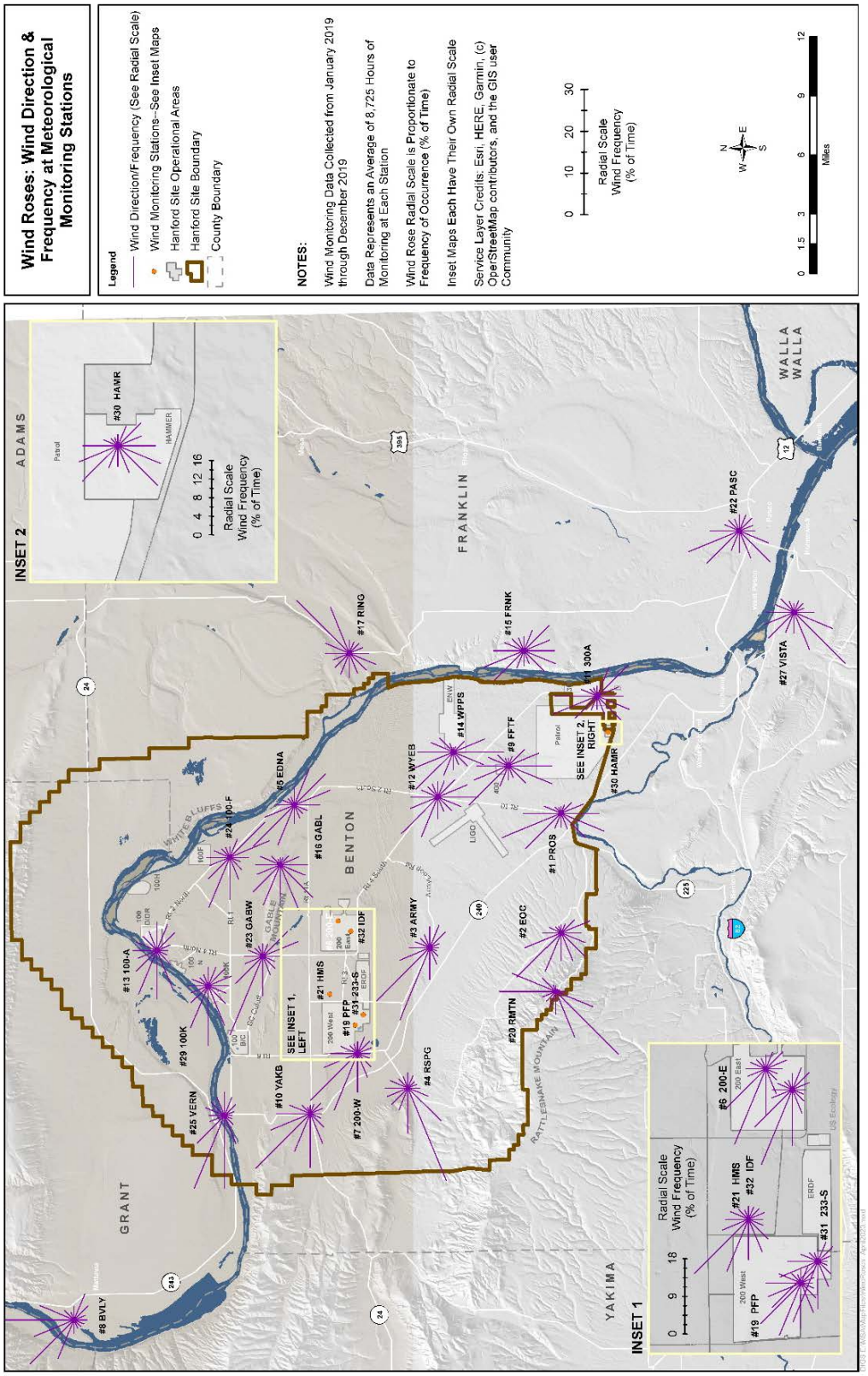

Figure 1-6. Meteorological Monitoring Network Wind Roses from 2019.
NOTE: Measured at a height of 30 ft (9 m).

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

1.6.1 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 2019.

Table 1-1. Hanford Meteorological Station Climatological Information for 1945 through 2019.

	Normal annual average	Highest monthly average	Lowest monthly average	Record highest monthly average	Record lowest monthly average	Highest daily	Lowest daily
Temperature °F (°C)	53.9 (12.2)	77.0 (25.0)	31.5 (-0.3)	82.8 (28.2)	12.1 (-11.1)	113 (45)	-23 (-31)
Relative Humidity %	55.3	80.6	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]	2.21 (5.6)	–
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 2019 was 52.4 °F (13 °C), which was 1.5 °F (0.8 °C) below normal. During 2019, 6 months were warmer than normal and 6 months were cooler than normal. May had the greatest positive departure at 3.5 °F (1.9 °C) above normal and February had the largest negative departure at 13.4 °F (7.4 °C) below normal.

Precipitation totaled 9.31 in. (23.6 cm), which is 130% of normal precipitation (7.14 in. [18.14 cm]). Greatest monthly total of precipitation was 2.35 in. (5.97 cm) in August and lowest monthly total was a 0.09 in (0.23 cm) in November. August 10 and 11 had the greatest 24-hour precipitation at 2.21 in. (5.61 cm). This is also the all-time greatest 24-hour precipitation in Hanford Meteorological Station history. Snowfall for 2019 totaled 30.5 in. (77.5 cm), which was 199% of normal (15.3 in. [38.6 cm]).

Average wind speed was 7.5 mph (3.3 m/s), which was 0.1 mph (0.04 m/s) above normal. Occurring on October 25, the peak gust for the year was 55 mph (24.6 m/s).

The growing season was 169 days in 2019. This made 2019's growing season below the normal of 184 days. The last frost in spring was April 15, and the first frost in fall was October 2. 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 2019.

Month	Temperature (°F)								Precipitation (in.)				Relative Humidity (%)		15-m Wind[b]				
	Averages				Extremes						Snowfall						Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure[c]	Highest	Date	Lowest	Date	Total	Departure[c]	Total	Departure[c]	Average	Departure[c]	Average Speed (mph)	Departure[c]	Speed (mph)	Direction	Date
Jan	41.4	28.8	35.1	+1.7	57	4	18	29	1.17	+0.23	0.2	-4.4	84.2	+4.4	5.9	-0.4	46	SSW	6
Feb	30.8	18.8	24.8	-13.4	42	3	4	7	1.65	+0.95	25.3	+23.0	79.2	+8.5	6.9	0.0	35	NNE	9
Mar	48.3	26.5	37.4	-9.1	70	22[d]	5	5	0.44	-0.13	4.4	+4.0	68.7	+11.5	6.0	-1.9	37	WSW	25
Apr	67.1	44.0	55.5	+2.0	80	18	32	15	0.71	-0.16	0	0	50.4	+2.1	9.5	+1.0	53	WNW	27
May	79.5	51.6	65.6	+4.5	93	31	38	1	0.92	+0.51	0	0	43.3	+0.1	8.7	-0.1	40	W	14
Jun	86.1	56.1	71.1	+1.5	102	13	42	7	0.30	-0.21	0	0	35.4	-4.2	10.0	+1.0	51	WNW	18
Jul	90.6	61.2	75.9	-1.2	101	23	54	19	0.36	+0.13	0	0	35.9	+1.8	8.9	+0.3	42	NW	23
Aug	92.2	62.4	77.3	+1.8	106	7	54	23	2.35	+2.17	0	0	39.7	+4.0	7.9	-0.1	48	WSW	21
Sep	78.1	53.4	65.7	-0.7	94	3	38	29	0.27	-0.04	T	+T	53.1	+10.2	8.0	+0.7	44	NW	7
Oct	60.6	35.7	48.2	-4.9	77	7	15	30	0.50	+0.01	T	+T	53.1	-3.0	7.8	+1.1	55	NW	25
Nov	47.7	28.5	38.1	-2.4	59	6	15	30	0.09	-0.86	T	-2.0	73.3	-0.6	6.1	-0.6	45	NE	27
Dec	39.4	29.1	34.2	+3.1	63	21[d]	19	2	0.65	-0.65	0.6	-3.7	88.3	+7.1	4.6	-1.3	47	WSW	31
Year[e]	63.5	41.3	52.4	-1.5	106	Aug 7	4	Feb 7	9.31	+2.17	30.5	+15.2	58.7	+3.4	7.5	-0.1	55	NW	Oct 25

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, Washington, 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 Hanford 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 2019 Activities.

DOE-RL continued to interact with the Tribes regarding Tribal access and use of the Hanford Site. In August 2019 DOE–RL established the Hanford State and Tribal Government Working Group (HSTGWG) meeting. The HSTGWG is focused on Hanford Site Cleanup, Long-Term Stewardship (LTS) activities, and Tribal program activities. HSTGWG members are DOE-RL, DOE-ORP, EPA, Washington State Department of Ecology, State of Oregon, CTUIR, Nez Perce Tribe, Confederated Tribes and Bands of the Yakama Nation, and Wanapum Band of Indians. The HSTGWG is held twice a year in advance of the Environmental Management State and Tribal Government Working Group.

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, including:

- Tribal training for DOE and Contractor managers
- HAMMER Tribal Subcommittee participation

- 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 2019 Activities.

In 2019, the Cultural and Historic Resources Program conducted NHPA reviews for 71 proposed projects. DOE-RL hosted 11 monthly meetings with Tribal representatives. DOE-RL consulted on one Memorandum of Agreement (MOA) and completed the signature process during the year. The MOA was developed to resolve adverse effects to a Traditional Cultural Property in the 100-K Area from a proposed pump–and-treat well installation.

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 2019 Activities.

Hanford NRDA work in FY 2019 focused on continuing the FY 2018 injury assessment studies and began work on three 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 seven assessment activities:

- Phase III 100-F Area evaluation
- Injury thresholds
- Chinook salmon modeling
- Terrestrial data compilation
- Information to help establish aquatic baseline and structure the aquatic assessment
- Shrub-steppe habitat restoration planning
- Aquatic storage and retention evaluation.

Two other projects were initiated in FY 2019:

- Aquatic restoration planning
- Development of a Legal Work Group and Kick-off Meeting.

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 2019, 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.

- 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 Site presentations; and other Hanford Site-related public involvement and information meetings, workshops, or activities.

For more information about Hanford Site cleanup activities, contact the 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

LA Strasser

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 consults with and includes 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

LA Strasser

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, CTUIR, and the Yakama Nation. Current members with their affiliations are listed on the HAB website at https://www.hanford.gov/files.cfm/20200124_Membership_List.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 2019, the HAB provided DOE with four 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 TPA, which describes how to implement the cleanup and permitting efforts; this includes milestones (TPA 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, 2019, a total of 1,349 TPA milestones were completed and 343 target dates were met. During 2019, 25 specific cleanup milestones were scheduled for completion; of those, 2 milestones were deleted, 18 milestones were completed on time, 5 milestones were being disputed, and zero milestones were in negotiation. In addition, two target dates were met, zero target dates were deleted or disputed, and there were no target dates in negotiation.

1.8.1.2 TPA-Approved Modifications.

During 2019, 16 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 2019, the DNFSB oversaw projects pertaining to each contractor at the Hanford Site (e.g., 324 Building, WTP, Central Plateau Risk Mitigation, and 242-A Evaporator). Reports produced by the DNFSB reporting on Hanford Site projects can be viewed at https://www.dnfsb.gov/documents.

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2019 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.

Radiation Protection of the Public and the Environment
The dose to a maximally exposed member of the public during 2019 was estimated to be 0.16 mrem, well below the U.S. Department of Energy public dose limit of 100 mrem/yr. This continues the trend of very low radiation exposure to members of the public.

Pollution Prevention and Waste Minimization
The Hanford Site continued diversion efforts for 1,020 metric tons of nonhazardous solid waste by maintaining a diverse recycling program. The Hanford Site received a five-star 2020 Electronic Product Environmental Assessment Tool purchaser award for the procurement of sustainable electronics.

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
- Four of DOE's contractors as permittees and co-operators
  - Bechtel National, Inc.
  - CH2M Plateau Remediation Company (CHPRC)
  - Pacific Northwest National Laboratory
  - Washington River Protection Solutions, LLC (WRPS).
- A fifth contractor, Mission Support Alliance, LLC (MSA), is also a permittee. However, MSA is not a co-operator.

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
- 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 2019, 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)
- 400 Area Waste Management Unit (Operating Unit 16)
- 276-BA Organic Storage Area (Closure Unit Group 32).

2.1.2.2 Regulatory Agency Inspections

SA Szendre

During fiscal year (FY) 2019, 90 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 Plutonium Uranium Extraction Facility (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 notices of noncompliance or enforcement actions for alleged violations of permit conditions/requirements and 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 1994) and WAC 173-303, "Washington State Dangerous Waste Regulations." The TSD units and other facilities inspected during 2019 included the following:

- 200 Areas Effluent Treatment Facility/ Liquid Effluent Retention Facility
- Waste Encapsulation and Storage Facility
- 222-S Laboratory
- 400 Area Waste Management Unit
- 242-A Evaporator
- 325 Building
- 324 Building
- B-Plant
- Hexone Storage and Treatment Facility
- Central Waste Complex
- Low-level Burial Grounds Trenches 31 and 34

- Plutonium Finishing Plant
- PUREX/PUREX Storage Tunnel
- Double-shell tank and single-shell-tank tank farms
- T-Plant
- Waste Receiving and Processing Facility
- Central Accumulation Area
- 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 2019 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 groundwater at 23 RCRA units on the Hanford Site. Section 8.0 includes a summary of groundwater monitoring activities for the RCRA units during 2019. DOE/RL-2019-65, *Hanford Site RCRA Groundwater Monitoring Report for 2019,* 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 Hanford 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, 5 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-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 ICs 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 described in DOE/RL-2001-41, ICs are assessed annually as required by the respective CERCLA and/or RCRA decision documents. 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 2019 annual assessment can be summarized as follows:

- Entry Restrictions
  - Active badging program and barricades are in place to control unauthorized entries.
  - Damaged fences were observed in 11 locations and repairs have been completed.
- Warning Notices
  - Hazardous Area Warning signs required by decision documents are in place; two were repaired/replaced in 2019.
  - "No Trespassing" signs along road perimeters were found to be damaged or illegible due to general weathering or fire; replacement signs were fabricated and installed in 2019.
- Land Use Management
  - LTS reviewed 28 Site Evaluations in 2019 to ensure adherence to existing land-use ICs
  - LTS approval is mandatory on Site Excavation Permits.
  - 146 Site Excavation Permit applications were evaluated in FY 2019 for IC compliance.
  - No change in land-use designations occurred in FY 2019 (e.g., industrial use).
  - No significant disturbances or natural subsidence/erosion was found on the waste sites with ICs.

  - Thirty-six waste sites in the 300 Area Industrial Complex with enhanced recharge controls were reviewed in 2019:
    - LTS improved and maintained drainage systems and in-place asphalt barriers to support the prevention of enhanced recharge IC. LTS continued facilitation of regular 300 Area Hanford Contractor Interface meetings.
    - Collaboration continues among the 300 Area contractors to minimize impact of discharges from fire hydrant flushing 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.

- Barriers – Engineered Controls
  - Controls are in place to maintain integrity of the cap at the Horn Rapids Landfill.

- Miscellaneous Provisions
  - Ten reportable trespassing incidents occurred on the Hanford Site in FY 2019. Operable units in the Central Plateau of the Hanford Site also have a number of ICs in both interim and final ROD documents. In FY 2019, 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:

- Tier Two Emergency and Hazardous Chemical Inventory, which provides information about hazardous chemicals stored at each facility in amounts exceeding minimum threshold levels

- Toxic Chemical Release Inventory, which describes total annual releases of certain toxic chemicals and associated waste management activities.

Table 2-2 provides an overview of reporting under the EPRCA during 2019.

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

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
302	40 CFR 355, "Emergency Planning 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 substance in quantity equal to or greater than threshold planning quantity or 500 lbs (230 kg), whichever is less.	Annually by March 1	Local Emergency Planning Committee; State Emergency Response Commission; Local Fire Departments
313	40 CFR 372, "Toxic Chemical Release Reporting"	Manufacture, process, or use at a facility, any listed Toxic Release Inventory chemical in excess of threshold amount during a CY. Thresholds are 25,000 lbs (11,300 kg) for manufactured or processed or 10,000 lbs (4,500 kg) for otherwise used except for persistent, bio-accumulative, toxic chemicals with thresholds under 100 lbs (45 kg).	Annually by July 1	EPA; State Emergency Response Commission

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-2020-06, *2019 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 58 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 2019.

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

CAS#	Chemical	TPQ	Average Amount (lb/kg)
8052-42-4	Asphalt	10,000	7,113,949/3,226,832
7647-14-5	Sodium Chloride	10,000	2,027,934/919,855
9003-55-8	Styene Polymer with 1,3-Butadiene	10,000	1,778,293/806,620
	Cement Mixture	10,000	2,085,983/946,185
68476-34-6	Diesel Fuel	10,000	2,625,492/1,190,903
8012-95-1	Mineral Oil	10,000	1,597,430/724,582
8006-61-9	Gasoline	10,000	759,256/344,392
74-98-6	Propane	10,000	716,556/325,024
7727-37-9	Nitrogen	10,000	842,246/382,036
7440-23-5	Sodium	10,000	2,351,028/1,066,408

The DOE/RL-20120-30, *2019 Hanford Site Toxic Chemical Release Inventory,* report was submitted to EPA and Ecology before the annual July 1 deadline. During calendar year (CY) 2019, the Hanford Site exceeded activity thresholds for lead, naphthalene, propylene, xylene, toluene, and sodium nitrite. 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
1330-20-07	Xylene	Gasoline used for stationary equipment
7632-00-0	Sodium Nitrite	Control pH in waste at Tank Farms

2.1.5 Environmental Release Reporting

CJ Nelson

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). At the Hanford Site, TSCA primarily involves regulation of polychlorinated biphenyls (PCBs). TSCA also regulates other constituents (e.g., asbestos and lead-based paint). 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.

- 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-2019-18, *2018 Polychlorinated Biphenyl Annual Report*, and DOE/RL-2019-17, *2018 Polychlorinated Biphenyl Annual Document Log*, to EPA on June 28, 2019, 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 was performed at the 242-A Evaporator under the risk-based disposal approval (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) radioactive (transuranic) PCB remediation waste. The waste was solidified at the Hanford Site T-Plant Complex to meet radiological treatment standards in preparation for disposal at the Waste Isolation Plant.
  - 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 2019, 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 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. The evaluation of many natural, cultural, ecological, and other 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 Council 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 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 2019. 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 EISs completed or underway at the Hanford Site during CY 2019.

2.2.2 Hanford Site Environmental Assessments.

Hanford Site EAs that were completed or underway in CY 2019 are described in this section.

2.2.2.1 Environmental Assessment for Rebuild of 12.6 Miles of the Benton-Othello Switching Station 115-kV Electrical Transmission Line on the Hanford Site, Washington (DOE/EA-2038).

An EA was prepared 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. The U.S. Department of the Interior, Fish and Wildlife Service, issued a Biological Opinion for the project on February 12, 2018.

DOE completed the final EA in July 2019 and determined that the Proposed Action would not constitute a major federal action significantly affecting the quality of the human environment within the meaning of NEPA. Therefore, preparation of an EIS is not required, and DOE issued its Finding of No Significant Impact on July 28, 2019.

2.2.2.2 Test Bed Initiative Environmental Assessment (DRAFT).

An EA is underway to analyze the potential environmental impacts of a proposed Test Bed Initiative (TBI). The TBI would involve a treatment demonstration using 2,000 gallons of tank waste staged in a double-shell tank. Cesium would be removed from the waste by inserting a pump in the double-shell tank with an in-tank filtration system and ion exchange column containing Crystalline Silicotitanate to capture the cesium. Work continued on the TBI-EA during FY 2019.

2.2.3 Hanford Site Categorical Exclusions.

Categorical exclusions (CXs) 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 49 CXs during CY 2019. Of these, 36 were annual CXs to cover routine and recurring work activities planned to be performed during CY 2019 at the Hanford Site (MSA – 36 annual CXs used to cover corrective, preventive, and predictive maintenance of existing water and sewer pumps and piping, electrical power poles and conductors, and telecommunication network cabling and antenna, no other Hanford contractors prepared annual CXs for approval by the NCO during CY 2019). A total of 13 activity-specific CXs (ASCXs) were approved by the NCO (MSA – 13 ASCXs to cover the siting, acquisition, construction or modification, operation, and removal of raw and sanitary water and sewer systems, electrical distribution systems, telecommunication systems, support buildings, and parking lots, no other Hanford contractors prepared ASCXs for approval by the NCO during CY 2019). Annual and ASCX approved by the DOE-RL 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 https://www.standards.doe.gov/.

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] (2 Pages)

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	>100, <500	*>1, <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-1153-2019)		
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

Table 2-5. Radiation Protection Standards for the Public and the Environment from All Routine DOE Operations.[a] (2 Pages)

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.

NOTE: International dose units shown in italics are not provided in the order or rules but are provided for information.

[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). 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*

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 CERCLA.

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. The EPA has delegated authority to Ecology and WDOH to implement state laws and regulations in lieu of EPA regulations implementing the *Clean Air Act.*

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-2020-08, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2019*).

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. 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. Renewal 2 continued to be in effect until a renewed permit was issued. Ecology issued Renewal 3 of the Air Operating Permit for a period of 5 years, effective August 1, 2019. Renewal 3 was issued to incorporate new WDOH and Ecology air emission licenses, approval orders, and updated regulatory requirements.

The Air Operating Permit is a compilation of applicable *Clean Air Act* requirements for both radioactive and criteria/toxic air pollutant emissions, including the radioactive air emissions license FF-01 issued by WDOH and Notice of Construction Approval Orders issued by Ecology. The Air Operating Permit requires the submittal of semiannual reports to the regulatory agencies documenting the status of required monitoring and permit deviations. In addition, an annual report documenting the compliance status of Hanford Site emission sources against applicable *Clean Air Act* requirements and an annual report that documents total emissions of criteria and toxic pollutants is also required.

The WDOH, Ecology, and the Benton Clean Air Agency conduct inspections of Hanford Site emission sources to verify compliance with applicable *Clean Air Act* requirements. Hanford Site contractors and DOE actively work to resolve any potential compliance issues identified during these inspections. During 2019, regulatory agencies conducted 44 *Clean Air Act* inspections on the Hanford Site.

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, applicable regulations are found at 40 CFR Part 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 2019: 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 operations were in effect (and issued to Bechtel National Inc.) during 2019: 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 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 2019 for microbiological, chemical, physical, and radiological constituents. There were no microbiological violations during the 2019 monitoring cycle and all eight water systems had chemical concentrations in drinking water that were well below the maximum contaminant levels established by EPA. The 200-West system had one detection for total coliform bacteria, but all repeat samples were satisfactory and no violation occurred. Table 2-6 provides selected drinking water standards. System-specific information and analytical results for 2019 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
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
Nickel	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 pi/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

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

Constituent	Drinking Water Standard [a]		Agency [b]
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

KJ 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, "Floodplain Management" and Executive Order 11990, "Protection of Wetlands." The review also addresses whether other significant resources (e.g., 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 100 ecological compliance reviews requested during FY 2019 from 17 functional departments on the Hanford Site. Of the 17 functional departments, those with a significant number of requests include Soil and Groundwater (16), Reliability Services (12), Remediation (10), Water and Sewer Utilities (10), and Electrical Utilities (6).

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; entering buffer areas at mid-day; and 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 of 1966* (NHPA), 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 65, "National Historic Landmarks Program"; 36 CFR 79, "Curation of Federally-Owned and Administered Archaeological Collections"; 36 CFR 800, "Protection of Historic Properties"; 43 CFR 7, Protection of Archaeological Resources"; and 43 CFR 10, "Native American Graves Protection and Repatriation and Regulations."

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

There were 71 NHPA Section 106 compliance reviews completed on the Hanford Site in 2019. There were 18 archaeological sites monitored under the NHPA Section 110 Site Conditions Monitoring Program. See Section 11.3.1 for additional information.

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 (https://ehs.hanford.gov/msds/). 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 and Tier II, 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) promotes 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 2019.

Table 2-7. Recycle Quantities.

Material	FY 2019 Total (metric tons)
Non-hazardous Solid Wastes	
Activated Carbon	44.50
Aluminum Cans	3.46
Cardboard	90.45
CI Shredded Paper	408.33
Electronics	23.23
Ferrous Metal	145.56
Furniture	101.04
Miscellaneous	50.66
Non-ferrous Metals	21.08
Plastic Bottles	41.72
Software/Media	1.22
Tires	52.89
Transformers	7.18
Wood Pallets	28.60
Total	**1019.92**
Regulated Solid Wastes	
Aerosol Cans	0.20
Antifreeze	3.60
Ballasts	4.16
Batteries	4.34
Fluorescent Bulbs	5.76
Lamps - Mercury Containing	0.01
Lead Acid Batteries	44.91
Toner Cartridges	5.31
Used Oil	36.89
Total	**105.18**

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 2019. The Green Electronics Council notified the Hanford Site that they received a five-star 2020 Electronic Product Environmental Assessment Tool (EPEAT) Purchasers Award for the combined application MSA submitted on behalf of MSA, CHPRC, WRPS, HPMC Occupational Medical Services, Veolia Nuclear Solutions – Federal Services, DOE-ORP, and DOE-RL for CY 2019. The goal of the EPEAT Purchaser Award 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, servers, and mobile phones with rating tiers of gold, silver, and bronze. EPEAT Purchasers earn one star for each product category, 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 323 metric tons, avoided the disposal of 32.6 metric tons of hazardous waste, eliminated 19 metric tons of solid waste, and avoided 1.4 metric tons of water

pollutant emissions. These efforts saved 1,472 MWh of electricity, reduced 702 metric tons of greenhouse gas emissions, and generated $116,756 in lifetime cost avoidance.

2.7.2.2 Accomplishments.

The Hanford Site contractors recycled 38% of non-hazardous solid waste, excluding construction and demolition (C&D) debris. In 2019, 1,019.92 metric tons of non-hazardous (i.e., plastic, aluminum, cardboard, paper, wood, and metal) and 105.18 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 gas emissions Scopes 1, 2, and 3. There was a 39% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2019 from the FY 2008 baseline; emissions in FY 2019 were 25,234.2 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 2019, contractors at the Hanford Site continued to divert C&D debris from landfill disposal. The Hanford Site diverted approximately 16% (1,814.03 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 2020:

- 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 2019 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 were maintained in 2019, 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

CJ Nelson

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. 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 2019.

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 29 documented occurrences of legacy contamination from January 1, 2019, to December 31, 2019. 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 (e.g., tumbleweeds, rodents, and birds). Tumbleweeds have a deep taproot that can move 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. Legacy contamination that is discovered is consolidated into quarterly reports.

2.9 Environmental Permits

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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 elsewhere in 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, was effective on April 1, 2013, with and expiration date of March 31, 2018. A permit renewal application was submitted to Ecology in August 2017 and determined to be complete by Ecology in November 2017. Renewal 2 remained in effect until Renewal 3 was issued. Ecology issued Renewal 3 of the Air Operating Permit for a period of 5 years, effective August 1, 2019.The AOP covers operations on the Hanford Site having a potential to emit airborne emissions. The permit is intended to provide a compilation of applicable Clean Air Act requirements for radioactive and nonradioactive emissions at the Hanford Site. It is implemented through federal and state programs.

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

Radioactive Air Emissions License for the 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).
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 expired December 31, 2019. A permit renewal application was submitted to and received by Ecology on December 12, 2019. A letter was received from Ecology on December 31, 2019, 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 (19-NWP-212).
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 expires December 31, 2024.
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.

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

Wildlife Permits		
Permit MB60138B-0, 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.		
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 the collection of fish for research 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 the collection of fish for research activities in the Columbia River. This review has no expiration listed.		
Permit 18-113, Scientific Collection Permit issued by WDFW to MSA for 2018 through June 2019, authorizes food fish, shellfish, game fish, and wildlife collection for research purposes. This permit is renewed annually.		
Permit 19-124, Scientific Collection Permit issued by WDFW to MSA for 2019 through June 2020, 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 2420 Stevens Center Pl Richland, WA 99354
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-RL = U.S. Department of Energy, Richland Operations Office Ecology = Washington State Department of Ecology MSA = Mission Support Alliance RCRA = *Resource Conservation and Recovery Act* WDFW = Washington State Department of Fish and Wildlife WDOH = Washington State Department of Health WTP = Waste Treatment and Immobilization 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 2019.

2.10.1 Enforcement Actions by Regulatory Program Area

During 2019 there were 10 regulatory agency compliance actions filed against the DOE and its contractors for alleged violations of regulatory requirements or other enforceable agreements. Ten compliance actions were issued by Ecology. Nine compliance actions resulted from regulatory agency inspections of DOE facilities on the Hanford Site (Section 2.1.2.2). The inspection reports also contained 24 concerns.

Table 2-9 summarizes the alleged environmental noncompliance notices by program area. Table 2-10 summarizes the 22 alleged environmental noncompliance notices cited against the DOE and its contractors during 2019 including a short description of the alleged noncompliances. Figure 2-1 shows alleged environmental noncompliance concerns, violations, and associated fines.

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.

Table 2-9. Alleged Environmental Noncompliance Summary by Program Area, 2014 through 2019.

Program Area	2014	2015	2016	2017	2018	2019
CAA	2	3	1	0	1	0
CWA	0	1	0	1	0	1
RCRA	7	16	22	33	21	9
CERCLA	0	0	1	0	0	0
Others	1	7	3	0	0	0
Total	10	27	27	34	22	10

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 Calendar Year 2019.

Agency	Document Number	Title	Alleged Noncompliance Description
Ecology	2020-02	ECOLOGY WARNING LETTER REGARDING INSPECTION AT THE 216-A-29 DITCH	Alleged non-compliance for inadequate sampling for ammonia in Well 299-E6-13 for the 216-A-29 Ditch.
Ecology	2019-13	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE CENTRAL WASTE COMPLEX AND WASTE RECEIVING AND PROCESSING PLANT	Alleged non-compliance for inaccurate location information in the Operating Record for container 0005819.
WDOH	2019-12	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE T PLANT COMPLEX	Alleged non-compliances for inadequate Land Disposal Restriction notifications, inadequate designation of Tank M-101, and inadequate management of waste in 221-T Tank and Cell 11-L.
Ecology	2019-11	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE 222-S LABORATORY	Alleged non-compliance for not implementing the Contingency Plan when analytical instrumentation generated heats cause smoke in the laboratory.
Ecology	2019-10	ECOLOGY WARNING LETTER BASED ON INSPECTION OF THE 400 AREA WASTE MANAGEMENT UNIT	Alleged non-compliance for inadequate inspections of ignitable and reactive waste, and inadequate designation of sodium stored in the Interim Examination and Maintenance Cell.
Ecology	2019-07	NON-COMPLIANCE WITH ST0004511 STATE WASTE DISCHARGE PERMIT DISCOVERED	Two discharges from the field log were not recorded on the electronic version and annual submittal of the site wide Significant Discharge Log for Calendar Year 2017.

Ecology = Washington State Department of Ecology
WDOH = Washington State Department of Health

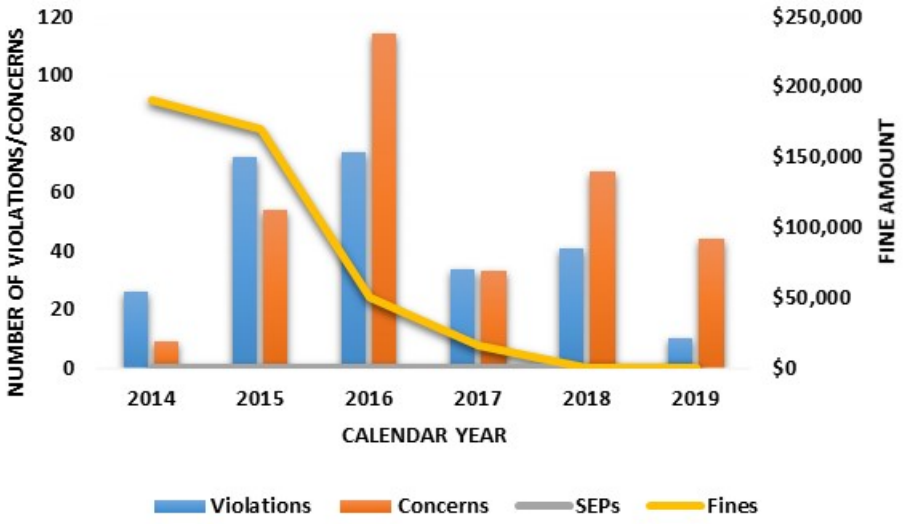

Figure 2-1. Alleged Environmental Noncompliance Violations, Concerns, and Associated Fines Summary.

2.10.2 Wastewater Permit Deviations

J Russell

During CY 2019, there were 18 non-compliances reported to regulatory agencies for wastewater permit deviations. Two of the events involved Large Onsite Sewage System permits and 16 involved State Waste Discharge Permits. In all cases, action was taken to repair and correct the non-compliant conditions; 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 2019 Wastewater Permit Deviations. (3 Pages)

Date	Permit Number Deviated	Reported To	Reason(s)
January 2	ST0004511	Ecology	Potable water leak within 300 ft of crib 216-A-29 and ditch 200-E-286.
January 27	ST0004511	Ecology	Potable water line leak resulting in approximately 96,000 gal of water to the ground.
February 2	ST0004511	Ecology	The permit limit for discharge duration was exceeded during water line flushing activities due to an operator inadvertently leaving the water line open.
March 18	ST0004502	Ecology	TEDF discharge permit ST0004502 Special Condition S2.A requires quarterly sampling for chloroform at TEDF Building 6653. The monthly average effluent limit for chloroform is 7 µg/L per Special Condition S1.A. Results from the February 20, 2019, sample were 9.40 µg/L, which exceeded the monthly average effluent limit for chloroform.

Table 2-11. CY 2019 Wastewater Permit Deviations. (3 Pages)

Date	Permit Number Deviated	Reported To	Reason(s)
April 2	ST0004502	Ecology	A leak was detected in an air vacuum relief valve at Manhole TL-03 of the TEDF transfer line and reported per ST0004502 Special Condition S3.E.
April 29	ST0004500	Ecology	State-Approved Land Disposal Site (SALDS) discharge permit ST0004500 Special Condition S4.A requires the implementation of instructions and procedures within the operations and maintenance manual. Once a month, the samplers obtain "depth-to-water" readings at groundwater wells 699-48-77C and 699-48-77D. In February and March 2019, these readings were not obtained due to weather preventing vehicle access to the SALDS.
May 8	ST0004502	Ecology	A leak was detected in an air vacuum relief valve at Manhole TL-07 of the TEDF transfer line and reported per ST0004502 Special Condition S3.E.
May 11	ST0004511	Ecology	Potable water line leak east of MO291 resulting in 72,000 gal of water released to the ground. The discharge limit exceeded 150 gal/min, resulting in an S8 Upset Condition.
May 23	ST0004511	Ecology	Potable water leak west of MO159 was within 300 feet of ditch 200-E-286 and crib 216-A-37-1.
June 17	HAN071	Health	25 gal of sewage was released to the ground from 2607-1E11 lift station holding tank. A leaking faucet resulted in the tank filling up ahead of the normal pumping schedule.
June 22	HAN068	Health	1,000 gal of sewage was released to the ground from 2601-W6 lift station vault. A leaking sprinkler resulted in the tank filling up inside the vault.
July 18	ST0004511	Ecology	500 gal potable water leak within 300 ft of crib 216-A-29 and ditch 200-E-286.
August 8	ST0004502	Ecology	TEDF discharge permit ST0004502 Special Condition S2.A requires monthly sampling for iron at TEDF Building 6653. The monthly average effluent limit for iron is 300 µg/L per Special Condition S1.A. The monthly average for July 2019 was 301 µg/L.
August 8	ST0004511	Ecology	500 gal potable water leak within 300 ft of crib 216-A-29 and ditch 200-E-286.
September 3	ST0004502	Ecology	A leak was detected in an air vacuum relief valve at Manhole TL-20 of the TEDF transfer line and reported per ST0004502 Special Condition S3.E.
October 29	ST0004500	Ecology	The SALDS discharge permit ST0004500 was noncompliant with Special Condition S2.A, because the semivolatile organic analysis were not extracted within its 7-day hold time. The noncompliance occurred because the GEL Laboratory in South Carolina was evacuated after Hurricane Dorian shifted its course.
November 7	ST0004502	Ecology	TEDF discharge permit ST0004502 Special Condition S4.A requires the implementation of instructions and procedures within the operations and maintenance manual. The sampling protocol required a nitric acid preservative be

Table 2-11. CY 2019 Wastewater Permit Deviations. (3 Pages)

Date	Permit Number Deviated	Reported To	Reason(s)
			added to the samples to ensure the pH is less than 2. Two manganese sample bottles were not properly prepared with the nitric acid preservative. The manganese samples were compliant with EPA method 200.8, because samples can be returned to the laboratory within 2 weeks of collection and acid preserved upon receipt in the laboratory. The manganese analyses were compliant with Special Condition S2.A, and the manganese monthly average was compliant with effluent limits in Special Condition S1.A.
November 20	ST0004511	Ecology	30,000 gal raw water line leak at B Reactor exceeded permit discharge rate limit of 150 gal/min.

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 https://www.govinfo.gov/app/details/CFR-2011-title10-vol4/CFR-2011-title10-vol4-part820.

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.

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.

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.

40 CFR 370. "Hazardous Chemical Report: Community Right-to-Know." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?SID=20b8ce1b28de96640107c074c3624fee&mc=true&tpl=/ecfrbrowse/Title40/40cfr370_main_02.tpl.

40 CFR 372. "Toxic Chemical Release Reporting: Community Right-to-Know." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?SID=c71bb36461a4218f9a9d2a5aef1422f0&mc=true&tpl=/ecfrbrowse/Title40/40cfr372_main_02.tpl.

40 CFR 761. "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." *Code of Federal Regulations*, as amended. Online at https://www.govinfo.gov/app/details/CFR-2010-title40-vol30/CFR-2010-title40-vol30-part761.

40 CFR 761.180. "Records and Monitoring." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?SID=2e7ecbe3aaf12249f28c9ad65dd95a1d&mc=true&node=se40.34.761_1180&rgn=div8.

40 CFR 763, "Asbestos." *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgi-bin/text-idx?SID=2137e21f065a9f61b5a40258dddc5aa6&mc=true&node=pt40.34.763&rgn=div5.

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2019 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 2019.

Electronic Stewardship
The Hanford Site disposed of 100% of electronics through government programs and certified recyclers in fiscal year 2019. For the electronics acquisition goal, 97.5% of eligible electronic procurements met the Electronic Product Environmental Assessment Tool (EPEAT) standard.

Water Management
The Hanford Site continued to reduce potable and non-potable water consumption intensity in fiscal year 2019 at 73% (gal/ft^2) and 37% (gal/ft^2) reduction, respectively.

Renewable Energy Intensity
The Hanford Site derived 8.7% 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 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 (FY) performance. Rankings for Hanford Site contractors are provided in Table 3-1 along with rankings for both DOE-RL and DOE-ORP.

As the services and infrastructure contractor for the Hanford Site, Mission Support Alliance (MSA) developed HNF-54800, *Hanford ORP/RL Site Sustainability Plan*, for the Hanford Site in FY 2020 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 sites use EMSs as the platform for sustainability program implementation. Environmental objectives were established and maintained in FY 2019, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship. Sustainability plans 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 3-1. DOE Contract Actions and Contractor Implementation. (2 Pages)

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

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

Actions, Implementation	Richland Operations Office				Office of River Protection		
	HPMC	CHPRC	MSA	WCH	VNSFS	BNI	WRPS
Most Recent Declaration of Conformance	March 2016	Sept 2018	Sept 2018	Sept 2018	Sept 2019	NA	Sept 2018
Contractor EMS Scorecard Rating	Green	Green	Green	NA	Green	NA	Green
DOE EMS Scorecard for 2019	Green			NA	Green		

NOTE: Green = meeting requirements
NA = Not Applicable
BNI = Bechtel National, Inc.
CHPRC = CH2M Plateau Remediation Company
DOE = U.S. Department of Energy
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

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

CHPRC = CH2M Plateau Remediation Company
MSA = Mission Support Alliance, LLC
VNSFS = Veolia Nuclear Solutions Federal Services
WRPS = Washington River Protection Solutions, LLC

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 toxic and hazardous material reduction, sustainable acquisition, compliance with electronic product environmental assessment tool standards, sanitary waste diversion, electricity use, facility fuel use, water use, vehicle fuel use, alternative fuel vehicle acquisitions, 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 2019 (Figure 3-1). DOE-HQ required that a minimum of 75% of all non-mission critical light-duty vehicles purchased during FY 2019 be alternative fuel vehicles (DOE O 436.1). Acquisitions for 43% of Hanford light duty vehicles were hybrid, electric, or use E85 (ethanol) fuel.

3.1.2 Alternative Fuel Use

The petroleum-based fuel target was met for FY 2019; however, the target for alternative fuel 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.

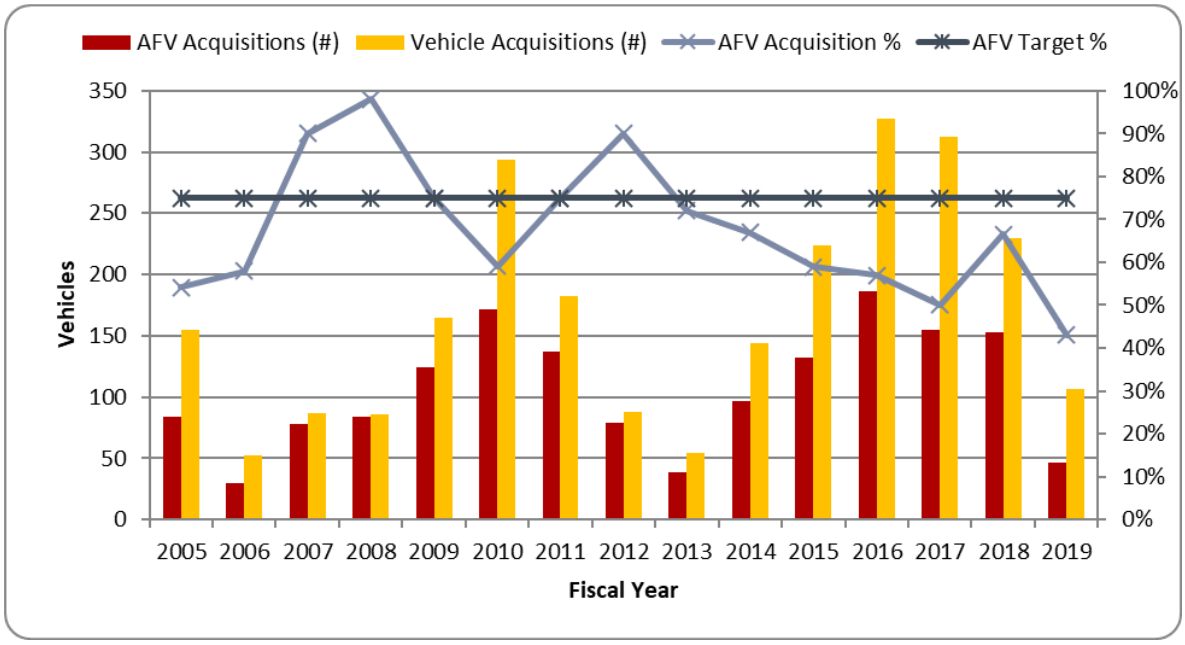

Figure 3-1. Fleet Management – Acquisitions Fiscal Years 2005 through 2019.
NOTE: AFV stands for alternative fuel vehicle

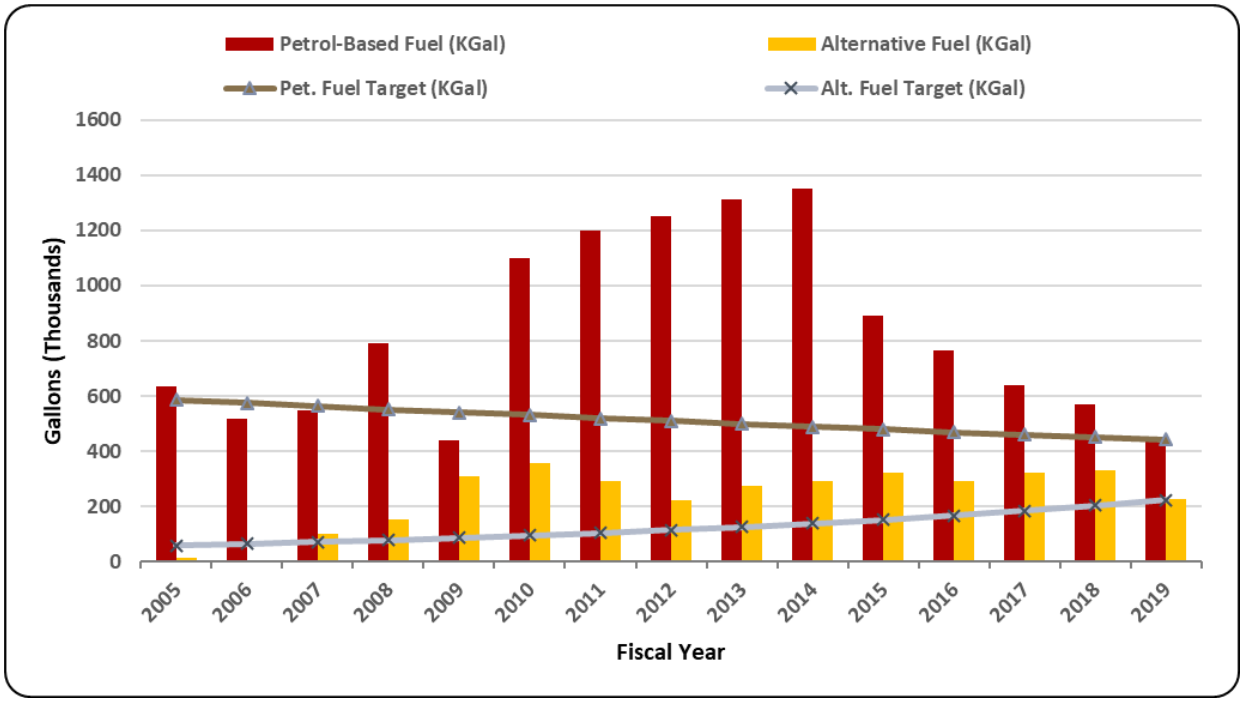

Figure 3-2. Vehicle Fuel Use – Fiscal Years 2005 through 2019.

3.1.3 Potable and Non-potable Water Use

The target objectives for potable water and non-potable water were met in FY 2019 (Figure 3-3). Fluctuations in target achievement can occur 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 to account for no less than 10% of the total electricity use in FY 2016 to 2017 and working towards increasing by 2.5% each year to reach 30% of total usage by FY 2025. The target objective for renewable electric energy was not met in FY 2019 (Figure 3-4) representing 8.7% 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 2019 (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.

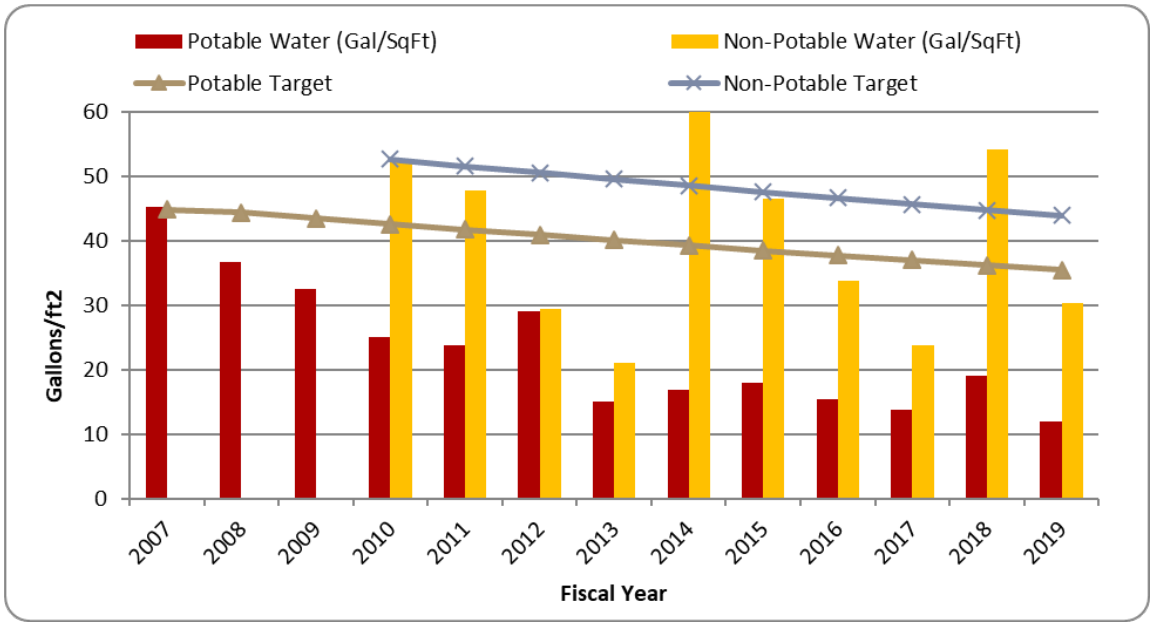

Figure 3-3. Water Use – Fiscal Years 2007 through 2019.

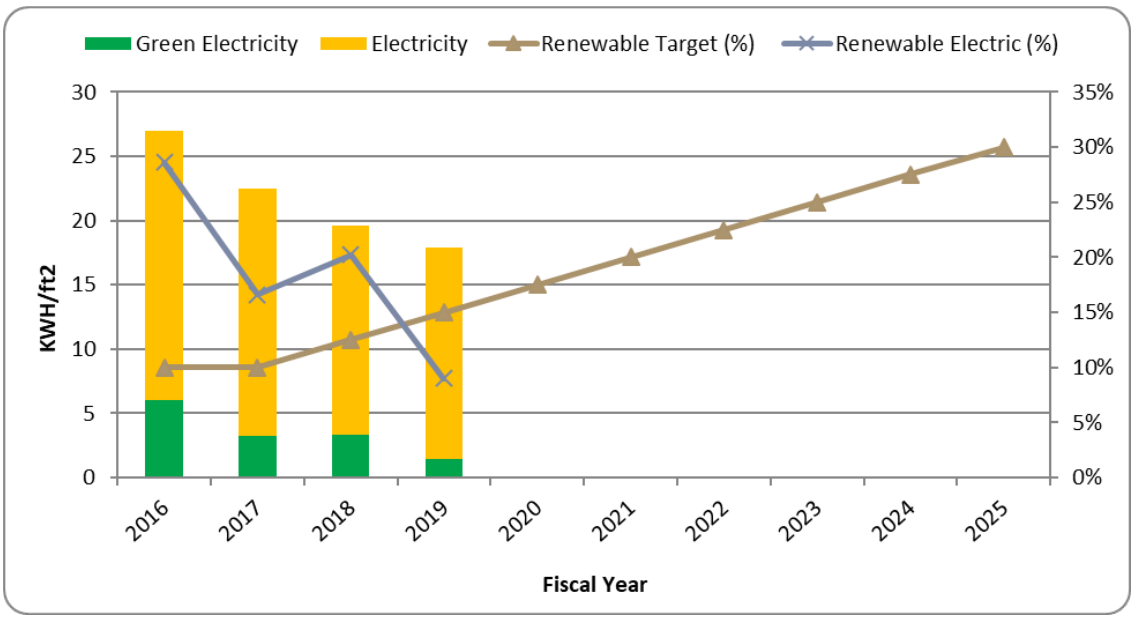

Figure 3-4. Electricity Use – Fiscal Years 2016 through 2019 with Target Objectives through 2025.

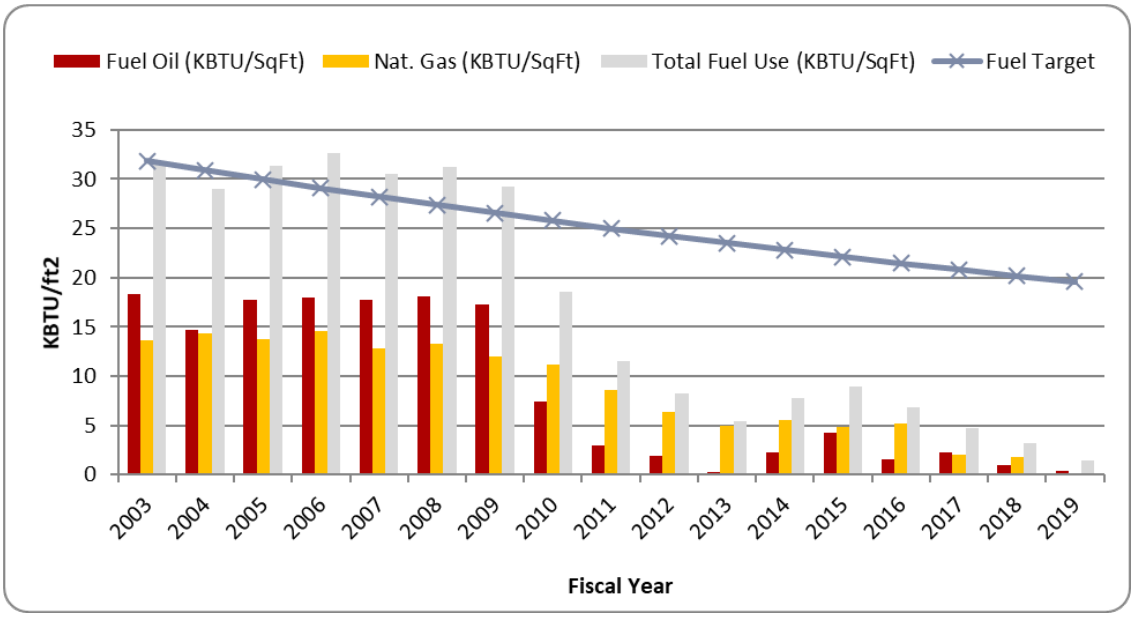

Figure 3-5. Facility Fuel Use – Fiscal Years 2003 through 2019.
NOTE: KBTU stands for one thousand British thermal units

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 2019 (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 objective for the Electronic Product Environmental Assessment Tool was met in FY 2019 with 97.5% 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, servers, 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 not achieved in FY 2019. 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 displayed in Figure 3-9.

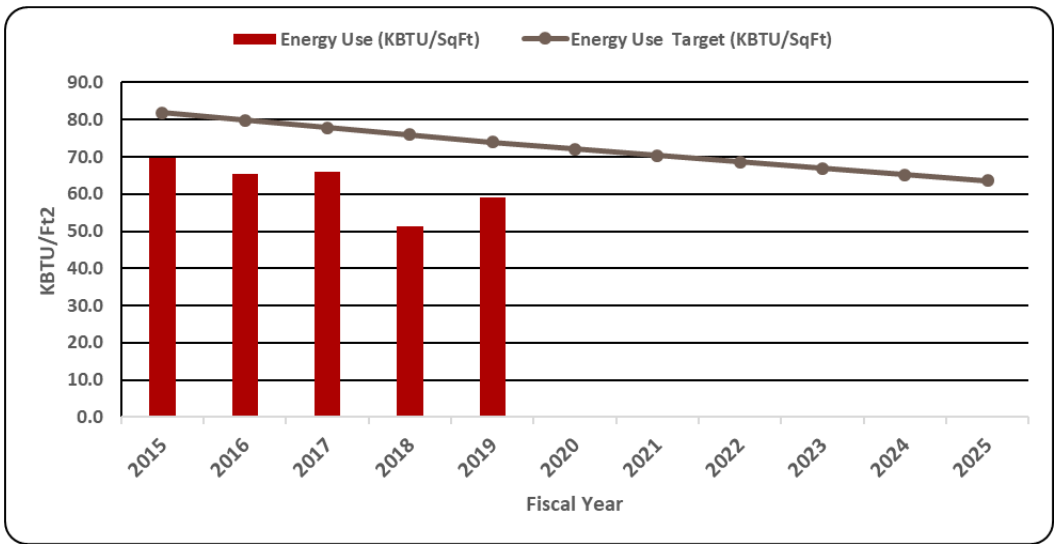

Figure 3-6. Facility Energy Use – Fiscal Years 2015 through 2019 with Target Objectives through 2025.

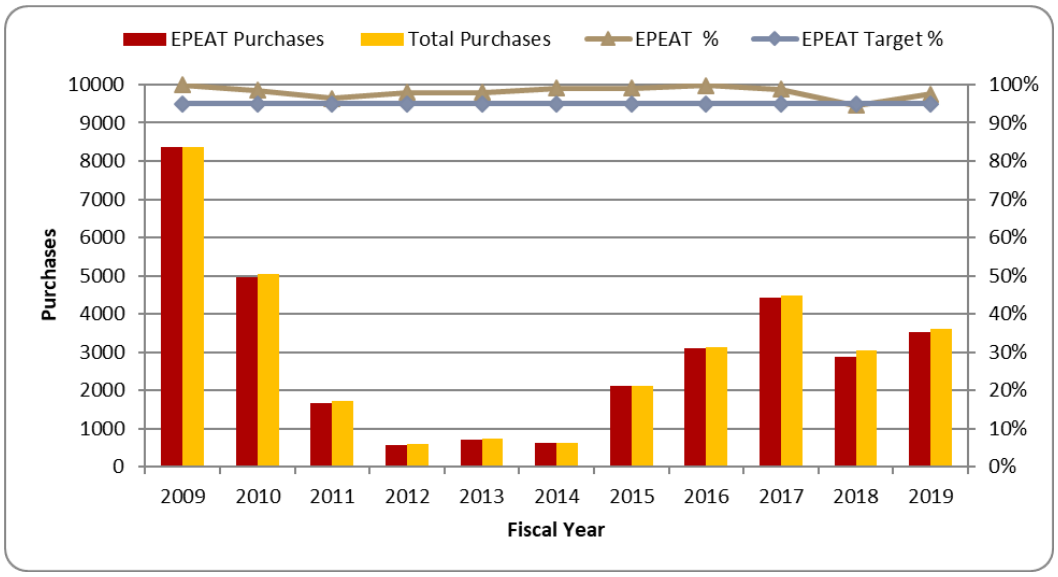

Figure 3-7. Electronic Product Environmental Assessment Tool Standards Compliance.

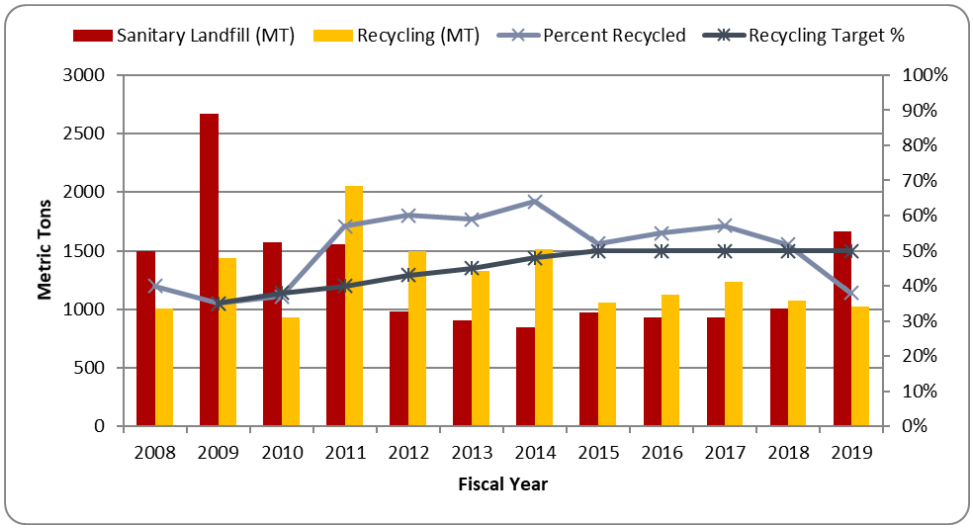

Figure 3-8. Sanitary Waste Reduction.

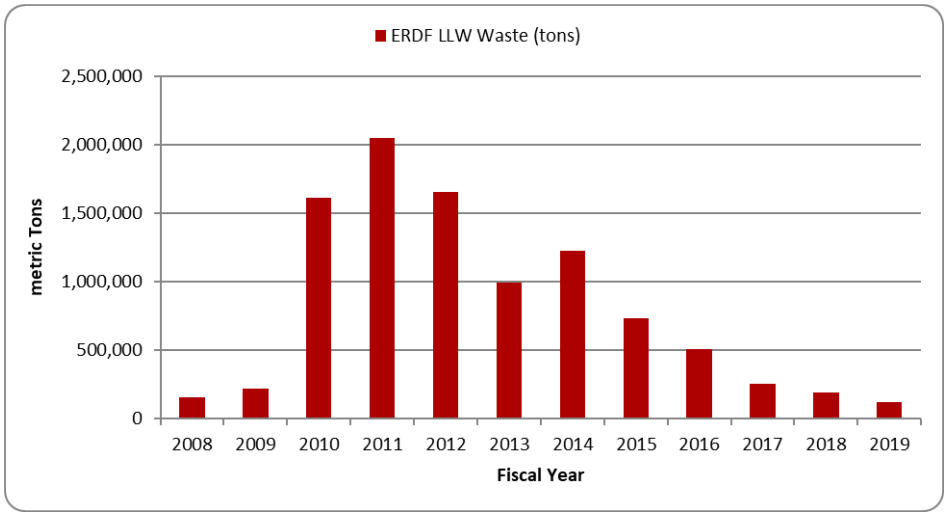

Figure 3-99. Onsite Waste Disposal – Fiscal Years 2008 through 2019 at the Environmental Restoration Disposal Facility.

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 conducted 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 June 2019. NSF-International Strategic Registrations, Ltd., an American National Standards Institute National Accreditation Board-accredited certification body for the international standard ISO 14001, conducted its assessment audit of the CHPRC EMS. Two 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. Five "noteworthy practices" were reported. There were zero nonconformities and two opportunities for improvement. The auditors concluded that CHPRC remains compliant with the ISO 14001 standard and recommended certification to the 2015 revision. The FY 2020 external assessment is scheduled for July 2020.

3.2.3 Mission Support Alliance, LLC

MSA completed a surveillance audit in July 2019 to maintain certification with ISO 14001. There were three system strengths, no major or minor nonconformities, and four opportunities for improvement. Highlights included employee environmental awareness and culture, environmental enthusiasm expressed across all functions and levels, and the Enterprise Service Platform. Opportunities for improvement included protecting documents in case of natural disasters, strengthening procurement processes to outline environmental requirements, tracking avoided greenhouse gas emissions by department, and strengthening interface agreements to communicate environmental requirements. 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 2019 Environmental Leadership Awards. The awards were established to recognize outstanding environmental performance by employees. The FY 2019 winners conducted the first of its kind Hanford Site Pollinator Study, which identified over 2,000 native bees and 100 plants as pollinator friendly. The development of pollinator friendly seed mix and bee nest boxes improved project revegetation efforts on the site. The restoration and resource conservation efforts will help return the Hanford Site to its natural habitat.

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 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. In 2019, WRPS pursued integrating the WRPS business practices and the EMS integrated assessment of the ISO 14001 elements into the Tank Operations Assessment program and the Corrective Action System. International Organization for Standardization elements that are not assessed through this venue by the beginning of the third year will be audited internally before the next external audit.

3.2.5 Veolia Nuclear Solutions Federal Services

During FY 2019, Veolia Nuclear Solutions – Federal Services (VNSFS) conducted three assessments to review VHSFS Hanford Laboratory's implementation of the EMS as described in WHL-MP-1044, "Environmental Management System Description," and its conformance with ISO 14001. Nine minor findings and zero Opportunities for Improvement were identified. VNSFS's last conformation audit was held in June 2019.

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. *Hanford ORP/RL Site Sustainability Plan.* Current Revision. 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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2019 Highlight

External Monitoring
Overall, the average dose rate levels measured in the operational areas during 2019 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 0.16 mrem (1.6 µSv)/yr for air emissions releases and releases to Columbia River water combined, which is 0.16% 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. Due to a lack of site-related radionuclides detected at levels greater than analytical minimum detectable activities in muscle tissue samples of game animals and fillet samples of fish, there was no basis for a quantitative dose screening of the recreationalist based on the 2019 wildlife data.

Clearance of Property with Potential for Residual Radioactivity
An estimated 37,000 items of personal property were cleared from the Hanford Site during 2019 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 2019.

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 2019 at 122 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). The average dose rate levels measured in the operational areas during 2019 were comparable to the previous years' levels (Figure 4-1).

Table 4-1. Thermoluminescent Dosimeter Locations and Results (mrem/yr)[a] in 2018 and 2019. (2 Pages)

Locations	No. of Dosimeters	2018		2019		% Change[e]
		Maximum[b]	Average[c,d]	Maximum[b]	Average[c,d]	
100-Areas	5	87	81 ± 10	88	83 ± 9	2%
100-K	14	205	89 ± 69	203	88 ± 68	0%
200-East	45	178	98 ± 46	199	96 ± 51	-1%
200-West	24	208	99 ± 56	206	96 ± 55	-3%
200-North (212-R)[f]	1	80	80 ± n/a	78	78 ± n/a	-2%
300 Area	8	88	82 ± 6	89	83 ± 7	<1%
300 TEDF	6	85	83 ± 3	85	83 ± 4	<1%
400 Area	7	90	83 ± 7	90	83 ± 6	<1%
CVDF	4	76	75 ± 2	75	74 ± 3	-1%
ERDF	3	84	82 ± 3	82	81 ± 2	0%

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

Table 4-1. Thermoluminescent Dosimeter Locations and Results (mrem/yr)[a] in 2018 and 2019. (2 Pages)

Locations	No. of Dosimeters	2018		2019		% Change[e]
		Maximum[b]	Average[c,d]	Maximum[b]	Average[c,d]	
IDF[f]	1	87	87 ± n/a	90	90 ± n/a	3%
WTP	14	164	95 ± 44	157	93 ± 44	-2%
Perimeter (offsite)	3	96	93 ± 4	96	87 ± 31	-6%
Reference (offsite)	1	74	74 ± n/a	71	71 ± n/a	-2%

[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 (previously included in 200-East Area count).
TEDF = 300 Area Treated Effluent Disposal Facility.
WTP = Waste Treatment Plant (includes 200-East Area and Perimeter locations previously counted).

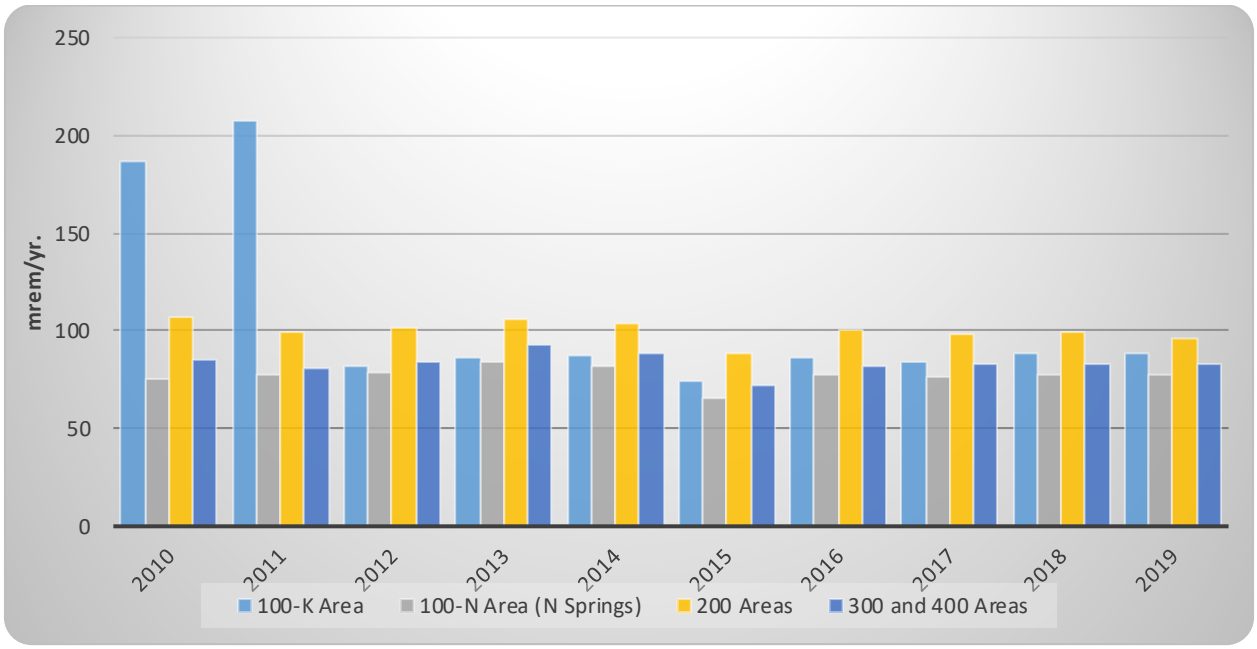

Figure 4-1. Average Thermoluminescent Dosimeter Results (mrem/year) in Selected Operational Areas.

4.1.1.1 100-K Area.

The 2019 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 2019. Locations established during 2016 along the River Corridor showed typical Hanford Site background dose rate levels during 2019. A new monitoring location was established during 2019 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 2019 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 2019 at locations near the PUREX tunnels showed dose rates at/near typical Hanford Site 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 2019 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 2019 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 2019. The TLDs nearest the site showed dose rate levels at/near typical Hanford Site background levels throughout the year.

4.1.1.5 200-North.

Dose rates measured in 2019 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 2019 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 2019 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 2019 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 2019 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 2019 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 2019 were approximately 10% less than dose rate levels measured near Hanford operational area locations.

4.1.2 Waste Disposal Sites Radiological Surveys

JE Cranna, 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 and to the groundwater. These areas are surveyed at least annually to assess the effectiveness of the barriers.

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, C Schaupp, R Perona

Potential radiological doses to the public and biota from Hanford Site operations in 2019 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 2019 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.16 mrem (1.6 µSv). This dose is 0.16% of the 100 mrem (1,000 µSv)/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 µSv), 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 [IRCP 1979a] and Supplement to Part 1 [IRCP 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 Pumphouse station, HRM 46.4) in 2019 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 2019 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 2019. 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 2019 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 non-migratory 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.

The total dose to the MEI at Horn Rapids Road in 2019 was calculated to be 0.16 mrem (1.6 µSv)/yr (Table 4-2; Figure 4-4). This dose is 0.16% of the 100 mrem (1,000 µSv)/yr public dose limit specified in DOE O 458.1 and 0.64% of the 25-mrem (250-µSv)/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 0.13 mrem (1.3 µSv)/yr or approximately 81% of the total dose of 0.16 mrem (1.6 µSv)/yr. Water pathway sources in the Columbia River contributed 0.029 mrem (0.29 µSv)/yr or approximately 19% of the total dose (19%).

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 54% of the total air pathways dose of 0.13 mrem (1.3 µSv)/yr. Consumption of food products containing tritium released from the 300 Area contributed approximately 17% of the total air pathways dose.

- Water Releases. Consumption of fish from the Columbia River contributed approximately 52% of the total water pathways dose of 0.029 mrem (0.29 µSv)/yr, food grown using Columbia River water withdrawn downstream from the Hanford Site contributed approximately 31%, and drinking water ingestion contributed 15%. Uranium isotopes and their radioactive progeny contributed approximately 95% 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. Downstream concentrations of potassium-40 were less than upstream concentrations in 2019.

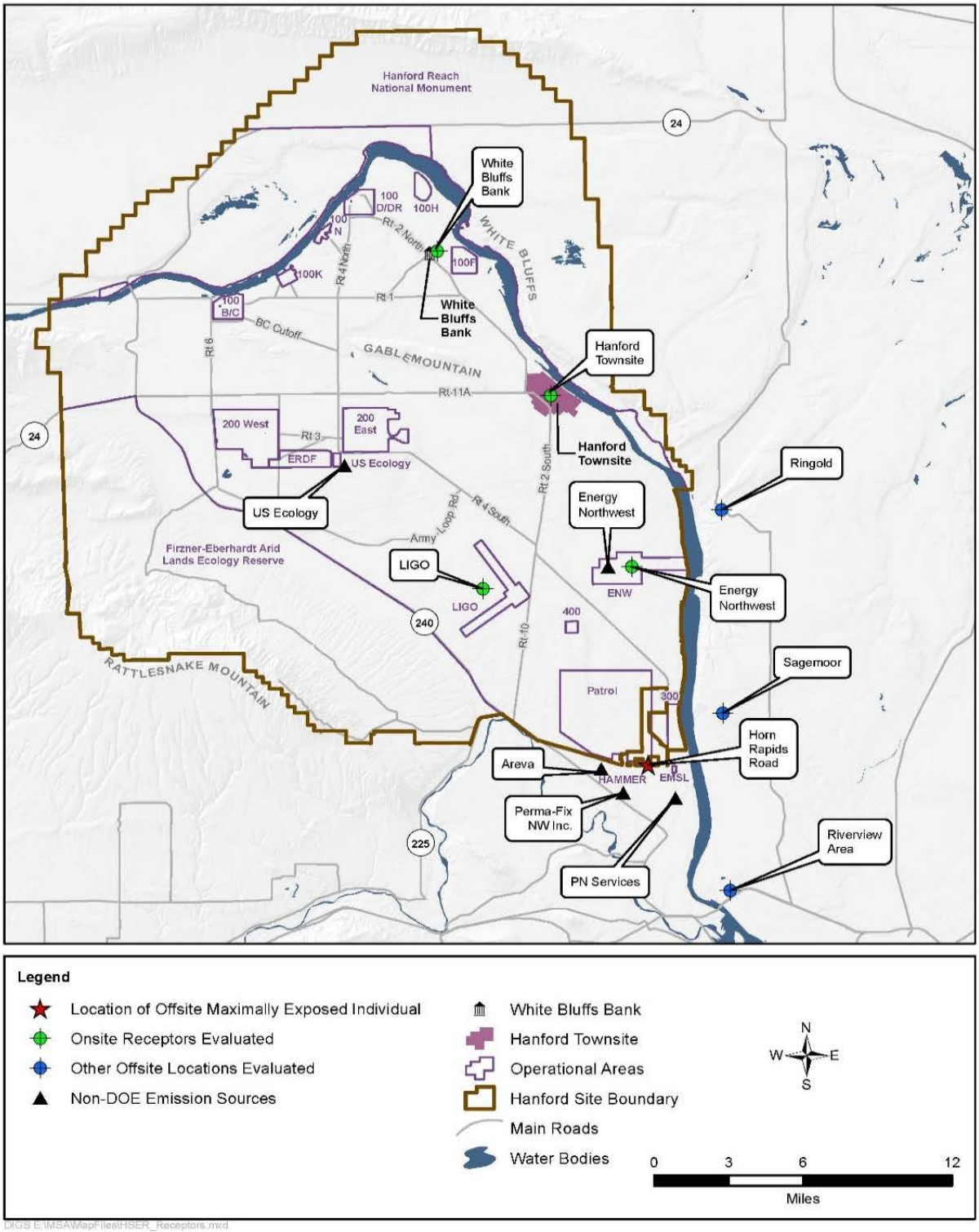

Figure 4-2. Locations Evaluated for Onsite and Offsite Receptors.

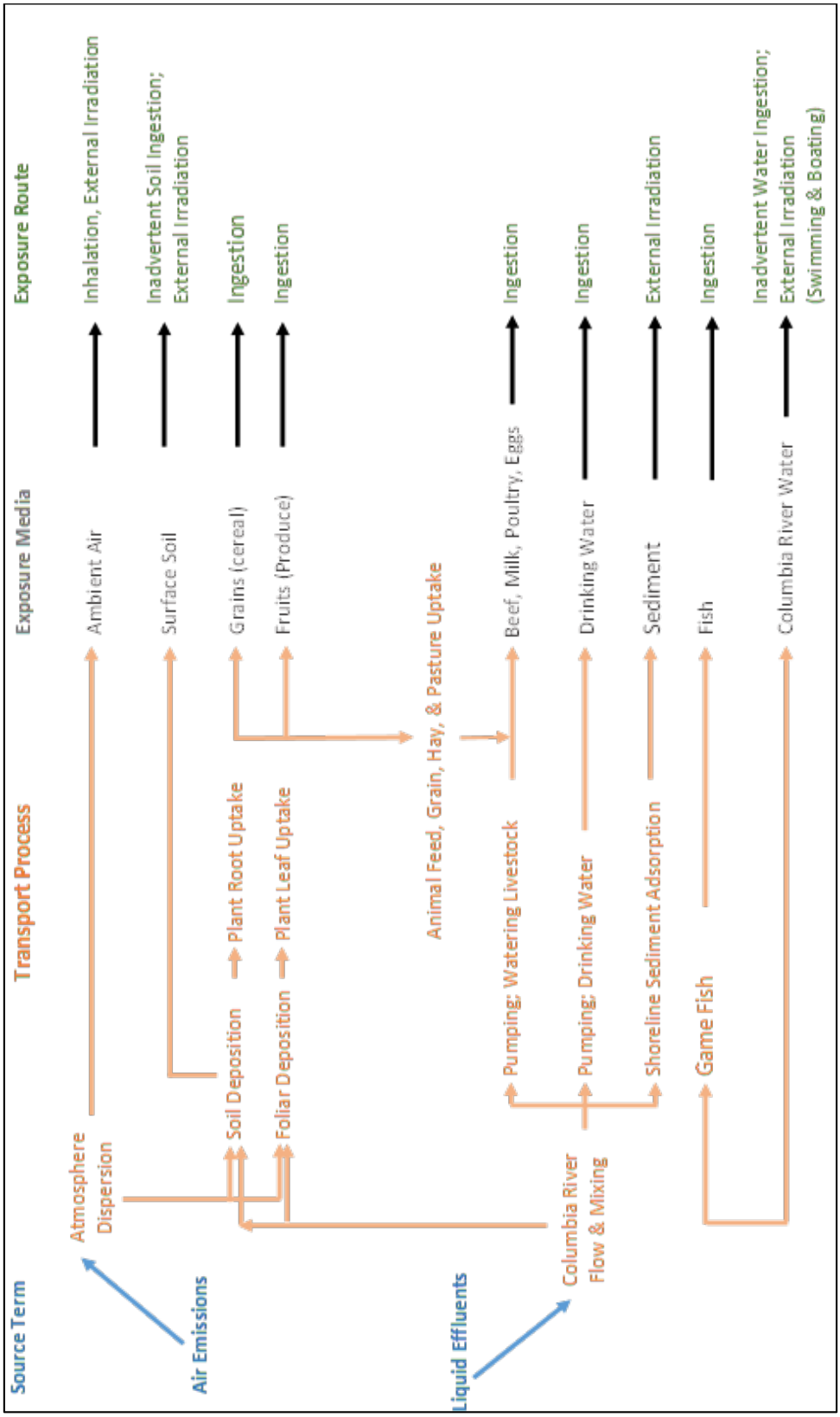

Figure 4-3. Conceptual Site Model of Exposure Pathways Evaluated in Dose Calculations (Horn Rapids Road Maximally Exposed Individual).

4.2.1.1 MEI Dose Discussion. The 2019 MEI dose of 0.16 mrem (1.6 µSv)/yr is less than the 0.28 mrem (2.8 µSv)/yr 2018 MEI dose (DOE/RL-2019-33), and less than the 0.22 mrem (2.2 µSv)/yr MEI dose calculated for 2017 (DOE/RL-2018-32). The difference between the 2019 and 2018 dose estimates is mostly attributable to overall lower concentrations of most radionuclides, resulting in lower food ingestion and inhalation doses in the 300 Area in 2019. Differences between the 2019 and 2017 MEI dose results are primarily attributable to lower inhalation doses in 2019 from radon isotopes.

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 21%, 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.

Table 4-2. Pathway Doses for the Hypothetical Maximally Exposed Individual Residing at Horn Rapids Road.

Release Type	Exposure Pathway	Dose Contributions from Operational Areas (mrem)[a]				
		100 Area	200 Areas	300 Area	400 Area	Pathway Total
Air	Food Ingestion	1.2E-06	1.9E-04	5.7E-02	6.8E-07	5.7E-02
	Inhalation	1.0E-05	6.1E-06	7.3E-02	8.7E-07	7.3E-02
	External, Soil Ingestion	1.3E-08	1.1E-07	1.4E-03	9.7E-09	1.4E-03
	Subtotal Air	1.1E-05	2.0E-04	1.3E-01	1.6E-06	1.3E-01
Water	Irrigation (food and soil ingestion; external)	NA [b, d]	9.1E-03 [(c)]	NA [d]	NA [d]	9.1E-03
	Drinking Water Ingestion	NA [b, d]	4.4E-03 [(c)]	NA [d]	NA [d]	4.4E-03
	Recreation (river water, sediments; external, ingestion)	NA [b, d]	8.4E-05 [(c)]	NA [d]	NA [d]	8.4E-05
	Fish Ingestion	NA [b, d]	1.5E-02 [(c)]	NA [d]	NA [d]	1.5E-02
	Subtotal Water	NA [d]	2.90E-02	NA [d]	NA [d]	2.9E-02
Air + Water Total		1.1E-05	2.9E-02	1.3E-01	1.6E-06	1.6E-01

[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

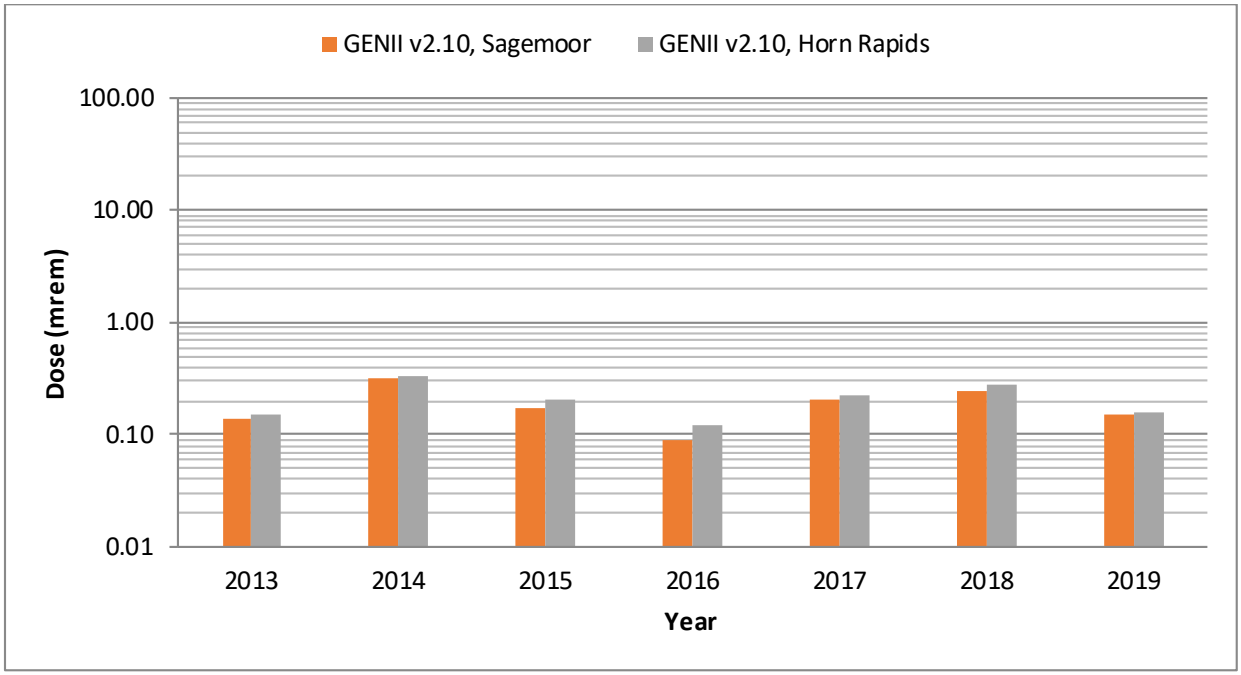

Figure 4-4. Total Dose for the Hypothetical Maximally Exposed Individual Over Time.

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 2019 modeled annual average air concentrations of tritiated water vapor (HTO) at the Horn Rapids Road MEI location and 2019 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.

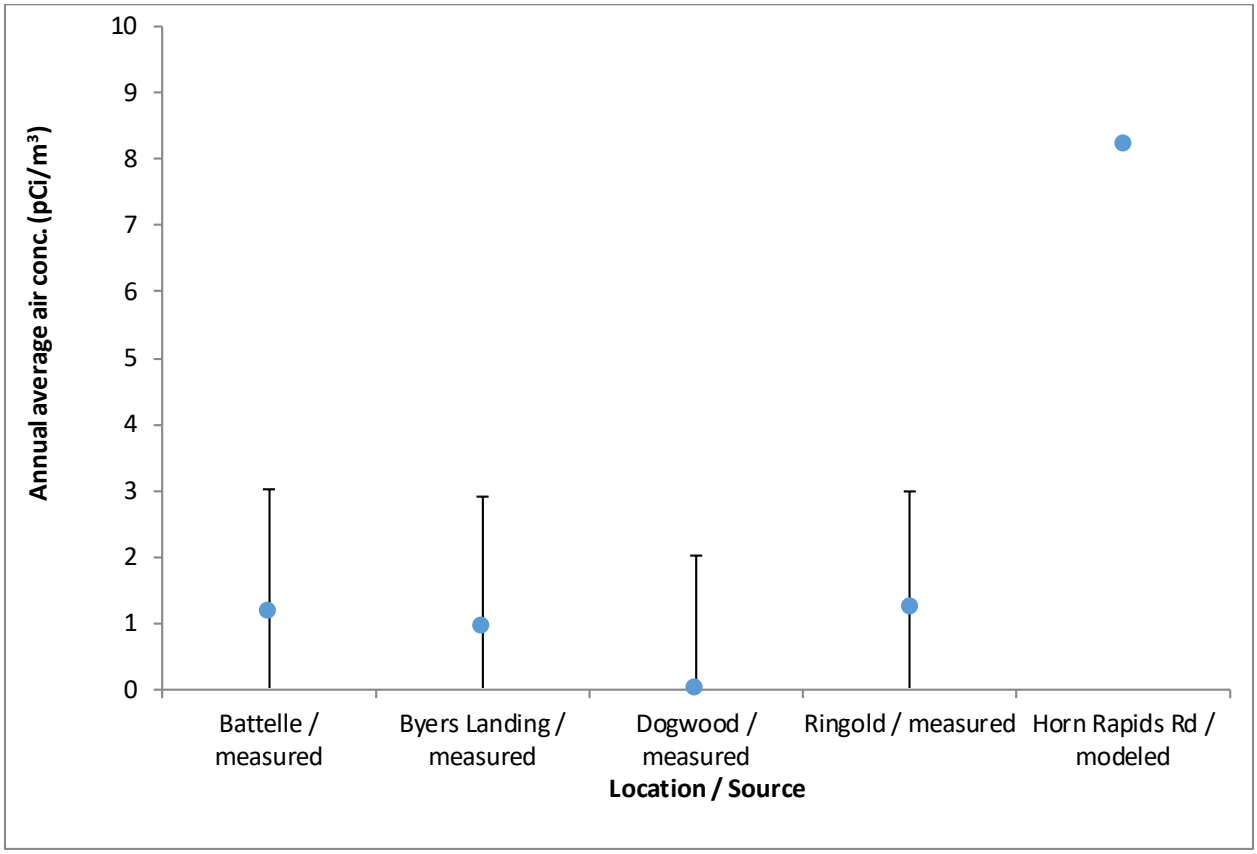

Figure 4-5. Comparison of Measured and Modeled Tritium Air Concentrations Near the 300 Area.
NOTE: Error bars are 95% confidence intervals of the mean

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 seven times the largest measured annual-average tritium concentration, which was measured at both the Battelle Complex air station and the Ringold area, and about three times larger than the 95% upper confidence interval of the average at the Battelle Complex and the Ringold area. 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 255 curies of HTO and elemental hydrogen combined) and possibly relatively low natural background levels of atmospheric tritium in 2019. 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/m^3 to the modeled values (Figure 11 in Barfuss 2007).

Samples of locally raised foodstuffs were collected in 2019 from four locations including the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. Sampled foodstuffs included fruits (apricots, melons, and tomatoes), leafy vegetables, potatoes, corn, milk, and wine. 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, and the minimum detectable activities for these samples ranged from approximately 5.0 to 7.4 pCi/g. The modeled carbon-14 concentrations in crops grown at the MEI location of Horn Rapids Road are far below these activities, with the largest value at 0.0001 pCi/g, corresponding to a calculated annual dose of 1E-05 mrem (0.0001 µSv)/yr. Carbon-14 was not detected in any of the nine milk samples collected from the East Wahluke area. The minimum detectable activities for milk ranged from 194 to 1,120 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 2.4E-06 mrem (0.000024 µSv)/yr.

- Strontium-90 was analyzed in 24 crop samples and detected in 1 leafy vegetable sample (0.0749 pCi/g) and 1corn sample (0.00521 pCi/g) from the Sunnyside area. Strontium-90 was not elevated in downstream Columbia River water samples in 2019 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, and the minimum detectable activities for these samples ranged from approximately 1.19 to 1.85 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 0.55 pCi/g. Tritium was detected in all nine samples of milk at average concentrations of approximately 28 pCi/L (Sagemoor) and 14 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 2019 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 2019 was 1.4 person-rem (0.014 person-Sv)/yr (Table 4-3), which is on the lower end of collective doses calculated in the past several years (Figure 4-6). Air pathway contributions from releases in the 300 Area contributed effectively 65% of the population dose, with water pathway releases contributing the other 35% of the population dose in 2019.

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

- Air Releases. Inhalation exposure contributed approximately 55% of the of the air pathways collective dose of 0.9 person-rem (0.009 person-Sv). The remaining air pathways collective dose is primarily related to consumption of food products grown downwind of the 300 Area. About 50% of the air pathways doses are due to inhalation of the radioactive progeny of radon-220 released from the 300 Area. Approximately another 40% 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 96% of the total water pathways collective dose of 0.5 person-rem (0.005 person-Sv). Uranium isotopes and their progeny contributed 86% of the water pathways dose. Tritium was identified in Columbia River samples in 2019 and contributed the 14% of the water-pathways dose.

The collective dose in 2019 of 1.4 person-rem (0.014 person-Sv) is on the lower end of collective doses calculated in the past several years (Figure 4-6). The decrease from the collective dose in 2018 could be attributable to different air dispersion patterns in 2019 resulting in the relatively lower collective dose result. Also, 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 collected as single 0.5-gal (2-L) grab samples, instead of water samples

at 1-hr intervals. The re-introduction of the continuous sampler for the entirety of 2019, with more representative sample data, could have also contributed to the decrease in the water pathways dose and the collective dose. 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	1.9E-04	1.8E-02	3.6E-01	2.9E-05	3.8E-01
	Inhalation	3.2E-03	9.3E-04	5.0E-01	5.3E-05	5.1E-01
	External, Soil Ingestion	2.6E-06	9.0E-06	9.1E-03	3.5E-07	9.1E-03
	Subtotal Air	3.4E-03	1.9E-02	8.7E-01	8.2E-05	9.0E-01
Water	Irrigation (food and soil ingestion; external)	NA [b, d]	9.4E-03 [c]	NA [d]	NA [d]	9.4E-03
	Drinking Water Ingestion	NA [b, d]	4.8E-01 [c]	NA [d]	NA [d]	4.8E-01
	Recreation (river water, sediments; external, ingestion)	NA [b, d]	7.2E-04 [c]	NA [d]	NA [d]	7.2E-04
	Fish Ingestion	NA [b, d]	5.7E-03 [c]	NA [d]	NA [d]	5.7E-03
	Subtotal Water	NA [d]	5.0E-01	NA [d]	NA [d]	5.0E-01
	Air + Water Total	3.4E-03	5.2E-01	8.7E-01	8.2E-05	1.4E+00

[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

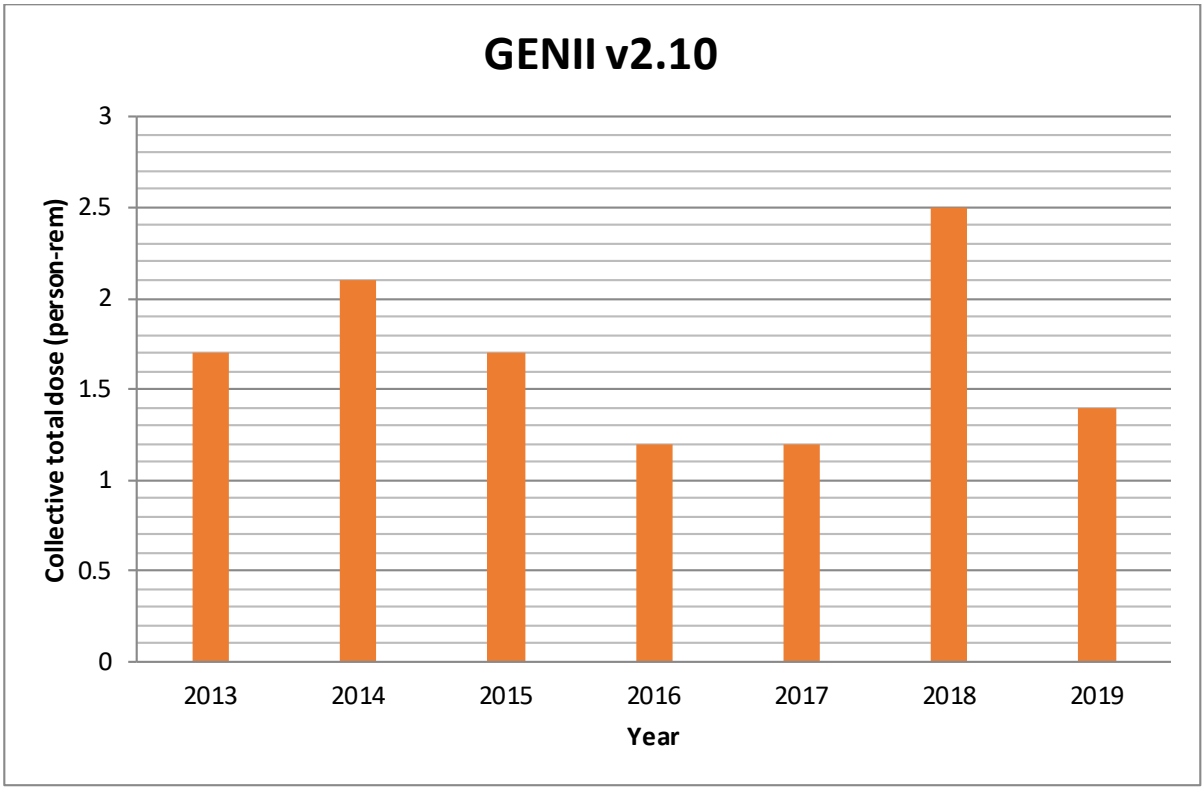

Figure 4-6. Collective Total Dose within a 50-mi (80-km) Radius.

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 µSv)/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 2019 air emissions at the Hanford Site, refer to DOE's report to EPA (DOE/RL-2020-08).

4.2.3.1 Dose from Stack Emissions to an Offsite Maximally Exposed Individual.

Using CAP88PC, the offsite MEI for air pathways in 2019 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 0.042 mrem (0.42 µSv)/yr, less than 1% of the EPA standard of 10 mrem (100 µSv)/yr. The CAP88PC result is approximately one-fifth of the all-pathways dose of 0.16 mrem (1.6 µSv) 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-µSv)/yr standard established in WAC 246-247, "Radiation Protection – Air Emissions." A release of 520 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 2019. A radon-220 dose of 0.088 mrem (0.88 µSv)/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 (0.088 mrem), radon-222 (0 mrem), and dose calculated for compliance with 40 CFR 61, Subpart H using the CAP88PC computer code (0.042 mrem [0.42 µSv]/yr) is approximately 0.13 mrem (1.3 µSv), which is the same as the Horn Rapids Road air pathways MEI dose of 0.13 mrem (1.3 µSv) 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-2020-08). 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-2020-08). The estimated dose from diffuse emissions to this MEI was calculated using the CAP88PC computer code to be 0.0089 mrem (0.089 µSv)/yr. Therefore, the potential combined dose from stack emissions, radon-220 and radon-222 emissions, and diffuse emissions during 2019 at the Laboratory Supply Warehouse location was 0.14 mrem (1.4 µSv)/yr, far below the 10 mrem (100 µSv)/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 2019 EPA air emissions report (DOE/RL-2020-08) 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 (0.032 mrem [0.32 µSv]) was at LIGO (DOE/RL-2020-08). The total dose attributable to 2019 stack emissions, fugitive source emissions, and radon-220 and radon-222 at LIGO was calculated using CAP88PC to be 0.040 mrem (0.40 µSv). Even assuming that a LIGO employee is continuously present, the estimated total dose to non-DOE onsite workers in 2019 was lower than the 0.14 mrem (1.4 µSv)/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 2019 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 2019 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 2019 from geese 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. A total of 20 goose samples were analyzed for either strontium-90 or gamma-emitting radionuclides, resulting in 110 radionuclide muscle results. The only radionuclide detected in the muscle tissue was potassium-40, a naturally-occurring primordial radioisotope that is not of Hanford Site origin. Elk samples were analyzed for strontium-90 or gamma-emitting radionuclides in bone, liver, kidney, and muscle tissue. A total of four elk samples were taken, resulting in 52 radionuclide results. Sstrontium-90 was detected in a single bone sample and potassium-40 was detected in one sample each in liver, kidney, and muscle tissue. For estimating dose from ingestion of game meat, radionuclide concentrations in muscle tissue are most applicable; therefore, dose is not estimated using the strontium-90 bone sample result. Because potassium-40 is not a site-related radionuclide, calculations of dose related to ingestion of game meat were not performed.

Fillet tissue and whole organism samples were obtained from walleye and whitefish in two river sections of the Hanford Reach and reference locations in 2019. Fillet samples were analyzed for gamma-emitting radionuclides, tritium, strontium-90, and isotopes of plutonium and uranium. Whole organism samples were only analyzed for strontium-90. A total of 18 walleye samples were analyzed, resulting in 122 radionuclide fillet or whole organism radionuclide results. All 10 detected radionuclide results were of potassium-40 in fillets (five from the 100 Area, four from the Hanford Townsite to 300 Area, and one from the upstream reference area). As noted above, potassium-40 is a radionuclide that is not associated with Hanford Site operations. A total of 16 whitefish samples were analyzed, resulting in 111 radionuclide fillet or whole organism results. Potassium-40 was detected in seven fillet samples (four from the 100 Area and three from the upstream reference area) and two whole organism samples (one from the 100 Area and one from the upstream reference area). Because site-related radionuclides were not detected at levels greater than analytical minimum detectable activities, calculations of dose related to ingestion of game fish were not performed.

The last time whitefish and walleye were sampled in 2017, detected radionuclides in fillet samples included potassium-40, uranium-234, and uranium-238. Based on the uranium isotope results, a fish ingestion dose of up to 0.15 mrem (1.5 µSv)/yr was calculated using tissue samples of walleye and whitefish.

No radionuclides originating at the Hanford Site were detected at levels greater than analytical minimum detectable activities in muscle tissue samples of game animals and fillet samples of fish. Therefore, there was no dose calculation for an outdoor recreationalist for 2019.

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 2019 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 two 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. Detected drinking water concentrations for tritium range from 962 to 4,740 pCi/L, and for gross beta from only 4.14 to 9.36 pCi/L.

Tritium was measured in four quarterly samples from backup well P-15 in the 400 Area, and one (fall) sample from each of the other three drinking water sources described above. Tritium was not measured above its analytical minimum detectable activity in the sample obtained from the 100-K Area. Tritium was detected in all four drinking water samples collected from the backup drinking water sources for the 400 Area (well P-15), in one sample from primary well P-14 in the 400 Area, and in one sample from the 200-West Area. The tritium concentrations measured for the samples from well P-14 (3,700 pCi/L) and the 200-West Area (962 pCi/L) were outside the range of values measured in the quarterly samples from well P-15 (4,420 to 4,740 pCi/L). Based on the average of the five 400 Area samples, the annual average 400 Area drinking water tritium concentration was 4,418 pCi/L (163 Bq/L). The 200-West Area sample is from the Columbia River and is not included in the average calculation. 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 2019 would be approximately 0.074 mrem (0.74 µSv). This estimate is well below EPA's drinking water dose limit of 4 mrem (40 µSv)/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} µSv/Bq) from ICRP Publication 72 (ICRP 1995) in the following manner:

$$4{,}418 \text{ pCi tritium/L} \times 1 \text{ L/day} \times 250 \text{ d/year} \times 6.7 \times 10^{-8} \text{ mrem/pCi} = 0.074 \text{ mrem } (0.74\ \mu\text{Sv})/\text{yr}$$

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. External exposure to a B Reactor visitor was estimated based on area dosimetry results (RC-TE-RC-61360). A visitor was assumed to be in the facility for one tour lasting 2 hours. The results of these dose calculations are presented in Table 4-4.

Table 4-4. Annual Doses for a Hypothetical Individual at National Historic Park Locations (2019).

Release Type	Exposure Pathway	Location	Dose Contributions from Operational Areas, mrem[a]		
			100 Area	200 Areas	Pathway Total
Air	Inhalation	Hanford Townsite	1.1E-04	1.2E-05	1.2E-04
		White Bluffs Bank	3.3E-04	9.2E-06	3.4E-04
N/A	Direct	B Reactor	3.6E-02	-	3.6E-02

[a] To convert mrem to International System dose units (µSv), multiply by 10.
N/A = not applicable

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 0.13 mrem (1.3 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 2019 because the MEI dose of 0.16 mrem (1.6 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.

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 2019 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, and uranium-238. Beryllium-7 was detected but is of cosmogenic origin and is not associated with the Hanford Site. Potassium-40 was also detected in sediments upstream, onsite, and downstream of the Hanford Site. Potassium-40 is a naturally occurring radionuclide and is not associated with releases from the reactors or any groundwater plumes entering the Columbia River. Therefore, dose associated with potassium-40 is not included in the biota dose assessment.

Most of the locations located on the Columbia River had samples collected from riverbank springs or seeps that carry groundwater contaminants into the Columbia River. Concentrations in springs or seeps are 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 carbon-14 (52%) and strontium-90 (46%); dose in the 300 Area is almost entirely (93%) 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 north of the 200-East Area plateau at 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 2019 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.

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. The 2019 doses were about two times less than those calculated for 2018 (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 maximum concentrations were: 2017 (uranium-234 at 658 pCi/L, uranium-235 at 34.7 pCi/L, uranium-238 at 623 pCi/L), 2018 (uranium-234 at 546 pCi/L, uranium-235 at 27.6 pCi/L, uranium-238 at 500 pCi/L), and 2019 (uranium-234 at 204 pCi/L, uranium-235 at 13.1 pCi/L, uranium-238 at 201 pCi/L). The maximum concentrations of uranium measured in 2019 were approximately three times lower than those measured in 2017. Further

documentation of the West Lake biota dose calculations, including the Tier 3 Biota Concentration Guides, is provided in Appendix D.

Table 4-5. Estimated 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 (2019)
		2017	2018	2019	
Upstream	Sediment, Water	0.018	0.015	0.014	Pass
100 Area	Sediment, Water	0.46	0.53	0.44	Pass
Hanford Townsite	Sediment, Water	0.014	0.013	0.017	Pass
300 Area	Sediment, Water	0.27	0.17	0.077	Pass
Downstream	Sediment, Water	0.016	0.014	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 (2019)
		2017	2018	2019	
1	Maximum Sediment, Water Concentration and Default Bioaccumulation	6.3	5.2	2.0	Fail
2	Average Sediment, Water Concentration and Default Bioaccumulation	4.3	3.8	1.1	Fail
3	Average Sediment, Water Concentration and Site-specific Bioaccumulation	0.095	0.11	0.06	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.

Biota dose calculations were implemented for terrestrial biota based on exposures to soils collected on and distant to the Hanford Site. The RESRAD-BIOTA computer code was used to evaluate potential effects on biota using the maximum concentrations of radionuclides measured in on and offsite soil samples, as tabulated in Appendix C. The radionuclides evaluated in soil are americium-241, cesium-137, europium-155, plutonium-238, plutonium-239/240, strontium-90, uranium-234, uranium-235, and uranium-238. Europium-155 was detected in two onsite soil samples, however, the detection of europium-155 is likely related to spectral interference from short-lived naturally-occurring radionuclides such as actinium-228. Furthermore, the half-life of europium-155 is 4.75 years, and this combined with

the fact that it is infrequently detected is why this detect is suspected to be interference from actinium-228 rather than it being site-related. Following the screening protocol, europium-155 was retained through the biota dose assessment. The results of 2019 screening calculations listed in Table 4-7 show the on and offsite soil concentrations passed the Tier 1 screen based on the maximum concentration. Nearly the entire estimated 2019 dose for onsite locations results from cesium-137 (85.2%) and strontium-90 (14.7%). Biota doses at offsite locations are likely related to background concentrations in soil. 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 (2019)
	2017	2018	2019	
Onsite	0.86	0.95	0.94	Pass
Offsite	Not measured	Not measured	0.027	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.

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 (0.852 pCi/g) and uranium-238 (0.147 pCi/g) in fish was 0.005 rad/day. Internal dose to terrestrial plants based on the maximum concentrations of americium-241 (0.00531 pCi/g), cesium-137 (0.074 pCi/g), plutonium-239/240 (0.0128 pCi/g), strontium-90 (0.217 pCi/g), uranium-234 (0.0289 pCi/g), uranium-235 (0.019 pCi/g), and uranium-238 (0.0331 pCi/g) was 0.0006 rad/day. Dose to terrestrial animals based on the maximum concentration of strontium-90 (0.123 pCi/g) in elk bones was 0.000007 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 2019 was 0.16 mrem (1.6µSv; Section 4.2.1). The annual dose for an average individual from Hanford Site operations in 2019, 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 0.0048 mrem (0.048 µSv). 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 µSv)/yr. Approximately 50% of the 620 mrem (6,200 µSv)/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 µSv]), cosmic background radiation (30 mrem [300 µSv]), and radon (radon-222) and thoron (radon-220) gases (230 mrem [2,300 µSv]) are shown relative to Hanford Site operational doses in Figure 4-8. The calculated radiological doses from Hanford Site operations in 2019 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 µSv]) is approximately 110 times larger than the 2019 Hanford Operations dose to the MEI receptor (0.16 mrem [1.6 µSv]).

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 µSv; 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 µSv).

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 2019 Hanford operations for the MEI in 2019 was 0.16 mrem (1.6 µSv [Section 4.2.1]) and 0.0048 mrem (0.048 µSv) for an average individual. The dose to the MEI is 0.16% of the 100 mrem (1,000 µSv) annual public dose limit specified in DOE O 458.1. Furthermore, the calculated radiological doses from Hanford Site operations in 2019 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 µSv]) is approximately 110 times larger than the 2019 Hanford operations dose to the MEI receptor (0.16 mrem [1.6 µSv]) and 4,000 times larger than the 2019 Hanford Operations dose to the average individual (0.0048 mrem [0.048 µSv]). Thus, the dose to the MEI receptor from 2019 Hanford Site operations is very small compared to natural background sources and the acceptable public dose limit.

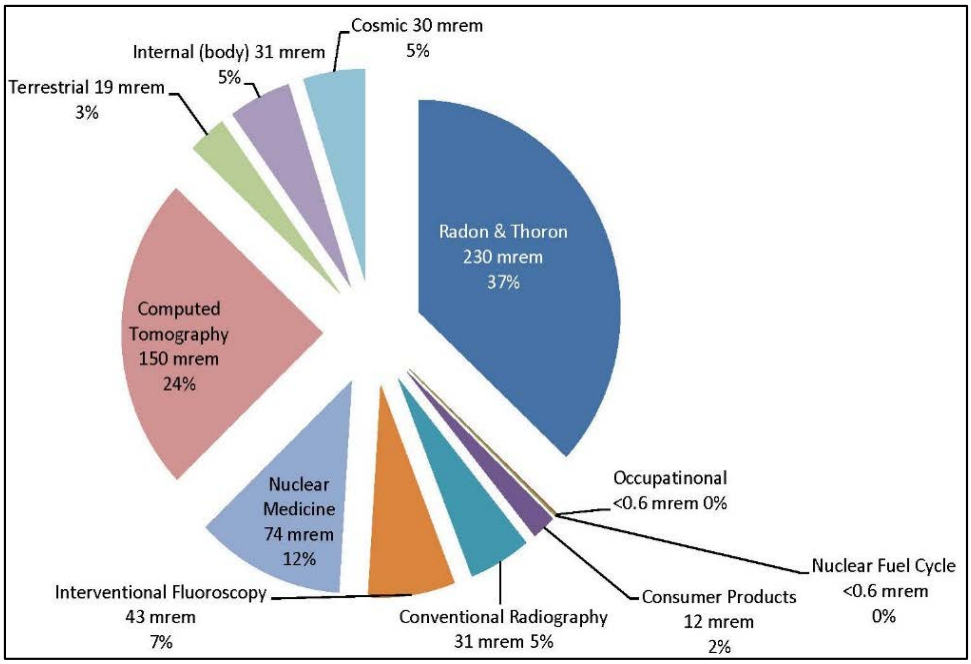

Figure 4-7. U.S. Annual Average Radiological Doses from Various Sources (2009 National Council on Radiation Protection and Measurements).

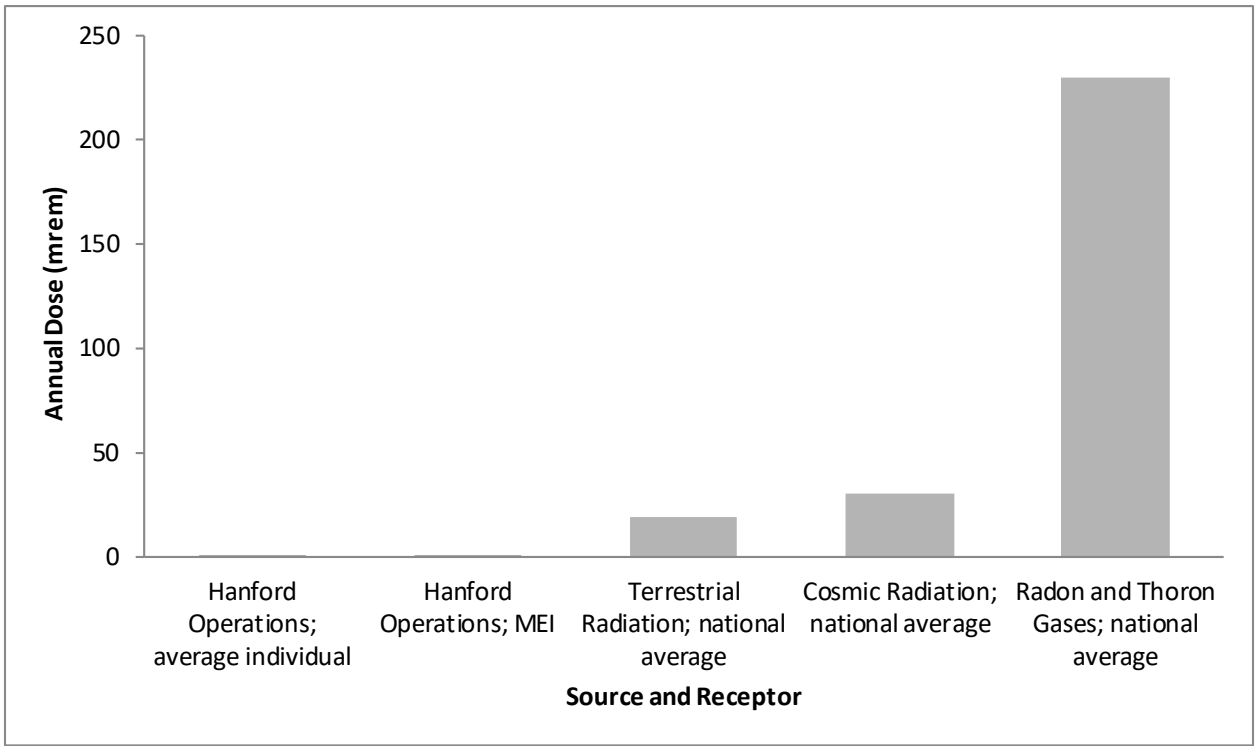

Figure 4-8. Radiological Doses from Hanford Site Operations Compared to Annual Average from Natural Sources.

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

Activity or Exposure Per Year	Risk of Fatality
Home accidents	100×10^{-6} [a]
Firearms (sporting accidents)	10×10^{-6} [a]
Flying as an airline passenger (cross-country roundtrip – accidents)	8×10^{-6} [a]
Recreational boating (accidents)	6×10^{-6} [a]
Riding or driving 300 mi (483 km) in a passenger vehicle	2×10^{-6} [a]
Dose of 1 mrem (10 µSv) annually	0 to 0.6×10^{-6} [b]
Natural background radiological dose (310 mrem [3,100 µSv]) annually	0 to 200×10^{-6} [b]
Dose to hypothetical MEI (2019 rate) of 0.16 mrem (1.6 µSv)/yr living near Hanford Site	0 to 0.1×10^{-6} [b]

[a] Real actuarial values.
[b] Upper bound calculated using 6×10^{-7} risk of developing a fatal cancer after receiving a 1 mrem (10 µSv) dose (ISCORS 2002).
MEI = maximally exposed individual

4.3 Radiological Clearance of Hanford Site Property

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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 2019 an estimated 37,000 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 2019.

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 2019 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. Four containers with approximately 80,000 lb (36,300 kg) of GAC were shipped offsite in 2019 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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2019 Highlight

Retrieval Highlights

- Installed, tested, and began operating the air, water, electrical, and leak detection infrastructure systems required for retrieval of the four AX single-shell tanks (SSTs).
- Completed Tank AX-102 waste retrieval installation and testing in July 2019.
- Single-shell tank AX-102 waste retrieval operations started August 2019, removing 69% (29,000 gal) of the original waste volume (42,000 gal) by calendar year end.
- Removed and disposed of five major long length components to prepare AX-104, AX-103, and AX-101 tanks for waste retrieval system installation, completing equipment removal activities at Tanks AX-104 and AX-103.
- Began installing AX-104 waste retrieval system for planned 2020 operation.
- Removed and disposed of four major long length components to prepare A-Farm tanks for ventilation and waste retrieval system installations.
- Completed A-Farm waste retrieval system design.
- Installed and completed preliminary testing of two new exhausters to ventilate A-Farm SSTs. Final testing and active ventilation of the A-Farm tanks to begin early 2020.
- Using improved equipment and methods, SST C-106 post-retrieval waste volume measured approximately 317 ft^3 (9 m^3). This meets the Tri Party Agreement (TPA) Appendix H retrieval goal as defined in M-045-00 of 360 cubic feet and provides a path forward for declaring C-106 retrieval completion.

Closure of Waste Management Areas

- Draft DOE O 435.1 Tier 1 (Waste Management Area [WMA] C) and Tier 2 (C-200 Series Tanks) Closure Plans are still under review by the U.S. Department of Energy (DOE).
- Request for Additional Information (RAI) on the Draft Waste Incidental to Reprocessing (WIR) Evaluation for WMA C were received from the Nuclear Regulatory Commission (NRC) in April 2019. A public meeting to review the NRC's RAIs was conducted in May 2019.
- U.S. Department of Energy, Office of River Protection's (DOE-ORP) Responses to Requests for Additional Information on the Draft WIR Evaluation for WMA C were transmitted to NRC in October 2019. A public meeting to review DOE-ORP's responses to the NRC's RAIs was conducted in October 2019.
- Resolution of Washington State Department of Ecology (Ecology) comments on three of four Hanford Federal Facility Agreement and Consent Order (HFFACO) Performance Assessment (See Appendix I in Attachment 2 – TPA Action Plan) documents related to landfill closure of WMA C has continued while the closure permitting process moves forward.

- Resolution of Ecology comments on the *Resource Conservation and Recovery Act of 1976* Tier 1 (SST Framework), Tier 2 (WMA C), and Tier 3 (241-C-200 Series Tanks) Closure Plans has continued while the closure permitting process moves forward.

- 241-C-200 Series Tank grout testing resulted in an initial evaluation of grouts used throughout the DOE complex, the selection and testing of a high-flow grout formula, and initial activities for selection of a bulk fill grout formula.

- Planning for field characterization of the contents of the 241-C-301 Catch Tank continued. Critical information to support future sampling, retrieval, and closure activities was obtained.

- Drilling, logging, and sampling of five direct push locations for the first WMA A-AX focus area in the area around tanks 241-A-104 and 241-A-105 was completed. Logging of 18 drywells in this focus area were also completed.

- A sampling plan for the second WMA A-AX focus area in the southwestern area of 241 A-Farm was completed and field work was initiated.

Performance Assessments

- The DOE O 435.1 Performance Assessment (RPP-ENV-58782) (i.e., one of the four HFFACO Performance Assessments – See Appendix I in Attachment 2 – TPA Action Plan) for WMA C and the complimentary Draft WIR Evaluation have been undergoing an independent consultative review by the U. S. Nuclear Regulatory Commission as a part of its consultation with DOE on the WIR-related decisions at WMA C.

- The review by the DOE Low-Level Waste Disposal Facility Federal Review Group of (LFRG) the Integrated Disposal Facility Performance Assessment documentation was completed.

- A draft DOE 435.1 Preliminary Performance Assessment (i.e., one of four HFFACO Appendix I Performance Assessment documents - See Appendix I in Attachment 2 – TPA Action Plan) for WMA A-AX was completed for DOE review.

Interim Surface Barriers

- Construction of the three interim surface barrier panel in SX Farm was completed.
- Design of an interim surface barrier for TX farm was also completed.

Removal of sludge located at 105-KW Basin.

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

Plutonium Finishing Plant Demolition

- Low hazard work was completed and final demolition of 234-5Z Building began in 2019.

5.0 Environmental Restoration and Waste Management

Environmental restoration and waste management activities continued on the Hanford Site during 2019. 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 Site Remediation

This section describes ongoing cleanup and remediation activities, as well as 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.

As of 2019, 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.

5.1.1 River Corridor

In 2019, waste site remediation within the River Corridor was primarily focused in 100-K Area and 300 Area, and details on these activities are summarized in the following two subsections. More than 85% of the accepted Waste Information Data System (WIDS) waste sites in the River Corridor have been cleaned-up under a record of decision (ROD) and/or interim remedial action ROD as further described in DOE/RL-2016-01, *Hanford Site Fourth CERCLA Five-Year Review Report*.

5.1.1.1 100-K Basins

SA McMahand

The 100-K Area (Figure 5-1) remediation activities included waste site remediation, cleanout of the 105-K West Basin, and groundwater P&T 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 ft^3 (28 m^3) of sludge. During 2019, removal and transport of the sludge from K-West Basin to T-Plant for dry storage was completed. 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. This includes 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 (TRU) 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.

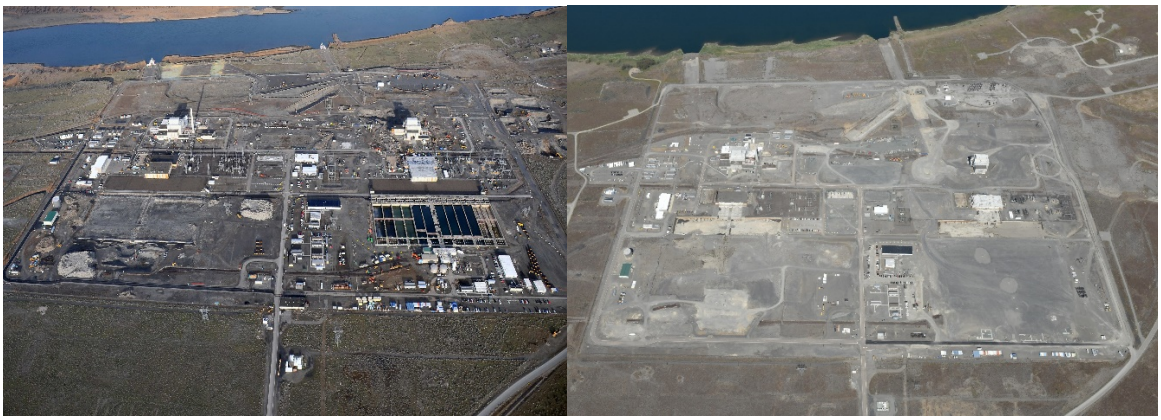

Figure 5-1. Aerial View of 100-K Area Looking North showing the site as it looked in 2010 on the left compared to 2019 view on the right.

100-K Area Remediation Progress and Accomplishments (2019)

- Completed transfer of sludge from 105-KW Basin engineered containers into 20 STSCs, which were transported to T-Plant for storage.

- An inventory of well-characterized 105-KW Basin sludge samples are being maintained for the site to enable testing of future treatment options. Conducting alternatives analysis, engineering evaluations, and process development and process/unit operation validation tests 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 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 are used to determine the contribution of the concrete walls and floors to the total radioactive material inventory remaining in the basin. This information supports development of waste profiles for the 105-KW basin low-level waste (LLW) demolition rubble that stands to be generated and shipped to Environmental Restoration Disposal Facility (ERDF) for disposal.

- Nuclear Fuel Fragment Specimens (NFFS) were found in the K Basin after containerization of sludge. This material is expected to be uniquely useful relative to future process testing in phase 2 of the sludge treatment project 2. In fiscal year (FY) 2016, Pacific Northwest National Laboratory (PNNL)

developed a plan to receive, repackage, and monitor the NFFS until it is used in Phase 2 testing. Receipt of NFFS is expected to be initiated in FY 2020.

- Continued groundwater pump-and-treat (P&T) 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 P&T system and identified a residual hexavalent chromium source area that is preventing attainment of the groundwater cleanup levels. 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 duration of the P&T operations.

  – Sediments are being analyzed to identify the characteristics of a secondary source to a chromium plume in the 100-K Area. Collected sediment samples are being analyzed 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 (PA) 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.

    A treatability test was conducted in the 100-K Area at a location that was determined to be a continuing source of hexavalent chromium groundwater contamination. The treatability test used soil flushing, or the application of clean water, to mobilize residual Cr(IV) in the vadose zone, where it continues to produce groundwater contamination above applicable standards, into groundwater where the KWP&T system can remove it to reduce the time required to achieve cleanup goals through mass removal. By the end of calendar year (CY) 2019, the KW infiltration gallery had discharged approximately 43 million gal (163 million L) of water to the soil column near the site of the 183.1-KW Headhouse.

    - Completed removal of asbestos from the 165-KW Building in preparation for demolition.

    - Started removal of the 166-KE fuel oil bunker, which supplied fuel oil to the boilers located in 165-KE Power Control Building. Removal of the fuel oil bunker will continue into 2020.

    - Completed demolition of 1724, 1724-KA, and 167-K Buildings.

    - Waste sites 100-K-50:2 and 100-K-94 are interim closed and backfilled.

    - Completed excavation and load out of contaminated material for the 100-K-99 waste site. Verification samples have been collected and waiting on results.

    - Excavation of waste sites 116-KE-2 (Figure 5-2) and 100-K-47:1 is ongoing. The overburden soil on the 100-K-47:2 waste site removal was started in 2019 and will continue into 2020. Overburden soil is considered clean and will be used as fill material once the waste sites have been remediated.

Figure 5-2. The 116-KE-2 Excavation Site. 105-KE Reactor Building is in the Background.

5.1.1.2 300-296 Waste Site.

LM Dittmer and JA Johanson

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).

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 2019, entries into the Airlock supported waste removal from A-, B-, C-, and D-Cells. Removal of the sample load-out room in the B-Cell gallery prepared the way to install the two remaining through-

support assemblies for the B-Cell remote excavator arms. These entries resulted in the shipment of 8 boxes of mixed LLW, 64 roll off container of LLW, and 32 drums of LLW to ERDF. Cell cleanout continues in A-Cell to make way for equipment installations in the cell, and in B-Cell to access the highly contaminated soil beneath the cell. Debris removal was completed in both C- and D-Cells.

Four pilot holes (of 22 micropile borings) were completed in Room 18 adjacent to B-Cell. These borings extend approximately 30 ft (10 m) below the B-Cell floor. They will be filled with grout as part of the structural modifications to provide support to B-Cell during floor removal and remote excavation activities.

In November 2019, 324 Building Disposition Project called a Stop Work for the 300-296 Remote Soil Excavation Project due to several contamination events. A Root Cause Analysis was conducted, and a Corrective Action Plan will be developed to provide the project with a path forward to resume project activities.

5.1.1.3 300 Area Waste Sites.

Interim stabilization of three waste sites in the 300 Area (300-5, 331-LSLT1, and 331-LSLT2) was completed in 2018. The 300-5 site consists of fuel-contaminated soil from previously removed buried unleaded gasoline and diesel 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. These waste sites will be remediated when the remaining 300 Area facilities are deactivated and removed.

5.1.1.4 400 Area

SA McMahand and RW Fisher

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 5-3). Built in the late 1970s, the original mission of the facility was to develop and test advanced fuels and materials and to serve as a prototype facility for future Liquid Metal Fast Breeder Reactor Programs. Other missions were also pursued. FFTF operated from April 1982 to April 1992 and provided the nuclear industry with significant advances in fuel performance, medical isotope production, material performance, and passive and active safety systems testing. The reactor was placed in a standby mode in December 1993. After multiple studies, a decision was made to complete facility deactivation, including removing all nuclear fuel, draining the sodium systems, and deactivating systems and equipment to place the facility in a low-cost, long-term S&M condition, all of which was completed in June 2009. FFTF remains in long-term S&M and routine surveillances are performed annually.

The FFTF decommissioning was included in DOE/EIS-0391, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington,* issued on November 12, 2012. 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 will 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 authorized disposal facility. Bulk sodium inventories would be processed at the Hanford Site for use in the WTP.

The 437 Building Maintenance and Storage Facility (MASF) is a multi-purpose high bay facility supporting mock-up fabrication, engineering scale testing, and training of operations personnel. The MASF 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 ft^2 (2,604.3 m^2) of area for mockup testing and training.

Major testing and development that took place in MASF in 2019 included the following:

- The Sludge Treatment Project utilized the Engineered Container Retrieval and Transfer System mockup including K-Basin Test Pool at MASF throughout 2019 to perform training and troubleshooting; the system will remain active until closure of K-Basin.

- K-Basin Garnet Filter Media Retrieval (GFMR) testing, development, and Operations/Construction training. Located at K-Basin are multiple filtration systems that require media removal for final closure. A system was developed, tested, and used for training by Operation and Construction personnel at MASF. Production equipment was then fabricated based on final design from this development effort and is currently being deployed at the K-Basin.

- A Sand Filter system located at the K-Basin will also require media retrieval so similarly, a Sand Filter Media Retrieval System also went through the same process at MASF. The production equipment is currently at MASF for future testing and training.

- The 300-296 (324) Project was supported through tooling development for cell cover block removal.

- The Waste Encapsulation and Storage Facility (WESF) W-135 Project started demolition of existing structure and started assembly of a large mockup cell structure in support of testing and training on remote equipment to support the cesium strontium capsule removal program.

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

5.1.2 Central Plateau

MJ Hickey

Central Plateau facilities include buildings and waste sites in the 200-East, 200-West, and 200-North Areas. The transition toward decommissioning encompasses surveillance, maintenance, and deactivation activities. The Central Plateau includes about 20 mi^2 (52 km^2) of land located 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.

The Inner Area of the Central Plateau 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.

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 mi^2 (168 km^2) 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 (ICs). 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.

5.1.2.1 200-PW-1, 200-PW-3, 200-PW-6, and 200-CW-5 Operable Units.

This operable unit group includes 22 waste sites located in the 200-East and 200-West Areas that are contaminated with plutonium or cesium from processing activities at 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 PUREX 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
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

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

New Operable Unit Group	Description	Predecessor Operable Units		Lead Regulatory Agency
200-CU-1	U –Plant Canyon: associated waste sites	No change		EPA
Outer Area				
200-OA-1 200-CW-1 200-CW-3	Sites located in the Outer Area 200-OA-1 contains soils sites not in 200-CW-3 that were in the previous OUs 200-CW-1 contains ponds not in 200-CW-3 200-CW-3 contains sites associated with the 200 North Areas.	200-CS-1 200-CW-1 200-CW-3 200-IS-1 200-MG-1/2	200-MW-1 200-SW-2 200-UR-1 200-UW-1	EPA

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 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 ERDF (Section 5.4.3.7) or waste acceptance criteria for offsite disposal at the 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.

5.1.2.2 200-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.

5.1.2.3 200-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. ICs and long-term monitoring will be required for waste sites in the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units where waste is left in place and unrestricted land use is precluded.

5.1.2.4 Plutonium Finishing Plant Complex.

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. Stabilization and recovery took the majority of 2018 with lower hazard work authorized to start again in September. Figure 5-4 provides a view of the PFP complex in December 2019.

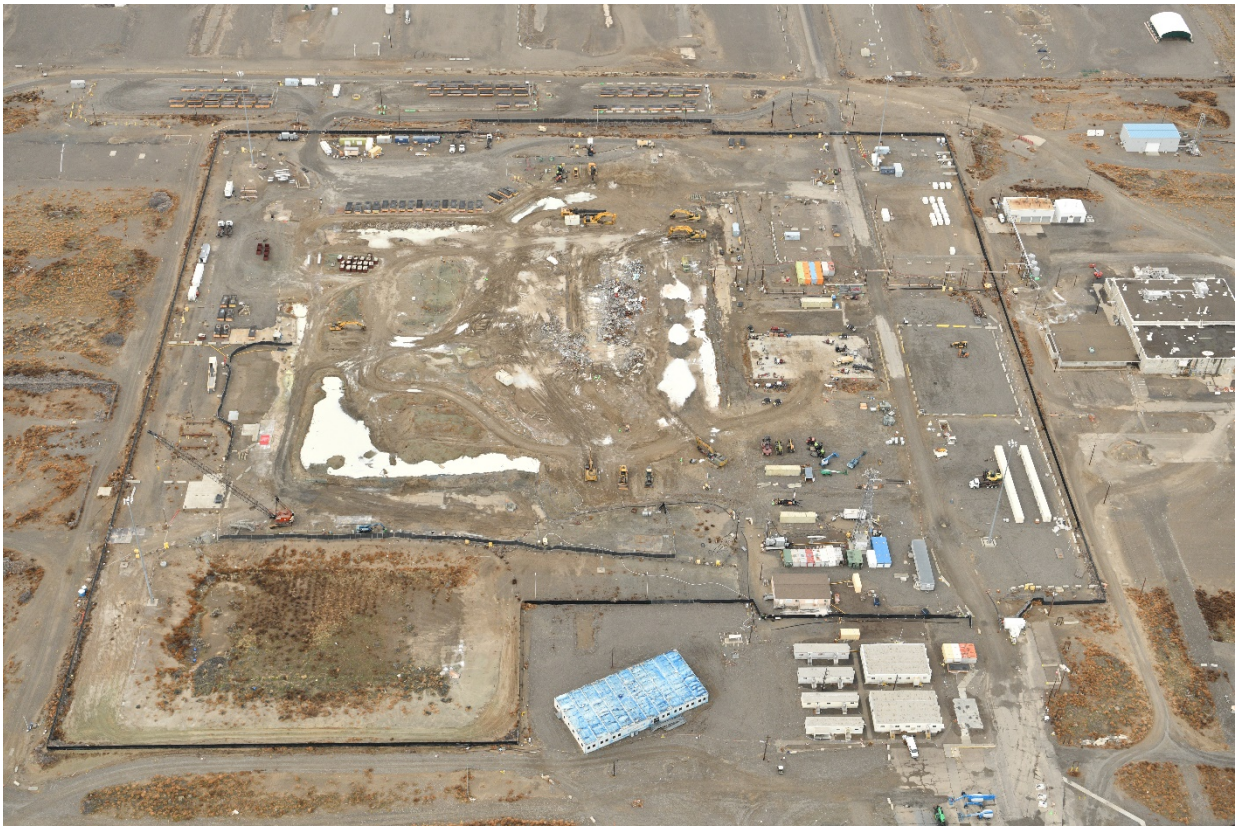

Figure 5-4. December 2019 Aerial View of the Plutonium Finishing Plant.

DOE authorized commencement of the final phase of work in October and demolition of the remainder of the 234-5Z Building, including TRU pipe removal from the tunnels, was completed in 2019. A summary of activities completed in 2019 is provided below:

- Completed lower-risk demolition of 234-5Z in October.
- Completed the final phase demolition of 234-5Z Building including removing TRU piping from the tunnels and demolition of the main process lines area (former Remote Mechanical A and Remote Mechanical C lines) in December (rubble load out not completed).
- Approximately 830 roll-on/roll-off containers were shipped to the ERDF in 2019.

5.1.2.5 200-WA-1/200-BC-1 Operable Unit (200-West Inner Area).

MJ Hickey

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 Operable Unit. 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.

- 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.

5.1.2.6 200-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 waste management areas (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 uses a comprehensive application of the technical cleanup principles for the Inner Area that is consistent with the 200-WA-1 Operable Unit.

Analysis of the waste sites in the 200-EA-1 Operable Unit followed the same pattern as the 200-WA-1 Operable Unit and used 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 unsigned 200-EA-1 work plan was provided to the Washington State Department of Ecology (Ecology) and DOE in September 2019 for signature. The document is waiting for completion of the TPA milestone negotiations so the implementation schedule in 200-EA-1 Chapter 6 can be completed.

An evaluation spanning over 20 years 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.

5.1.2.7 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 Reduction-oxidation [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.

Due to the concerted effort to remove PFP, no action has been taken on this initiative since 2011. Current CERCLA environmental documents that are being developed are taking in consideration what impacts the scheduled activities will have on the Canyon Disposition Initiative.

5.1.2.8 200-IS-1 Operable Unit.

MJ Hickey

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. This work plan will be updated to incorporate additional pipelines that have been identified since 2011.

5.1.2.9 200-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 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 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 was issued in March 2018.

5.1.2.10 200-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 were completed in 2018.

An evaluation of vadose zone remediation technologies was prepared, 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.

Remedy options for Central Plateau sources are limited but are needed to support 200-DV-1 treatability decisions and subsequent feasibility studies for the deep vadose zone and perched water in the Central Plateau, which serve as a long-term contaminant sources to groundwater. The maturation of coupled treatment strategies is being conducted to address the remediation of the complex biogeochemistry of contaminant mixtures in both the vadose and perched water zones. Identification of combined technologies, amendment delivery mechanisms, and combined technology and monitoring approaches are being completed, to provide key indicators for remedy transitions. This information will be used to identify potential treatability tests for the 200-DV-1 Operable Unit.

5.1.2.11 200-CB-1 Operable Unit (B-Plant Canyon).

This operable unit includes the B-Plant Canyon Building (221-B) and the 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). Waste sites near the B-Plant Canyon currently assigned to the 200-EA-1 and 200-IS-1 Operable Units were reassigned to the 200-CB-1. Cesium and strontium capsules located in the WESF are not included in the scope of the 200-CB-1 Operable Unit.

5.1.2.12 200-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. A final decision is needed for the surrounding waste sites in the 200-WA-1 Operable Unit in order to construct the U-Plant Canyon cap.

5.1.2.13 200-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 50 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 and 200-IS-1 Operable Units have been reassigned to the 200-CP-1 Operable Unit. The 200-CP-1 RI/FS work plan was initiated in February 2020 and is on schedule to submit the Draft A document to Ecology for review in September 2020.

5.1.2.14 200-CR-1 Operable Unit (REDOX Canyon).

This operable unit includes the REDOX Canyon Building (202-S), exterior components of the ventilation system (e.g., filters), and 12 soil waste sites located in the vicinity. Specific sites are listed in the TPA Action Plan (Ecology 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 have been reassigned to the 200-CR-1 Operable Unit to facilitate remediation. The 200-CR-1 work plan has not been initiated.

5.1.2.15 200-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.

5.1.2.16 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 SWL 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 Groundwater Remediation Support

TM Brouns

PNNL is providing scientific and technological contribution to the Hanford Site cleanup mission that enhances credibility and defensibility for cleanup decisions and actions with regulatory and stakeholder acceptance and reduces 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.

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.

5.1.3.1 Remediation Support.

Candidate remediation technologies were 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 proceeding with a technical impracticability waiver application for the iodine-129 plume in the 200-UP-1 Operable Unit. A technical basis for a technical impracticability waiver for iodine-129 was provided by PNNL. Relevant parameters and information were 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.

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 were 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 were identified. The development of quantitative conceptual models will 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 was supported. Real-time monitoring was provided of amendment injection using ERT 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 a remedy PA. PNNL conducted the laboratory assessment of sediment samples to quantify the uranium mobility change induced by the phosphate treatment. This information is a key aspect of the PA and role of the enhanced attenuation portion within the overall passive attenuation approach for the plume.

5.1.3.2 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.

ERT was also demonstrated to be a viable geophysical approach for monitoring potential remediation activities within the perched water aquifer. The effectiveness of subsurface electrodes emplaced within a horizontal well was demonstrated through simulation. The use of horizontal subsurface electrodes, in combination with surface electrodes, significantly improved the ability of ERT to image deep subsurface features and monitor remediation activities, even in the presence of buried metallic pipes and tanks.

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. The approach includes the use of data from existing wells, tracer tests, and geophysical monitoring of the tracer test to identify remediation needs associated with chromium in the lower aquifer.

PNNL-Hanford Online Environmental Information Exchange (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. 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.

5.2 Waste Management Activities

WE Toebe, KL Chase, SR Myrick, JR Hultman

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

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 TRU, high-level waste (HLW), or 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. TRU waste is stored in vaults, in storage buildings, on aboveground storage pads, and retrievably buried cribs and vaults. 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.

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, 2019, 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. All data is current as of December 31, 2019.

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.

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

Waste Category		2014	2015	2016	2017	2018	2019
Mixed	Tons	140	657	609	452	523	571
	Metric tons	127	596	552	410	474	518
Radioactive	Tons	572	1550	665	828	2680	658
	Metric tons	519	1408	603	751	2434	597

[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]		2014	2015	2016	2017	2018	2019
Mixed	Tons	38.4	97.9	105	83.3	118	120
	Metric tons	35	88.9	95.3	76	107	109
Radioactive	Tons	57	91.4	113	133	130	187
	Metric tons	52	82.9	102	121	118	170

[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		2014	2015	2016	2017	2018	2019
Containerized (DW Only)	Tons	103	76.8	69.4	68.5	84.5	67.9
	Metric tons	93.4[b]	69.7[b]	63.0[b]	62	76.6	61.6
Containerized (MW Only)	Tons	33.7	65.7	69.7	90.4	56.9	36.6
	Metric tons	30.6[c]	59.6[c]	63.2[c]	82	51.6	33.2
Bulk Solids (DW Only)	Tons	22.1	—		0	0	0
	Metric tons	20.1	—		0	0	0
Bulk Solids (Non-Rad/Non-DW)	Tons	—	—		0	0	0
	Metric tons	—	—		0	0	0
Bulk Liquids (DW Only)	Tons	22	—	1	0	0	0
	Metric tons	20	—	1.36	0	0	0
Bulk Liquids (Non-Rad/Non-DW)	Tons	—	—		0	0	0
	Metric tons	—	—		0	0	0
Totals	**Tons**	**181**	**142**	**140**	**158.9**	**141.4**	**104.5**
	Metric tons	**164**	**129**	**127**	**144**	**128.2**	**94.8**

[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

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.

The Hanford Site's waste management facilities are primarily located on the Central Plateau. The 2019 updates for each of these facilities (listed below) are provided in the subsections that follow.

- Tank Farms
- 222-S Laboratory
- Central Waste Complex (CWC)
- Waste Receiving and Processing Facility (WRAP)
- T-Plant Complex
- Canister Storage Building (CSB)
- Low Level Burial Grounds
- WESF
- Integrated Disposal Facility (IDF)
- ERDF
- Effluent Treatment Facility (ETF)
- Liquid Effluent Retention Facility (LERF)
- 200 Area Treated Effluent Disposal Facility (TEDF)

- 242-A Evaporator
- WTP.

5.2.1 Tank Farms

S Scott, T Brouns

Hanford's 54.1million gal (205.5 million L) of highly radioactive and chemical waste is stored in 177 underground tanks until it is prepared for disposal (Figure 5-5). 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 retrieval of waste from 16 tanks was declared completed by the end of CY 2019: 15 C-Farm tanks and S-112. At the end of CY 2019 tank C-106 retrieval status was "complete and in review."

S-102 was never declared complete; status is interim stabilized. AY-102 is a DST and was retrieved, inspected and staged for closure per a Settlement Agreement that does not fall under the TPA or Consent Decree for SST retrievals. 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 2019 related to their operation and closure.

The 1998 Hanford Federal Facility Agreement and Consent Order (HFFACO or TPA) established milestones for the retrieval of residual waste solids and interstitial liquids from the 149 aging single-shell tank systems by 2018. In 2010, having completed retrieval of only seven tanks, the DOE and the state of Washington entered into a Consent Decree (Washington v. DOE, Case No. CV-08-5085-FVS (E.D. Wa. October 25, 2010). The Consent Decree established discrete milestones for retrieving 10 C-Farm tanks, and the selection and retrieval of an additional 9 SST.

As of FY 2019, 16 tanks have been retrieved under the TPA and Consent Decree: C-101, C-102, C-103, C-104, C-105, C-107, C-108, C-109, C-110, C-111, C-112, C-201, C-202, C-203, C-104, and S-112. Retrieval of tank C-106 has not been declared complete. In 2019, using improved equipment and methods, the C-106 post-retrieval waste volume measured approximately 317 ft^3 (9 m^3). This meets the TPA Appendix H retrieval goal as defined in milestone M-045-00 of 360 ft^3 (9 m^3) and provides a path forward for declaring C-106 retrieval completion.

Four AX-Farm and five A-Farm SST were selected as the next nine tanks to be retrieved under the Consent Decree (Figure 5-6). Building on C-Farm retrieval lessons learned, an integrated infrastructure system (air, water, electrical, and leak detection) has been installed in AX Farm that will be expanded into A Farm (Figure 5-7). To prepare tanks for installation of waste retrieval equipment, obsolete equipment is removed. Removal efforts are complete for three of the four AX Farm tanks. Installation of the AX-102 waste retrieval system was completed in July 2019 and retrieval operations started in August 2019 (Figure 5-8). By calendar year end, an estimated 69% (~29,000 gal [110,000 L]) of the starting waste volume (~42,000 gal [159,000 L]) had been removed from AX-102 using sluicing and high-pressure water technologies. Installation of the AX-104 waste retrieval system remains ongoing with retrieval operations scheduled to start in mid-2020.

The A Farm waste retrieval system design was completed in 2019 and removal of obsolete equipment continues. Two new exhausters were installed and preliminary testing completed in 2019. Final testing and active ventilation of the A Farm tanks will begin in early 2020 improving work and environmental safety.

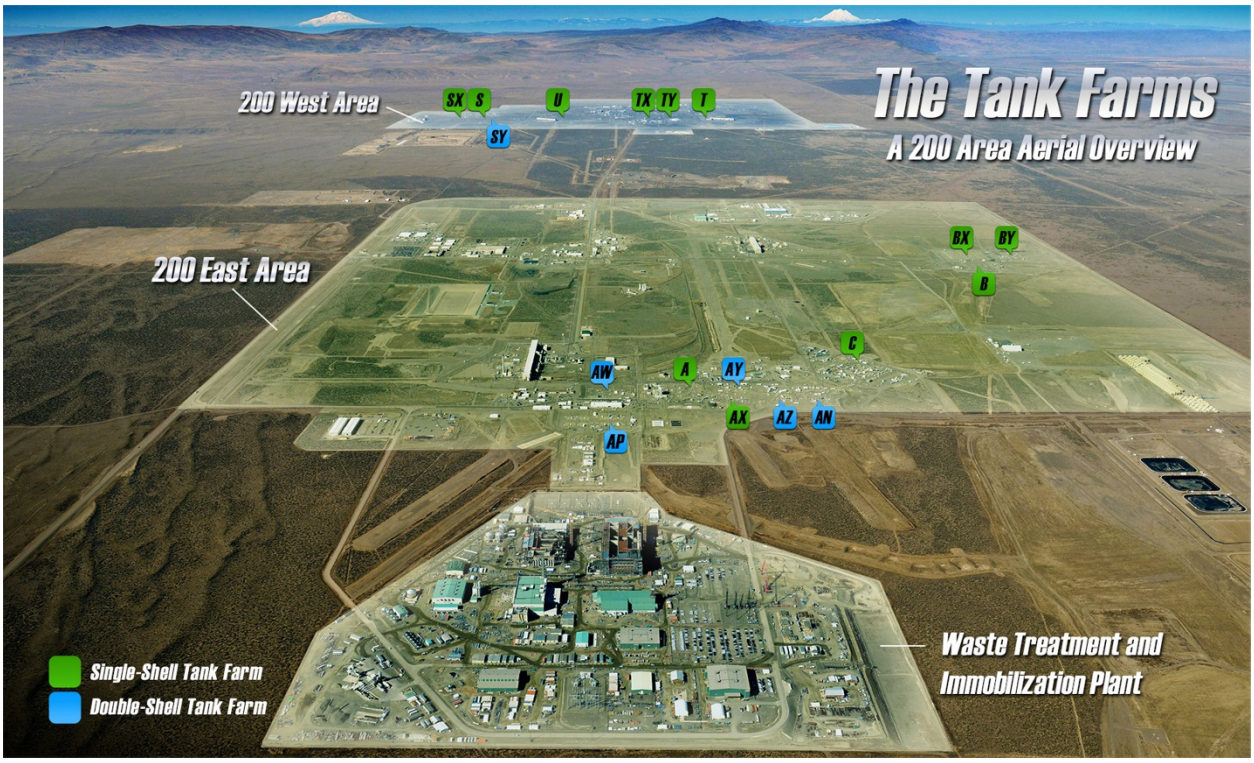

Figure 5-5. Aerial Over of the 200 Areas Tank Farms.

Figure 5-6. AX-Farm (Aerial Photograph, January 2020).

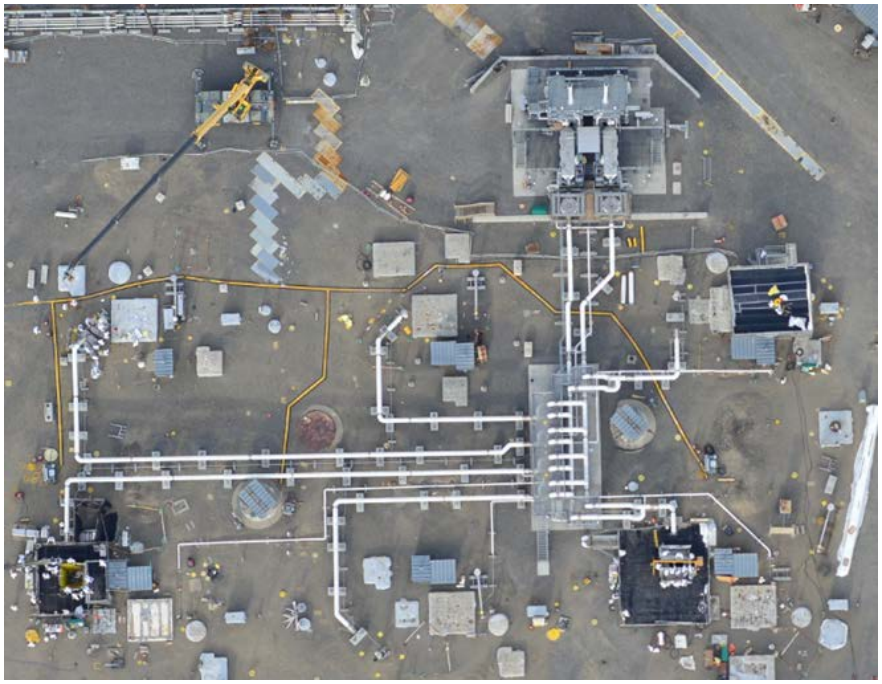

Figure 5-7. A-Farm Ventilation System (Aerial Photograph, January 2020).

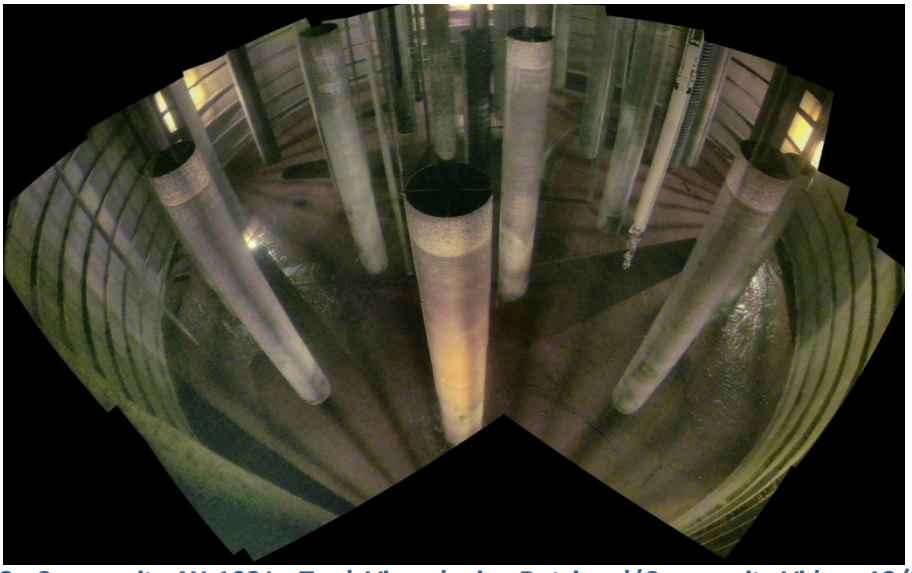

Figure 5-8. Composite AX-102 In-Tank View during Retrieval (Composite Video, 12/3/2019).

5.2.1.1 Single-Shell Tank System

The SST system was constructed between 1943 and 1964 to store mixed waste generated on the Hanford Site; 59 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 2019, retrieval of waste from the AX Farm tanks was started, transferring it to newer, safer DSTs to prepare to feed tank waste to the WTP.

At the end of CY 2019 there were 28.5 million gal (107.9 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 2019.

5.2.1.2 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 facility 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.

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	2019
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	25,782
	L	97,796	98,224	98,000	101,195	100,597	97,630	96,676	96,481	95,314	97,584
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	6,387
	L	48,817	98,2234	22,516	22,323	23,526	24,041	23,685	23,825	24,141	24,175
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	19,395
	L	49,082	62,902	78,101	78,873	77,071	73,588	73,002	72,653	71,173	73,410
242-A Evaporator											
242-A Evaporator volume evaporated	gal	548	0	0	0	793	1,329	305	557	220	10
	L	2,074	0	0	0	3,002	5,031	1,154	2,108	833	37.8
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	28,535
	L	111,420	111,945	110,806	110,477	108,978	108,210	108,009	108,732	108,168	108,005
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	28,381
	L	111,302	111,401	110,466	110,053	108,471	107,676	107,574	108,179	107,725	107,422
SSTs year-end waste supernatant volume[b]	gal	31	144	90	112	134	141	115	146	118	154
	L	117	545	340	424	507	534	435	553	447	583

[a] Multiply volumes shown by 1,000. 1 gallon = 3.785 liters.
[b] Tank waste volume data is calculated from HNF-EP-0182
DST = double-shell tank
SST = single-shell tank

A routine visual inspection of the tank AY-102 annulus conducted in August 2012 revealed accumulation of solids in the annular space. It was determined solids were present in the annulus as the result of a leak from the primary tank (RPP-ASMT-53793, *Tank 241-AY-102 Leak Assessment Report*). AY-102 retrieval operations began in March 2016 with supernatant removal and Sluice Cannon operation (RPP-RPT-59728, *Retrieval Completion Status Report for Tank 241-AY-102*). On February 15, 2017, following water flushes of the transfer equipment, WRPS notified Ecology "sludge retrieval from 241-AY-102 was completed in accordance with the AY-102 Recovery Project Waste Retrieval Work Plan." Notification of retrieval completion was provided by letter 17-TF-0021, dated February 23, 2017.

At the end of CY 2019, there were 25.8 million gal (97.7 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 2019.

Safe storage, retrieval, and transfer of radioactive waste liquids, salts, and sludge are the primary focus of WRPS. 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. PNNL is providing technical support for baseline processing, risk reduction, and/or alternative management strategies in a number of key areas. Highlights of 2019 achievements are provided below.

- Subsurface Transport Over Multiple Phases – Water-Air-Energy (STOMP-WAE) modeling was conducted to understand possible pathways for water intrusion into the leak detection system in order to better understand potential causes of secondary liner corrosion. The STOMP-WAE simulator was 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. Identification of temperature effects and seasonal variation in recharge rates provide the technical basis for assessing DST corrosion and risks associated with extending their service life.

- Under-tank nondestructive examination technology capable of delivery to the primary tank bottom of Hanford's DSTs is being pursued. 2019 achievements included expansion of tank bottom visual inspection deployments through DST refractory air slots as well as continued development of several volumetric inspection technologies. Visual inspections of the primary tank bottom in DSTs was incorporated as a programmatic activity following successful development efforts in 2019. Approximately 3 to 4 inspections are being conducted each year now in parallel to planned ultrasonic testing equipment deployments. Robotic tools built for tank bottom visual inspection underwent design modifications and upgrades through 2019 to accommodate newly developed volumetric inspection sensor packages. These designs are intended to progress through fabrication, testing, and qualification in the 2020/2021 years and be ready for field trials.

- The robotic air-slot volumetric inspection system (RAVIS) that is being engineered for Hanford tank bottom inspections (Figure 5-9) underwent design reviews and-site acceptance testing (requirement verification testing). The RAVIS is a robotic ultrasonic guided wave inspection system that is being

designed and tested for its ability to reliably inspect physically inaccessible tank bottom plates and welds via the air-slots beneath the tanks (Figure 5-10). Testing was performed in 2019 to demonstrate whether the RAVIS air-slot sensor and air-slot robotic crawler sub-systems were capable of meeting the functional, performance, and other requirements established for the Non-visual (Volumetric) Nondestructive Examination Technology Development Program. Two 1-week test campaigns were completed to evaluate the flaw detection performance of the air-slot sensor and perform preliminary testing with the air-slot crawler (Figure 5-9). Test results were used as a basis for 1) declaring the air-slot sensor ready for advancement to flaw detection qualification in 2020, and 2) and identifying robotic design improvement to make prior to robot qualification (estimated completion in 2021).

- Advanced data processing and data reduction strategies are being implemented to convert non-destructive evaluation inspection results to flaw location and size information needed to inform operational decisions on remaining tank service life or repair for tank life extension.

- In-service repair approaches are being evaluated as a means of tank life extension. The feasibility of repairing carbon steel plate using Cold-Spray—a candidate method for in-service repair of HLW tanks on the Hanford Site—was evaluated in 2019. Feasibility tests were conducted using commercial Cold-Spray equipment to provide the basis for a set of Cold-Spray process parameters for carbon steel primary tanks and secondary liners that produce long-term, high-density deposits for metallurgically sound repairs. The effort demonstrated the buildup of a mild-steel deposit over the top of simulated flaws in 0.5-in. (1.27-cm) steel plate. The tank operations contractor would use the process parameters with commercial Cold-Spray technology for a deployable system to restore the corrosion allowance and leak integrity of primary tanks and secondary liner and, thereby, extending tank service life.

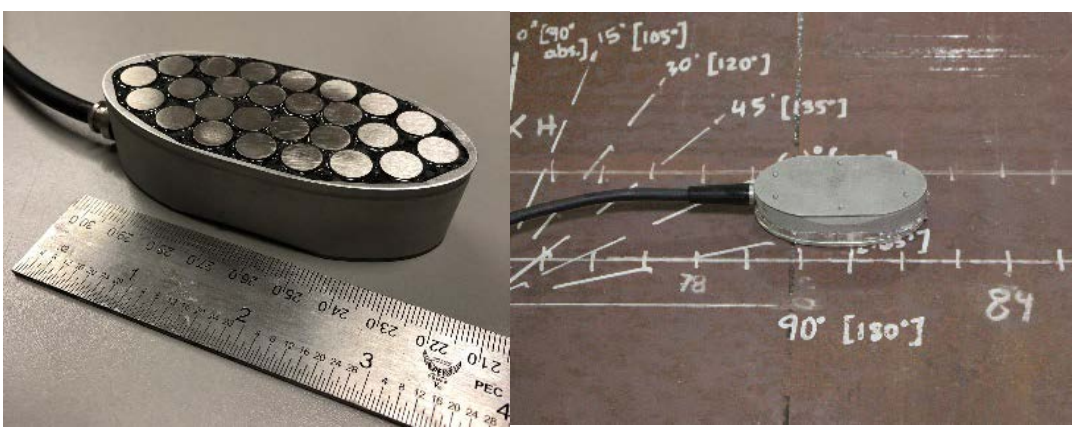

Figure 5-9. Photographs of the 2019 Model of the RAVIS Air-Slot Non-Destructive Evaluation Sensor. Left: the front face of the sensor with an array of 26 ultrasonic elements that will work together to focus and steer an ultrasonic sound field 360 degrees around the sensor to inspect physically inaccessible tank bottom plates and welds using ultrasonic guided waves. Right: the air-slot sensor coupled to the bottom plate of a primary tank test mock-up during flaw detection testing.

Figure 5-10. Photographs of the RAVIS Robotic System During 2019 Testing. Left: the RAVIS deployment crawler on the lower sidewall of a primary tank mock-up as it deploys the air-slot crawler in a mock-up air-slot (the deployment crawler will deploy itself, the air-slot sensor and the air-slot crawler through a DST riser and annulus). Right: the RAVIS air-slot crawler inside a mock-up air-slot underneath the bottom plate of a primary tank test mock-up as it positioned and coupled the air-slot sensor for inspection (the air-slot crawler will deploy the air-slot sensor under a tank via the air-slots, and position the air-slot sensor under a tank).

- A thermal oxidation vapor abatement technology is being evaluated for treatment of selected tank farm vapor chemicals of concern. Based on successful demonstration testing of a commercial thermal oxidation system (NUCON International Inc., Columbus, Ohio) on simulated tank vapors in 2018, PNNL and WRPS are designing a tank farm production system to be installed on SST BY-108. BY-108 was selected for the demonstration because it contains one of the more challenging mixtures of chemicals of potential concern. The assessment and selection of BY-108 was performed in 2019. The demonstration testing, to be conducted in 2022 and 2023, is a key component of the Vapor Consent Decree with the state of Washington. The installation and testing of the Thermal Oxidation System on BY-108 will provide a set of field data on the efficacy of the destruction of chemicals of potential concern in a relevant operational environment. The test data will advise 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 are being developed to facilitate tank farm industrial hygiene functions, including exposure assessments. The Tank Vapors Data Access and Visualization application was developed in FY 2018. During FY 2019, accomplishments included the deployment of a set of analysis and visualization tools to assist industrial hygiene professionals in performing routine exposure assessments for tank farms, facilities, and job-specific work activities. In FY 2020, enhancements to prior tools are also being deployed to increase access to underlying data sets Additional work to apply the Chemical Mixture Methodology to historical sampling results to supplement the exposure assessment process will also be performed.

- Numerical and computational evaluations were completed to enable “repurposing” of AP-106 as a treated low-activity waste (LAW) lag storage vessel to support direct feed LAW (DFLAW) treatment A technical evaluation for risk mitigation of planned AP-106 operations was completed 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. Results informed baseline operations changes and additional analytical and computational evaluations were conducted to evaluate these changes and establish tolerable risk levels for AP- 106 "repurposing" operations. The AP-106 retrieval and mixing operations were successfully completed as predicted by the technical evaluation.

- Structural integrity analysis of record was completed 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 the Hanford Site. 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 gal (2.7 million L) of additional storage volume in the eight AP tanks. In 2017, a similar analysis was performed 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 and the analysis is on schedule 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 (4.3 million liters). Verified tank structural models were used to assess the addition of new tank dome risers for increased access during waste retrieval. These models were also used in 2019 to evaluate the current as-built condition of the AX SSTs.

- Online configured sensors are being developed 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 online instruments could be qualified and configured for field deployment (tank farms) in the future to provide real-time chemical analysis results, offset the demand for traditional sampling and offline analysis, and drive worker exposure hazards as low as reasonably achievable.

- An online configured Raman spectroscopy system is also being tested to support the measurements of very low concentration Raman-active analytes in the Low Activity Waste Facility off gas streams and Effluent Management Facility (EMF) waste streams. By using alternate wavelength laser systems combined with enhance chemometrics, Raman sensitivities are greatly improved and can monitor low concentration chemical flow streams in real-time. This can improve process monitoring and significantly lower laboratory sampling costs and operational costs. This effort is evaluating long term process improvements for DFLAW operations.

- WRPS worked with the Tank Integrity Expert Panel Corrosion Subgroup to develop new DST waste chemistry limits to prohibit stress corrosion cracking and minimize pitting corrosion. The technical basis for the new waste chemistry limits utilized a statistically designed test matrix and subsequent corrosion testing to develop a pitting factor relating inhibitive and aggressive waste constituents. The proposed controls were validated against historical testing results to ensure that they were appropriately conservative. The new DST waste chemistry limits better protect the tanks from

halide-induced pitting corrosion while remaining protective against stress corrosion cracking. The controls were implemented into WRPS requirements documents in October 2019.

- WRPS obtained core samples of tank 241-AY-101 and 241-AN-107 during FY 2019 Core samples collect solids material and oftentimes provide a full vertical compositional profile. They are an integral part of understanding the current condition of the DSTs and evaluating any potential corrosion risks associated with the waste.

5.2.2 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:

- Reaching agreement with regulatory agencies on the content of closure plans to allow closure of the 241-C-200 Series Tanks to proceed.
- Developing closure documents for other WMA C components.
- Completing field work required to retrieve 241-C-301 Catch Tank.
- Evaluating the conditions of 244-CR Vault and seven WMA C diversion boxes.
- Completing the U.S. Nuclear Regulatory Commission (NRC) and public review of the Waste Incidental to Reprocessing (WIR) Evaluation and the DOE O 435.1 PA for WMA C and finalizing both documents for public release.
- Completing resolution of comments received from Ecology on three of the four HFFACO initial drafts of PA-related documents (see Appendix I in Attachment 2 – Action Plan of TPA) for WMA C (RPP-ENV-58806, Rev 0; RPP-RPT-58329, Rev 2; RPP-RPT-59197, Rev 1)
- Performing maintenance on the completed DOE O 435.1 PA for WMA C.
- Completing initial drafts of two of the four HFFACO PA-related documents (See Appendix I in Attachment 2 – Action Plan of TPA) for WMA A-AX.
- Developing a WMA A-AX Closure Conceptual Design.
- Performing field work at WMA A-AX to support characterization and closure efforts.
- Designing interim surface barriers and planning for future interim measures.
- Monitoring the performance of implemented interim measures.
- Conducting soil characterization to support interim measures.

Closure activities in CY 2019 included performing field and engineering activities to support WMA C closure, conducting and planning characterization activities at WMA A-AX, planning for WMA A-AX Closure, and continuing to develop and get approval of WMA C closure documents. All closure documents requiring regulatory approvals for the first phase of closure of WMA C were with the approving organizations in CY 2019.

By the end of CY2019:

- The draft WMA C WIR Evaluation had undergone a public review and review by the U.S. Nuclear Regulatory Commission was underway.
- Resolution of comments received from Ecology on the RCRA Tiers 1 (SST System), 2 (WMA C), and 3 (241-C-200 Series Tanks) Closure Plans was underway.
- Resolution of comments received from Ecology on three of the four HFFACO PA documents (See Appendix I of Attachment 2 – Action Plan) for WMA C was underway.
- The DOE Order 435.1 Tier 1 (WMA C) and Tier 2 (241-C-200 Series Tanks) Closure Plans were under review by DOE.
- Grout formulas for closure of the 241-C- Series tanks and associated pipe encasements were developed and initial testing completed.
- Drilling, logging, and sampling of five direct push locations for WMA A-AX Focus Area 1, the area around tanks 241-A-104 and 241-A-105 (per RPP-PLAN-62041) was completed. Logging of 18 drywells in this focus area were also completed.
- RPP-PLAN-63020, *Sampling and Analysis Plan for WMA A-AX Focus Area 2 (Southwestern Area of A Farm)* was developed and field work was initiated.
- RPP-PLAN-63022, *Field Sampling and Analysis Plan for Soil Sampling Between Tanks T-102 and T-105,* was developed. Field work to support characterization for interim measures is anticipated to be initiated in CY 2020.

5.2.2.1 Performance Assessments.

Work was conducted during CY 2019 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.

Resolution of comments received from Ecology on three of the four HFFACO initial drafts of PA analysis documents (Appendix I in Attachment 2 – TPA Action Plan) for WMA C (RPP-ENV-58806; RPP-RPT-58329; RPP-RPT-59197) have continued. The fourth HFFACO analysis document, the DOE Order 435.1 PA, is outside of Ecology's regulatory oversight.

In addition, Maintenance and Monitoring Plans and an Unresolved Waste Management Question procedure were maintained in support of 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), (See Appendix I in Attachment 2, TPA Action Plan. To meet these requirements, U.S. Department of Energy, Office of River Protection (DOE-ORP) released a set of four complementary HHFACO PA analysis (See Appendix I in Attachment 2, TPA Action Plan) reports (RPP-ENV-58782; RPP-ENV-58806; RPP-RPT-58329; RPP-RPT-59197) in FY 2016. Each of the analysis reports focus 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 2019, DOE O 435.1 Performance Assessment (RPP-ENV-58782) and the complimentary Draft WIR Evaluation for WMA C were undergoing an independent review by the NRC as a part of its consultation with DOE-ORP on the WIR-related decisions at WMA C. Public meetings on the Draft WMA C WIR Evaluation were held in May to review NRC's Request for Additional Information and in October to review DOE-ORP's responses to the NRC's Request for Additional Information in October of 2019.

PNNL provided different types of technical support to the PAs during CY 2019, including technical peer reviews of PA documents and response to regulator comments. In addition, PNNL continue to strengthen the conceptual model basis for tank farms by identifying the potential impacts of small-scale heterogeneities on both past leak and closure scenarios.

In CY 2019, a draft preliminary PA for WMA A-AX was prepared to meet the requirements of DOE O 435.1. Other WMA A-AX HFFACO PA documentation (See Appendix in Attachment 2, TPA Action Plan) 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 supporting documents were prepared in CY 2019 that included model package reports of the flow and contaminant transport numerical modeland the system model, and environmental model calculation files that document all calculations included in the Preliminary PA.

5.2.2.2 Interim Surface Barriers.

Two interim surface barriers were constructed at T and TY tank farms in 2008 and 2010, respectively. Monitoring of these two barriers is ongoing and monitoring results are reported annually. Interim surface barriers were also constructed over SX Tank Farm in 2018 and 2019 to meet TPA Milestone M-045-92V. The SX Tank Farm interim surface barriers (i.e., Barrier 1 [South], Barrier 2 [North], and Expansion Barrier) were constructed of modified asphalt. Located south of SX Tank Farm, an evapotranspiration basin is being used to dispose of water collected by the interim surface barriers.

The design of a modified asphalt barrier for TX tank was completed and approved for construction by Ecology in 2019 (Meeting TPA Milestones M-045-92W and M-045-92X, respectively). A Maintenance and Performance Monitoring Plan for Interim Barriers was also submitted to Ecology in 2019 to meet TPA Milestone M-045-92AC.

5.2.3 Central Waste Complex

K Chase, J Fullmer

A solid waste storage facility located in the 200-West Area (Figure 5-11), the CWC qualifies for RCRA interim status in accordance with WAC 173-303-805 and operates under interim status standards of WAC 173-303-400(3). 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 (MLLW), TRU, and PCB radioactive. The CWC can store as much as 735,000 ft^3 (20,800 m^3) 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 TRU waste from waste retrieval operations. As of December 31, 2019, the volume of waste currently stored in the CWC Outside Storage Areas is approximately 143,687 ft^3 (4,069 m^3) and the volume of waste currently stored at CWC is approximately 409,830 ft^3 (11,605 m^3).

Figure 5-11. Aerial View of the Central Waste Complex.

5.2.4 Waste Receiving and Processing Facility

J Fullmer

The WRAP facility began operating in 1997 with the mission to analyze, characterize, and prepare drums and boxes of low-level, mixed, and TRU wastes for disposal (Figure 5-12). The 52,000-ft^2 (4,800-m^2) facility, along with two 21,500-ft^2 (2,000-m^2) 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 TRU 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 5-12. A worker loads 65 drums of mixed low-level waste debris for shipment from the Waste Receiving and Processing Facility to Perma Fix Northwest.

5.2.5 T-Plant Complex.

JR Hultman

The T-Plant Complex (Figure 5-13) is located in the 200-West Area and provides waste treatment, storage, and decontamination services for the Hanford Site and offsite facilities. The T-Plant Complex qualifies for RCRA interim status in accordance with WAC 173-303-805 and is operating under interim status standards of WAC 173-303-400(3). The T-Plant Complex received 13 additional STSC shipments of K-Basin sludge for storage during CY 2019, bringing the total to 20 STSCs at T-Plant.

Figure 5-13. Aerial View of the T-Plant Complex.

5.2.6 Canister Storage Building

DJ Watson

The CSB is a large 42,000-ft^2 (3,902-m^2) 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 the National Repository. The CSB was originally planned to be used for the storage of glass logs of vitrified tank wastes. Per the *National Environmental Policy Act* ROD to the DOE/EIS-0245F, *Final 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 Basin spent nuclear fuel in December 2000.

Adjacent to the CSB is the Interim Storage Area, which also contains spent nuclear fuel from other sources packaged in various containers. This spent nuclear fuel will be subsequently repackaged and sent to the National Repository.

5.2.7 Low-level Burial Grounds

JR Hultman, KL Chase, SR Myrick

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 TRU 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.

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

Trenches 31 and 34 (Figure 5-14) 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 containers 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.

As of December 31, 2019, Trench 31 contains approximately 250,960 ft^3 (7,106 m^3) of waste in approximately 4,082 waste containers. Trench 34 contains approximately 191,019 ft^3 (5,409 m^3) of waste in 5,341 waste containers. In 2019, 149 containers totaling 14,593 ft^3 (413 m^3) of waste were disposed of in Trenches 31 and 34.

5.2.7.2 Low-Level Waste Burial Ground, Trench 94.

The LLBG Trench 94 received two defueled U.S. Navy reactor compartments in 2019. The total number of reactor compartments received into Trench 94 (218-E-12B Burial Ground) is 135 as of December 31, 2019. All U.S. Navy reactor compartments shipped to the Hanford Site for disposal in trench 94 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 1,362 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).

Figure 5-14. Trenches 31 (Bottom Trench) and 34 (Top Trench) are Used to Store and Dispose of Low-Level Waste and Mixed Low-Level Waste from Hanford Site Work.

5.2.8 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 qualifies for RCRA interim status in accordance with WAC 173-303-805 and is operating under interim status standards of WAC 173-303-400(3). 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-ft^2 (1,860-m^2) 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. Other building areas for instrumentation, monitoring, utility support, and manipulator repair associated with Cell G and the pool cells remain in service.

In May 2018 DOE issued an amended *Record of Decision (ROD) to the Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*

(DOE/EIS-0391) for the management of cesium and strontium capsules at the Hanford Site. This amended ROD is found in the 83 FR 23270. The decision was to transfer the capsules in storage at WESF to a new interim dry storage facility.

In CY 2019 Ecology prepared and issued for public comment a draft RCRA Part B permit for WESF including provisions for removal and packaging the capsules for dry storage. In CY 2019, Ecology also prepared and issued for public comment a draft RCRA Part B permit for the Capsule Storage Area for the interim storage of the capsules. Permits are planned to be issued in CY 2020 for both facilities as a precursor to commencement of construction associated with capsule removal from WESF and interim storage at the Capsule Storage Area.

5.2.9 Integrated Disposal Facility

WA Borlaug, BL Lawrence, L Dittmer

The IDF (Figure 5-15) 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 (HDPE)-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) was originally intended for disposal of low-level radioactive waste (non-RCRA permitted) and the west cell (cell 1) was for disposal of MLLW (radioactive and RCRA-regulated hazardous waste). The west cell is currently a permitted TSD facility under the Hanford Site RCRA Permit (WA7890008967). A Permit Modification Request was submitted in 2019 to Ecology to allow disposal of MLLW in both cells (e.g., vitrified LAW from the WTP). The permit modification adds non-CERCLA waste from Hanford projects, secondary waste from WTP, and mixed waste generated by IDF operations to be disposed of in IDF.

The IDF has a process design capacity of 2.89 million ft^3 (82,000 m^3). The IDF is referenced in DOE/EIS-0391 as a future disposal option for Hanford Site wastes.

Figure 5-15. Aerial View of the Integrated Disposal Facility.

5.2.10 Environmental Restoration Disposal Facility

WA Borlaug, BL Lawrence, L Dittmer

The ERDF (Figure 5-16) 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 5-16. 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 MLLW 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 mi^2 (4.1 km^2). 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, "Design and operating requirements"). 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 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 (4.6-m)-thick enhanced RCRA Subtitle-C final cover will be placed over the cells.

As of December 31, 2019, DOE and its contractors have disposed of 18.5 million tons (16.8 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 mi^2 (570 km^2) 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.

5.2.11 200 Area Effluent Treatment Facility.

S Scott

The 200 Area ETF (Figure 5-17) 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 (ST0004500) and the 200 Area ETF Delisting Petition approval conditions. The treated effluent is stored in tanks, sampled and analyzed, and discharged via a dedicated pipeline to the State-Approved Land Disposal Site (also known as the 616-A Crib), 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 4.45 million gal (16.8 million L) of wastewater from LERF in CY 2019.

Figure 5-17. The Effluent Treatment Facility Receives Liquids from the Liquid Effluent Retention Facility.

5.2.12 Liquid Effluent Retention Facility.

South of the ETF, the LERF (Figure 5-18) consists of three RCRA-compliant surface impoundments to store process condensate from the 242-A Evaporator, groundwater from various operable unit P&T 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 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 receives liquid waste resulting from RCRA- and CERCLA-regulated cleanup activities.

The volume of wastewater received for the LERF basin storage in CY 2019 was approximately 2.34 million gal (8.87 million L). The largest single contributor to wastewater received into LERF was approximately 0.41 million gal (1.56 million L) of mixed waste burial trench leachate. Approximately 4.45 million gal (16.8 million L) of wastewater in LERF was treated at ETF in CY 2019. Treated effluent wastewater is discharged to the State-Approved Land Disposal Site. The volume of wastewater being stored in the LERF at the end of CY 2019 was approximately 9.82 million gal (37.2 million L).

Figure 5-18. The Liquid Effluent Retention Facility is Located in the Central Part of the Hanford Site.

5.2.13 200 Area Treated Effluent Disposal Facility.

Located east of the 200-East Area, the 200 Areas' TEDF (Figure 5-19) 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 (ST0004502).

The 200 Area TEDF consists of a 12-mi (19.3-km)-long pipeline, three lift stations, a sample station (Building 6653), and two adjacent 5-ac (2-ha) infiltration 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 2019 was approximately 75.7 million gal (286 million L).

Figure 5-19. 200 Area Treated Effluent Disposal Facility Ponds A and B.

5.2.14 242-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.

CY 2019 (EC-10) processing realized a feed volume of 35,000 gal (132,000 L), and a waste volume reduction of 10,000 gal (38,000 L) prior to flushing. After accounting for flushing, the net result was an increase in volume of feed tank AW-102 of 21,000 gal (79,000 L). Following the campaign, problems with the feed pump in AW-102 were identified during electrical testing. The pump will be replaced prior to the next waste processing campaign.

5.2.15 Hanford Tank Waste Treatment and Immobilization Plant

D Faulk

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 (Balance of Facilities [BOF]). Construction of the WTP is managed in accordance with the RCRA Permit. In 2019, Bechtel National Inc. (BNI) 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 DFLAW. The DFLAW approach calls for the treatment of tank waste in the LAW facility by the end of 2023.

As construction is completed, the plant systems and buildings are transferred to a startup and testing phase to perform testing to verify the systems and equipment functions as intended. After the startup phase, a commissioning phase ensures the utilities and process systems are integrated and ready to support future plant operations.

A description of the WTP facilities and the progress at each facility in 2019 is provided in the following sections.

5.2.15.1 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 2019, DOE and BNI, along with an independent review team, completed an extensive collaborative effort to resolve a series of technical questions related to the Pretreatment and HLW facilities. In June 2019, the last of eight technical decisions for the Pretreatment Facility was resolved. Four years of both small and large-scale testing confirmed that pulse jet mixers can properly mix tank waste to ensure there are no flammable gas buildups inside the facilities' vessels. This concluded BNI's work requested by the DOE to successfully resolve the technical decisions for the Pretreatment and HLW facilities identified by an industry expert panel and DOE Secretary of Energy in 2012.

5.2.15.2 High-Level Waste Facility.

At this facility, HLW is combined with materials in glass forming high temperature melters and poured into waste container canisters to form a solid, immobilized glass form. In 2018 and 2019, resumption and progress of HLW design engineering activities resumed and has been a primary focus; progress continued to deliver active facility procurements. Limited construction has progressed since 2016. In 2019, equipment such as a thermal catalytic oxidizer, ammonia dilution skid, and radioactive liquid disposal vessel were received for future installation. The catalytic oxidizer and ammonia dilution skid are used to safely destroy organics and nitrogen oxides, the liquid disposal vessel stores recycle generated from off gas processing. Design review was successfully completed for radioactive liquid disposal and melter feed systems and the Facility Preliminary Documented Safety Analysis was also submitted.

5.2.15.3 Low-Activity Waste Facility.

In 2019, DOE and BNI opened the doors to a commissioning workforce at a 20,000-ft^2 (-m^2) two-story annex connected to the LAW Facility. The annex houses the plant's control room and is key to controlling Direct-Feed Low-Activity Waste operations. The LAW Facility alone contains 93 systems. By

the end of 2019 nearly 90% of the Facility systems had finished construction and transitioned into the startup and testing phase while 38% had completed startup and entered the commissioning phase.

5.2.15.4 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 2019, the Laboratory realized several significant accomplishments. The first team chemists began performing the first scientific work taking place inside the Laboratory. The chemists prepared for their transition to the Hanford Site by first honing their skills and instruments at a smaller-scale offsite lab at Columbia Basin College in Pasco, Washington. During 2018 and 2019, while at the offsite lab, the laboratory team collaborated with WTP engineers to analyze glass made from a slurry of low-activity waste simulant and glass-forming materials. This same analytical method will verify the glass vitrified in the Low-Activity Waste Facility meets DOE standards.

During 2019, scientific instruments were installed in the Laboratory and by the end of the year, startup and testing was nearly finished. A majority of systems were handed over to the commissioning phase during the year.

5.2.15.5 Balance of Facilities.

The WTP's BOF is made up of 14 non-nuclear infrastructure support buildings necessary for the plant's DFLAW operation. 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. By mid-2019, workers had transitioned all buildings into the startup and testing phase; and by the end of 2019 completed handovers for nearly 83% of a total of 54 BOF systems to the commissioning phase. Final grading, earthwork, and roadway construction also progressed. Of these accomplishments, startup efforts included work for a standby diesel generator building, a steam plant, cooling tower building, and final earthwork and grading surrounding fuel oil and water treatment facilities.

5.2.15.6 Effluent Management Facility.

During low-activity waste vitrification, secondary liquid waste is generated from the melter off-gas system and during waste transfer pipe flushing. These liquids will go to the WTP EMF where excess water is evaporated, and the remaining concentrate is sent back into the vitrification process. EMF has four structures: the main processing facility, a utility building, an electrical distribution building, and the low point drain building. In 2019, EMF piping and electrical work progressed, main roofing structural steel was installed, and the building was enclosed with siding and roofing. The team also installed all remaining major vessels inside the facility. A prefabricated 13.8-kilovolt electrical distribution building was also received, assembled and energized. The work involved installing nearly 5,800 ft (1,768 m) of assorted electrical cables and 11,900 ft (3,627 m) of fiber optic cable to the EMF electrical building.

5.3 Long-Term Stewardship

J. Shoemake, G Berlin

The Hanford Site's Long-Term Stewardship (LTS) Program is responsible for managing over 220 mi^2 (570 km^2) of the Hanford Site, an area that includes more than 1,700 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. This documentation was prepared for each segment or area transitioned to LTS. The LTS program maintains an internal library of documents referenced in the turnover packages 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 (Figure 5-20).

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 ICs 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 Hanford Site's fourth CERCLA 5-year review was completed in 2017 (DOE/RL-2016-01) and the next review is due in 2022.

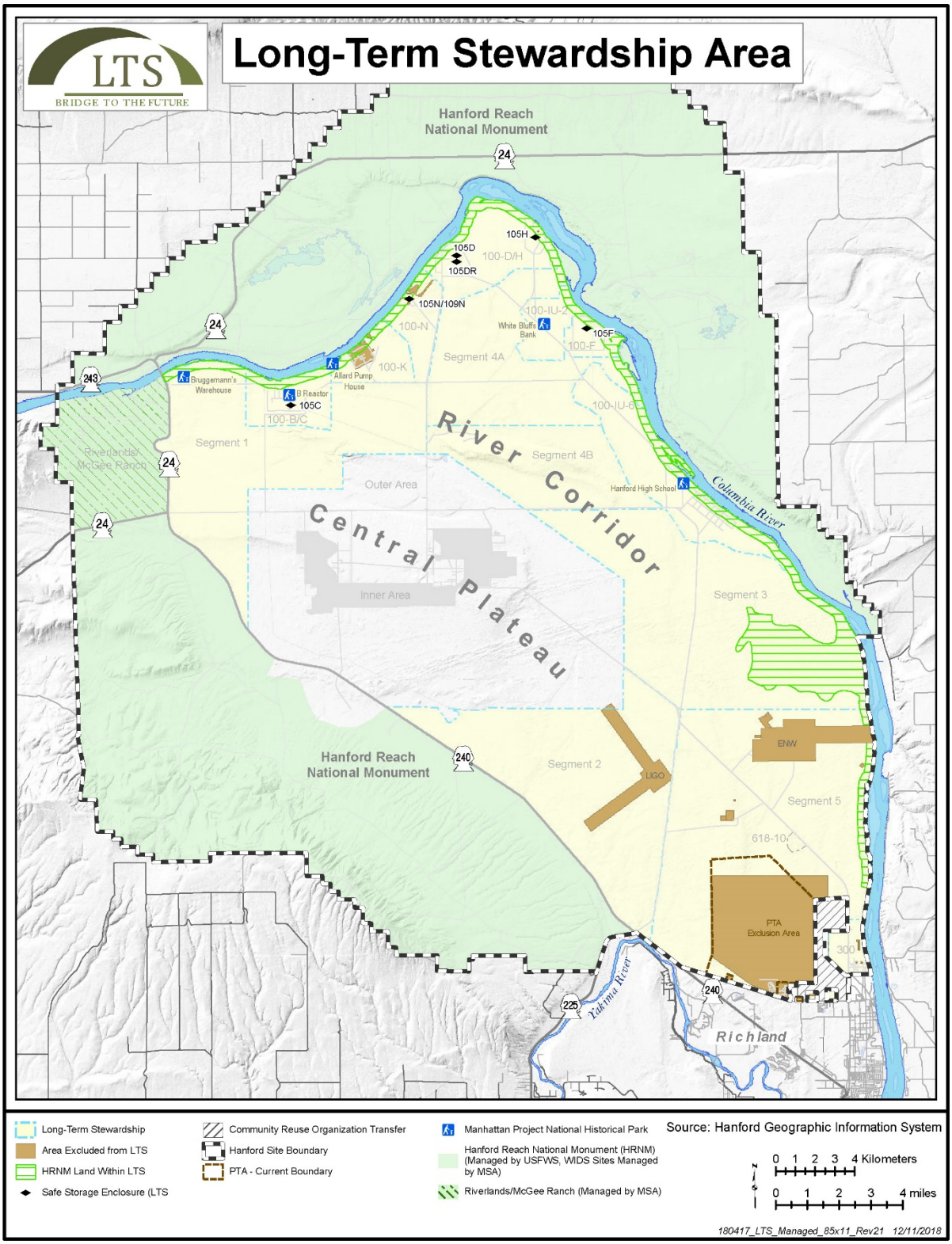

Figure 5-20. Land Areas Managed by the Long-Term Stewardship Program as of 2019.

The LTS Program also manages post-cleanup obligations, including S&M of interim-stabilized reactor facilities (i.e., safe storage enclosures [SSEs]), WIDS sites, ICs, radiological control posted areas, and revegetated site areas as well as managing other post-cleanup obligations. The LTS Program is also responsible for coordinating Hanford Site CERCLA Five-Year Reviews. In 2019, the following activities included:

- S&M activities of the six 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; upgrading signage on each SSE; sealing gaps in vestibule doorways and siding; and maintaining areas 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 ensure that the SSEs are maintained in a safe, environmentally secure, and cost-effective manner until subsequent closure during the final disposition phase of decommissioning.

- S&M of WIDS sites, which included annual inspections of 38 accepted WIDS sites and active WIDS sites, as required; assessing 221 waste sites with ICs 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 remain at the site above levels that allow for unlimited use and unrestricted exposure.

- S&M of 26 remaining radiological posted areas, which included inspections of proper postings, conducted annual contamination surveys and implemented 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 ac (38.4 ha) in 2018 and 2019 that either needed complete rework of the site or supplemental work with shrubs and/or forb plugs. New revegetation approaches are being implemented on the Hanford Site to help sites meet their success criteria within their five-year monitoring window.

- 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 2019, the LTS Program decommissioned 11 underground injection wells within the 100-B/C, 100-N, 100-D, 100-H, and 100-F Areas.

- Management and maintenance of the Hanford Site's LTS Records Library. As of late 2019, over 25,000 records were captured and stored in the LTS electronic records database. These records include historical cleanup information, as well as records created during the execution of LTS activities.

- Updated and issued revision 9 DOE/RL-2001-41, *Sitewide Institutional Controls Plan for the Hanford Site CERCLA Response Actions and RCRA Corrective Actions,* to include the additional ICs required by *Record of Decision: Hanford Area Superfund Site 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (DOE et al. 2018).

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.

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2019 Highlight

Effluent Releases
Nonradiological and radiological air effluent releases for calendar year 2019 were similar to calendar year 2018 releases and below permit limits and applicable standards.

Surveillance Program
Air sampling was conducted at 97 stations either on the Hanford Site or at offsite locations. For the year, the operational availability for all stations was approximately 98% and approximately 97% 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 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 2019 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 2019]. 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 through the Tri Party Agreement Administrative Record Public Information Repository website (http://pdw.hanford.gov/arpir/). 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 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 have been generally 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. 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 42 stacks that operated on the Hanford Site during calendar year (CY) 2019. Table 6-2 shows the curies released from these stacks in CY 2019.

The quantity of radionuclide air emissions reported in 2019 were similar in magnitude to those reported in 2018. Table 6-2 summarizes Hanford Site radioactive airborne emissions in 2019.

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (2 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
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

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (2 Pages)

Stack ID	Facility	Individual Sample Analyses	Additional Sample Analyses
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	90Sr, 137Cs, 238Pu, 239Pu, 241Am^{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, Am^{241}
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
MASF = Material and Storage Facility
PUREX = Plutonium Uranium Extraction Facility
WESF = Waste Encapsulation and Storage
WRAP = Waste Receiving and Processing

Table 6-2. Hanford Site Radioactive Airborne Emissions in Calendar Year 2019.

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
Americium-241	4.9E-06	5.6E-07	6.8E-08	5.4E-09	NA	5.5E-06
Americium-243	NA	NA	NA	5.3E-08	NA	5.3E-08
Carbon-14	NA	NA	NA	1.1E-04	NA	1.1E-04
Cesium-137	9.8E-06	3.7E-06	3.9E-07	1.3E-07	1.1E-11	1.4E-05
Cobalt-60	ND	7.1E-08	ND	5.9E-08	NA	1.3E-07
Curium-243/244	NA	NA	NA	5.6E-11	NA	5.6E-11
Europium-152	ND	ND	ND	2.1E-09	NA	2.1E-09
Europium-154	ND	ND	ND	3.1E-08	NA	3.1E-08
Gadolinium-153	NA	NA	NA	9.1E-11	NA	9.1E-11
Gross Alpha	2.2E-05	2.3E-06	1.1E-06	1.2E-07	1.9E-07	2.6E-05
Gross Beta	3.2E-05	1.2E-05	1.9E-06	4.8E-06	1.6E-06	5.2E-05
Iodine-129	NA	1.2E-03	NA	NA	NA	1.2E-03
Krypton-85	NA	NA	NA	1.2E-02	NA	1.2E-02
Neptunium-237	NA	NA	NA	1.4E-08	NA	1.4E-08
Plutonium-238	8.0E-07	ND	ND	3.5E-08	NA	8.4E-07
Plutonium-239/240	6.5E-06	3.3E-07	6.5E-07	2.6E-09	2.3E-13	7.5E-06
Plutonium-241	2.8E-05	ND	1.7E-07	ND	NA	2.8E-05
Radium-226	NA	NA	NA	3.7E-10	NA	3.7E-10
Radon-220	NA	NA	NA	5.20E+02	NA	5.20E+02
Ruthenium-106	ND	ND	ND	1.4E-08	NA	1.4E-08
Sodium-22	NA	NA	NA	NA	2.1E-10	2.1E-10
Strontium-90	7.4E-06	1.7E-06	3.2E-07	8.0E-08	NA	9.5E-06
Technicium-99	NA	NA	NA	4.3E-06	NA	4.3E-06
Tritium (elemental)	NA	NA	NA	9.20E+01	NA	9.20E+01
Tritium (tritiated water vapor)	NA	NA	NA	1.63E+02	NA	1.63E+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

Ci = curies
NA = Not applicable
ND = Not detected

6.1.2 Criteria Air Pollutants

Typical Hanford Site facility operations emit non-radioactive air pollutants. The emissions of non-radioactive air pollutants fall under two general categories: criteria pollutants and hazardous or toxic air pollutants (TAPs). The *Clean Air Act Amendment of 1990* (CAA) requires EPA to establish National Ambient Air Quality Standards criteria for six air pollutants commonly found all over the U.S. The EPA regulation 40 CFR 50, "National Primary and Secondary Ambient Air Quality Standards," defines

allowable concentrations in the ambient air for carbon monoxide, lead, nitrogen dioxide, particulate matter, sulfur dioxide, and ozone. Ground level ozone is not typically emitted directly into the air but is created by chemical reactions between oxides of nitrogen and volatile organic compounds. The ozone creation occurs when pollutants emitted by cars, boilers, and other sources chemically react in the presence of sunlight. As a precursor to ozone creation, volatile organic compounds are often regulated instead of ozone. Given the nature of Hanford Site operations and relative small quantity of criteria pollutants emitted, sampling or monitoring the ambient air for chemical compounds is not required. Some Hanford Site facilities and projects do have source specific sampling and monitoring requirements specified in individual Washington State Department of Ecology (Ecology) air permit approval orders. See Section 6.1.3 for more information on source specific sampling and monitoring. See Section 6.1.4 for more information on reported emissions of pollutants during CY 2019.

6.1.3 Hazardous and Toxic Air Pollutants

Hazardous air pollutants (HAPs) and TAPs are defined in federal and state regulations as chemicals, compounds, and substances known or suspected to be dangerous to human health or the environment. Under the CAA, EPA is required to regulate emissions of HAPs. The original CAA listed 189 substances but has since been modified through rulemaking to a reduced list of 187 HAPs. In addition to the federal HAP list, the *Washington Administrative Code* establishes a list of TAPs that includes 142 of the federal HAPs, excludes 45 federal HAPs, and adds 296 chemicals for a total of 438 regulated substances.

The EPA oversees HAP emissions through a series of regulations promulgated as "New Source Performance Standards" and "National Emissions Standards for Hazardous Air Pollutants." These EPA regulations are applicable to specific source categories and work activities (e.g., working with asbestos during building renovation and demolition). Ecology has adopted a broader approach and regulates all TAP emissions without regard to source categories. Any new or modified source of TAP air emissions in Washington State is potentially subject to Ecology regulation.

As required by WAC 173-460-080, "First Tier Review," projects and individual sources with estimated emissions of TAPs that exceed *de minimis* levels listed in WAC 173-460-150, "Table of Acceptable Source Impact Level, Small Quantity Emission Rate and De Minimis Emission Values," are required to submit a notice of construction (NOC) application. These NOC applications quantify project emissions, perform computer-based dispersion modeling analyses, and are subject to Ecology review and approval. Ecology issues NOC approval orders specifying emission limits and sampling or monitoring requirements, which are subsequently incorporated in the Hanford Site AOP (Ecology 2019).

Pursuant to WAC 173-460-090, "Second Tier Review," if dispersion modeling shows any TAP exceeding the acceptable source impact levels, a second tier review or health impact assessment must be performed to demonstrate the estimated emissions represent an acceptable health risk to members of the public. In previous Hanford Site NOC applications, dispersion modeling demonstrated dimethyl mercury (DMM) emissions as the only TAP above the acceptable source impact level values. The source of DMM emissions is the future planned tank waste retrieval, transfer, and treatment processes within the Hanford Site tank farms and the Waste Treatment and Immobilization Plant. The current DMM health impact assessment completed in 2015 (RPP-ENV-59016) was approved by Ecology (Ecology 2016). Consistent with the Ecology publication 08-02-025, "Guidance Document: First, Second, and Third Tier Review of Toxic Air Pollution Sources," (Ecology 2015), the health impact assessment includes eight additional TAPs. The additional TAPs exhibit neurotoxic health effects similar to DMM and emissions

estimates exceeded their respective WAC 173-460-150 Small Quantity Emission Rate values. The eight additional TAPs were included to produce a more comprehensive assessment of risk.

6.1.4 Reporting

The EPA promulgated the Air Emissions Reporting Rule (AERR) as implemented in federal regulation 40 CFR 51 Subpart A, "Air Emissions Reporting Requirements." The AERR requires state and local air pollution control agencies to submit emissions inventories for criteria pollutants to EPA's Emissions Inventory System. The EPA uses these submittals, to build the National Emissions Inventory. Ecology implements this AERR as a reporting requirement through WAC 173-400-105, "Records, Monitoring, and Reporting," and the Hanford Site AOP Section 5.9. Every year, facilities that have an AOP must send their Air Emissions Inventory (AEI) to Ecology electronically through the Washington Emissions Inventory Reporting System. Reporting TAP compounds in the AEI is not required unless explicitly specified in project-specific Ecology air permit approval orders. One exception to this TAP reporting exclusion is ammonia. Ammonia, included in the state list of TAPs but excluded from the federal list of HAPs, is specifically requested in the federal and state reporting regulations.

Hanford Site facilities use a combination of measurements and calculations to estimate emissions for the annual AEI report. Calculated emission estimates use published EPA formulae and emission factors (*Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources* [EPA 1995]). The AEI report organizes the emissions from across the Hanford Site into 19 reporting categories called "Emission Points." Each Emission Point can include data from a single source or multiple sources. The most significant source of emissions is combustion of fossil fuels diesel, gasoline, natural gas, and propane. Routine operations burn fossil fuels to produce steam and provide a local source of light and electricity. The largest fraction of emissions and sources in 2019 were:

- Oxides of nitrogen (15 tons); sitewide combustion of diesel fuel contributed 66% of this total
- Carbon monoxide (8 tons); boilers operating in the 300 Area contributed 74% of this total
- Volatile organic compounds (7 tons); the onsite gasoline vehicle fuel station contributed 80% of this total
- Ammonia (2 tons); the double shell tanks storing mixed radioactive and hazardous waste in the Tank Farms contributed 92% of this total.

Figures 6-1 and 6-2 show locations for sources contributing the largest fractions of non-radiological effluents. Table 6-3 summarizes the reported Hanford Site emissions of nonradioactive air pollutants discharged to the atmosphere in CY 2019. See the 2019 AEI report for more information (DOE 2020).

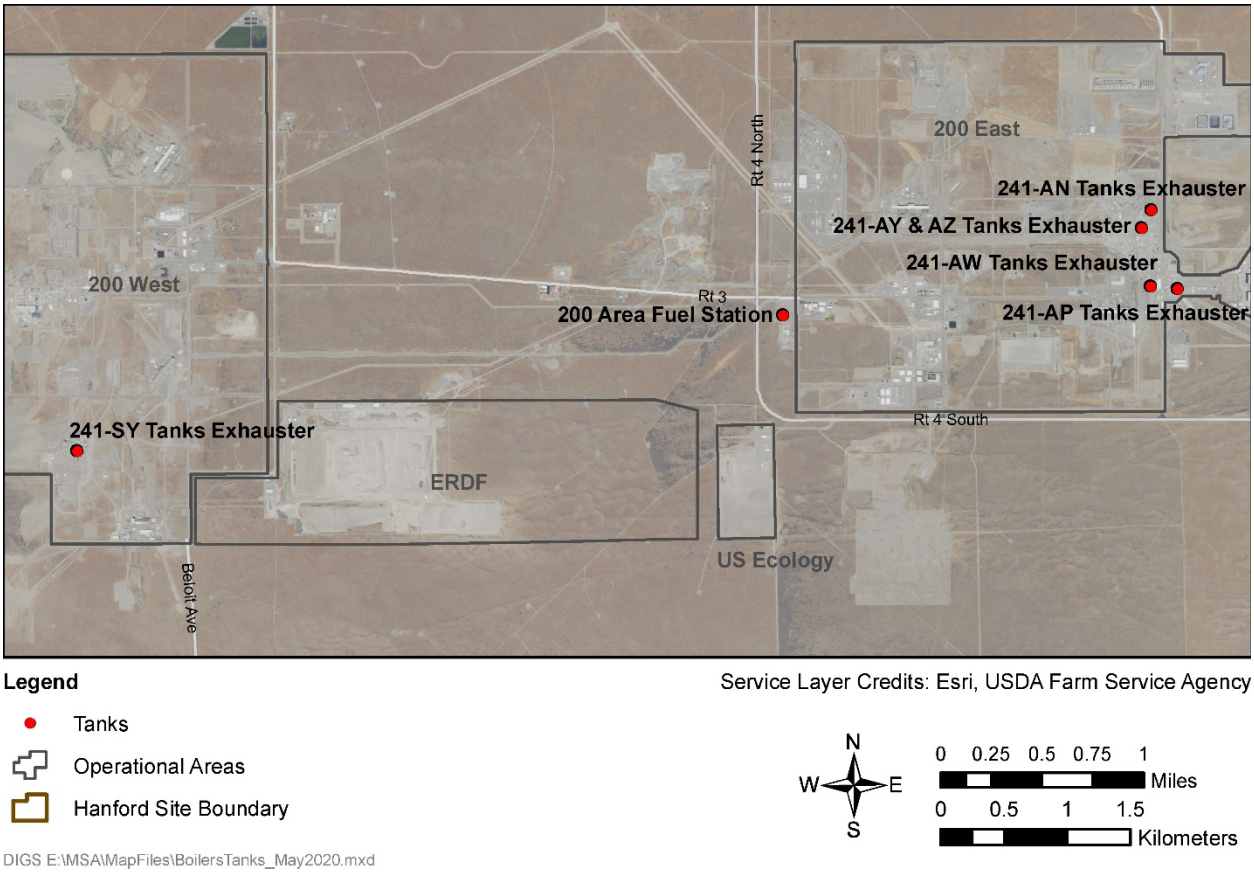


Figure 6-1. Sources Contributing to Volatile Organic Compounds and Ammonia Effluents.

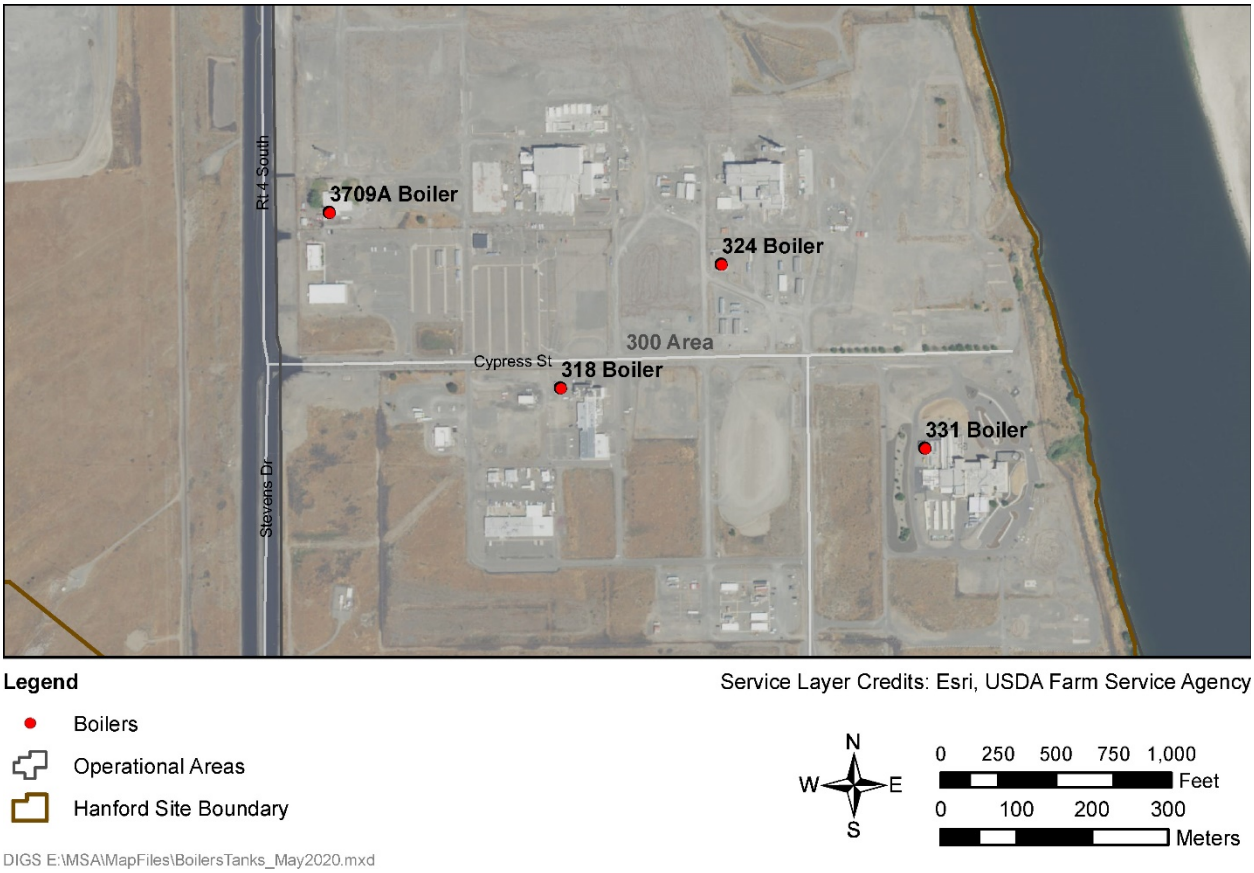


Figure 6-2. Sources Contributing to Carbon Monoxide Effluents.

Table 6-3. Calendar Year 2019 Hanford Site Air Emissions Inventory (DOE/RL-2020-07).

Pollutant	2019 Releases		
	Ton	lb	Kg
Particulate matter	1.0	2,057	933
Lead	0	0	0
Nitrogen oxides	14.7	29,625	13,438
Sulfur oxides	0.6	1,274	578
Carbon monoxide	8.5	16,980	7,702
Volatile organic compounds	6.5	12,961	5,879
Ammonia	2.0	3,911	1,774

6.2 Radioactive 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 78 locations across the Hanford Site was used during 2019 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 2019 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
Onsite			
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, N973, 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

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
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
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 2019 by continuously drawing air through multi-column samplers containing adsorbent silica gel. The water-vapor samplers were exchanged every 4 weeks to prevent sample loss as a result of breakthrough (i.e., oversaturation). The collection efficiency of the silica gel adsorbent is discussed in "Ambient Air Sampling for Tritium-Determination of Breakthrough Volumes and Collection Efficiencies for Silica Gel Adsorbent" (Patton et al. 1997). The collected water was distilled from the silica gel and analyzed for its tritium content.

Figure 6-3 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 µSv)/yr under conditions of continuous exposure. The 2019 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 2019.

6.2.1.1 Monitoring Results

100-K Area. Air was monitored in 2019 at seven locations in the 100-K Area, and analytical results showed radionuclide concentrations at or below typical Hanford Site levels. Cesium-137 and uranium-238 were detected in approximately 15% of the samples. All other radionuclides of concern were below analytical detection limits.

200-East Area. Air sampling was conducted at 28 locations in the 200-East Area during 2019. Generally, radionuclide levels measured were similar to those in previous years. Cesium-137 was detected in approximately 10% of the samples. Uranium-234 and uranium-238 were detected in approximately 20% of the samples.

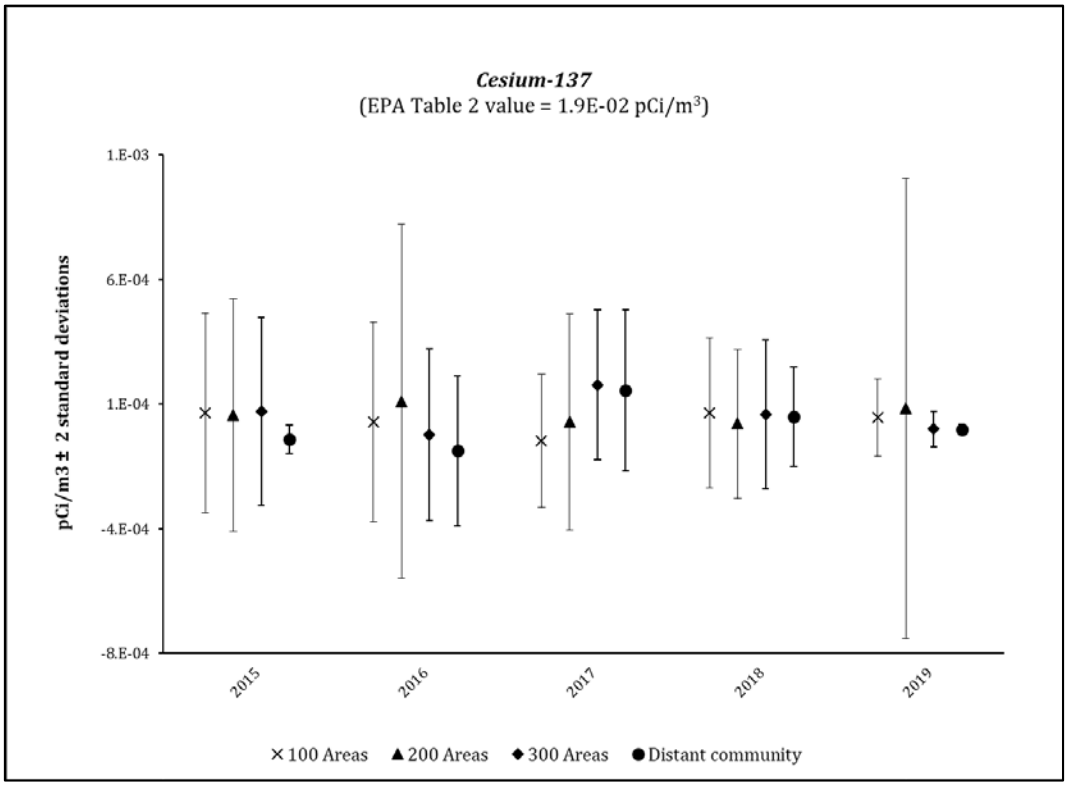
200-West Area. Air sampling was conducted at 23 locations in the 200-West Area during 2019. Radionuclide levels measured were, in general, similar to results for previous years. Uranium-234 and uranium-238 were detected in less than 10% of the samples. Plutonium-239/240 and americium-241 were detected in approximately 17% of the samples.

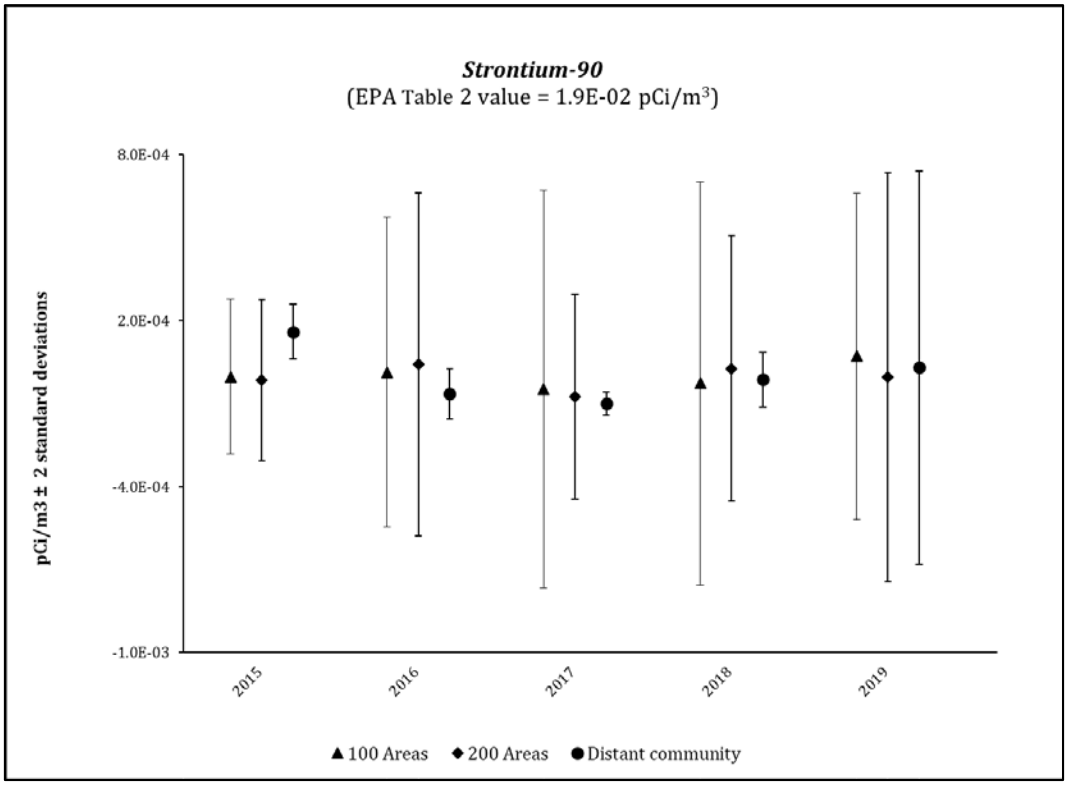
Plutonium Finishing Plant (200-West Area) Demolition. Low-risk clean-up activities continued at the Plutonium Finishing Plant during 2019 No airborne releases of radiological materials occurred during the year and air sample results obtained from seven sampling stations were at levels typically measured in the 200-West Area. Plutonium-239/240 was detected in approximately 50% of the samples and americium-241 was detected in approximately 30% of the samples.

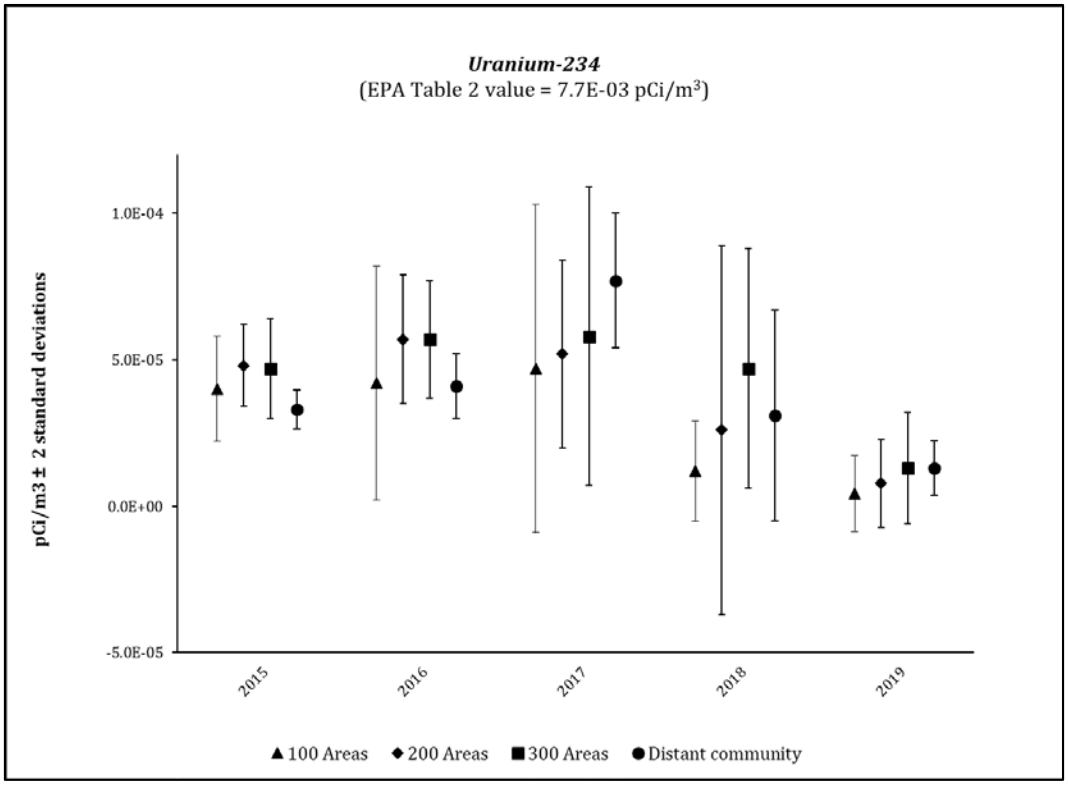
300 Area. Air sampling was conducted at seven locations in/near the 300 Area during 2019. At stations within the 300 Area, analytical results showed radionuclide concentrations similar to previous years'

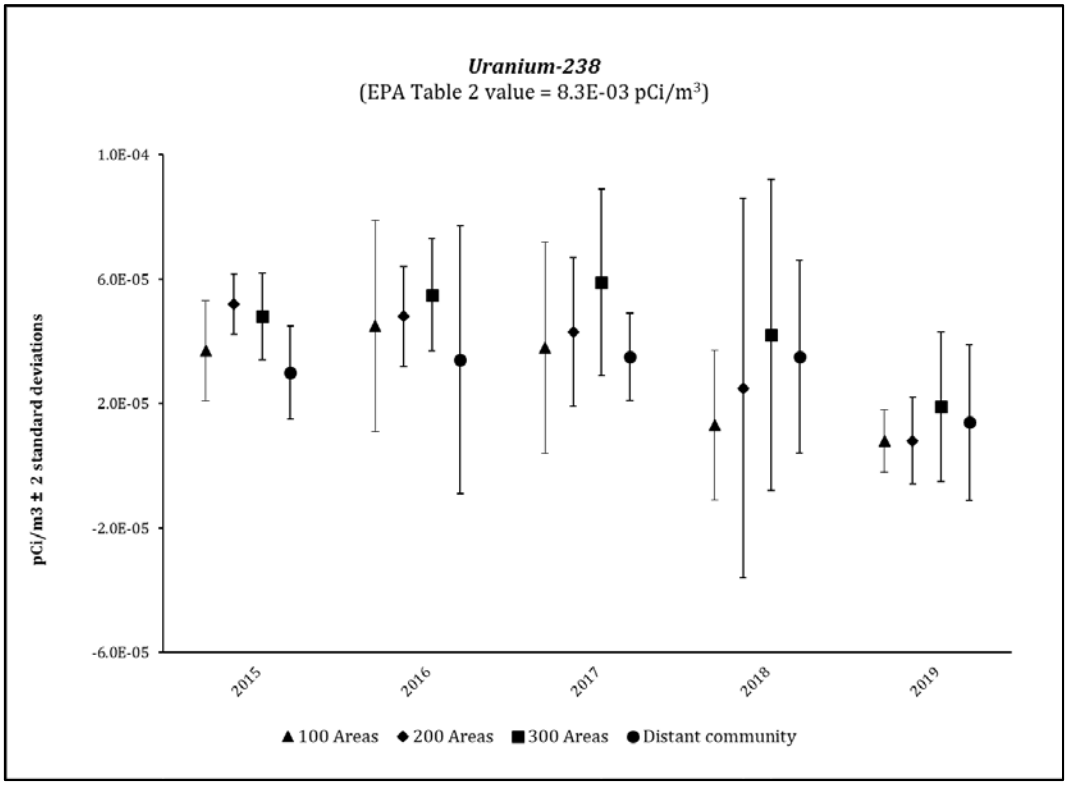
results. Uranium-234 and uranium-238 were detected in approximately 30% and 60% of the samples, respectively; tritium was detected in approximately 2% of the samples. All other radionuclides of concern were below analytical detection limits. At the 300 Treatment Effluent Disposal Facility station located just north of the 300 Area, air sample results were similar to those measured in previous years. Tritium was not detected in samples collected during 2019.

Environmental Restoration Disposal Facility (ERDF). Air sampling in support of ERDF operations was conducted at five locations at ERDF. These locations included three project-specific stations and two upwind stations that are part of the 200-West Area monitoring network. Radionuclide levels measured at this site were lower than previous years. No radionuclides were detected in samples collected during 2019.




Strontium-90
(EPA Table 2 value = 1.9E-02 pCi/m3)
pCi/m3 ± 2 standard deviations
8.0E-04
2.0E-04
-4.0E-04
-1.0E-03
2015
2016
2017
2018
2019
100 Areas
200 Areas
Distant community


Uranium-234
(EPA Table 2 value = 7.7E-03 pCi/m3)
pCi/m3 ± 2 standard deviations
1.0E-04
5.0E-05
0.0E+00
-5.0E-05
2015
2016
2017
2018
2019
100 Areas
200 Areas
300 Areas
Distant community



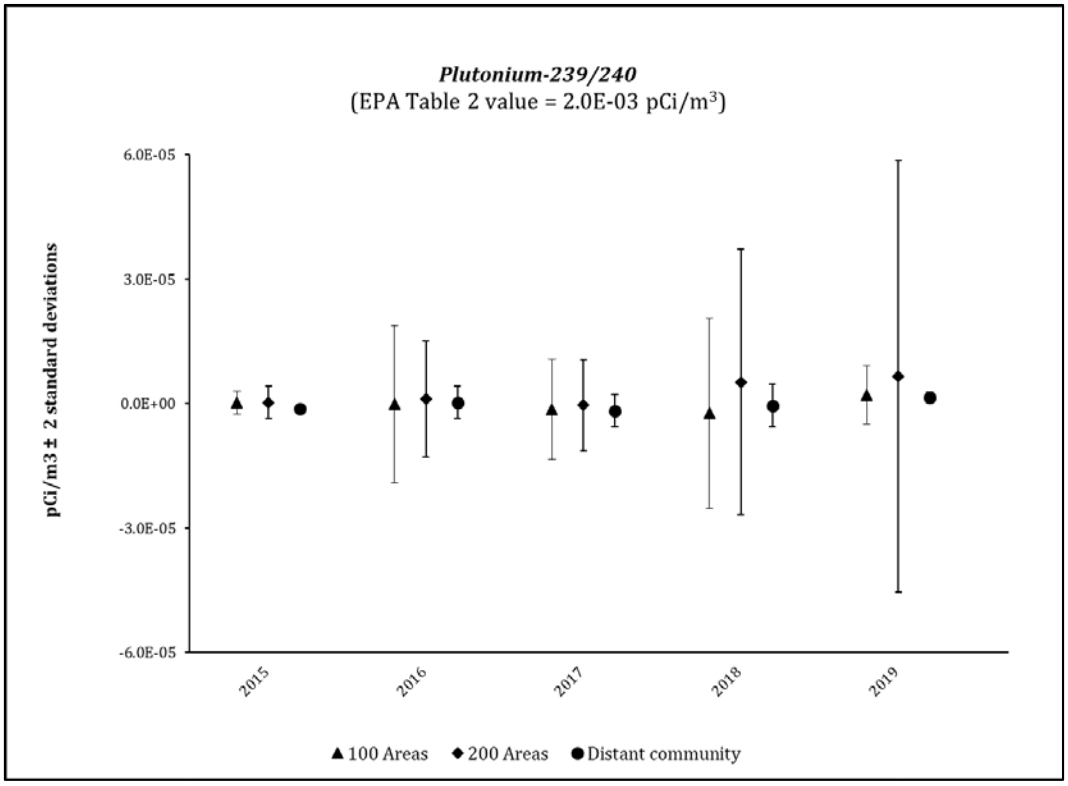


Figure 6-3. Hanford Site Average Radionuclide Concentrations in Air Samples Compared to Distant Community Samples.

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 2019 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 6-4; 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.

6.2.2.1 Monitoring Results.

Sample results in 2019 showed very low radiological concentrations in air. Gross alpha and gross beta concentrations in the air samples collected in 2019 from the perimeter and nearby Hanford Site communities were comparable to each other and slightly higher than samples from the distant community. Concentrations in 2019 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 2019 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, cesium-137, strontium-90, and plutonium isotopes were not detected in any of the offsite air samples collected during 2019. Annual average results from 2015 through 2019 for selected radionuclides are compared to onsite values in Figure 6-5.

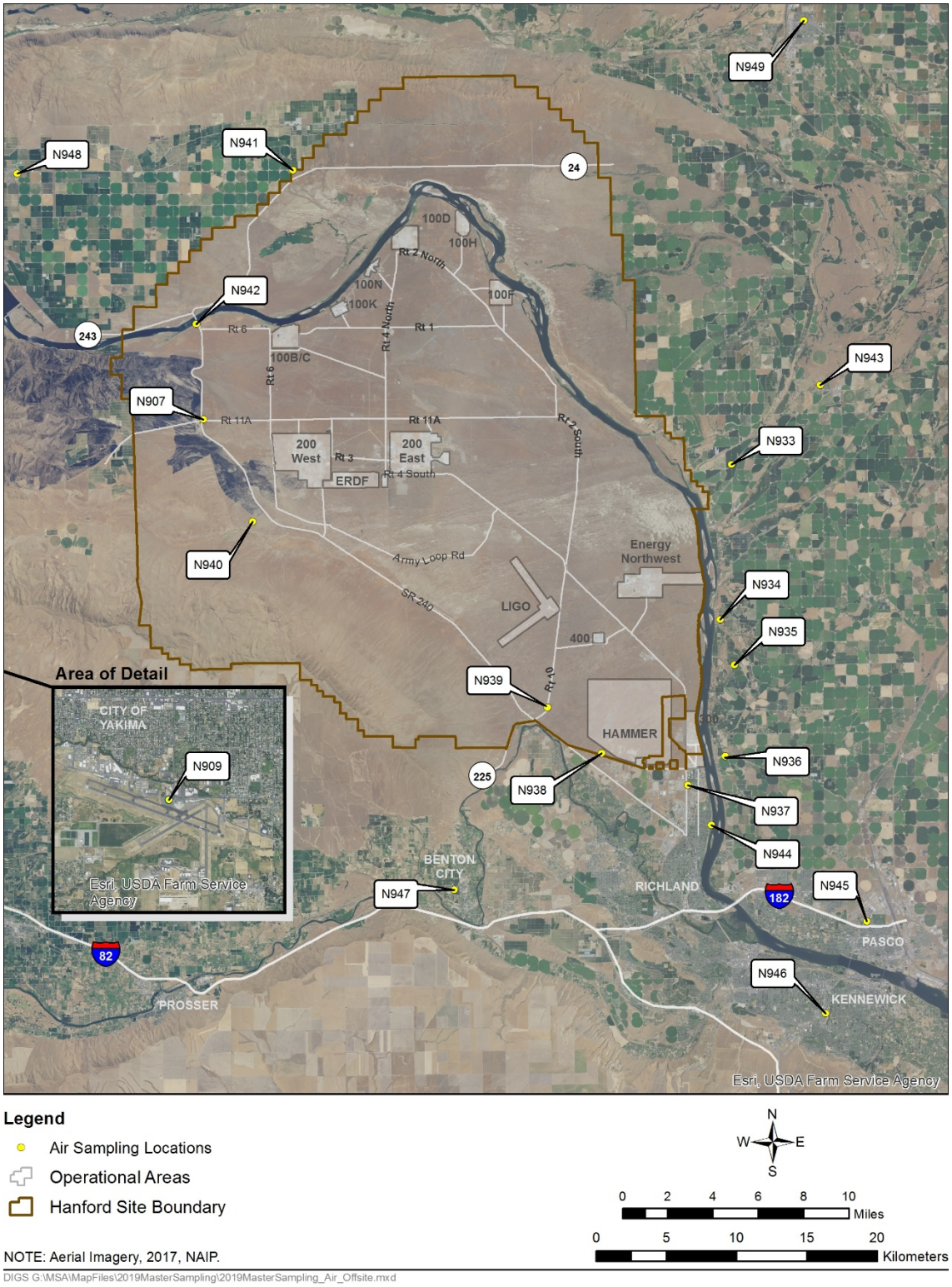
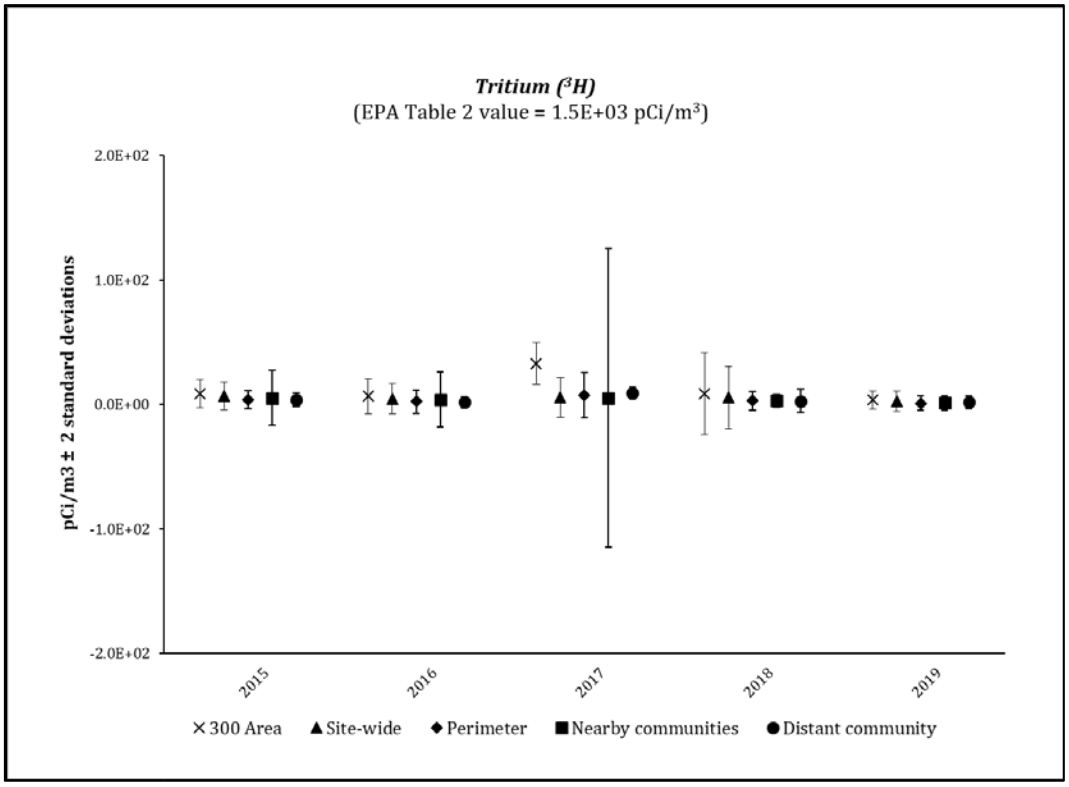
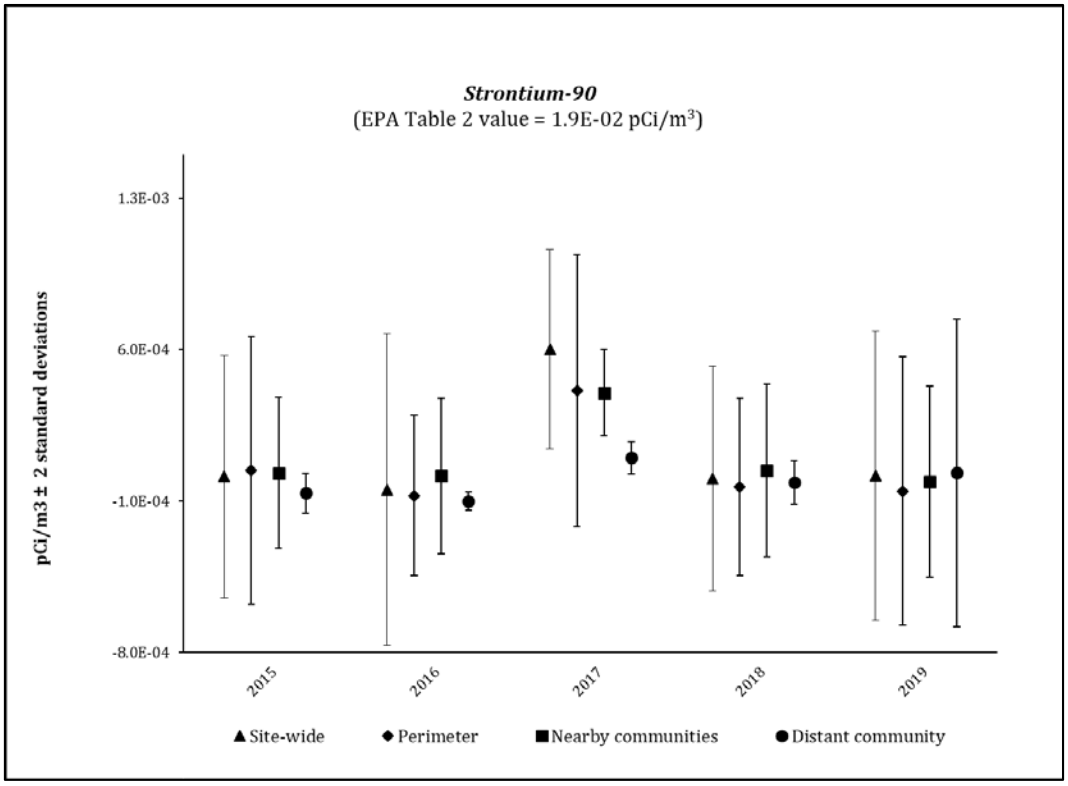
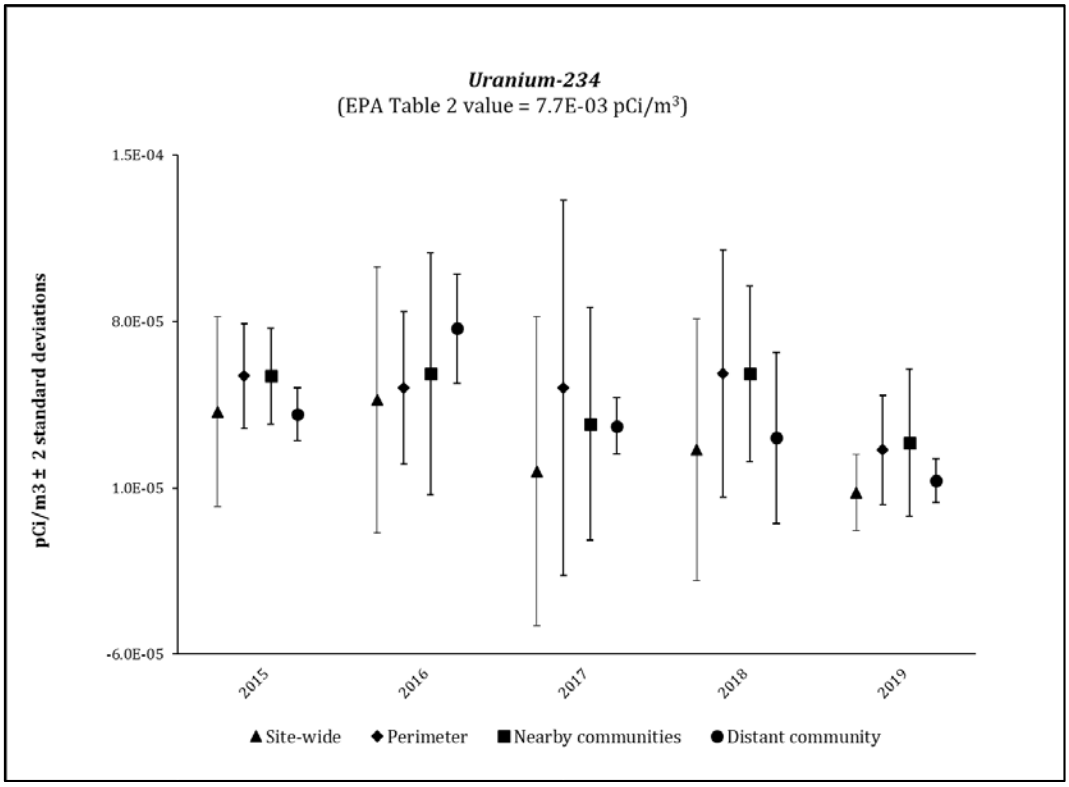
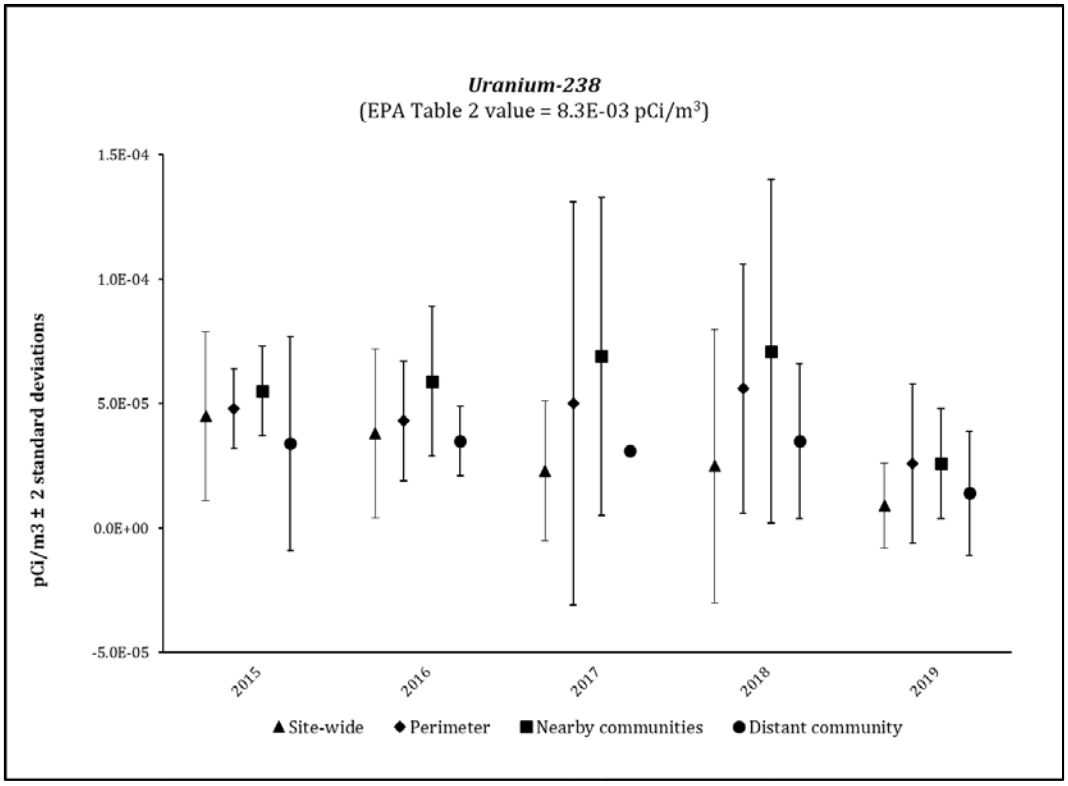


Figure 6-4. Offsite Air Sampling Locations for Calendar Year 2019.


Tritium (^3H)
(EPA Table 2 value = 1.5E+03 pCi/m³)
pCi/m3 ± 2 standard deviations
2.0E+02
1.0E+02
0.0E+00
-1.0E+02
-2.0E+02
2015
2016
2017
2018
2019
300 Area
Site-wide
Perimeter
Nearby communities
Distant community


Strontium-90
(EPA Table 2 value = 1.9E-02 pCi/m³)
pCi/m3 ± 2 standard deviations
1.3E-03
6.0E-04
-1.0E-04
-8.0E-04
2015
2016
2017
2018
2019
Site-wide
Perimeter
Nearby communities
Distant community


Uranium-234
(EPA Table 2 value = 7.7E-03 pCi/m³)
pCi/m3 ± 2 standard deviations
1.5E-04
8.0E-05
1.0E-05
-6.0E-05
2015
2016
2017
2018
2019
Site-wide
Perimeter
Nearby communities
Distant community


Uranium-238
(EPA Table 2 value = 8.3E-03 pCi/m³)
pCi/m3 ± 2 standard deviations
1.5E-04
1.0E-04
5.0E-05
0.0E+00
-5.0E-05
2015
2016
2017
2018
2019
Site-wide
Perimeter
Nearby communities
Distant community

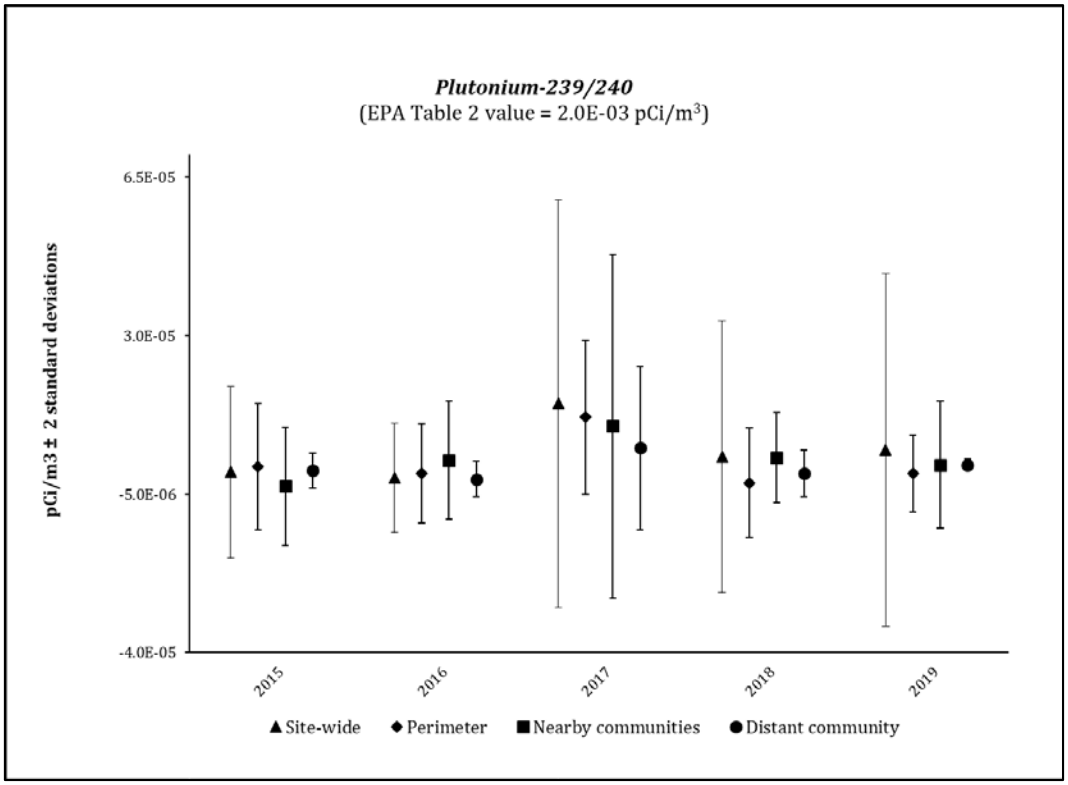


Figure 6-5. Radionuclide Concentrations in Air Samples (1 pCi = 0.037 Bq).

6.3 References

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2019 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 (EPA) Community Water System requirements. All of the U.S. Department of Energy-owned Hanford Site systems were in compliance with drinking water standards for 2019.

Columbia River Surface Water
Concentrations of most radionuclides in samples collected at the City of Richland intake facility were comparable with 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 2019 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 2019 were comparable to previous years with cesium-137 and uranium isotopes consistently detected at most sediment collection locations.

Columbia River Shoreline Seep Water
In 2019 sample collections, tritium concentrations were slightly elevated in a sample collected near the Hanford Townsite when compared to all other shoreline seep results.

Hanford Site Pond Water and Sediment
The 2019 West Lake water and sediment samples were collected and analyzed for radiological contaminants; concentrations were similar to results shown in previous years.

Offsite Irrigation Water
Tritium concentrations from fixed-station locations at the City of Richland intake facility and Priest Rapids Dam were similar to irrigation levels in 2019.

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 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 establish 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 2019. 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 the Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Federal Training Center 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.

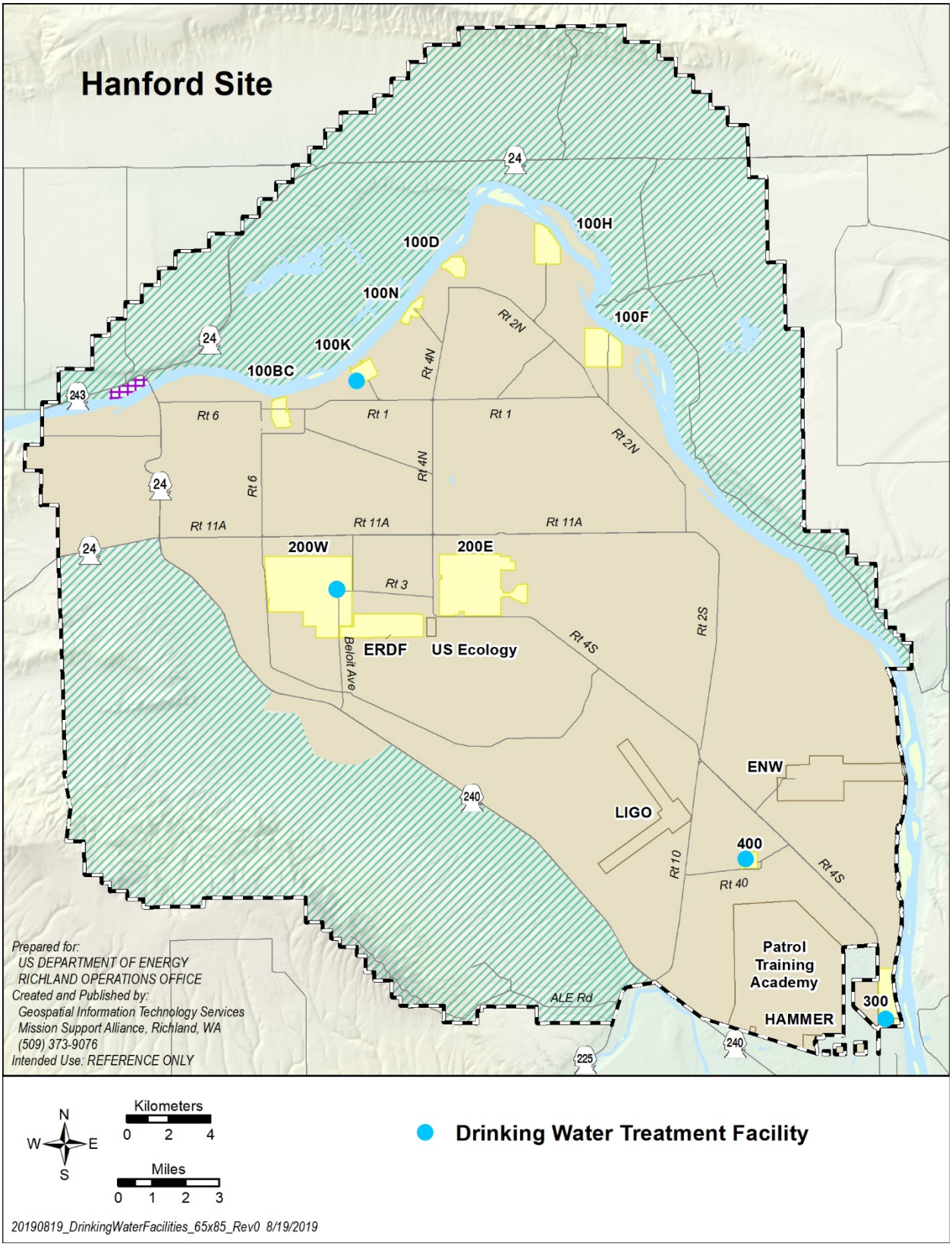

Figure 7-1. Drinking Water Treatment Facilities.

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=11039.

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 Mission Support Alliance, CHPRC, and PNNL (Table 7-1) performed monitoring (including chemical, physical, and microbiological 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. 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 but analytical results are available online via the Washington State Department of Health Sentry system.

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 2019. Contaminant concentrations measured during the year were similar to those observed in recent years as described in the annual Hanford Site environmental reports for 2017 (DOE/RL-2018-32) and 2018 (DOE/RL-2019-33).

PNNL Environmental Sampling 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 2019 were below state and federal maximum allowable contaminant levels (Table 7-2). The gross alpha 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), as was gross beta results for seven of the eight water samples analyzed and tritium for one of the two water samples analyzed.

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 2019, PNNL Environmental Sampling 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 (3,700 ± 885 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. (2 Pages)

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]	0.79	±	1.15	15 [d, e]
	200-West Area	Quarterly	Tap	4 [c]	0.64	±	1.32	
	400 Area	Quarterly	Tap	4 [c]	1.28	±	1.23	
	400 Area Well P-14	Quarterly	Well	4 [c]	0.91	±	1.45	
Gross beta	100-K Area	Q Comp [f]	Tap	4 [c]	0.84	±	4.85	50 [e]
	200-West Area	Q Comp [f]	Tap	4 [c]	1.17	±	1.33	
	400 Area	Q Comp [f]	Tap	4	8.39	±	2.25	
	400 Area Well P-14	Q Comp [f]	Well	4	8.67	±	1.03	
Tritium	100-K Area	A Comp [g]	Tap	1 [c]	176	±	300	20,000 [e]
	200-West Area	A Comp [g]	Tap	1 [c]	962	±	409	
	400 Area	Quarterly	Tap	4	4597.50	±	291.38	
	400 Area Well P-14	A Comp [g]	Well	1	3700	±	885	
Strontium-90	100-K Area	A Comp [g]	Tap	1 [c]	0.28	±	0.71	8 [d, e]

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

Constituent	System	Frequency	Sample From	Samples Analyzed at Each Location	Annual Average (pCi/L)[a, b]			Standard
	200-West Area	A Comp [g]	Tap	1 [c]	0.52	±	1.05	
	400 Area	A Comp [g]	Tap	1 [c]	1.39	±	1.10	
	400 Area Well P-14	A Comp [g]	Well	1 [c]	0.02	±	0.78	

[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.

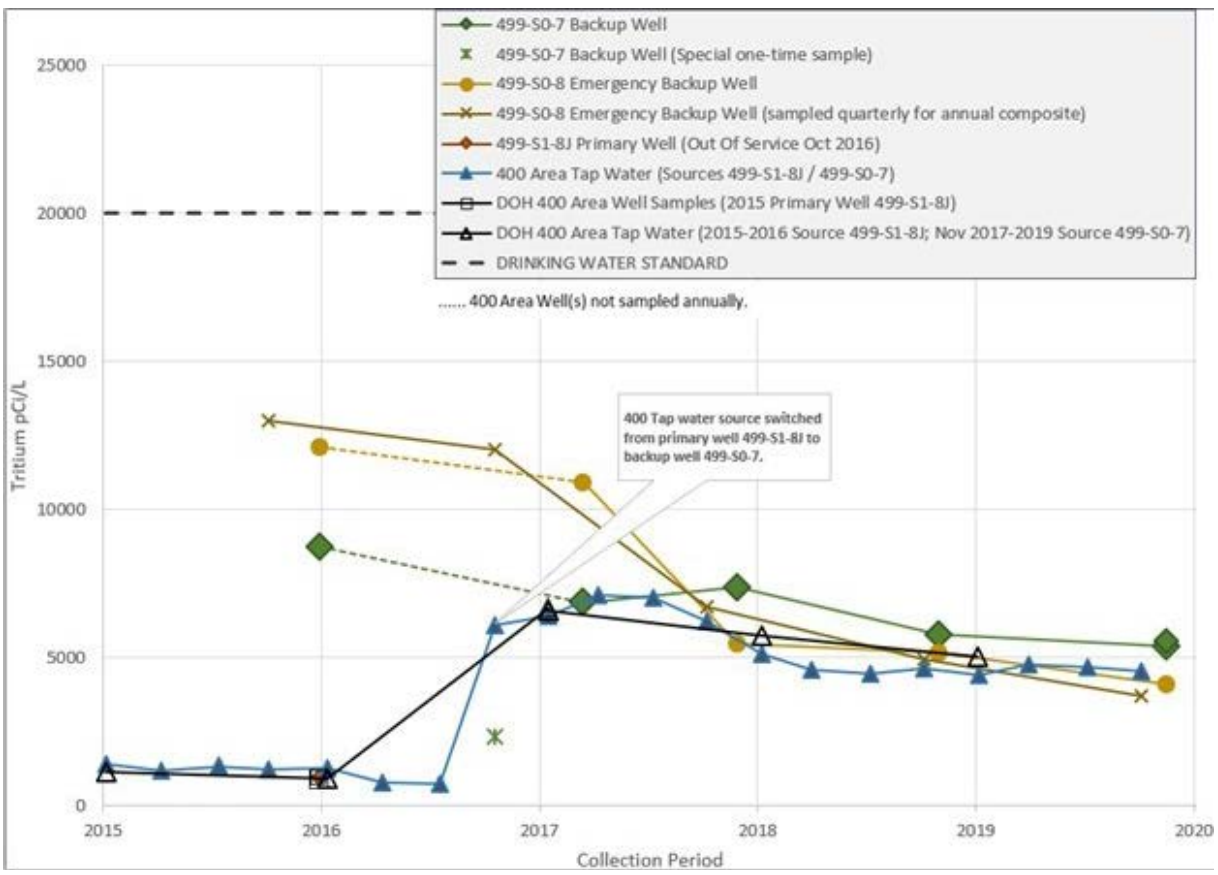

Figure 7-2. 400 Area Tritium Concentrations in Drinking Water (2014-2019) (multiply pCi/L by 0.037 to convert to Bq/L).

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]	Backup Drinking Water Well 499-S0-7 (P-15; pCi/L) [a]
November 19, 2019	No Sample	4,100 ± 865 [b]	5,465 ± 212 [C]

[a] Multiply pCi/L by 0.037 to convert to Bq/L. [b] Reported concentration ± 2 total propagated analytical error.
[c] Two samples collected 11/19/19, annual average ± 2 times the standard deviation.

7.2 Columbia River Surface Water

ME Hoefer

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 mi^2 (670,000 km^2) 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. 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 2019. The annual average flow of the Columbia River downstream of Priest Rapids Dam was approximately 94,505 ft^3 (2,676m^3)/sec, slightly below the most recent 10-year average annual flow rate of 115,831 ft^3 (3,280 m^3)/sec (USGS 2013). The highest monthly average flow rate occurred during May (147,154ft^3 [4,167m^3]/sec; Figure 7-4). The lowest monthly average flow rate occurred during September (56,918ft^3 [1,611m^3]/sec) based on mean daily flows. Daily average flow rates varied from 42,233 to 3,183,204 ft^3 (1,183 to 5,130 m^3)/sec in 2019. 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.

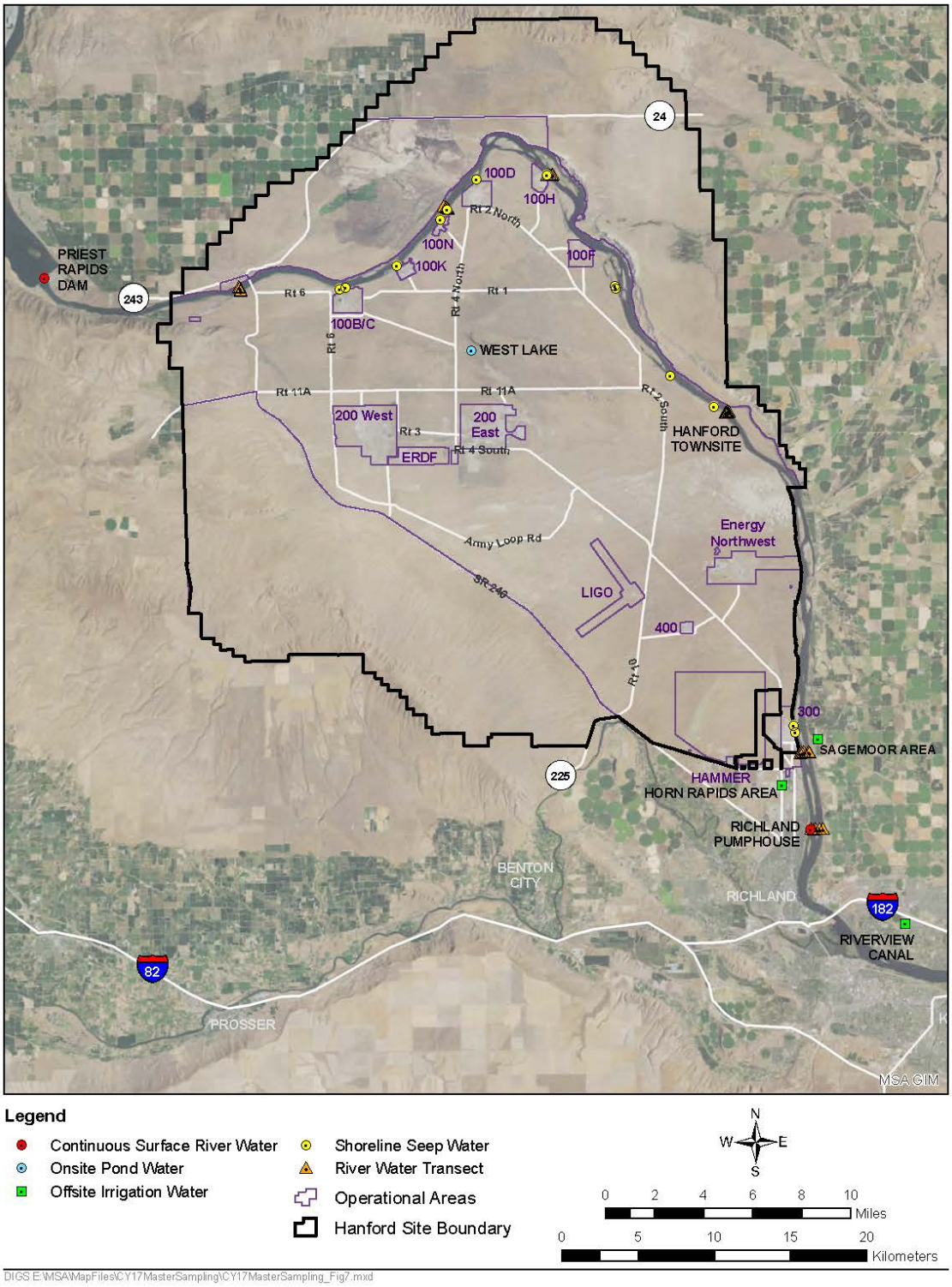

Figure 7-3. Surface Water and Sediment Sampling Locations.

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)
	Grab (transects)	Semi-annual	Volatile organic compounds
Richland	Grab (transects)	Semi-annual	Anions, mercury, metals (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), 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, gamma energy analyses, low tritium[(b)], strontium-90
Horn Rapids Battelle Sports Complex	Grab	3/year	Alpha, beta, gamma energy analyses, low tritium(b), strontium-90
Sagemoor Irrigation Canal	Grab	3/year	Alpha, beta, gamma energy analyses, low tritium(b), strontium-90

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, hexavalent chromium, isotopic uranium[b], isotopic plutonium[c], metals, mercury, strontium-90, and total organic carbon
Hanford Reach[d]	Annually	Anions, Cr+6, gamma energy analyses, hexavalent chromium, 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, hexavalent chromium, 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, hexavalent chromium, 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.

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.

7.2.1 Monitoring

In 2019, 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 consists 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 (i.e., 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 1% 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 2019. At both locations, concentrations were similar and lower than the guideline standards. Drinking water supplied by the City of Richland travels through the water treatment plant before it is available for public use.

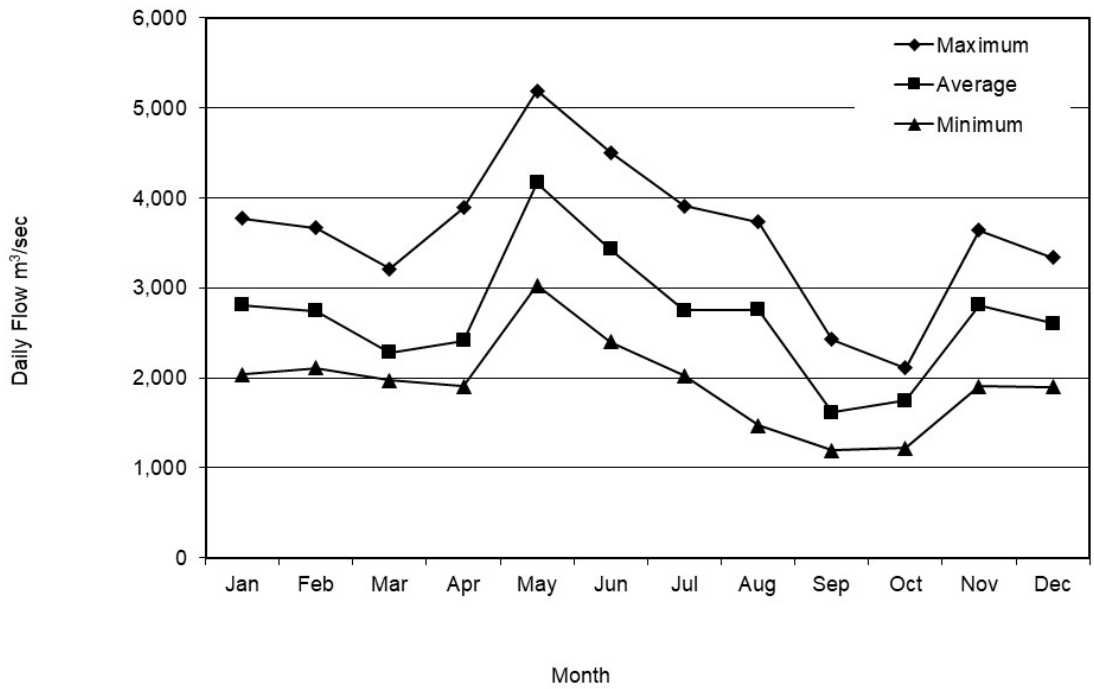

Figure 7-4. Columbia River Flow Rates at Priest Rapids Dam (multiply m^3/sec by 35.31 to obtain ft^3/sec).

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 2019, 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 2019 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 Area 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 2019 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). 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 2019 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 2019, and for the previous 5 years, are summarized in Appendix C, Tables C-7 and C-8.

Due to operational issues with the Richland Pumphouse sampling system during the first half of calendar year (CY) 2019, 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 2019. 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 2019 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 pCi/L (740 Bq/L).

The Hanford Site source of tritium entering the river is from groundwater upwelling and shoreline seepage. Although representative of river water used by the City of Richland for drinking water (first municipal water source downstream from the Hanford Site), tritium concentrations measured at the City of Richland shoreline tend to be elevated when compared to average historical tritium concentrations across the river at this location. This bias is attributable to a 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 2019 confirmed the existence of a concentration gradient in the river under certain flow conditions discussed in this section.

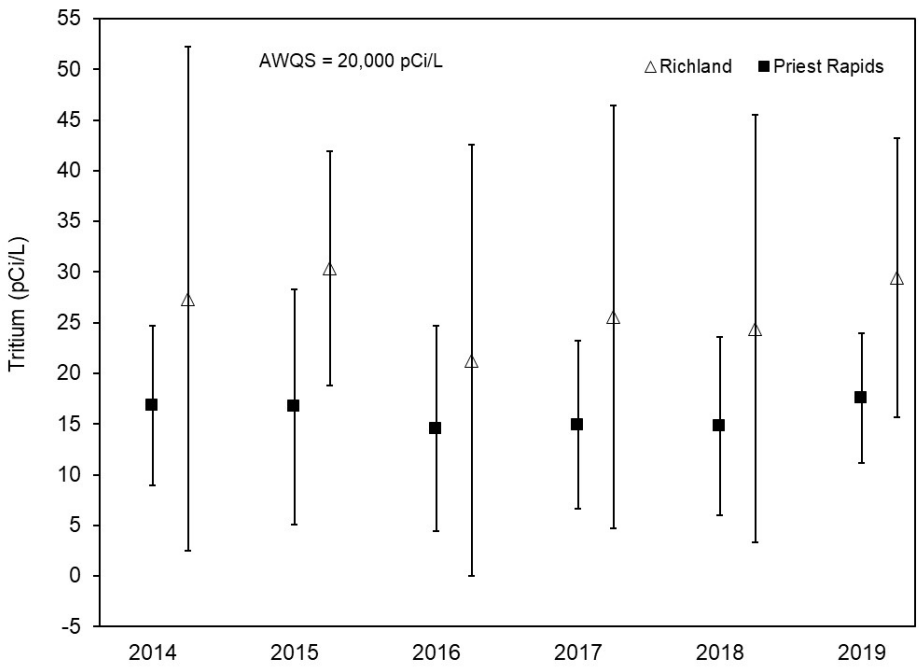

Figure 7-5. 2019 Annual Tritium Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (±2X standard deviations, AWQS=ambient water quality standard; Washington State AWQS for tritium is 20,000 pCi/L [740 Bq/L]).

The extent to which samples taken at the City of Richland drinking water intake overestimate the average tritium concentrations in the Columbia River at this location is variable and appears to be related to the flow rate of the river just before and during sample collection.

Average strontium-90 levels measured in Columbia River water, collected upstream and downstream of the Hanford Site during 2019, were similar to those reported in previous years (Figure 7-6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Area.

Historically speaking, some of the highest strontium-90 levels that have been found in Hanford Site groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Although concentrations of strontium-90 remained elevated until the mid-1990s, the levels seen both upstream and downstream today are very similar. 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 number of reasons, but the decline is likely due to radioactive decay, and to a permeable reactive barrier within the groundwater that was put into place by DOE. The barrier essentially 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 2019 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 2019 were slightly lower than those averages measured at the City of Richland (0.58 pCi/L total uranium).

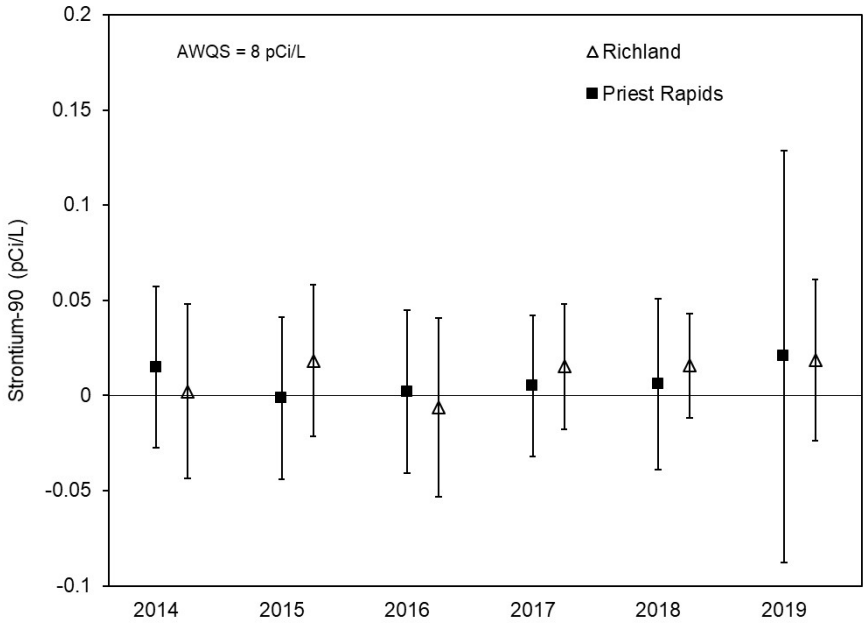

Figure 7-6. 2019 Annual Strontium-90 Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (±2 standard deviations, AWQS = ambient water quality standard).

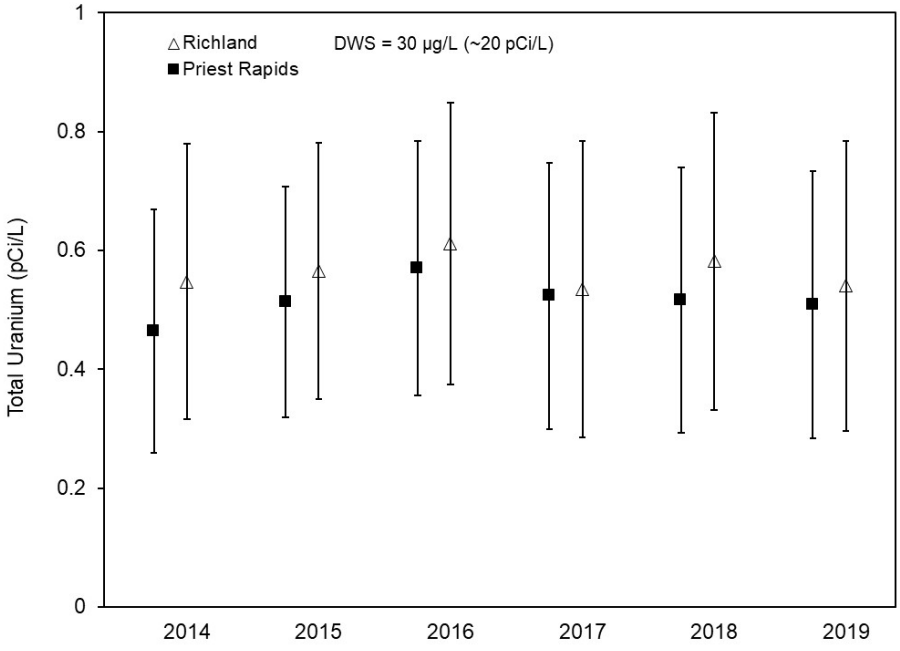

Figure 7-7. 2019 Annual Uranium Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (±2 standard deviations; DWS = drinking water standard).

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; PNNL-16805).

There is no Washington State ambient surface water quality criterion directly applicable to uranium; however, total uranium levels in the river during 2019 were well below the EPA drinking water standard of 30 µg/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 2019 were below analytical detection limits. One sample collected upstream at Priest Rapids Dam did show plutonium-239/240 at an extremely low concentration.

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-9. 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. There were no detections of strontium-90 in 2019 Columbia River transect samples. All measured concentrations of radionuclides consistently detected 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 2019 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 less than 1% of the Washington State Drinking Water Quality Standard of 20,000 pCi/L.

Hanford Reach transect samples collected in 2019 were similar to upstream reference concentrations for most locations with no detections of strontium-90. The maximum strontium-90 concentration was from a sample collected at the Vernita transect HRM 0.3 station-3. Average strontium-90 concentrations at the Priest Rapids Dam fixed-location monitoring station were greater than those measured at the Richland Pumphouse and in all Richland Pumphouse (RPH)-HRM 46.4 transect samples.

Uranium concentrations in all transect samples collected during 2019 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 Franklin County shoreline (RPH-HRM 46.4 station-9). Uranium-236 concentrations from the 300 Area transects were below analytical detection limits.

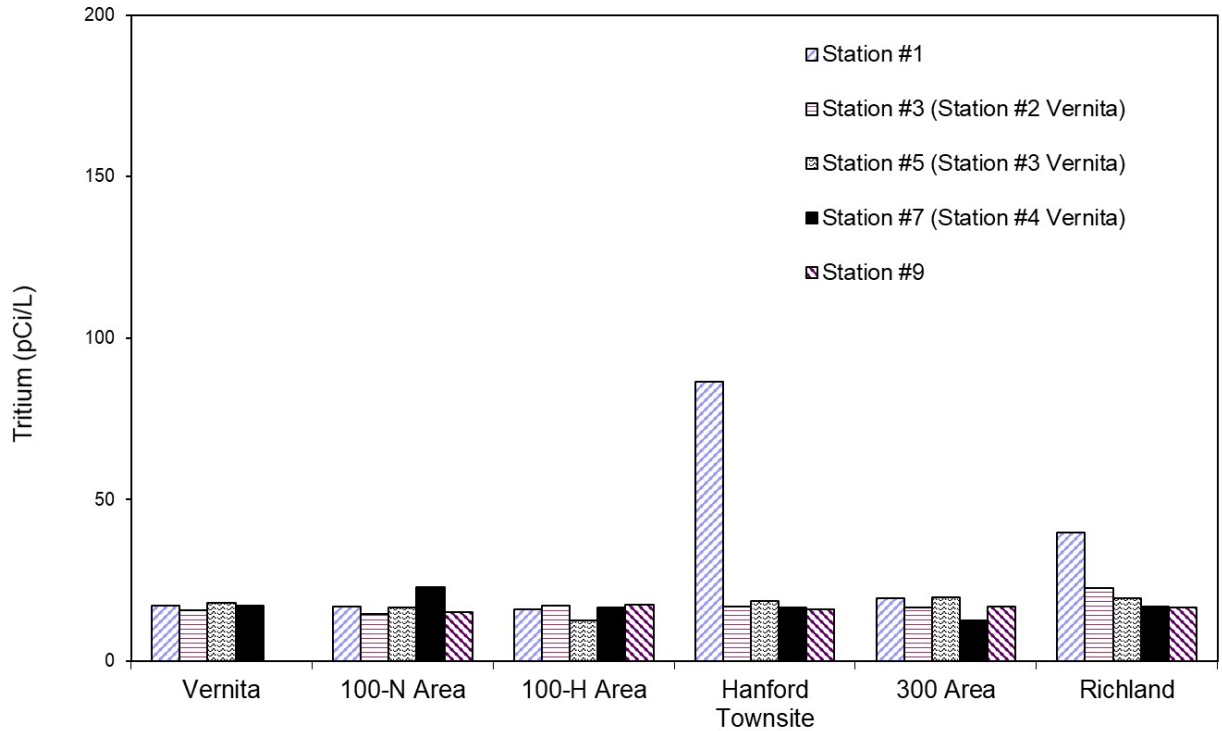

Figure 7-8. 2019 Tritium Concentrations in Cross-River Transect Water Samples (Hanford Reach, Columbia River).

7.2.3 Inorganic and Organic Chemical Results

Inorganic and organic water quality data were compiled in 2019 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, thallium, uranium, and zinc. All dissolved metal concentrations in river water were well below the Washington State ambient surface water quality criteria for the protection of aquatic life (Appendix C, Table C-10).

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 Richland Pumphouse HRM 46.4 station-9 (Franklin County shoreline) had a maximum nitrate concentration of 1,380 µg/L, which was slightly higher than the next highest transect result found at RPH-HRM 46.4 station-1 (Benton County Shoreline), which measured 1,300 µg/L. All other samples collected throughout the Hanford Reach had average concentrations that were approximately 20% of those measured at the RPH-HRM 46.4 station-1 location. Concentrations of chloride were slightly elevated at RPH-HRM 46.4 station-9 when compared to other transect locations (Figure 7-9) found throughout the Hanford Reach. RPH-HRM 46.4 concentrations of sulfate were also slightly elevated when compared to transect samples collected throughout the Hanford Reach. Sulfate and chloride levels found at Vernita Bridge HRM 0.3 stations were comparable to the 300 Area HRM 43.1 stations.

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).

Annual average concentrations of chloride measured downstream at the City of Richland and upstream at the Vernita Bridge transect locations were similar. 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 97 µg/L in 2019.

Concentrations of chromium 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 2019 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 database. The two major organic contaminants monitored in 2019 were trichloroethane and dichloroethane, 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-11).

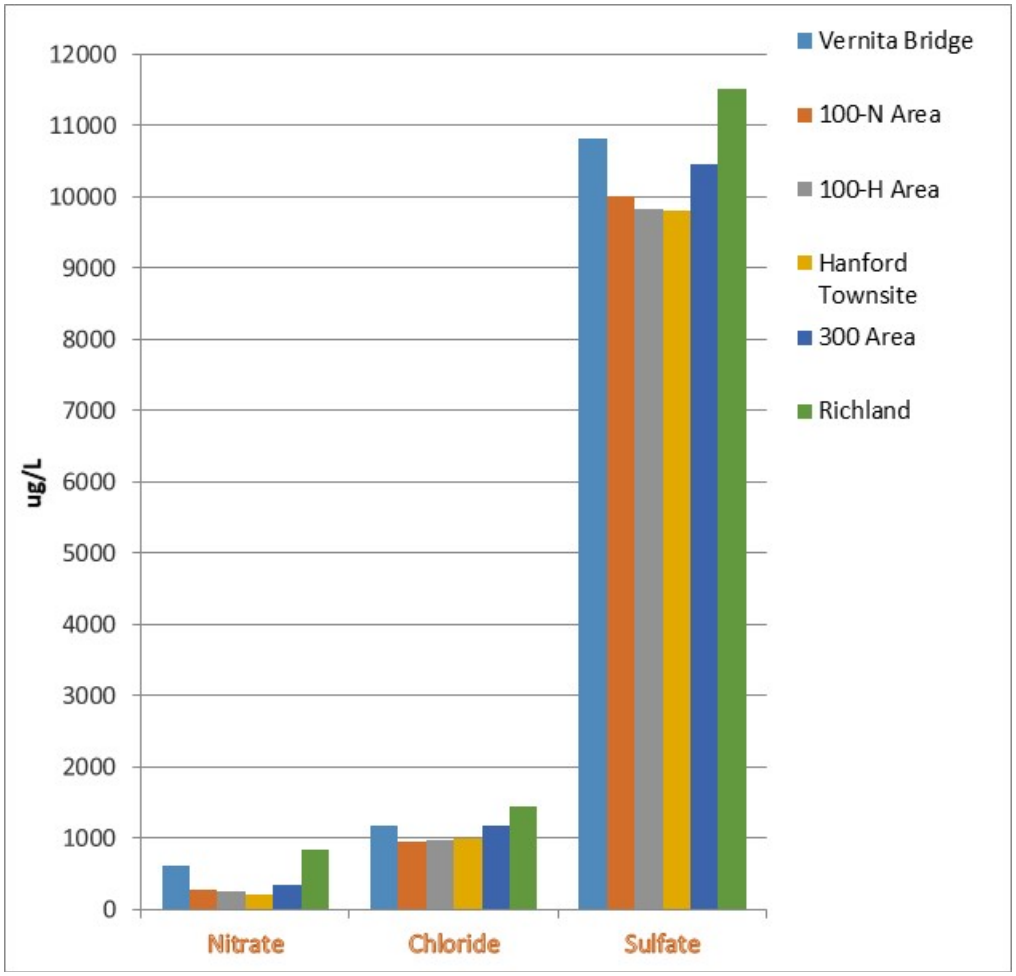

Figure 7-9. 2019 Selected Anion Concentrations in Columbia River Transect Samples (micrograms/liter).

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 Hanford Site, the 100-K Spring 63-1 shoreline sediment location, White Bluffs and Hanford Sloughs on the Hanford Reach, and downstream of the Hanford Site in the reservoir pool located above McNary Dam.

7.3.1 Monitoring

In 2019, 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) during late summer/early fall (Figure 7-13). 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 2019 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 2019 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 at McNary Dam had higher concentrations than those seen along the Hanford Reach (Figure 7-11). Note: both Figures 7-10 and 7-11 have upper and lower bars that represent maximum and minimum values, which may be similar to the average and, therefore, not visible.

Uranium-234 concentrations were slightly elevated at the 300 Area Spring DR 42-2 location compared to other sediment samples collected from the Hanford Reach, McNary, and Priest Rapids Dam samples in 2019. All other sediment detections were comparable to historic values. Other radionuclide detections and concentrations found in Hanford Reach river sediment were similar to those reported in previous years; there were no significant glaring differences between locations.

Total uranium averaged 1.7 pCi/g for the Hanford Reach, while Priest Rapids and McNary Dam concentrations averaged 2.6 pCi/g and 2.7 pCi/g, respectively (Figure 7-12). Note: upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible.

The value for cesium-137 in the Hanford Slough of the Hanford Reach was slightly elevated (0.28 pCi/g concentration) compared to other Hanford Reach sample locations (0.08 pCi/g average concentration). McNary Dam had a slightly lower cesium-137 average concentration compared to Priest Rapids Dam sediment results (0.19 pCi/g and 0.22 pCi/g, respectively). The average, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (2014 to 2019) are presented in Figures 7-10, 7-11, and 7-12.

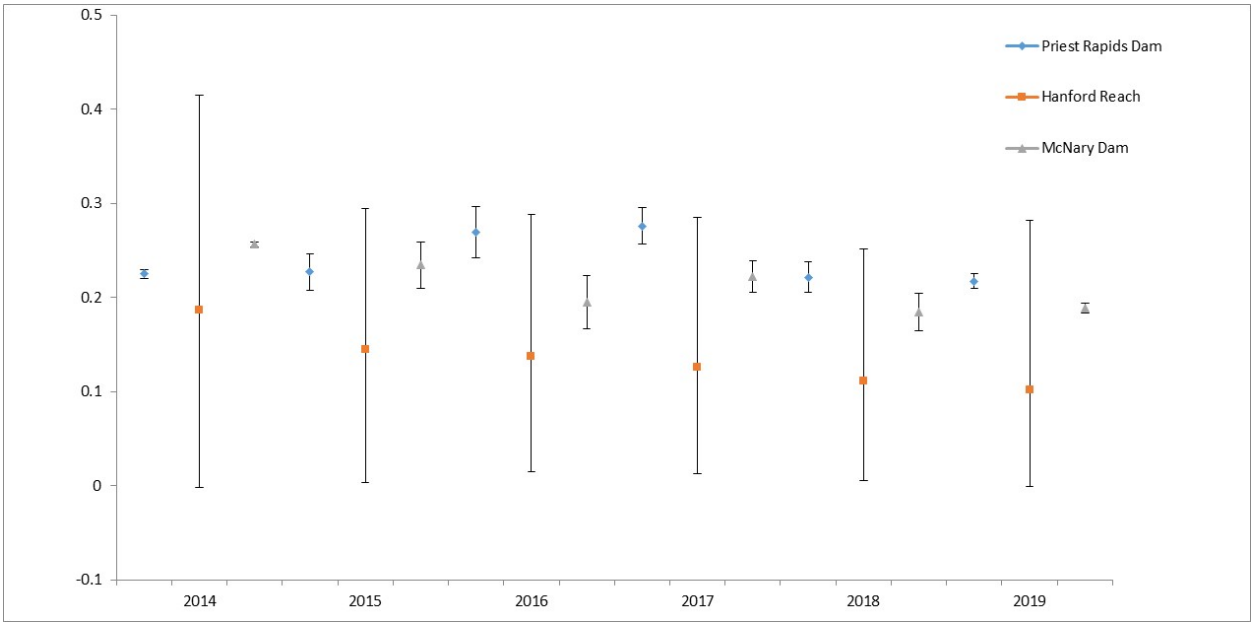

Figure 7-10. Cesium-137 Average, Maximum (top), and Minimum (bottom) Concentrations Measured in Columbia River Sediment (results shown are in pCi/g ±2 standard deviations).

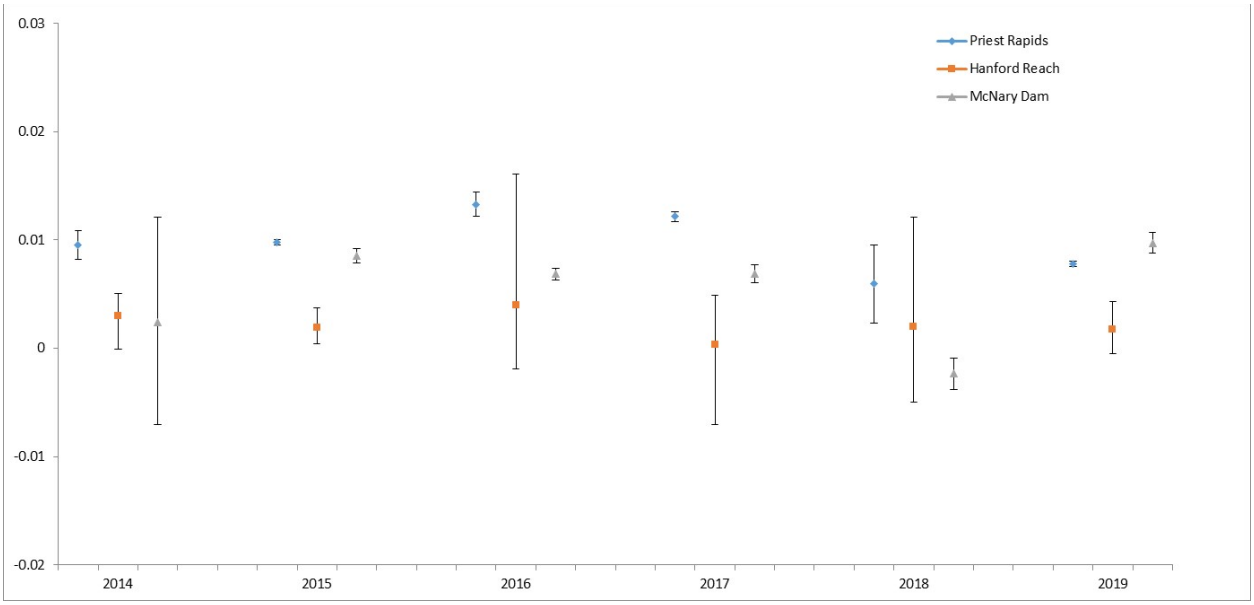

Figure 7-11. Plutonium-239/240 Average, Maximum (top), and Minimum (bottom) Concentrations Measured in Columbia River Sediment (results shown are in pCi/g ±2 standard deviations).

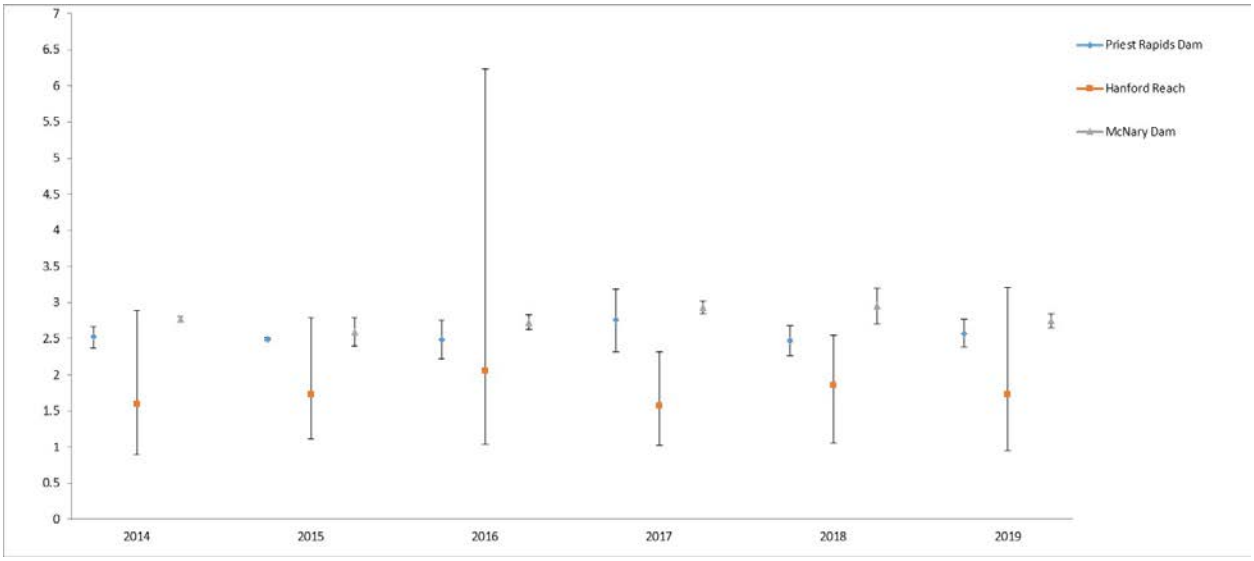

Figure 7-12. Uranium Average, Maximum (top), and Minimum (bottom) Concentrations Measured in Columbia River Sediment (results shown are in pCi/g ±2 standard deviations).

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, 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 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 Hanford Slough 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 Hanford Slough.

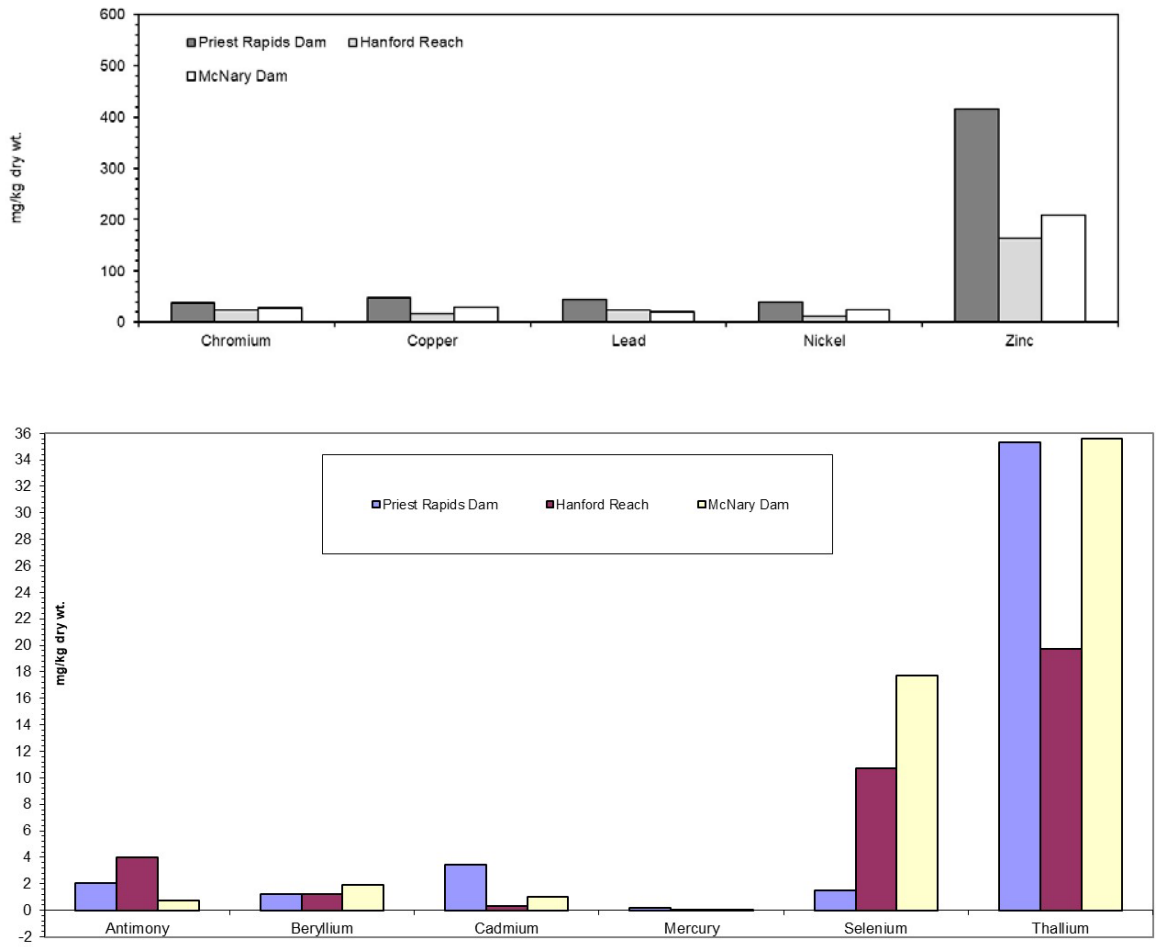

Figure 7-13. Selected Metals Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (Washington and Oregon), 2019.

7.4 Columbia River Seep Water

In 2019, 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 Appendix C.

Table 7-6. Columbia River Seep Monitoring.

Location[a]	Sample Type	Sampling Frequency	Analyses
100-B Area	Grab	Annually	Alkalinity, anions, metals (filtered/unfiltered), strontium-90, tritium, VOA[c]
100-D Area	Grab	Annually	Alkalinity, alpha, anions, beta, metals (filtered/unfiltered), strontium-90, technetium-99, tritium, isotopic uranium[b]
100-F Area	Grab	Annually	Alkalinity, anions, metals (filtered/unfiltered), strontium-90, tritium, VOA[c]
100-K Area	Grab	Annually	Alkalinity, alpha, anions, beta, carbon-14, metals (filtered/unfiltered), strontium-90, technetium-99, tritium, VOA[c]
100-N Area	Grab	Annually	Alkalinity, alpha, anions, beta, metals (filtered and unfiltered), strontium-90, TPH, tritium
300 Area	Grab	Annually	Alkalinity, alpha, anions, beta, metals (filtered/unfiltered), tritium, isotopic uranium[(b)], uranium-236, VOA[c]
Hanford Townsite	Grab	Annually	Alkalinity, alpha, anions, beta, iodine-129, metals (filtered/unfiltered), strontium-90, technetium-99, tritium, VOA[c]

[a] Refer to Figure 7.3; Locations may contain multiple shoreline seeps with differing analyses.
[b] Uranium-234, uranium-235, and uranium-238
[c] 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 2019. 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 2019, 13 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 2019 in water from riverbank seeps entering the Columbia River along the Hanford Site. A listing of the 2019 sampling results is provided in Appendix C, Table C-14.

Tritium concentrations varied widely with location. The highest tritium concentration measured in riverbank seeps was at the Hanford Townsite 28-2 riverbank seep (24,100 pCi/L ± 4,690 pCi/L [892 ± 174 Bq/L]), which was slightly above the Washington State ambient surface water quality criterion of 20,000 pCi/L (740 Bq/L) . No tritium results exceeded the Biota Concentration Guide (DOE/EH-0676) level for Riparian Animal receptors (265,000,000 pCi/L). Tritium concentrations in riverbank seep water samples were higher compared to maximum concentrations in 2019 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 2019 were comparable to the previous 5 years of concentrations reported in riverbank seeps.

Two water samples from riverbank seeps near the old Hanford Townsite area (Hanford Townsite 25-4; Hanford Spring 28-2) were collected in 2019 and submitted to a laboratory for iodine-129 analysis using an ultra-trace analytical method. Laboratory results showed the concentrations 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 20% of the DOE-derived concentration standard for riparian animals. 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 maximum uranium concentration in this seep water sample was slightly lower (7.5 pCi/L ± 0.28 pCi/L uranium-234) than the EPA drinking water standard limit of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]). The 2019 concentrations of uranium-234, uranium-235, and uranium-238 were lower than those measured during 2014 through 2018.

During 2019 riverbank seep collections, three locations recorded detections of gross alpha. The 300 Area Spring 42-2, 300 Area Spring DR 42-2, and Hanford Townsite 25-4 riverbank seeps had detections. The

maximum concentration was recorded in at the 300 Area Spring DR 42-2 location (14.8 pCi/L ± 4.4 pCi/L) which fell just below the Washington State Ambient Water Quality criteria (15 pCi/L; DOE O 458.1).

During 2019, gross beta detections occurred in 100-K 63-1, 100-N 8-13, 100-N 89-1, 100-H 152-2, and Hanford Spring 25-4 Areas. Detectable concentrations in all riverbank seep water samples along the Hanford Spring Reach were elevated when compared to maximum gross beta concentrations in irrigation water collected from the Horn Rapids Battelle Sporting Complex (3.0 pCi/L ± 1.9 pCi/L) and Riverview (2.3 pCi/L ± 1.6 pCi/L) collection locations. The highest gross beta concentration was measured in the Hanford Townsite 28-2 riverbank seep (45 pCi/L ± 4.8 pCi/L [1.7 ± 0.18 Bq/L]), which was 90% 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 a seep water sample from 100-F Spring 211-1 (31,300 µg/L). Dissolved chromium concentrations were highest in the 100-B Spring 39-2 Area (8.3 µg/L).

Concentrations of most metals measured in water collected from seeps along the Hanford Site shoreline during 2014 through 2019 were below the Washington State ambient surface water chronic toxicity levels (WAC 173-201A). All 2019 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 Hanford Environmental Information System database. The two major organic contaminants monitored in 2019 were trichloroethane and dichloroethane, 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 2019, 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 7-14
[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 2019 shoreline seep sediment samples were similar to those measured in Columbia River sediment samples collected at Priest Rapids and McNary Dams. Cesium-137 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 2014 through 2019.

7.4.3.2 Metals Results.

Concentrations of metals in Hanford Reach sediment samples collected in 2019 were similar to concentrations found in McNary and Priest Rapids Dam sediment samples, with the exception of antimony, where higher average concentrations were seen. Shoreline sediment collected from the 100--H Spring 145-1 area had the highest level of arsenic (11.3 mg/kg) when compared to other Reach and Columbia River sediment samples. The highest concentrations of beryllium (2.1 mg/kg) and chromium (47.3 mg/kg) was measured in a sample from the 100-D Spring 102-1 location. Lead concentrations found in the Hanford Slough (54.9 mg/kg) topped all other 2019 sediment collections (Appendix C, Table C-16). Currently, there are no Washington State freshwater sediment quality criteria to compare against the measured values.

7.4.3.3 Hexavalent Chromium Results.

All 2019 sediment sample collections were recorded as non-detects. The McNary and Priest Rapids Dam sediment samples had the highest concentrations of hexavalent chromium when compared to all other sediment collection locations (Appendix C, Table C-17).

7.4.3.4 Total Organic Carbon Results.

All Columbia River sediment samples collected in 2019 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 2019 Priest Rapids Dam sample that mirrored historical observations (Appendix C, Table C-18).

7.5 Pond Water and Sediment

West Lake pond water and sediment (Figure 7-3) sampling was conducted twice (during early spring/late spring) during 2019. 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 2019 with sampling conducted twice during the year (early and late spring). 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 2019 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, and all levels were within the historic range of sample results for this location (Figure 7-15).

7.5.2 West Lake Sediment

Biannual Sediment samples were collected during early and late spring from West Lake during 2019. 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. There were detections for all analytes with the exception of technetium-99. Detections of all radionuclides during 2019 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 2019 and a summary of those collected during the previous 5 years are shown in Appendix C, Table C-1.

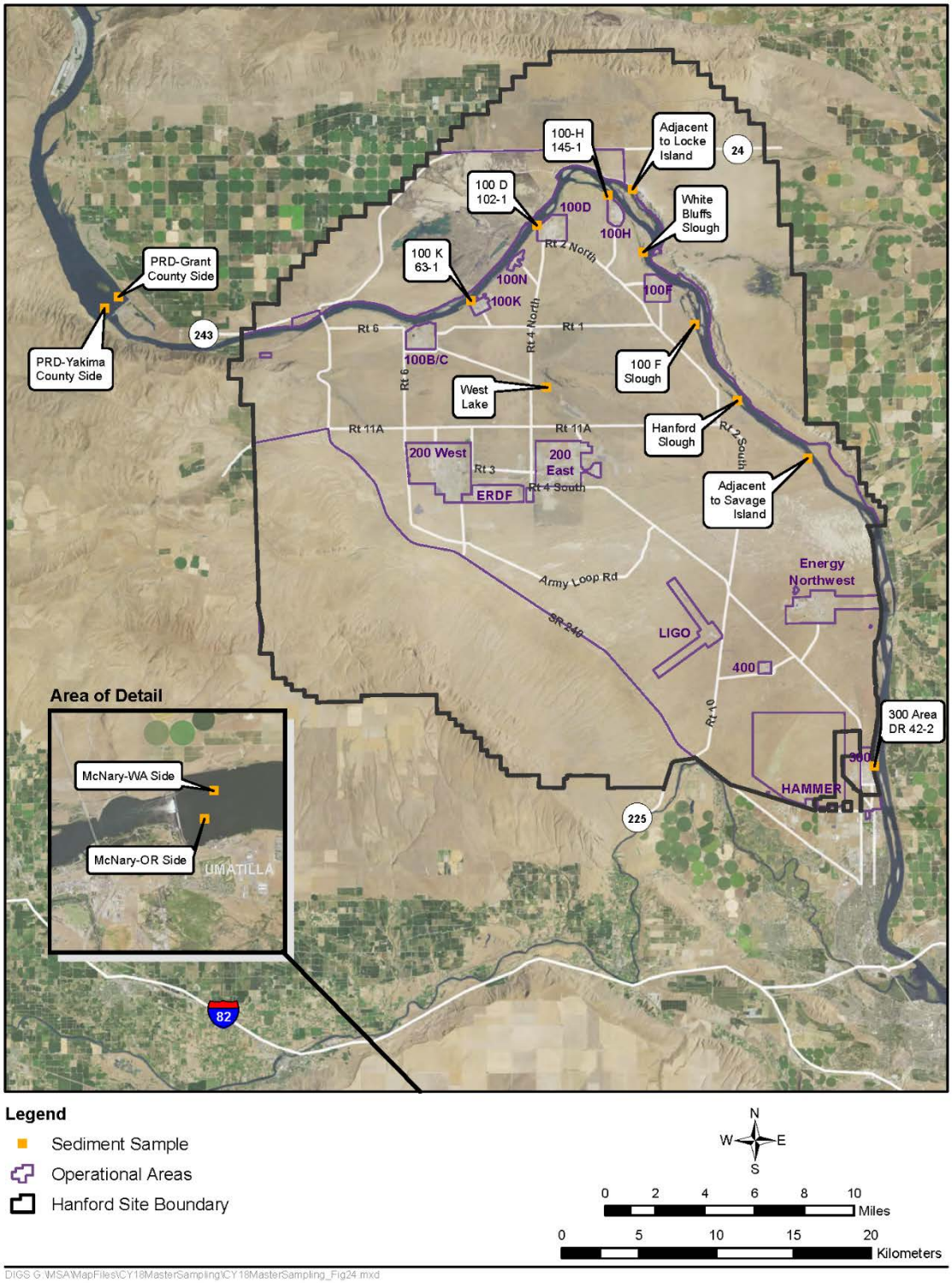

Figure 7-14. Sediment Collections Sampling Locations Collected in Fiscal Year 2019.

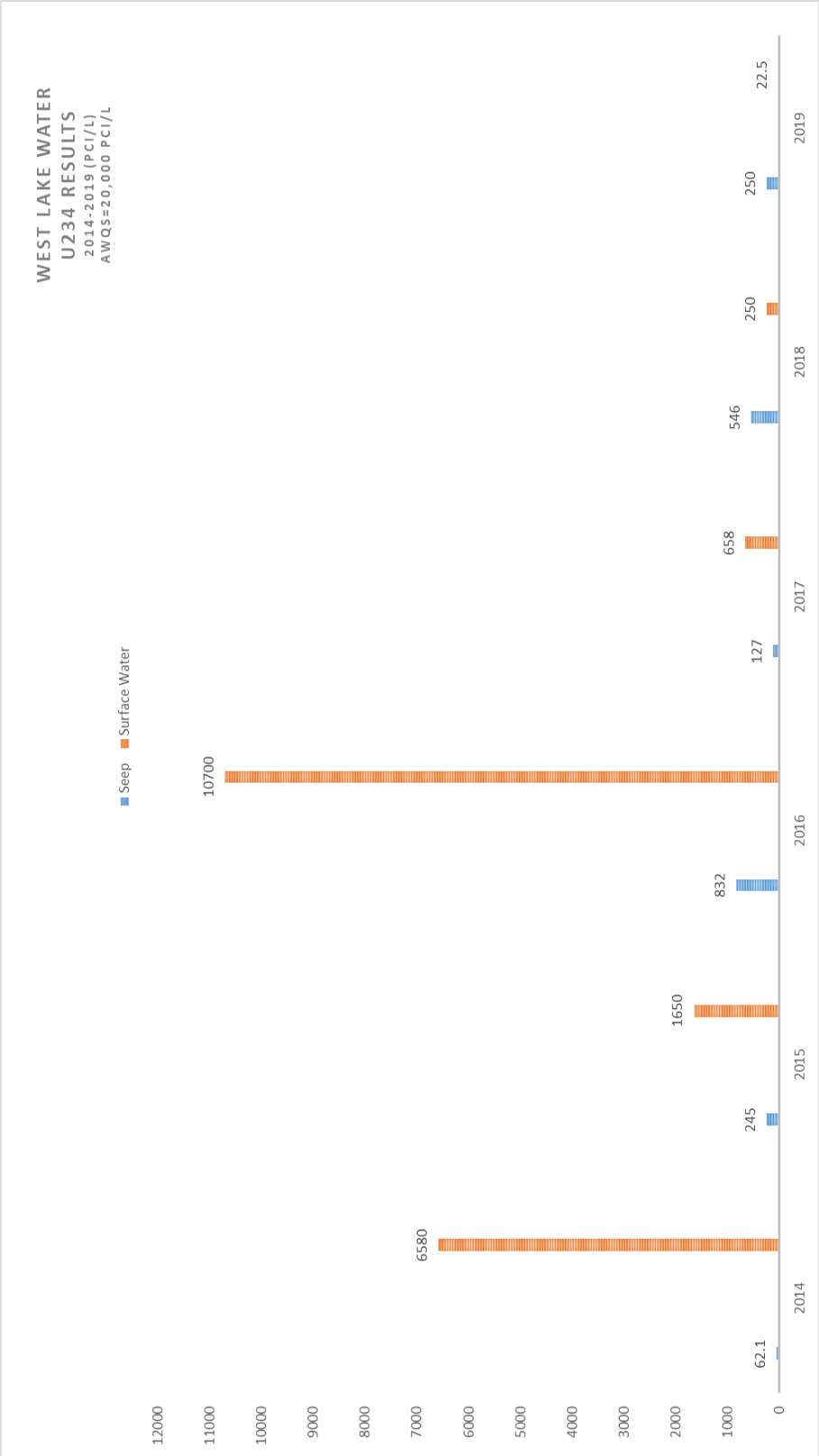

Figure 7-15. 2014 Through 2019 West Lake Uranium-234 Water Results.

7.6 Offsite Irrigation Water

Water 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 of radionuclides. The consumption of food products (Section 10.1) irrigated with Columbia River water downstream of the Hanford Site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual and any other member of the public (Section 4.2.1).

7.6.1 Offsite Irrigation Water Monitoring

Irrigation water samples were collected in 2019 from a canal located on the east side (left bank) of the Columbia River downstream of the Hanford Site at Riverview (Road 68 in 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 2019 were close to levels detected in Columbia River transect water samples collected upstream (Vernita Bridge HRM 0.3) and downstream (RPH-HRM 46.4) of the Hanford Site

Tritium was the only radionuclide detected in any of the samples collected during 2019. Maximum tritium levels from irrigation water collected in the Riverview (16.0 pCi/L; 0.59 Bq/L) and the Sagemoor area (18.7 pCi/L; 0.70 Bq/L) were comparable, while the Horn Rapids area (38.8 pCi/L; 1.4 Bq/L) had the highest concentrations reported. The 2019 Columbia River transect average tritium results from Vernita measured 17.1 pCi/L (0.63 Bq/L), while those at Richland had an average concentration of 23.1 p/Ci/L (0.85 Bq/L).

The 2019 irrigation results were also similar to concentrations reported in the fixed-station locations in Richland, Washington, and at Priest Rapids Dam. The Columbia River Priest Rapids Dam fixed-station water average tritium concentration was 17.5 pCi/L (0.65 Bq/L), while the Columbia River Richland Pumphouse fixed-station water had an annual average of 29.7 pCi/L (1.10 Bq/L). Radionuclide concentrations from irrigation water samples collected during 2019 and in the previous 5 years are shown in Appendix C, Tables C-19, C-20, and C-21.

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 ground and Columbia River were ceased. Non permitted discharges to the ground stopped in the 1990s and the last permitted discharges to the Columbia River stopped in March 2011. In CY 2019, 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 2019. See Section 8.0, Groundwater Monitoring, for more information on groundwater pump-and-treat systems.

7.7.1 Point Source Discharges

The EPA defines a point source of pollution in 40 CFR 122, "EPA administered Permit Programs: The National Pollutant Discharge Elimination System," as any discrete conveyance such as a pipe, ditch, channel, tunnel, conduit, well, discrete fissure, or container from which pollutants are or may be discharged. There are two liquid effluent point sources discharging liquids to the ground operated in CY 2019 on the Hanford Site: the Effluent Treatment Facility (ETF) and Treated Effluent Disposal Facility (TEDF).

7.7.1.1 200 Area Effluent Treatment Facility.

Hanford's ETF, in operation since 1995, is located in the 200-East Area and treats mixed radioactive and dangerous liquid waste. In 2019 the ETF treated and discharged approximately 4.7 million gal (17.8 million L) of liquid waste (Table 7-8). The ETF influent consists of multiple waste streams from Hanford facilities including process condensate from the 242-A Evaporator, leachate from land waste disposal sites, and water from the 100-K Basins. Most liquid waste streams are initially stored at the Liquid Effluent Retention Basin Facility, located near the ETF. The ETF waste treatment system removes toxic metals, radionuclides, and ammonia in addition to destroying organic compounds. After treatment, the liquid is not considered a dangerous waste per 40 CFR 261, Appendix IX, "Identification and Listing of Hazardous Waste." The liquid is stored in tanks, sampled, and analyzed for comparison with permit limits, then discharged in batches to the State-Approved Land Disposal Site (SALDS) located north of the 200-West Area (Figure 7-16) per the requirements of State Waste Discharge Permit Number ST0004500 (Ecology 2014).

The ETF waste treatment system does not remove tritium, a radioactive isotope of hydrogen, which cannot be easily or cost-effectively removed. The ST0004500 discharge permit does not include radionuclide limits as the EPA's definition of pollutant in 40 CFR 122 excludes radioactive materials regulated by DOE under the *Atomic Energy Act of 1954* (AEA). DOE O 458.1 requires the concentration of radioactive liquid discharges to be less than the derived concentration standard values established in DOE-STD-1196-2011, *Derived Concentration Technical Standard*. The location of SALDS was chosen because the long groundwater travel time required to migrate from this location to the Columbia River allows tritium concentrations to decrease to below the drinking water standard by dispersion and radiological decay. Hydrologic modeling, as well as analyses of groundwater, continues to demonstrate the disposal of tritium-containing water to SALDS is protective of the Columbia River.

Table 7-8 contains the volume of liquid discharged, curies of tritium released, average concentrations and fraction of the DOE derived concentration standard during CY 2019. See Appendix C, Table C-25 for a summary of ETF sample results. See Sections 5.2.11 for more information on ETF.

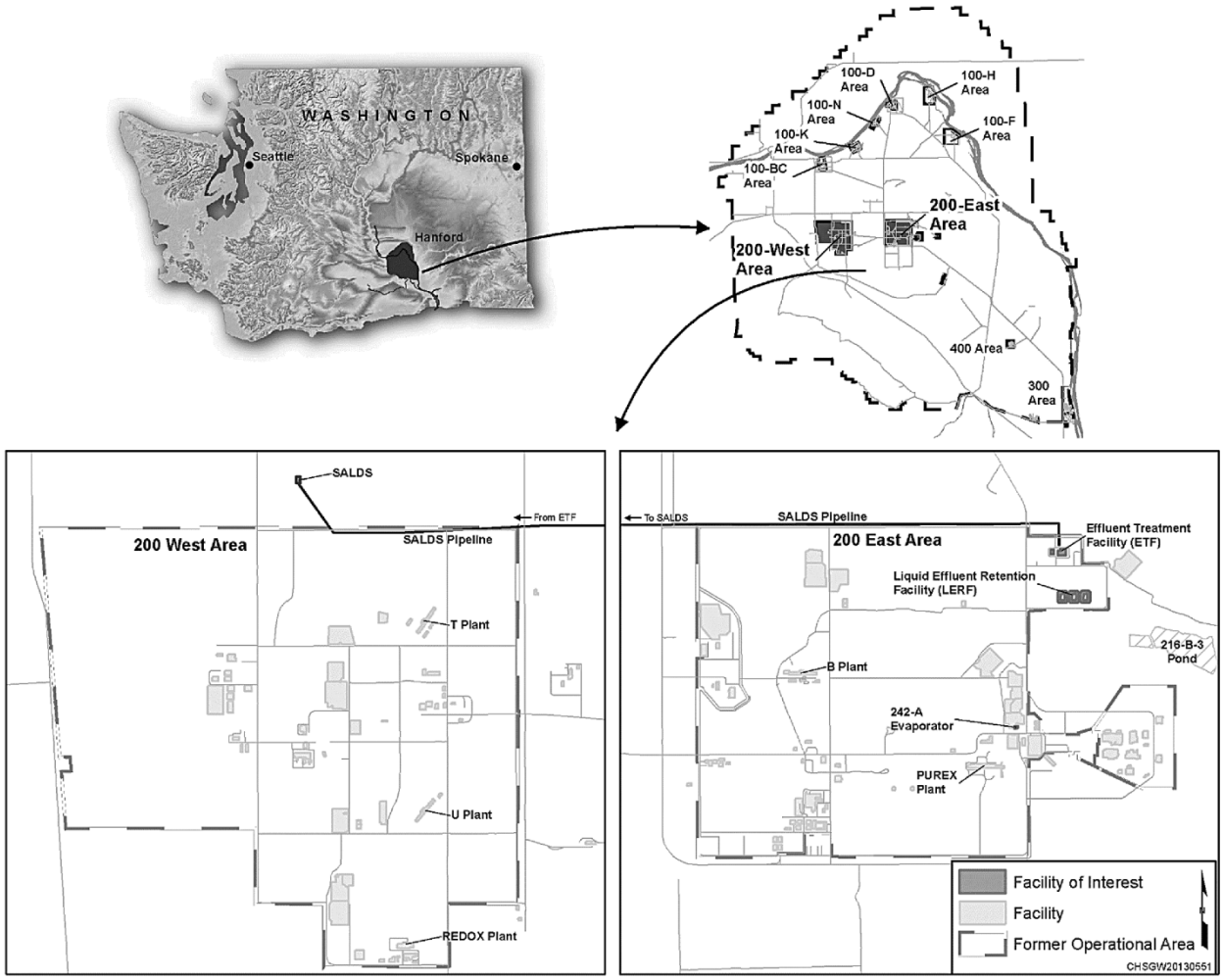

Figure 7-16. Location of Effluent Treatment Facility and State-Approved Land Disposal Site.

Table 7-8. Calendar Year 2019 Tritium Discharges to the State-Approved Land Disposal Site.

Month	Effluent Discharge (gal)	Tritium Released (Ci)	Average Concentration (µCi/mL)	Fraction of DCS (%)
January	0	0	0	0.0%
February	0	0	0	0.0%
March	0	0	0	0.0%
April	0	0	0	0.0%
May	899,344	2.90	8.5E-04	45%
June	625,256	0.98	4.1E-04	22%
July	633,043	0.75	3.1E-04	16%
August	1,251,293	1.49	3.1E-04	17%
September	535,711	0.54	2.6E-04	14%
October	537,269	0.61	3.0E-04	16%
November	0	0	0	0.0%
December	186,874	0.20	2.9E-04	15%
2019 TOTAL	4,668,790	7.45	4.2E-04	22%

Ci = curies
µCi/mL =micro-curies per milliliter
DCS =Derived Concentration Standard, ingested water for tritium = 1.9E-03 µCi/mL
SALDS =State Approved Land Disposal Site

7.7.1.2 200 Area Treated Effluent Disposal Facility.

The TEDF provides a collection, conveyance, and disposal system for treated effluent from buildings in the 200 Areas (Figure 7-17). It is located in the 200-East Area and consists of an 11 mi (17.7 km) long of buried pipelines connecting three pumping stations, the 6653 Building, and two 5-ac (2-ha) infiltration disposal 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 TEDF discharge is periodically sampled to verify permit compliance (Table C-25). The volume of non-radioactive, non-dangerous waste disposed to this facility in 2019 was approximately 75.7 million gal (287 million L). See Section 5.2.13 for more information on TEDF.

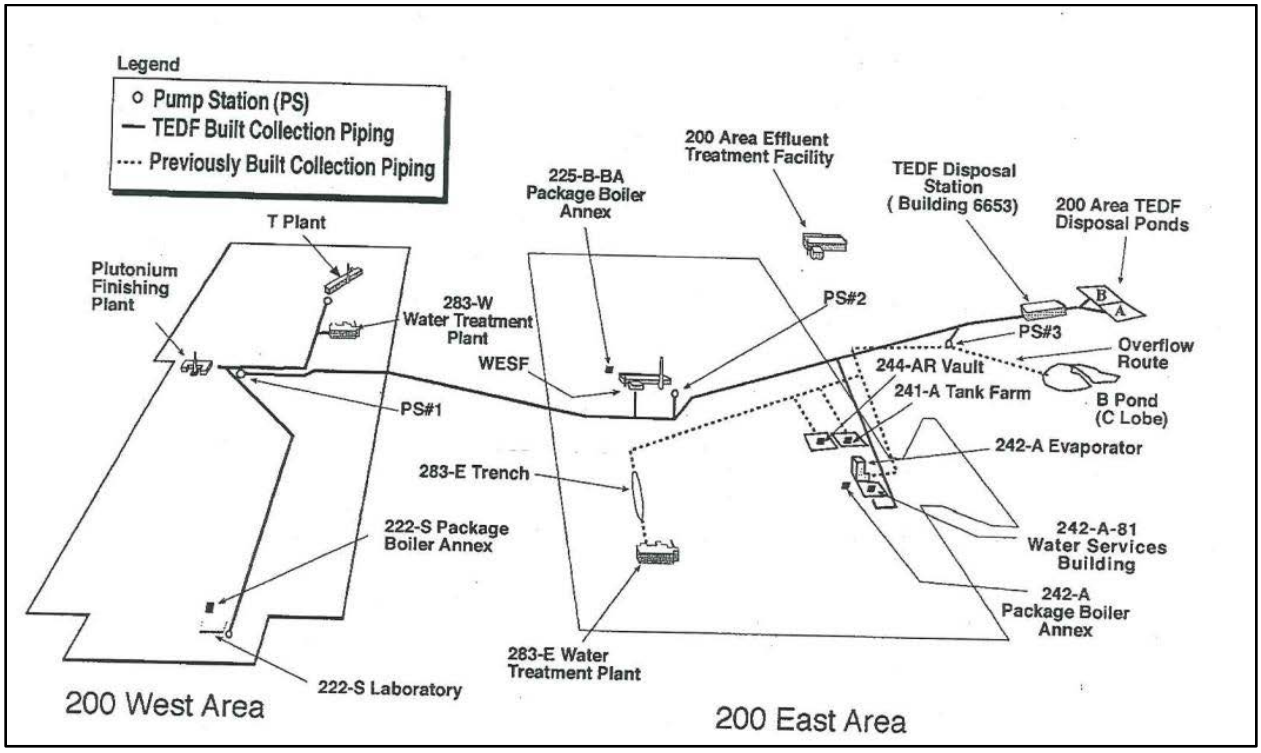

Figure 7-17. Location of the Treated Effluent Disposal Facility.

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 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 2019 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 7-18). 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.

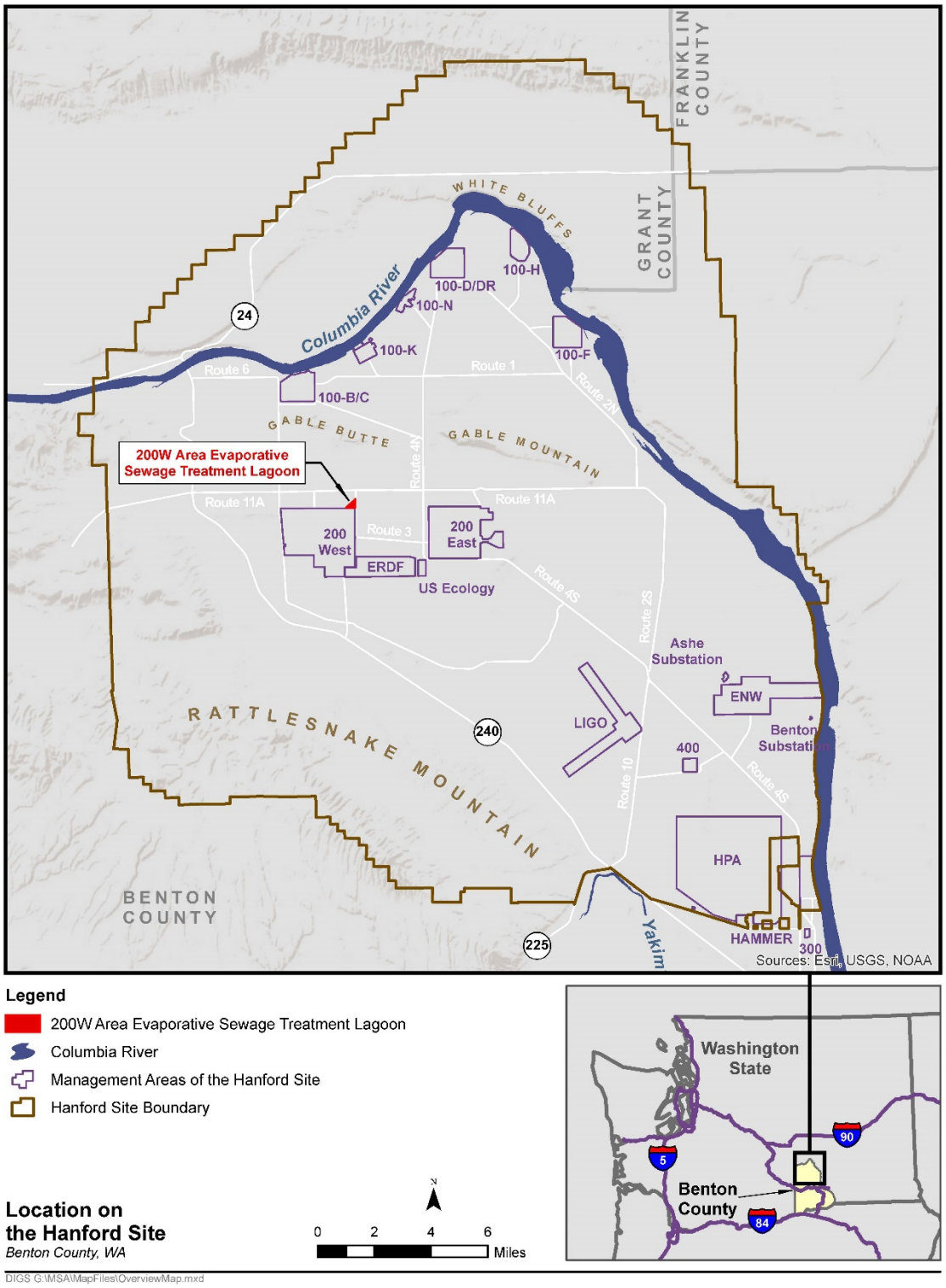

Figure 7-18. Location of the Evaporative Sewage Treatment Lagoon.

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2019 Highlights

Contaminant Plume Areas
The estimated area of Hanford Site groundwater contaminant plumes above regulatory standards in 2019 was 62 mi^2 (160 km^2), about 5% less than 2018. 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 103 kg of hexavalent chromium in 2019 and 3,589 kg in their lifetimes.
- Pump-and-treat systems in the 200-West Area removed 1,917 kg of carbon tetrachloride in 2019 and 30,951 kg since 1994. Other groundwater contaminants removed by pump-and-treat systems in the 200 Areas include chromium, cyanide, technetium-99, and uranium.
- The U.S. Department of Energy continued to make progress on other groundwater remedial actions in 2019, 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 2019, the U.S. Department of Energy drilled 44 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 2019. DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2019,* 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 four plumes and the combined plume footprint (all contaminants) have changed over the years.

8.1 River Corridor

The 100 and 300 Areas form 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.

Figure 8-3 illustrates the contaminant plumes along the River Corridor where concentrations exceeded cleanup levels in 2019. Beyond the mapped plume boundaries, additional contamination may be present at concentrations below contour levels. Maps in DOE/RL-2018-66 provide all of the data, whether above or below contour levels. Table 8-1 compares the maximum concentrations measured in 2019 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 total area of the hexavalent chromium plumes has decreased markedly since 2002 due to waste site removal, groundwater remediation by pump-and-treat (P&T) systems, and natural attenuation (Figure 8-4). The size of the tritium plume has declined due to natural attenuation, but the uranium and strontium-90 plumes are attenuating more slowly. The interpreted size of the 100-FR trichloroethene (TCE) plume increased in 2019 based on data from new monitoring wells.

Figure 8-5 illustrates the maximum contaminant concentrations in the River Corridor over time. Maximum concentrations of contaminants such as tritium, strontium 90, and nitrate have declined.

DOE has established derived concentration standards for use in conducting the radiological environmental protection program. 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 >100 mrem/yr in the River Corridor is primarily from strontium-90 in the 100-N Area and uranium in the 300 Area.

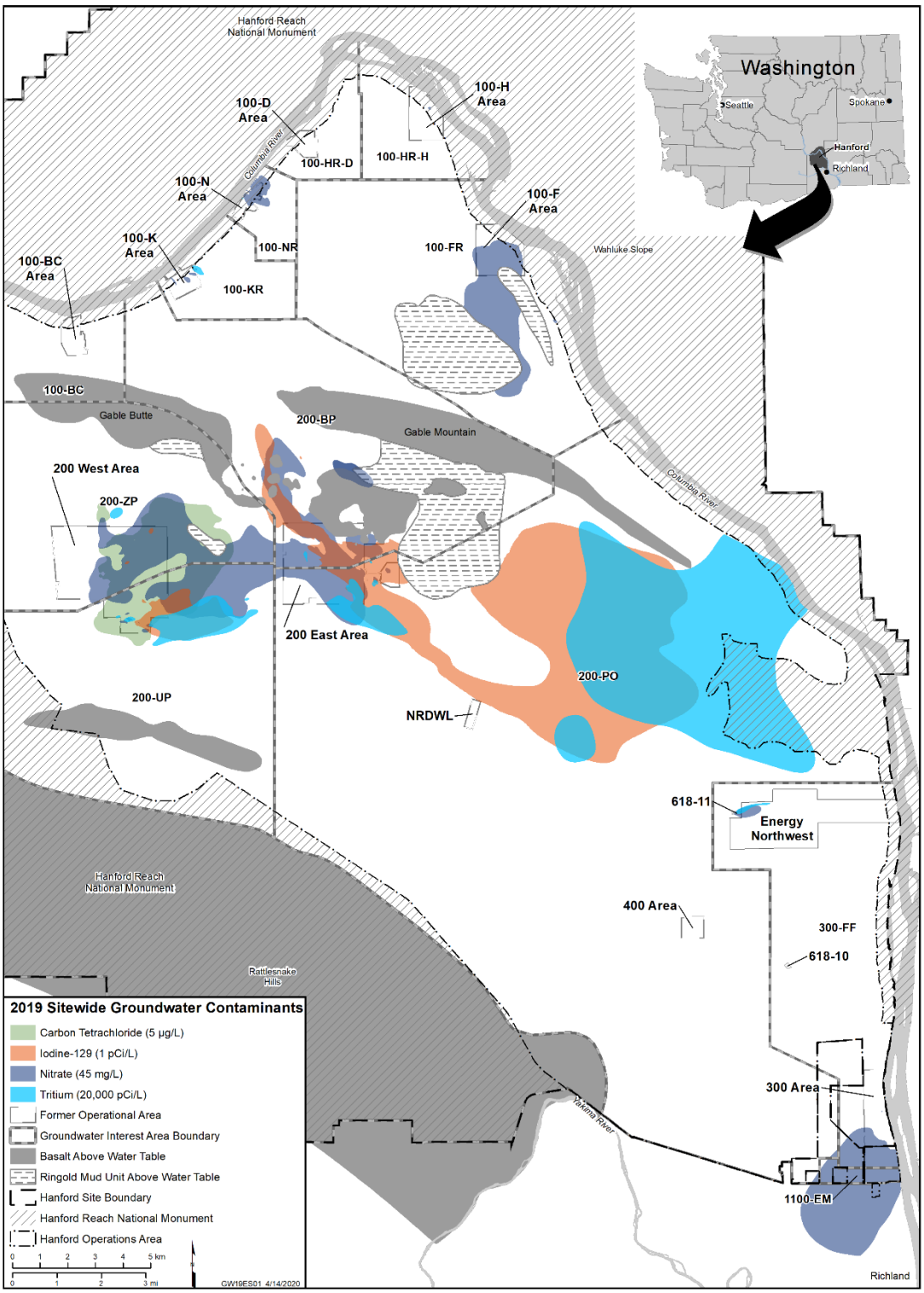

Figure 8-1. Regions of the Hanford Site and Most Extensive Contaminant Plumes.

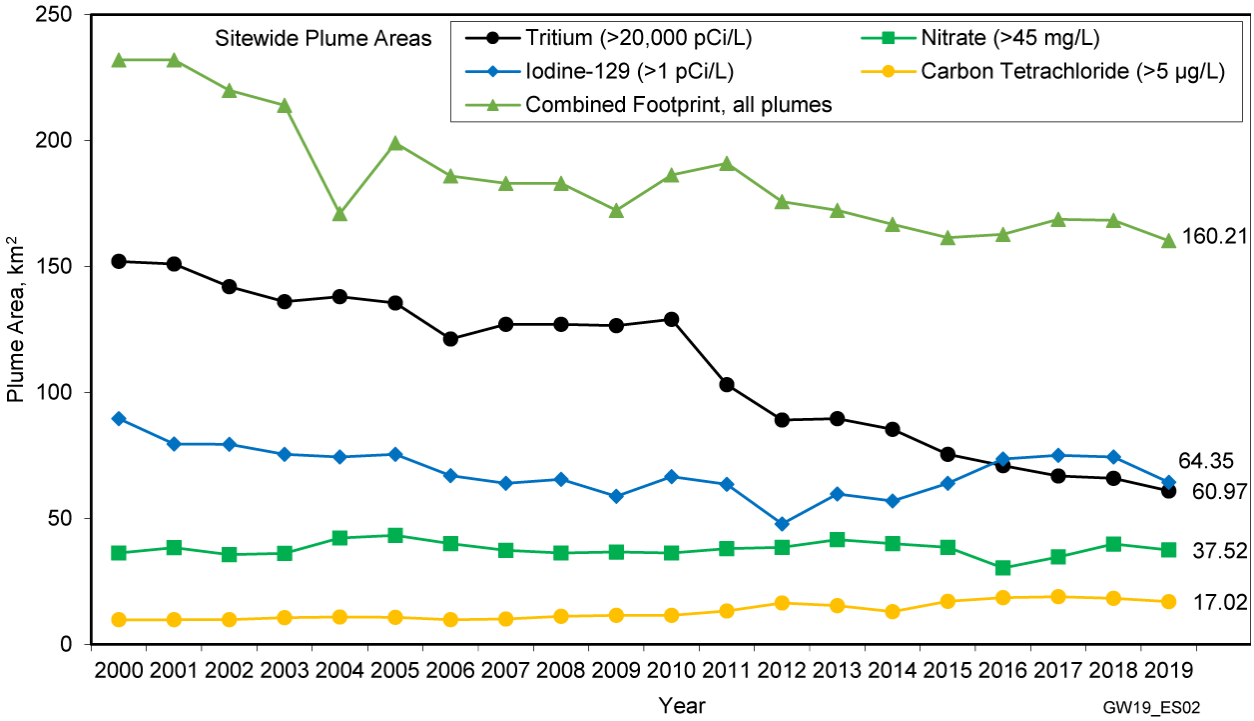

Figure 8-2. Hanford Site Plume Areas.

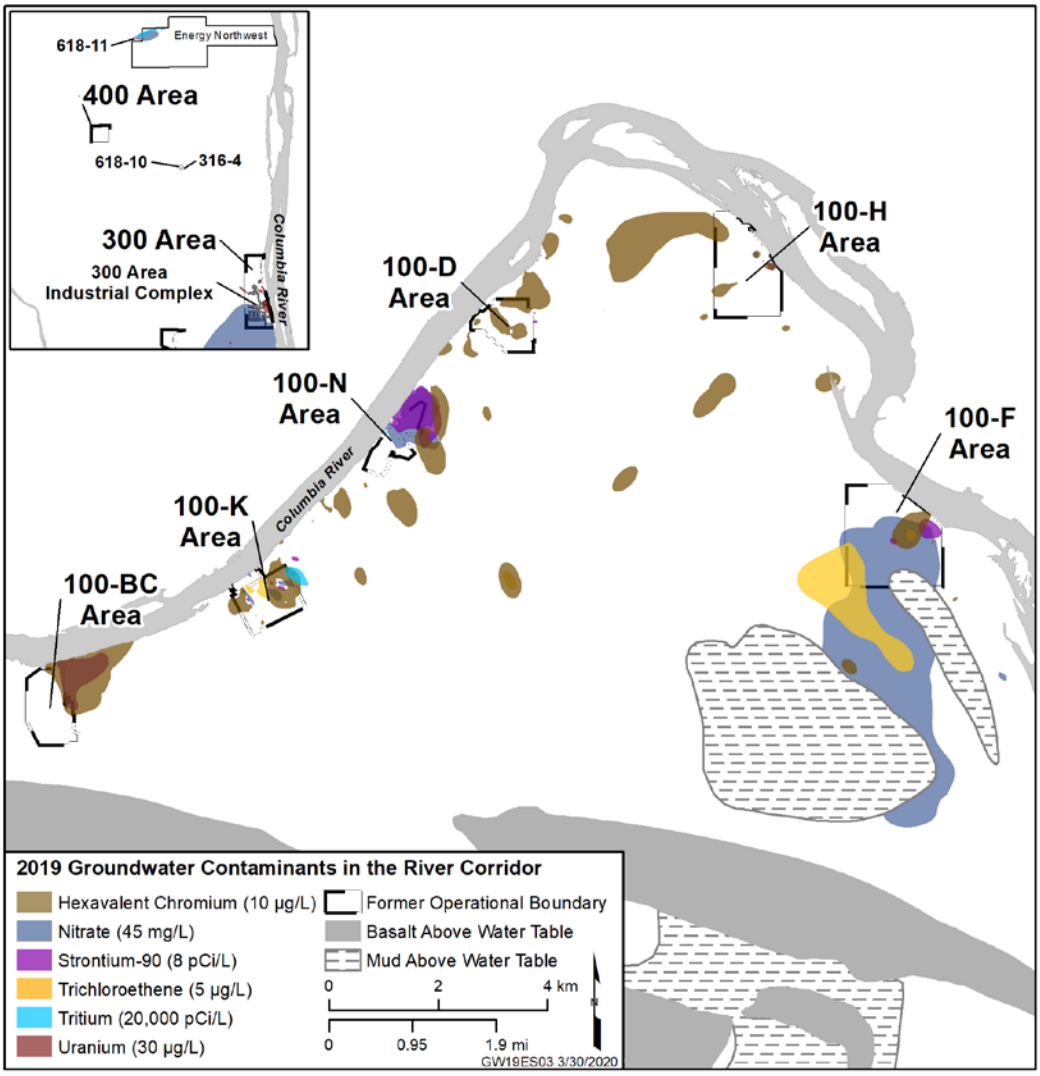

Figure 8-3. Groundwater Contaminant Plumes in the River Corridor.

Table 8-1. River Corridor Groundwater Contaminants, 2018 and 2019. (2 Pages)

Groundwater Interest Area	Maximum Concentrations							
	Year	Carbon-14 (pCi/L)	Cr(VI) (µg/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
100-BC	2019	N	63.1	12.0	34.3	4.6	9,860	5.1
	2018	N	57	19.5	61.8	6.19	8,840	6.9
100-FR	2019	N	53.8	281	112	20.1	3,050	11.0

Table 8-1. River Corridor Groundwater Contaminants, 2018 and 2019. (2 Pages)

Groundwater Interest Area	Maximum Concentrations							
	Year	Carbon-14 (pCi/L)	Cr(VI) (µg/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
	2018	63.8	58.0	304	135	15	3,180	27.7
100-HR	2019	N	833	345	29.0	N	5,690	49.0
	2018	N	800	416	24.5	N	16,200	89
100-KR	2019	42,600	1,700	102	1,230	7.6	405,000	14.8
	2018	32,900	528	88.5	4,050	7.3	225,000	22.4
100-NR	2019	485	124	319	11,400	N	326,000	9.3
	2018	274	123	190	11,600	N	383,000	13.4
300-FF	2019	N	8.88	252	N	1.57	251,000	1,510
	2018	N	20.5	208	4.38	1.5	450,000	3,600
1100-EM	2019	N	3.4	137 [a]	N	N	N	32.2 [a]
	2018	14	N	137 [a]	N	N	N	35.4 [a]
Standard [b]		2,000	10	45	8	5	20,000	30
Half-life (years)		5,730	N/A	N/A	28.8	N/A	12	>159,000
Mobility		High	High to moderate	High	Slight	Moderate	High	Moderate

Note: Colors and listed values indicate maximum concentration, as follows:

- ≤ Standard
- > Standard and ≤10 × standard
- >10 × standard and ≤100 × standard
- >100 × standard and ≤1,000 × standard
- >1,000 × standard

[a] Originates from offsite sources.
[b] Drinking water standards for all but Cr(VI) (aquatic standard).
Cr(VI) = hexavalent chromium
N = not detected or not analyzed
N/A = not applicable

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 in 2019 (and Since Startup)
100-BC-5	RI/FS report and proposed plan released in 2019	Cr(VI), strontium-90, TCE, and tritium	No interim action required; final action pending	N/A
100-FR-3	ROD for final action signed in 2014	Cr(VI), nitrate strontium-90, and TCE	MNA	N/A
100-HR-3	ROD for final action signed in 2018	Cr(VI), total chromium, nitrate, and strontium-90	P&T for Cr(VI) and total chromium 1997–2019; MNA for nitrate and strontium-90	Cr(VI): 54.7 kg (2,601 kg)
100-KR-4	Interim ROD; Draft B RI Report released for regulatory agency review in 2019; FS report in progress	Cr(VI), total chromium, carbon-14, nitrate, strontium-90, TCE, and tritium	Interim action P&T for Cr(VI) 1997–2019; soil flushing in 2019	Cr(VI): 48.6 kg (988 kg)
100-NR-2	Draft B RI/FS report released for regulatory agency review in 2019	Strontium-90, TPH-D, nitrate, Cr(VI), total chromium, and tritium	Interim action permeable reactive barrier for strontium-90; removal of TPH-D	Strontium-90: not applicable TPH-D: 1.23 kg (20 kg)
300-FF-5	ROD for final action signed in 2013	Uranium, gross alpha, *cis*-1,2-dichloroethene, TCE, nitrate, and tritium	Enhanced attenuation (sequestration) for uranium; MNA for others	N/A
1100-EM-1	ROD signed in 1993	TCE	No longer required; remedial action objectives achieved	N/A

[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.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cr(VI) = hexavalent chromium
FS = feasibility study
MNA = monitored natural attenuation
N/A = not applicable
P&T = pump and treat
RI = remedial investigation
ROD = Record of Decision
TCE = trichloroethene
TPH-D = total petroleum hydrocarbons-diesel range

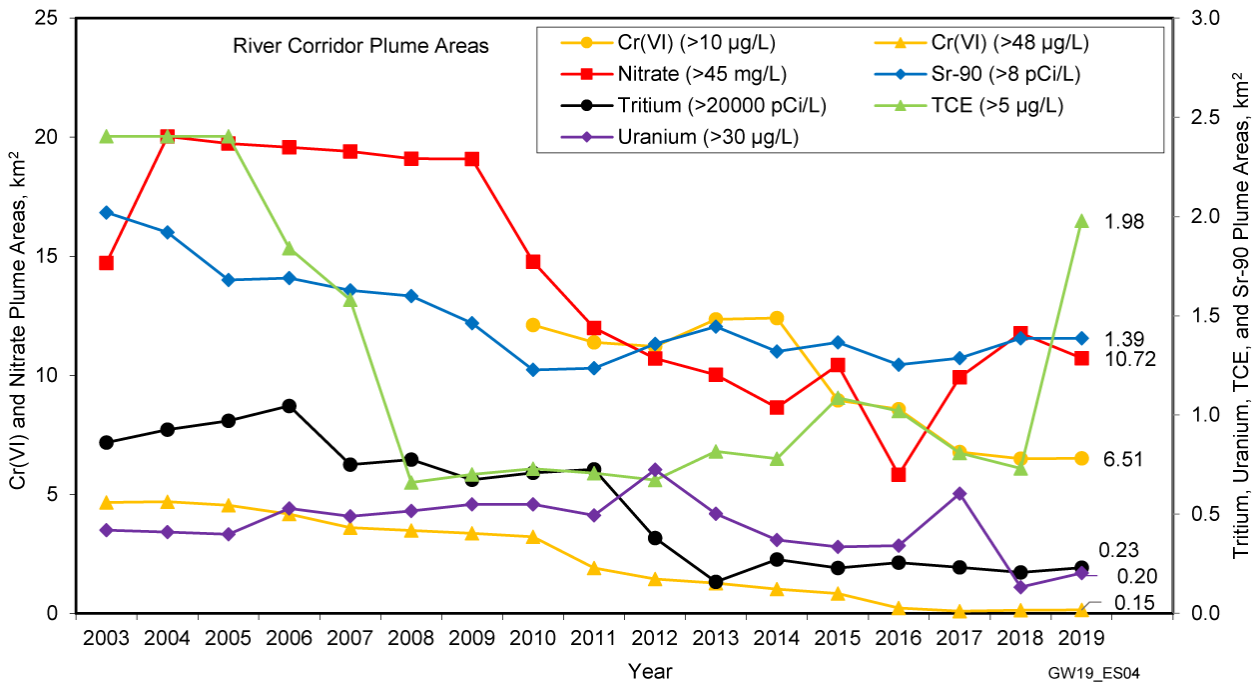

Figure 8-4. River Corridor Plume Areas.

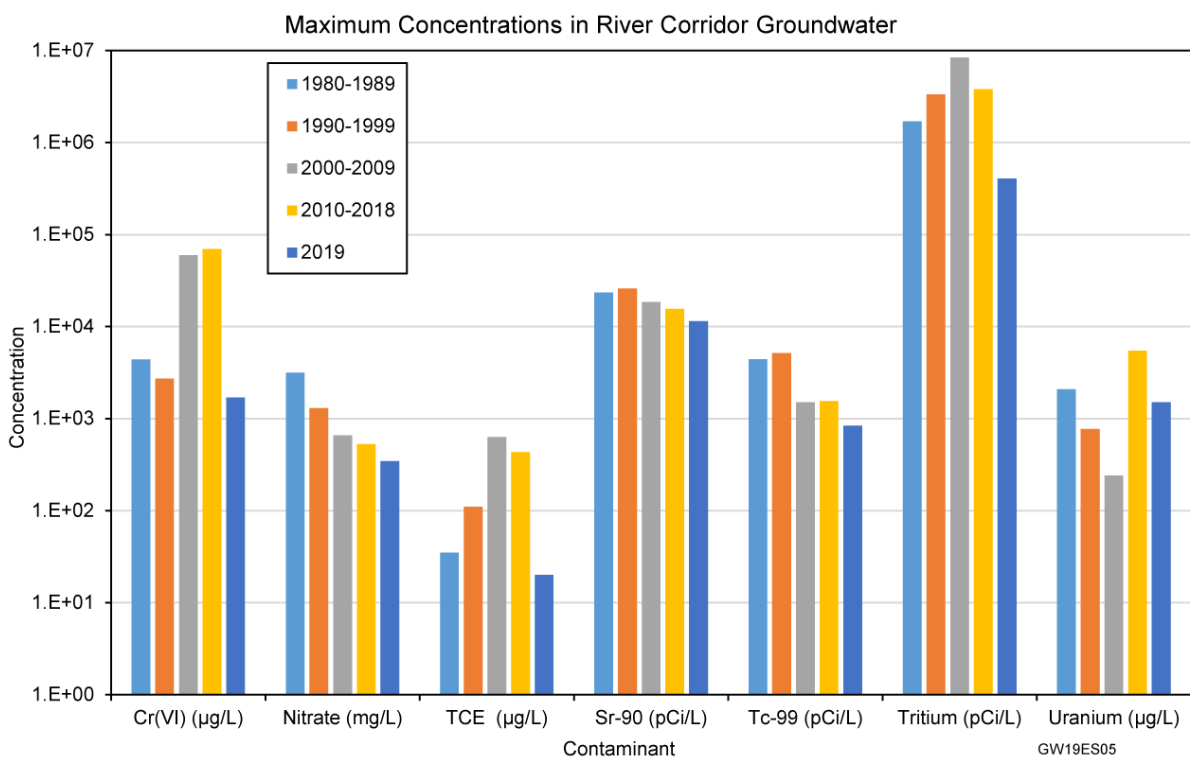

Figure 8-5. Maximum Concentrations of River Corridor Contaminants Over Time.

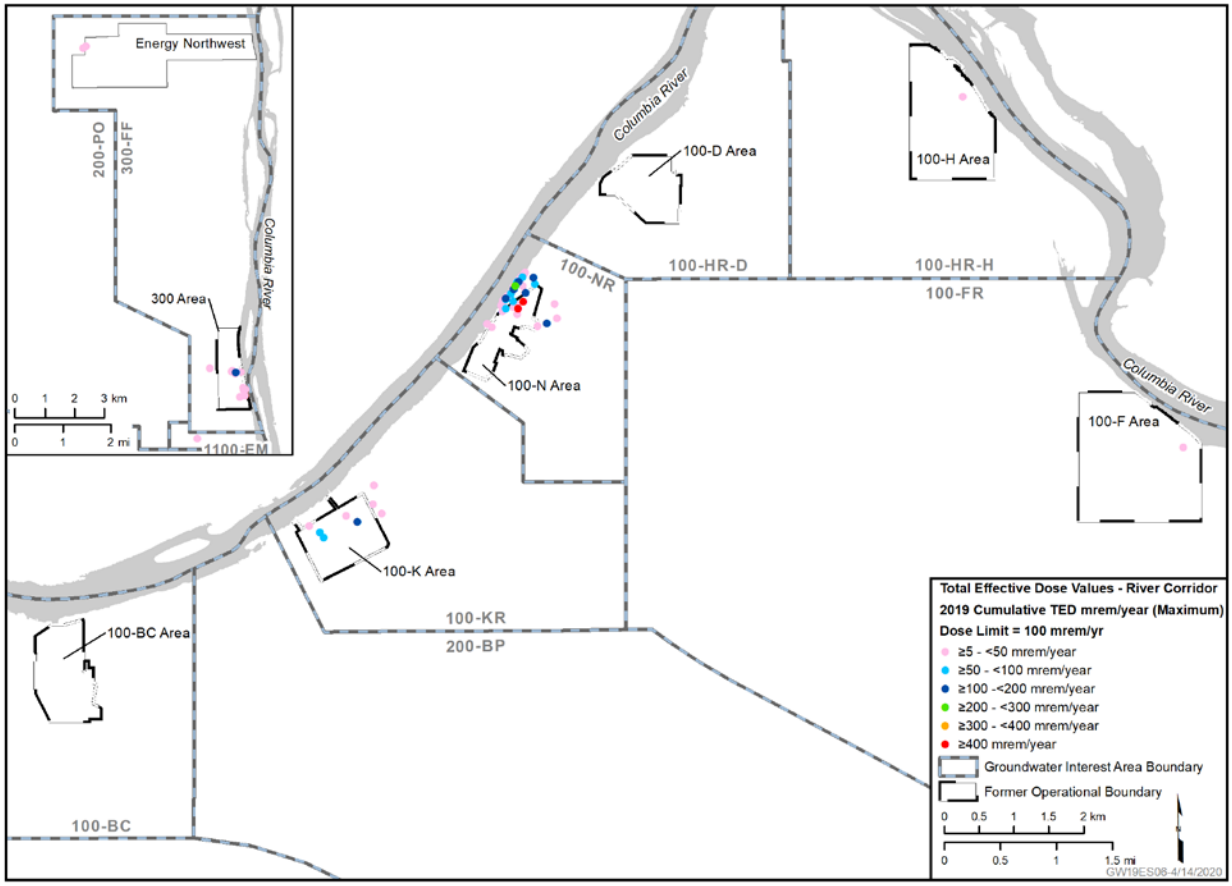

Figure 8-6. Groundwater Dose Calculation for the River Corridor.

The following activities or changes occurred in the River Corridor in 2019:

- **100-BC**
  - A remedial investigation (RI)/feasibility study (FS) report (DOE/RL-2010-96) and proposed plan (DOE/RL-2016-43) for remediation were released, and public comments on the proposed plan were received.

- **100-FR**
  - Six new monitoring wells were installed. Data from the new wells resulted in the interpreted nitrate plume to shrink and the TCE plume to expand.

- **100-HR**
  - The hexavalent chromium plumes in the unconfined aquifer continued to shrink in response to ongoing groundwater remediation, and concentrations continue to decline. One extraction well and two injection wells were installed in the unconfined aquifer to support remediation in 2019.

  - A potentiometric map and hexavalent chromium plume map were created for the Ringold upper mud aquifer for the first time in 2019. Six new monitoring wells and one new extraction well were installed in 2019 to improve monitoring and remediation of that aquifer.

  - Draft A of the remedial design/remedial action work plan (DOE/RL-2017-13) was released in 2019 for regulatory review.

- **100-KR**
  - In 2019, a soil flushing treatability test was implemented at the 183.1KW Headhouse area to address a continuing source of groundwater contamination (DOE/RL-2017-30). The goal of soil flushing was to flush hexavalent chromium from the deep portions of the vadose zone into the groundwater and then capture the material with the active P&T system.

  - Draft B of the 100-K RI report (DOE/RL-2010-97) was released in 2019 for regulatory agency review. The revision incorporates supplemental data associated with the 105-KE fuel storage basins and 116-KE-3 Crib and reverse well, as well as data collected to support soil and groundwater interim remedial actions.

- **100-NR**
  - Draft B of the 100-N Area RI/FS report (DOE/RL-2012-15) was released in November 2019 for regulatory agency review. The RI/FS report will be used to support future cleanup decisions specified in a proposed plan and Record of Decision (ROD) planned for 2021.

- **300-FF**
  - Two stages of uranium sequestration have been conducted in the 300 Area Industrial Complex, and monitoring of the Stage B wells continued in 2019.

  - Nine uranium sequestration boreholes were drilled for post-treatment soil samples.

  - One new monitoring well was installed in the 300 Area to monitor the 324 Building, and a replacement monitoring well was installed at the 618-10 Burial Ground.

  - Nitrate concentrations increased in one monitoring well near the 618-11 Burial Ground.

- **RCRA**
  - Post-closure corrective action monitoring continued at the 183-H Solar Evaporation Basins and the 300 Area Process Trenches in 2019.

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 in some areas continues to migrate into the groundwater. DOE is expanding remediation activities in the 200 Areas to contain and remove contamination from the vadose zone and groundwater.

Figure 8-7 shows the Central Plateau groundwater contaminant plumes in 2019, and Table 8-3 compares the maximum contaminant concentrations measured in 2019 and 2018 in the Central Plateau groundwater interest areas.

Groundwater beneath portions of the Central Plateau is being remediated under CERCLA. Table 8-4 summarizes the status of CERCLA remediation for the Central Plateau groundwater and deep vadose zone operable units. In 2019, P&T systems continued to remove carbon tetrachloride, technetium-99, uranium, and other contaminants from groundwater.

The size of the Central Plateau tritium plume continued to decline in 2019 due to natural attenuation, which includes radioactive decay (Figure 8-8). The technetium 99 and uranium plume areas continued to decline gradually due to groundwater remediation. The interpreted nitrate plume increased in 2019 because of changes in the 200-West P&T as part of an optimization study. The size of the carbon tetrachloride plume declined between 2018 and 2019. The hexavalent chromium plume area increased in recent years as data from new wells became available.

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

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

The following activities or changes occurred in the Central Plateau in 2019:

- **200-BP**
  - Groundwater was extracted from two wells in the B Complex area in 2019, and concentrations and plume sizes of nitrate, technetium-99, uranium, and cyanide continued to decline in monitoring wells.
  - Perched water continued to be extracted from three wells in the B Complex area to reduce migration of contamination to groundwater.
  - Four new monitoring wells were drilled in 2019 to complete the B Complex removal action performance monitoring network.
  - DOE issued an interim action FS for the 200-BP-5 and 200-PO-1 Operable Units (DOE/RL-2018-30, *200-BP-5 and 200-PO-1 Groundwater Operable Units Feasibility Study for Interim Action*), and Rev. 0 of a proposed plan for interim action remediation (DOE/RL-2018-58, *Proposed Plan for Interim Action Remediation of the 200-BP-5 and 200-PO-1 Operable Units*). The U.S. Environmental Protection Agency, Washington State Department of Ecology, and DOE are pursuing an interim ROD for these two groundwater operable units to expedite remediation of the technetium-99 and uranium groundwater plumes.
- **200-PO**
  - The large tritium plume originating from sources in the 200-East Area continued to shrink in 2019 due to dispersion and radioactive decay.

- In 2019 the highest tritium concentration in groundwater was 4,240,000 pCi/L in a well near the 216-A-36A Crib. This concentration was much higher than the maxima in recent years (Figure 8-9). The well, which is nearly dry, had not been sampled since 2002, when the concentration was 5,570,000 pCi/L.

- Three new wells were installed to monitor the Integrated Disposal Facility.

- **200-UP**
  - Groundwater extraction and treatment for Waste Management Area S SX and the U Plant area continued in 2019. Contaminant concentrations have declined in many monitoring wells in response to remediation.

  - In 2019, three new wells were installed to characterize the uranium plume near U Plant, and two wells were installed to monitor the Environmental Restoration Disposal Facility.

- **200-ZP**
  - As a result of remediation by the 200-West P&T, carbon tetrachloride concentrations have declined in locations where the highest levels were formerly present. The downgradient, lower concentration portion of the plume not captured by the P&T system is expected to attenuate naturally over time, as described in the 200-ZP-1 Operable Unit ROD.

  - In 2019, an optimization study plan was implemented, and biological treatment was suspended to improve contaminant capture and increase removal of carbon tetrachloride. This resulted in higher nitrate concentrations in treated water reinjected into the aquifer, which are expected to be remediated by monitored natural attenuation.

  - Three new monitoring wells, one new injection well, and one new extraction well were installed for the 200-West P&T in 2019.

- **RCRA**
  - RCRA groundwater monitoring continued at 20 dangerous waste management units in the Central Plateau in 2019.

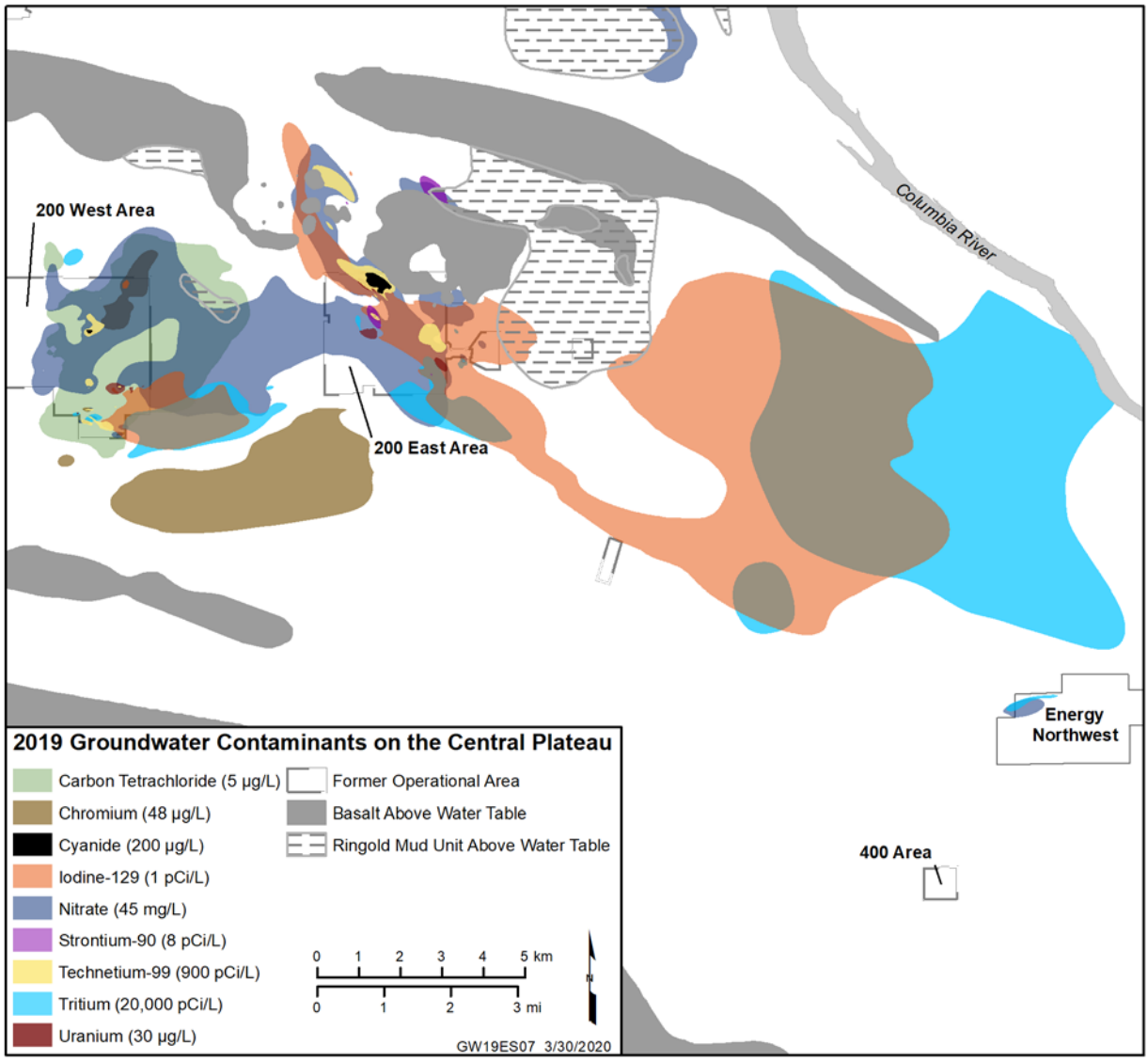

Figure 8-7. Groundwater Contaminant Plumes in the Central Plateau.

Table 8-3. Central Plateau Groundwater Contaminants, 2018 and 2019

Groundwater Interest Area	Year	Maximum Concentrations							
		Carbon Tetrachloride (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)
200-BP	2019	0.83	38.2	7.14	974	337	25,500	28,700	641
	2018	0.80	39.0	9.87	1,060	602	29,100	33,700	1,100
200-PO	2019	N	159	12.2	133	11.9	6,300	4,240,000	68
	2018	N	130	13.1	159	14.8	4,850	365,000	71
200-UP	2019	408	463	23.7	211	37.1	15,200	222,000	2,100
	2018	428	373	23.0	270	23.5	30,900	187,000	3,520
200-ZP	2019	1,830	175	2.15	553	N	25,200	58,100	4.9
	2018	1,750	140	1.87	664	N	13,800	56,000	3.5
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

Note: Colors and listed values indicate maximum concentration, as follows:

- ≤ Standard
- > Standard and ≤10 × standard
- >10 × standard and ≤100 × standard
- >100 × standard and ≤1,000 × standard

N = not detected or not analyzed
N/A = not applicable

Table 8-4. 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 2019 (and Since Startup)
200-BP-5	Implemented action memorandum (2016); FS and draft proposed plan released in 2019	Cyanide, iodine-129, nitrate, strontium-90, technetium-99, tritium, and uranium	Groundwater extraction removal action (2015–2019)	Cyanide: 47 kg (207 kg) Nitrate: 63,411 kg (285,774 kg) Technetium-99: 56.5 g (313.5 g) Uranium: 22.4 kg (187 kg)
200-PO-1	FS and draft proposed plan released in 2019	Iodine-129, tritium, nitrate, strontium-90, technetium-99, and uranium	None to date; pending interim action decision	Not applicable

Table 8-4. 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 2019 (and Since Startup)
200-UP-1	ROD for interim remedial action signed (2012); submitted remedial design investigation report for the southeast chromium plume (2019)	Technetium-99, uranium, carbon tetrachloride, Cr(VI), total chromium, iodine-129, nitrate, tritium, trichloroethene, chloroform, tetrachloroethene, strontium-90, and 1,4-dioxane	Interim actions: P&T near U Plant (2015–2019) P&T at WMA S-SX (2012–2019) Hydraulic containment for iodine-129 (2015–2019) MNA	Nitrate: 21,646 kg (223,924 kg[b]) Technetium-99: 23 g (401 g[b]) Uranium: 14 kg (967 kg[b])
200-ZP-1	ROD for final remedial action signed (2008)	Carbon tetrachloride, Cr(VI), total chromium, iodine-129, nitrate, technetium-99, trichloroethene, and tritium	P&T and MNA (2012-2019)	Carbon tetrachloride: 1,917 kg (30,951 kg[b]) Chromium: 68.5 kg (506 kg) Nitrate: 245,982 kg (2,186,276 kg)
200-DV-1[c]	Implemented action memorandum (2016); characterization of the deep vadose zone in progress	Nitrate, technetium-99, uranium, tritium, total chromium, and Cr(VI) (perched water)	Removal action: Perched water extraction (2011–2019)	Nitrate: 1,280 kg (5,364 kg[b]) Technetium-99: 2.7 g (10.7 g[b]) Uranium: 63 kg (294 kg[b])

[a] Contaminants of concern are listed for operable units with RODs for final action and implemented action memoranda. The primary contaminants of potential concern are listed for the other operable units.
[b] Totals includes mass from P&T system under earlier RODs for interim action and 200-DV-1 Operable Unit treatability test.
[c] Deep vadose zone operable unit.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cr(VI) = hexavalent chromium
FS = feasibility study
MNA = monitored natural attenuation
P&T = pump and treat
ROD = Record of Decision
WMA = waste management area

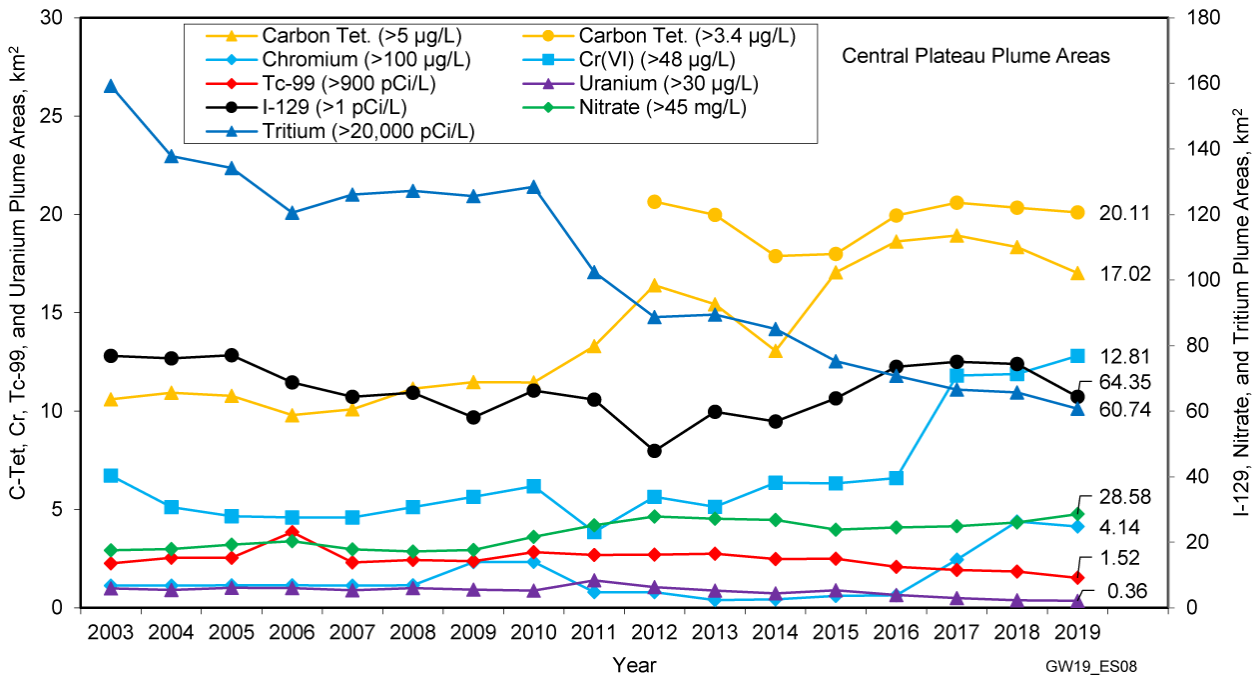

Figure 8-8. Central Plateau Plume Areas.

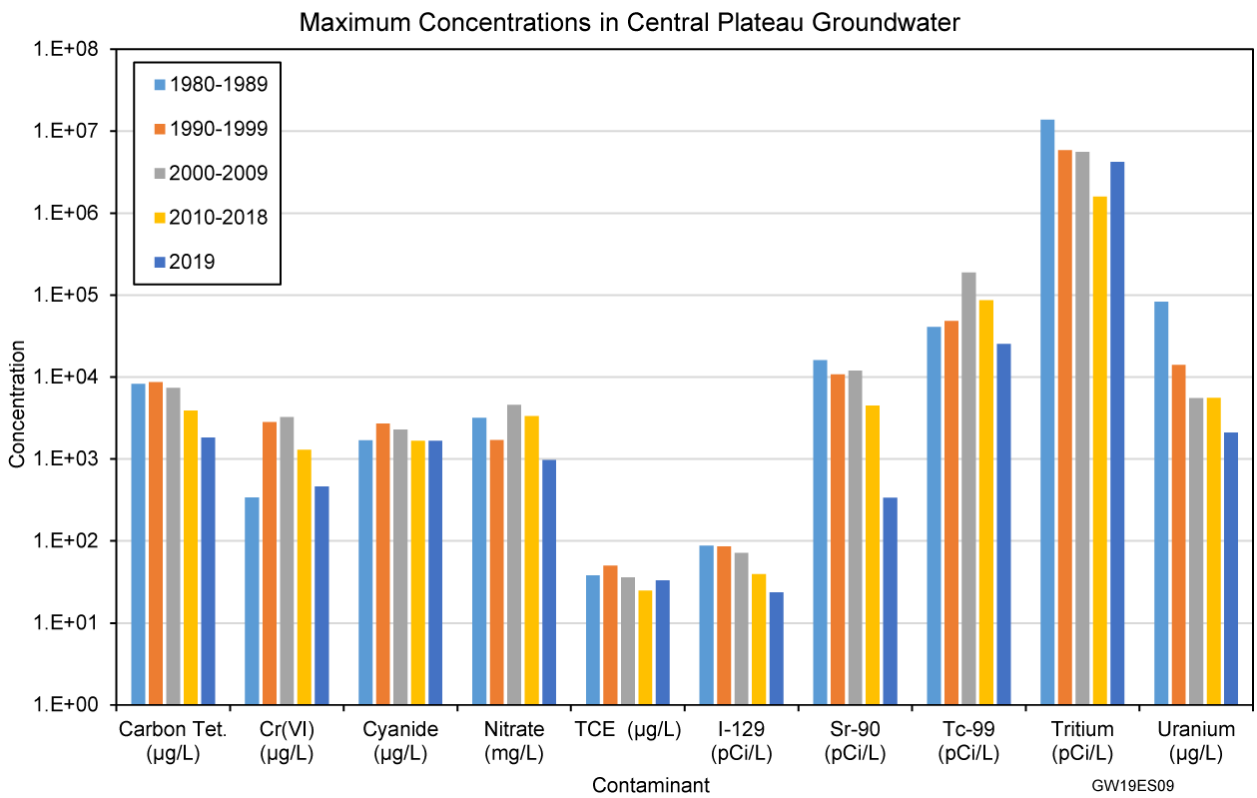

Figure 8-9. Maximum Concentrations of Central Plateau Contaminants over Time.

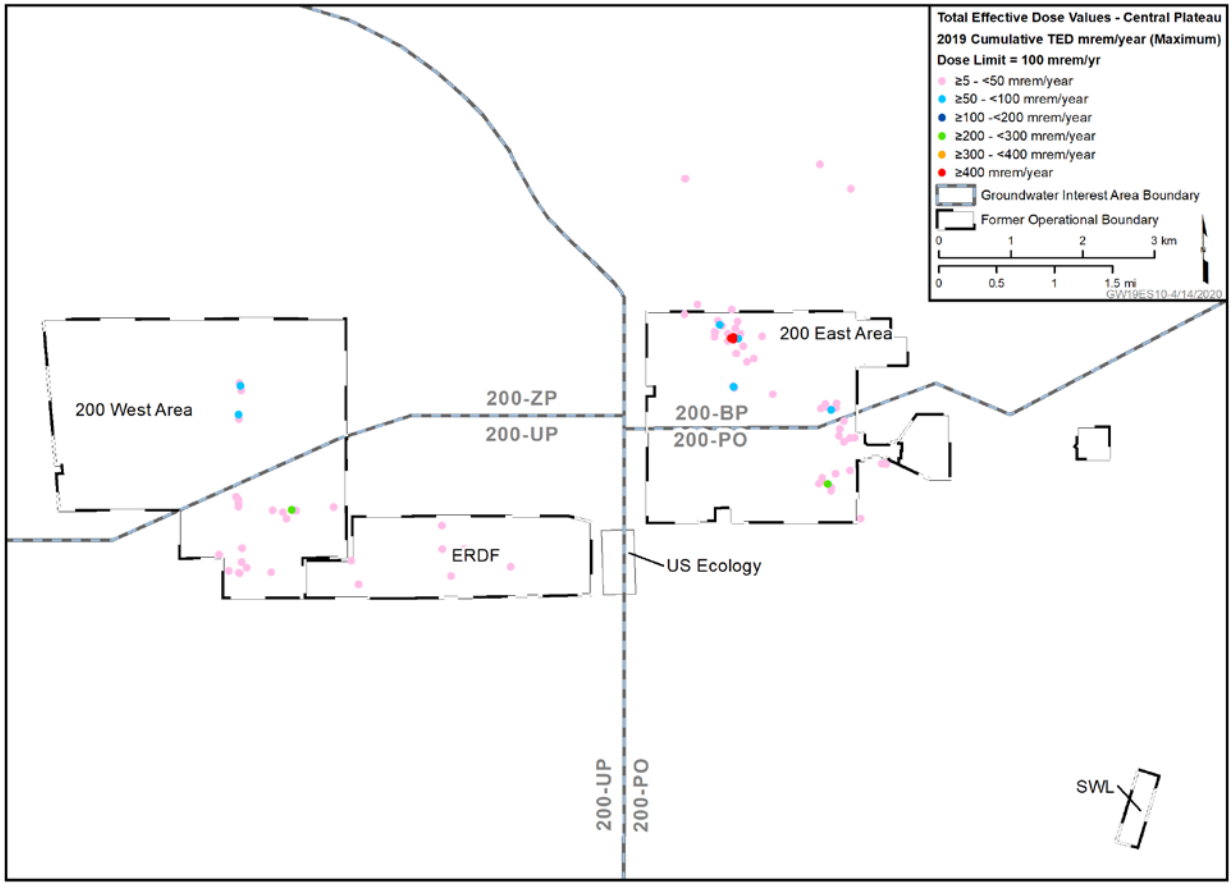

Figure 8-10. Groundwater Dose Calculation for the Central Plateau.

8.3 References

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2019 Highlight

Routine Surveillance Soil Sampling
A total of 86 surface soil samples were collected in calendar year 2019; 68 samples were collected on the Hanford Site and 18 samples were collected from offsite locations. 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 calendar year 2019 identified seven instances of radiological contamination in surface soil, resulting in six locations posted as contamination areas and one location 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 collected in 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) 2019 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	D053, D055, D057, D059, D061, D063[b], D065, D067, D069, D071, D073, D075, D077, D079, D143[c]	May-June	^{90}Sr, Pu-iso, U-iso, GEA
Trench 94 (200-East Area)	D458, D460, D461	May-June	^{90}Sr, Pu-iso, U-iso, GEA
200-West Area	D001, D005, D013, D015, D019, D023, D025, D027, D029, D035, D037, D039, D041, D047[b], D049, D051, D111[c]	May-June	^{90}Sr, Pu-iso, U-iso, GEA, ^{241}Am
Plutonium Finishing Plant (200-West Area)	D007, D009, D031, D033, D043, D045[b]	May-June	^{90}Sr, Pu-iso, U-iso, GEA, ^{241}Am
ERDF at N482 (200-West Area)	D146	May-June	^{90}Sr, Pu-iso, U-iso, GEA
300 Area	D120, D121, D123[b], D125, D126, D132[c], D140[c], D207	May-June	^{90}Sr, Pu-iso, U-iso, GEA
400 Area	D130	May-June	^{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	D081, D083, D085, D087, D089, D091[b], D093, D095, D097, D099, D101, D103, D105, D107, D109, D113[c], D145[c]	May-June	^{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]
68	15	23	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 2019*. 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 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 2019 are summarized in Appendix C, Table C-4. While there are no specific DOE limits for radionuclide concentrations in soil, the 2019 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. The average strontium-90 soil values in the 200-West Area were also slightly higher than the Hanford Site background level but well below the Environmental Surveillance dose-based limit for an offsite member of the public.

In general, radionuclide concentrations in soil samples collected in CY 2019 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 2019 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 2019 soil samples. Figure 9-1 shows the annual average soil concentrations of selected radionuclides in the 100, 200, 300, 400, and 600 Areas compared to the Hanford Site background concentrations (DOE/RL-96-12) for 2019 and the preceding 5 years. Appendix C, Table C-4 shows the annual average and maximum concentrations of radionuclides in surface soil samples by area during 2019 and the preceding 5 years.

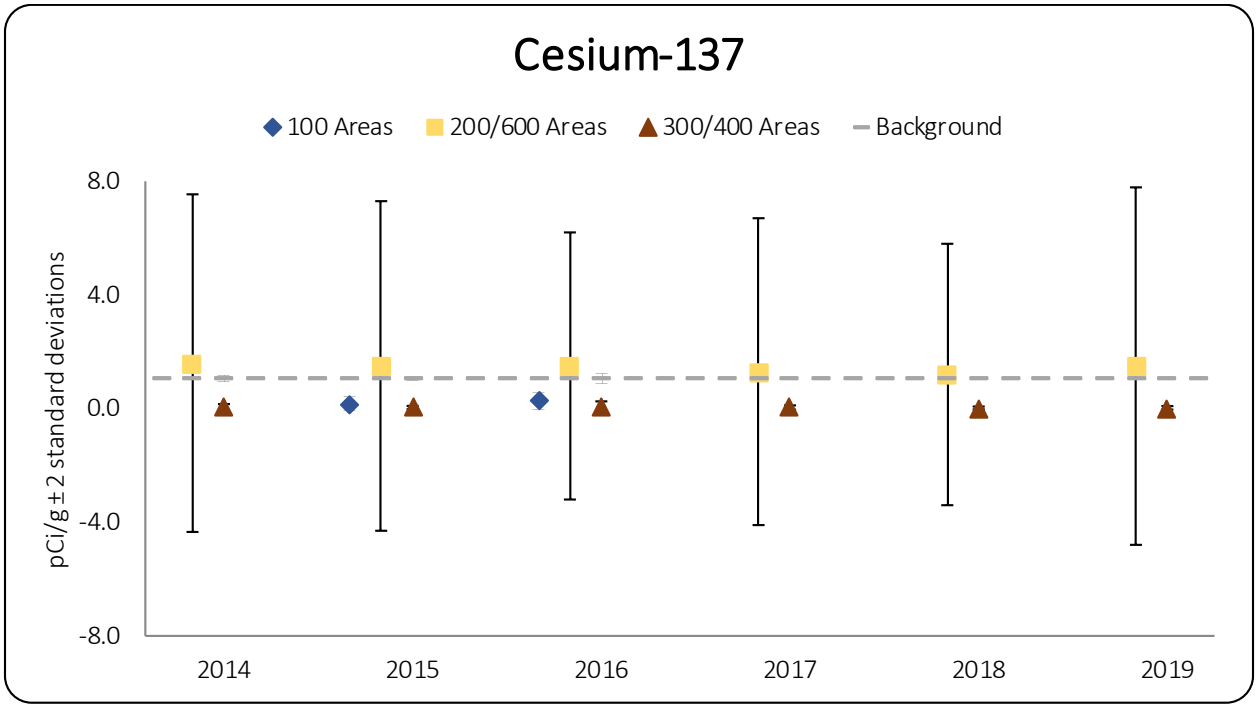
Table 9-3. Concentration Limits for Selected Radionuclides (pCi/g). (2 Pages)

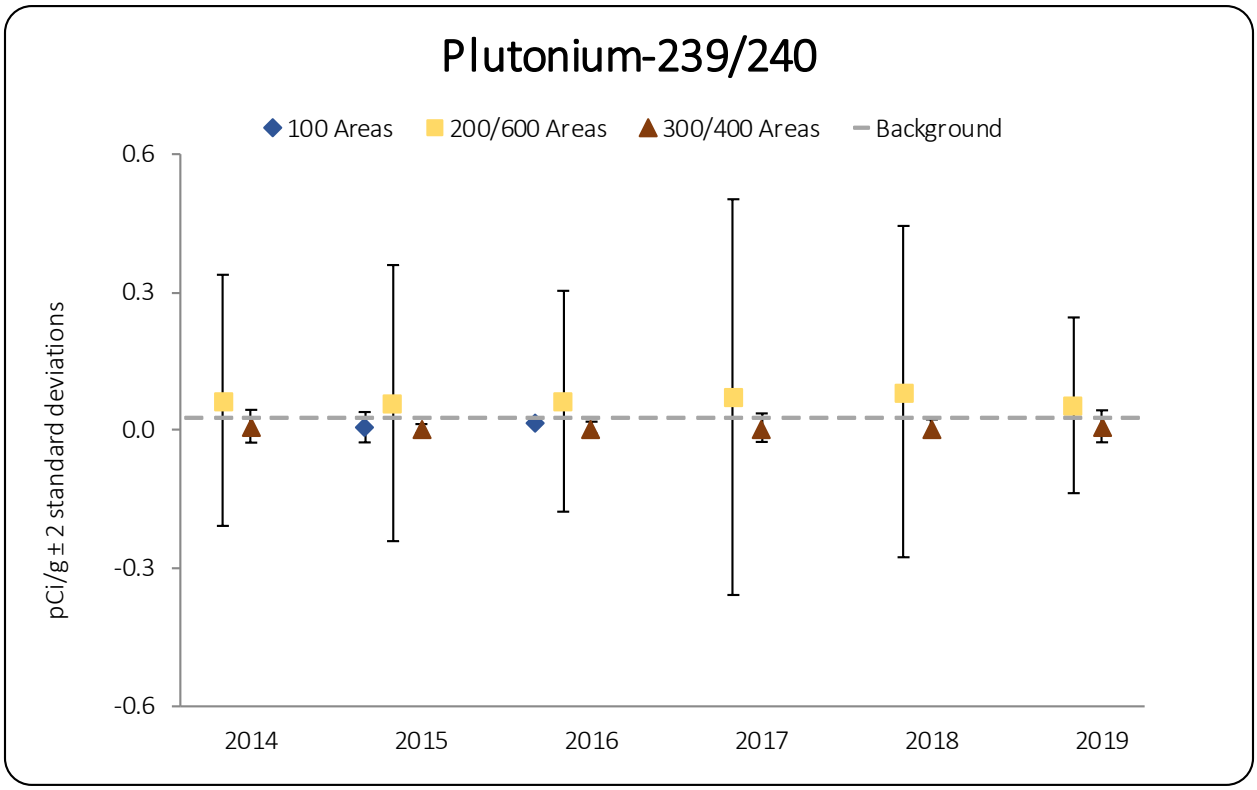
Isotope	Hanford Background (90th Percentile)[a]	Environmental Surveillance Dose-based Reporting Limit for Offsite Exposure Scenarios[b]	Preliminary Remediation Goal for the Outdoor Worker Exposure Scenario[c]
Americium-241	N/A	20	613
Cesium-137	1.05	0.51	10.8
Plutonium-238	0.004	33	3,438

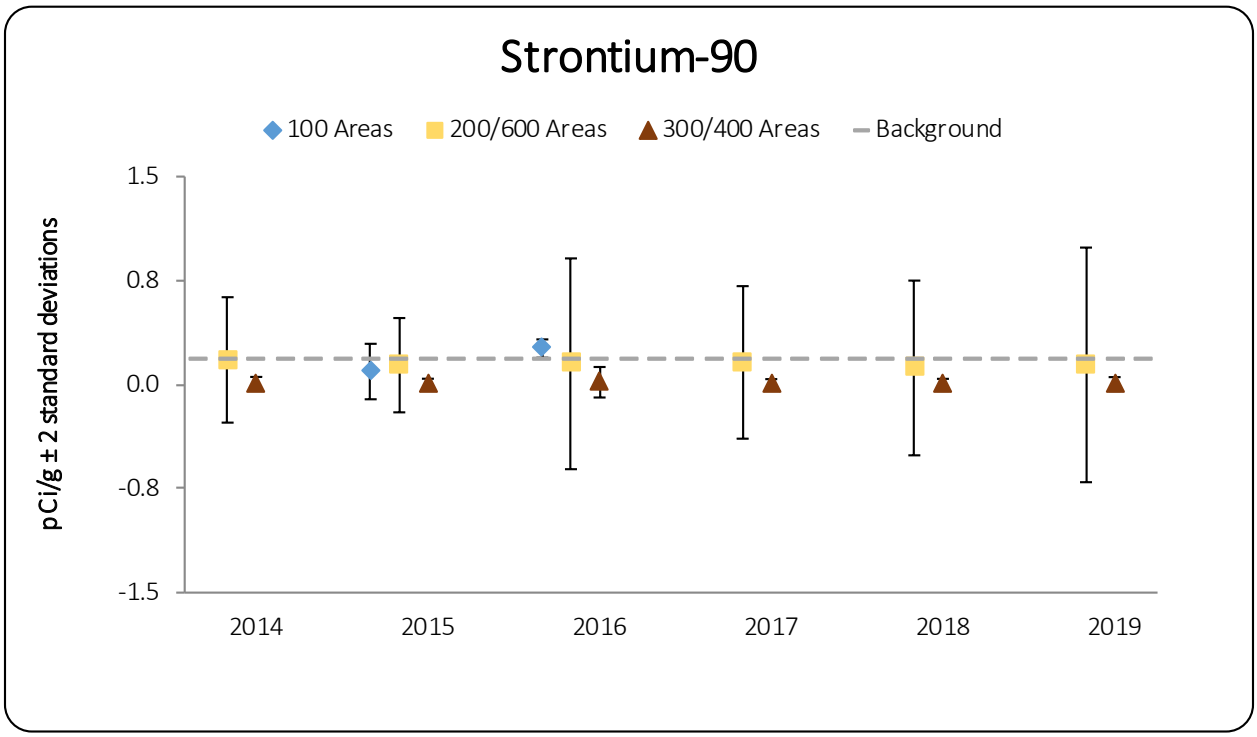
Table 9-3. Concentration Limits for Selected Radionuclides (pCi/g). (2 Pages)

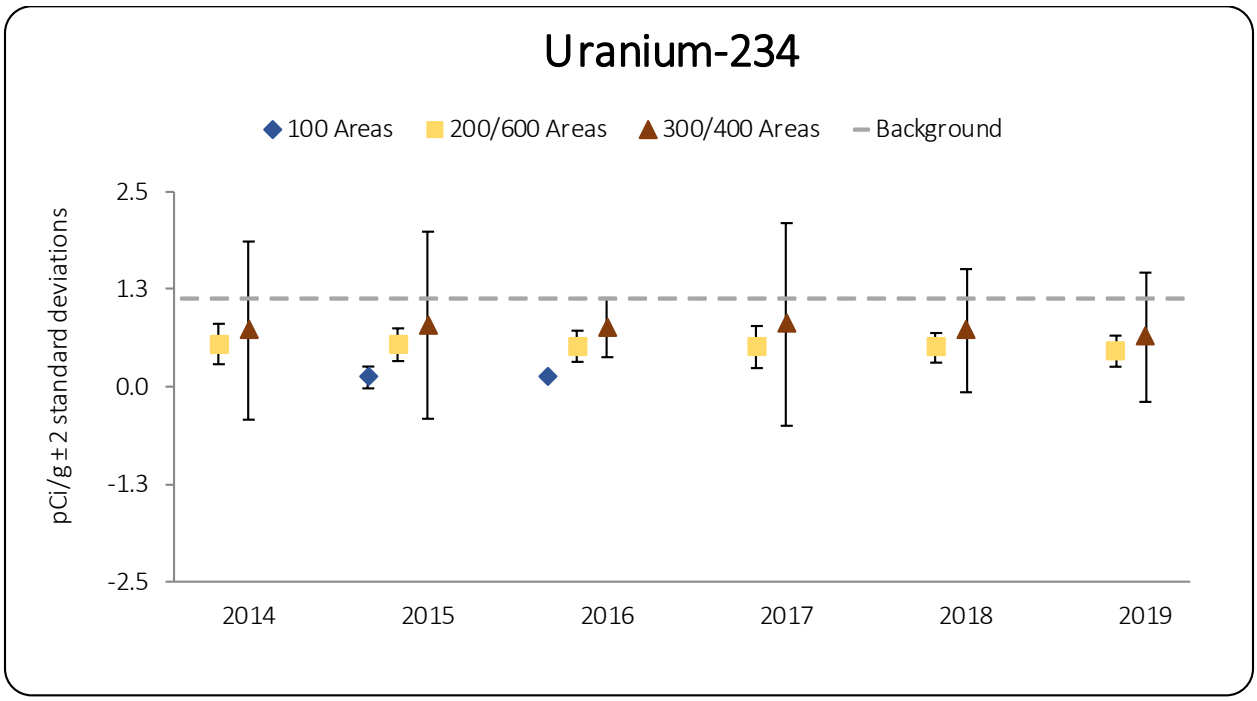
Isotope	Hanford Background (90th Percentile)[a]	Environmental Surveillance Dose-based Reporting Limit for Offsite Exposure Scenarios[b]	Preliminary Remediation Goal for the Outdoor Worker Exposure Scenario[c]
Plutonium-239/240	0.025	31	2,971
Strontium-90	0.178	55	1,190
Uranium-234	1.10	150	2,201
Uranium-235	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 *Calculation of Soil Radiological Preliminary Remedial Goals for the Outdoor Worker Scenario* (ECF-HANFORD-16-0133) that correspond to a target cancer risk level of $1x10^{-4}$ 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




Plutonium-239/240
100 Areas
200/600 Areas
300/400 Areas
Background
pCi/g ± 2 standard deviations
0.6
0.3
0.0
-0.3
-0.6
2014
2015
2016
2017
2018
2019


Strontium-90
100 Areas
200/600 Areas
300/400 Areas
Background
pCi/g ± 2 standard deviations
1.5
0.8
0.0
-0.8
-1.5
2014
2015
2016
2017
2018
2019



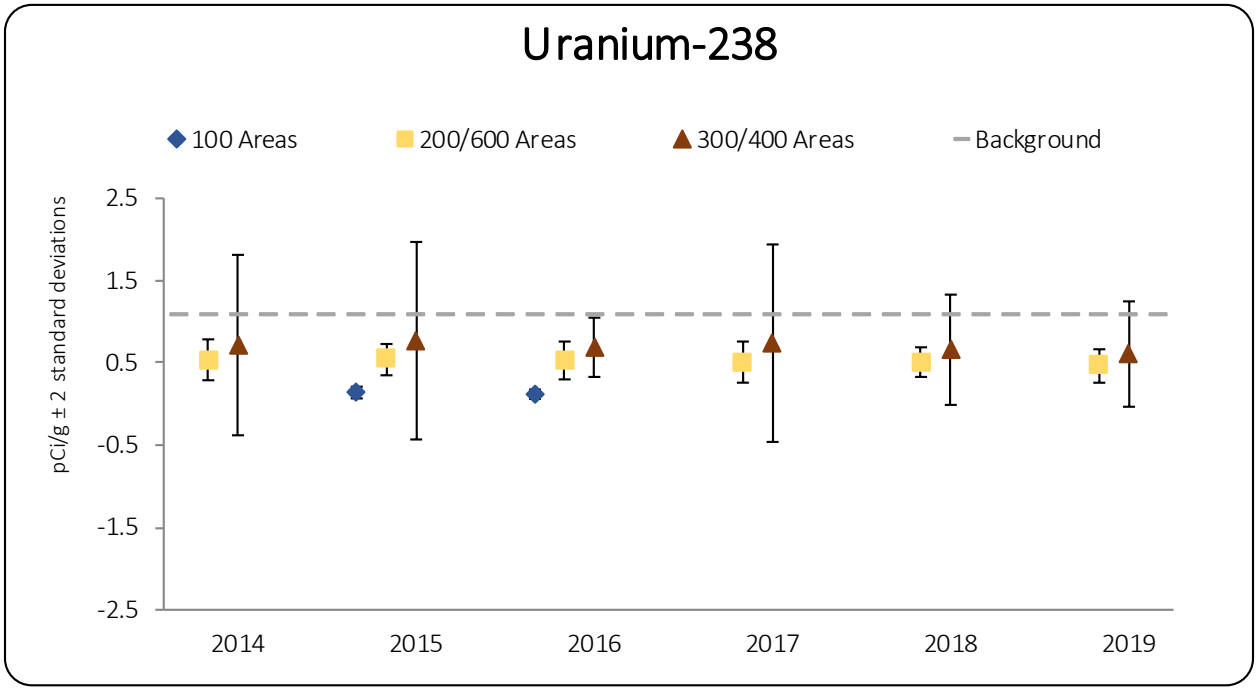


Figure 9.1. Average Concentrations of Select Radionuclides in Hanford Site Soil Samples, 2014–2019.
(As a result of figure scale, some uncertainties [error bars] are concealed by the point symbol)

Soil sampling was conducted at 18 locations in the 200-East Area, including Trench 94 during CY 2019. Generally, radionuclide levels measured in the 2019 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 2019, routine soil sampling was conducted at 24 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 2019. 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 2019 around Trench 94 of the 218-E-12B waste site in the 200-East Area. Radionuclide levels measured in the 2019 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.

Uranium-234 and uranium-238 were detected in all 86 surface soil samples collected from the Hanford Site in CY 2019. Soil samples 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 20% of the soil samples collected in the 300/400 Areas and 55% of soil samples collected from the 200 and 600 Areas. Of the 32 detections in the 200/600 Areas, 25 were from locations in and around the 200-West Area. The concentrations measured were within historical ranges.

9.1.2.3 Strontium-90.

Strontium-90 was detected in approximately 44% of the samples collected in the 200 and 600 Areas. In general, the concentrations measured were within historical ranges. However, at location D009 in the 200-West Area near the PFP, the strontium-90 result was slightly higher than the Hanford Site 5-year maximum concentration.

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 D053 in the 200-East Area.

9.1.2.5 Americium-241.

Americium-241 analysis was performed on 23 samples in the 200-West Area in support of the current deactivation and decommissioning project at the PFP. Americium-241 was detected at 15 of the 23 locations at concentrations similar to those seen in 2016, 2017, and 2018.

9.2 Offsite Soil Sampling

Soil samples from offsite locations are collected every 3 to 5 years. 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 handbook DOE-HDBK-1216-2015.

During 2019, soil samples were collected from 18 locations around the perimeter of the Hanford Site and nearby and distant communities. The locations and analyses of offsite soil samples collected in CY 2019 are depicted in Table 9-4.

Table 9-4. Offsite Soil Monitoring Locations and Sample Analyses. (2 Pages)

Soil Monitoring Location[a, b]	EDP Codes[c]	Analyses
N end Vernita Bridge	D424	GEA, ^{90}Sr, U-iso, Pu-iso
Wahluke Slope	D425	GEA, ^{90}Sr, U-iso, Pu-iso
Berg Ranch	D426	GEA, ^{90}Sr, U-iso, Pu-iso
Ringold	D427	GEA, ^{90}Sr, U-iso, Pu-iso
W end Fir Road	D428	GEA, ^{90}Sr, U-iso, Pu-iso
Taylor Flats No. 2	D429	GEA, ^{90}Sr, U-iso, Pu-iso
Sagemoor Farms	D430, D493[d]	GEA, ^{90}Sr, U-iso, Pu-iso, ^{241}Am
Byers Landing	D431	GEA, ^{90}Sr, U-iso, Pu-iso
Benton City	D433	GEA, ^{90}Sr, U-iso, Pu-iso
Sunnyside	D434	GEA, ^{90}Sr, U-iso, Pu-iso, ^{241}Am
McNary Dam	D435	GEA, ^{90}Sr, U-iso, Pu-iso
Walla Walla	D436	GEA, ^{90}Sr, U-iso, Pu-iso
Washtucna	D437	GEA, ^{90}Sr, U-iso, Pu-iso
Toppenish	D438	GEA, ^{90}Sr, U-iso, Pu-iso
George	D439[e]	GEA, ^{90}Sr, U-iso, Pu-iso
Othello	D440[e]	GEA, ^{90}Sr, U-iso, Pu-iso
Wanapum	D441[e]	GEA, ^{90}Sr, U-iso, Pu-iso

Table 9-4. Offsite Soil Monitoring Locations and Sample Analyses. (2 Pages)

[a] Samples are collected approximately every 3-5 years
[b] Samples were collected in June 2019
[c] EDP Code=environmental data point code = sample location code
[d] Quality assurance duplicate sample
[e] Collocated sampling location with WDOH
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

9.2.1 Offsite Soil Sampling Results

The analytical results from soil samples collected from around the perimeter of the Hanford Site and nearby and distant communities in CY 2019 are summarized in Appendix C, Table C-5. Radionuclide concentrations in soil samples collected in CY 2019 at offsite locations were compared to results from 2001, 2004, 2008, and 2015. In 2019, the observed average concentrations in soil samples for all isotopes were generally similar to their respective averages from 2001, 2004, 2008, and 2015. The maximum concentrations for cesium-137, americium-241, plutonium-238, and plutonium-239/240 were similar to the maximum concentrations observed in 2001, 2004, 2008, and 2015; however, the maximum concentrations for strontium-90 and uranium were lower than the maximum concentrations observed in previous years. The Hanford sitewide average soil concentrations in 2019 were higher than at site perimeter and distant locations for the radionuclides measured (Appendix C, Table C-6). This was consistent with historical data and reflected the higher sitewide soil concentrations associated with years of nuclear materials production.

9.3 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 2019 identified seven instances of radiological contamination in surface soil. Of the seven soil contamination events reported, six were posted as contamination areas and one was cleaned up and contaminated material disposed of onsite in licensed burial grounds. Table 9-5 summarizes the general locations of soil contamination incidents discovered during 2019 and Table 9-6 provides the number of contamination incidents from 2000 through 2019.

Table 9-5. Hanford Site Soil Contamination Occurrences discovered in CY 2019.

Location	2019 Incidents
100 Area	0
200-East Area	
Tank farms	1
Burial grounds	1
Cribs, ponds, and ditches	3
Fence lines	0
Roads and railroads	1
Unplanned release sites	0
Underground pipelines	0
Liquid Effluent Treatment Facility/Effluent Treatment Facility	0
Miscellaneous	1
200-West Area	
Tank farms	0
Burial grounds	0
Cribs, ponds, and ditches	0
Fence lines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	0
Miscellaneous	0
Cross-site transfer line	0
200-BC cribs and trenches	0
200-North Area	0
300 Area	0
400 Area	0
600 Area	0
Total	**7**

Table 9-6. Hanford Site Soil Contamination Occurrences from 2000 through 2019.

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
2019	**7**

9.4 References

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2019 Highlight

Routine Vegetation Sampling and Radiological Surveys
A total of 52 vegetation samples were collected in calendar year 2019; 44 samples were collected on the Hanford Site and 8 samples were collected from offsite locations. Generally, the concentrations of radionuclides in these samples were consistent with those seen in previous years.

Radiological surveys performed in calendar year 2019 identified 29 instances of radiological contamination in vegetation. All 29 were Russian thistle (*Salsola tragus*) plants or fragments. Of the 29 instances, 2 locations were posted as a contamination area and 27 were cleaned up and disposed of at a licensed facility.

Food and Farm Products
In calendar year 2019, 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 2019, Canada goose, walleye and whitefish were collected and submitted to laboratories for radiological and metals analyses. A total of 31 animals were collected in 2019 for obtaining samples.

10.0 Biota Monitoring

JR Draper

The U.S. Department of Energy's (DOE) subcontractor Mission Support Alliance 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. Mission Support Alliance'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., alfalfa, apricots, corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in calendar year (CY) 2019 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, product availability, and historical trending purposes). These foodstuffs are utilized 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 distributed 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:

- Downwind (east and southeast) of the Hanford Site where airborne emissions or contaminated dust from the site potentially would be deposited
- 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 from 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 2019 were below the analytical laboratory detection levels; however, some potential Hanford Site-produced contaminants (e.g., tritium) were found at low levels in some milk samples and wine must. An anomaly did occur in both a corn and leafy vegetable sample from the reference area (Sunnyside), as both had detections of strontium-90. 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 µSv/yr) (DOE/RL-91-50). Agricultural products sampled in CY 2019 are listed in Table 10-1 and are described in the following sections.

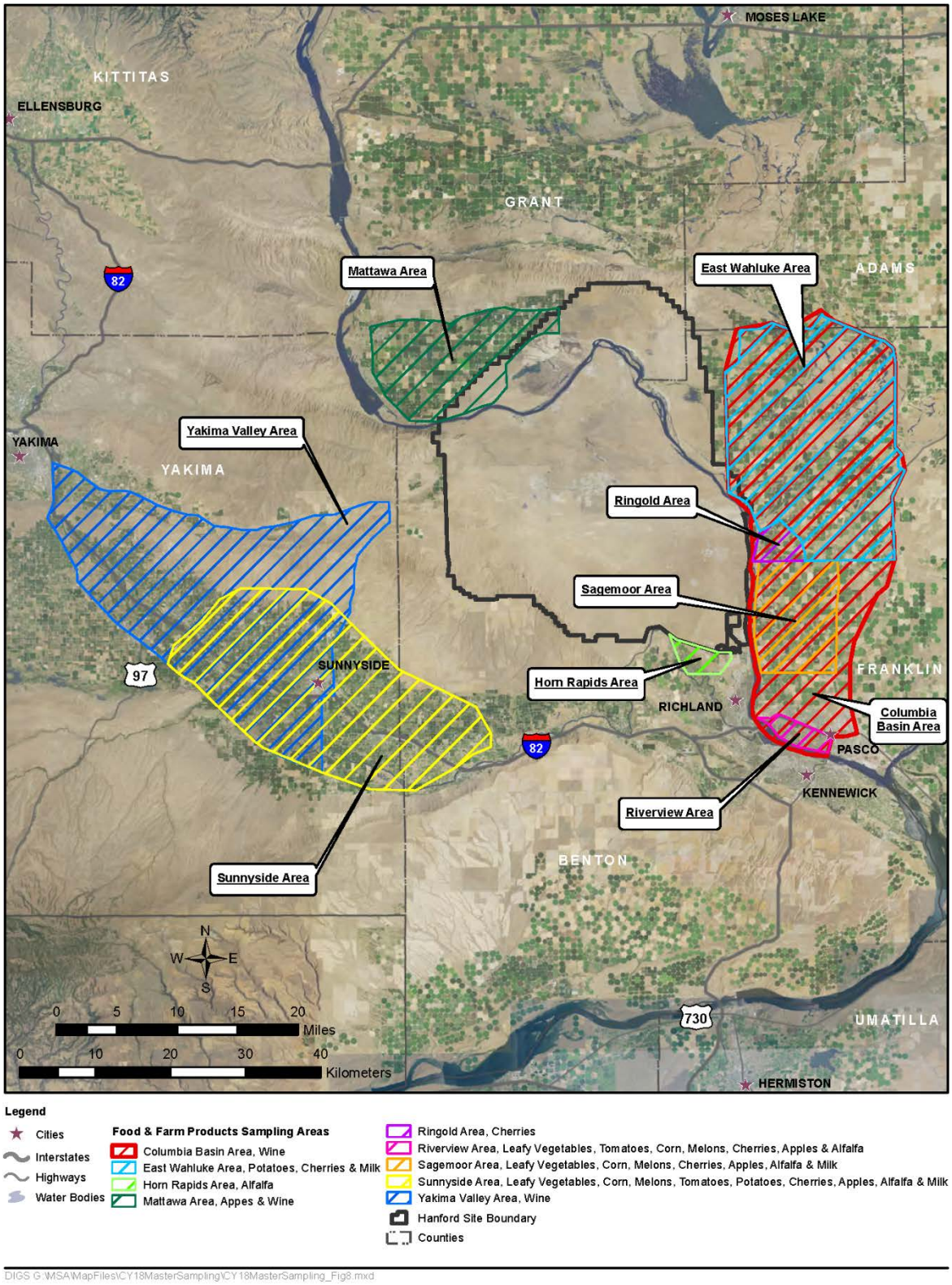


Figure 10-1. Agricultural Monitoring Locations.

Table 10-1. Agricultural Monitoring Location.

Product	Sampling Locations	Analytes
Alfalfa	East Wahluke, Riverview, Sagemoor, and Sunnyside	^{14}C, Gamma, Sr-90
Apricots	East Wahluke, Riverview, Sagemoor, and Sunnyside	^{14}C, Gamma, Sr-90
Corn	East Wahluke, Riverview, Sagemoor, and Sunnyside	^{14}C, Gamma, Sr-90
Leafy vegetables	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)

10.1.1 Milk

Milk samples were obtained quarterly in CY 2019 from several dairies in the East Wahluke and Sagemoor sampling areas. Milk was not obtained from a dairy in the Sunnyside area in 2019 due to closure of the dairy plant in late 2017. Surveillance personnel are attempting to locate a new Sunnyside-area dairy to sample. Unfortunately, a number of dairies in the lower Yakima Valley have closed in recent years due to restrictions and overhead costs, this has made it increasingly difficult to find a location to sample from.

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 milk samples collected in CY 2019. Overall concentrations of the nine detections ranged from a maximum of 31.2 pCi/L (1.15 Bq/L) in a Sagemoor area sample to a minimum of 11.9 pCi/L (0.44 Bq/L) in an East Wahluke area sample. Annual average concentrations for the two sampling areas were 21.7 pCi/L (0.80 Bq/L). Specific location average was 28.2 pCi/L (1.0 Bq/L) for Sagemoor (n = 5) and 13.7 pCi/L (0.51 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 2019 milk samples.

10.1.1.3 Cesium-137.

No cesium-137 was detected in milk samples collected and analyzed in 2019.

10.1.1.4 Potassium-40.

Naturally occurring potassium-40 was detected in all milk samples collected in CY 2019. Concentrations ranged from a maximum of 1,640 pCi/L (61 Bq/L) in a Sagemoor area sample to a minimum of 1,320 pCi/L (49 Bq/L) in a Sagemoor area sample.

10.1.2 Fruit, Vegetables, and Farm Products

Alfalfa, apricot, corn, leafy vegetable (e.g., lettuce), melon, potato, tomato, and wine must samples were collected from upwind and downwind sampling areas during the CY 2019 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 2019.

An individual leafy vegetable sample (East Wahluke) had a detectable concentration of beryllium-7; however, these concentrations were within historical range and follow typical result patterns. One additional sample of leafy vegetables (Sunnyside) had a detection of strontium-90 but the value reported (0.075 pCi/L; 0.003 Bq/L) was well below DOE project dose-based reporting limits and was within historical limits measured at this location. All remaining fruit and vegetable contaminant concentrations were reported as non-detects (with the exception of naturally-occurring potassium-40) and were well within historical range.

All wine must samples collected in CY 2019 had detectable concentrations of tritium within the historical range, but concentrations were slightly lower than those seen in CY 2018. Mattawa area wine had an average of 17.1 pCi/L (0.63 Bq/L), Columbia Basin wine had average tritium results of 55.8 pCi/L (2.1 Bq/L) and Yakima Valley had an average of 13.5 pCi/L (0.50 Bq/L). All wine must values for 2019 were well below the Washington State drinking water standard of 20,000 pCi/L (740 Bq/L).

Maximum tritium levels from irrigation water collected in the Riverview (16.0 pCi/L; 0.59 Bq/L) and the Sagemoor (18.7 pCi/L; 0.70 Bq/L) area were comparable, while the Horn Rapids (38.8 pCi/L; 1.4 Bq/L) area was slightly higher.

The 2019 irrigation results were similar to concentrations reported in the fixed-station locations in Richland, Washington, and at Priest Rapids Dam. The Columbia River Priest Rapids Dam fixed-station water average tritium concentration was 17.5 pCi/L (0.65 Bq/L), while the Columbia River Richland Pumphouse fixed-station water had an annual average of 29.7 pCi/L (1.10 Bq/L).

10.2 Fish and Wildlife Monitoring

JW Wilde

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during the CY 2019 included mountain whitefish (*Prosopium williamsoni*), walleye (*Prosopium williamsoni*), and Canada goose (*Branta canadensis*). Monitoring fish and wildlife for uptake and

exposure to Hanford Site operations-produced contaminants ensures that consumption of fish and wildlife obtained from Hanford Site environs does not pose a threat to human health and provides long-term contamination trends. These species were selected and analyzed 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 2019. 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 analyzed for strontium-90 contamination and analyzed by gamma spectrometry to detect a number of gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples.

Most fish and wildlife samples are collected on and around the Hanford Site and analyzed for human-pathway exposure every 2 to 3 years, with samples obtained at locations determined not to be affected by Hanford Site effluents and emissions approximately every 5 years.

Strontium-90 is present in Hanford Site environments because of past Hanford Site operations and waste disposal practices. Contaminated groundwater entering the Columbia River through shoreline springs in the 100-N and 100-H Areas is the primary source of measurable Hanford Site-produced strontium-90 in the Columbia River. Chemically similar to calcium, strontium-90 consequently accumulates in hard tissues rich in calcium such as bones, antlers, and eggshells. In addition, strontium-90 has a biological half-life in hard tissue from 14 to 600 days (PNL-9394, *Ecotoxicity Literature Review of Selected Hanford Site Contaminants*). Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90; however, because strontium-90 does not accumulate in edible portions of fish and wildlife, it generally does not contribute much to the human dose (NCRP 2009).
Cesium-137 is present in Hanford Site environments because of past Hanford Site operations, waste disposal practices, and from historical worldwide fallout resulting from nuclear weapons testing. Cesium-137 is particularly important to the human food chain because the isotope is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Cesium-137 is an indicator of recent exposure to radioactive materials because it has a relatively short biological half-life (less than 200 days in muscle and less than 20 days in the gastrointestinal tract [PNL-9394]).

Gamma spectrometry results for most radionuclides generally are too low to measure or the concentrations measured are considered artifacts of low background counts. Low background counts occur at random intervals during sample counting and can produce occasional spurious false-positive results. For many radionuclides, concentrations were below analytical laboratory detection levels.

A number of trace metals associated with Hanford Site operations have a potential to accumulate in certain fish and wildlife tissues. These metals are contaminants of potential concern (e.g., copper, lead, and mercury), particularly along the Hanford Site Columbia River shoreline where contaminated groundwater flows into the river. Hanford Site historical operations have resulted in the production of both radiological and non-radiological wastes, including trace-metal emissions in a variety of forms including: liquid and solid wastes that were placed in disposal sites (trenches, cribs, ditches, ponds), underground storage tanks and fly ash (produced from burning coal in coal-fired steam/power plants) released to the atmosphere. The fly ash contains trace metals and natural radionuclides that may have deposited on soil surfaces around the 100 Area reactors.

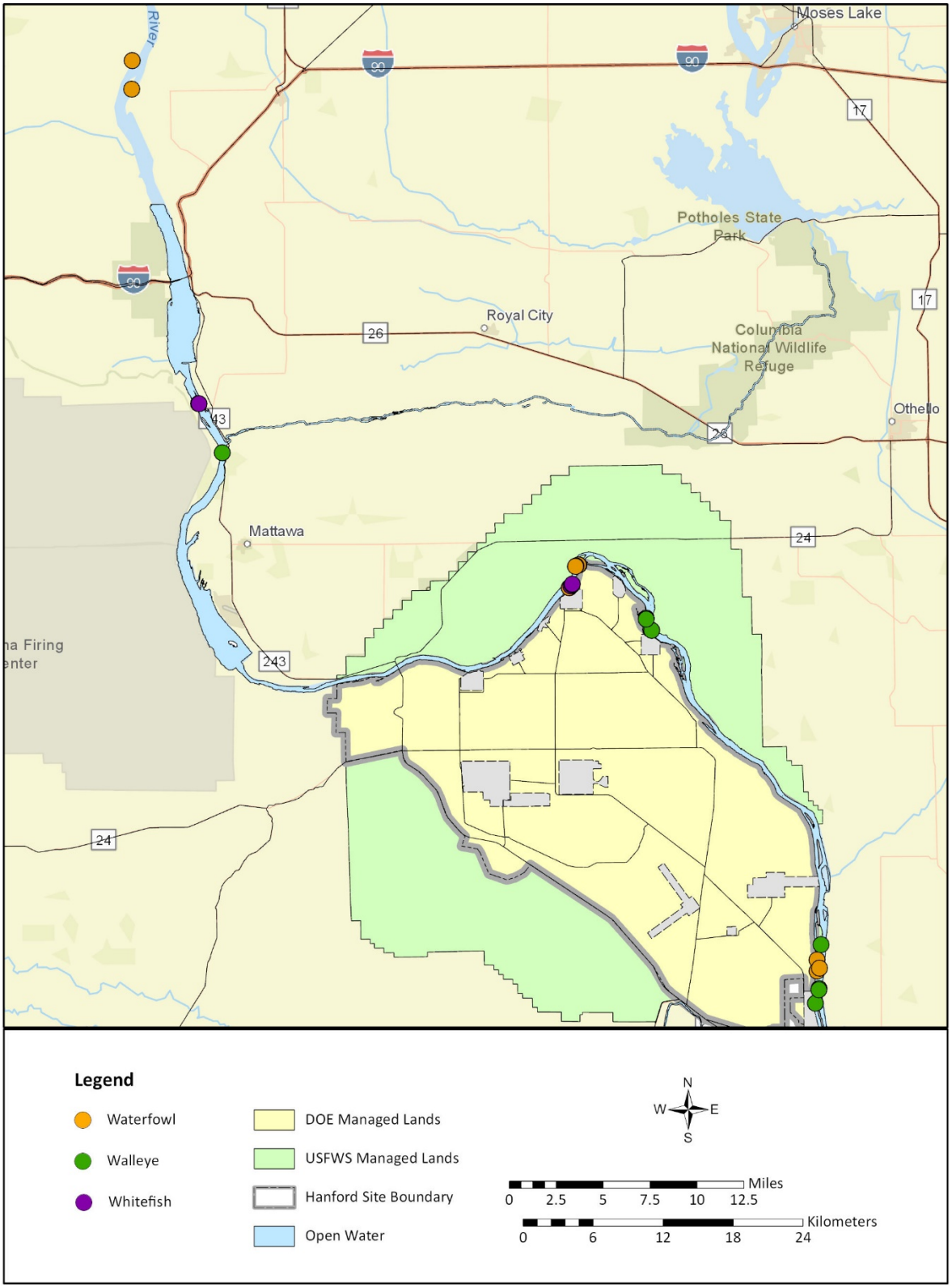


Figure 10-2. Animal Monitoring Locations.

Table 10-2. Wildlife Monitoring Analysis.

Biota	Offsite Locations	Onsite Locations	Gamma	Strontium-90	Trace Metals
Fish (mountain whitefish)	1	2	9	9	2
Fish (walleye)	1	2	10	10	2
Waterfowl (Canada goose)	1	2	10	10	0

10.2.1 Mountain Whitefish

In 2019, mountain whitefish were sampled and analyzed for radiological contaminants. Whitefish are harvested for food along the Hanford Reach of the Columbia River, and could potentially contribute to human exposure through ingestion. Many sportsmen have found that the flesh of the whitefish is of good quality, being firm, palatable, and tasty with a bony structure similar to trout.

Eight mountain whitefish were collected from two locations along the Hanford Reach, including a reference area (five along the 100-D shoreline, and three from the reference location at Priest Rapids Lake above Priest Rapids Dam). One whole fish from the 100 Areas was sent to the Washington State Department of Health (WDOH). Eight filet samples, including one duplicate, were submitted for analysis. Six carcass samples, including one duplicate, were submitted for analysis.

10.2.1.1 Cesium-137.

Manmade gamma-emitting radionuclide cesium-137 was not detected above the lab detection limit (0.092 pCi/g [0.003 Bq/g] wet weight) in any of the whitefish filet samples analyzed. The lab detection limit is well below the 0.340 pCi/g [0.013 Bq/g] DOE reporting limit. These results are consistent with those reported historically near the Hanford Site.

10.2.1.2 Strontium-90.

Manmade gamma-emitting radionuclide strontium-90 was not detected above the lab detection limit and was not detected above the far-field environmental surveillance dose-based reporting limit (0.039 pCi/g [0.001 Bq/g] wet weight) in any of the whitefish filet samples analyzed. The lab detection limit is well below the 0.14 pCi/g (0.005 Bq/g) DOE dose-based reporting limit.

10.2.1.3 Uranium.

Uranium isotopes (uranium-234, uranium-235, uranium-238) were not detected above laboratory detection limits (0.024pCi/g [0.001 Bq/g] wet weight) in any samples submitted. These results are consistent with those reported historically near the Hanford Site.

10.2.1.4 Trace Metals.

Two whitefish samples were analyzed for 19 different trace metals. Nine trace metals were detected in samples above the analytical detection limit at any location. Table 10-3 provides a summary of the 2019 metal analyses for the whitefish samples.

Table 10-3. Metals Analyses for the Mountain Whitefish Samples.

Isotope	Samples	Detects
Aluminum	2	0
Antimony	2	1
Arsenic	2	0
Barium	2	0
Beryllium	2	0
Cadmium	2	0
Chromium	2	0
Copper	2	2
Lead	2	2
Manganese	2	2
Mercury	2	2
Nickel	2	0
Selenium	2	2
Silver	2	0
Thallium	2	1
Thorium	2	0
Uranium	2	1
Zinc	2	2

Surveillance data sets for trace-metal concentrations in fish both on and near the Hanford Site are relatively small with variable results. At this time, no established federal or state adverse-effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue. Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about contribution effects are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment. The WDOH lists mountain whitefish as a species retaining high concentrations of chemical contaminants and metals, and consumption should be limited to one meal per month (https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories).

10.2.2 Walleye

In 2019, walleye were sampled and analyzed for radiological contaminants. Walleye are a major game fish and a favorite food along the Hanford Reach of the Columbia River for anglers and could potentially contribute to human exposure through ingestion. Many sportsmen have found that the flesh of the walleye is one of the best eating freshwater fish anywhere.

Nine walleye were collected from three locations along the Hanford Reach, including a reference area (four from waters adjacent to the 100 Areas, four fish from waters adjacent to the Hanford Townsite through the 300 Area, and one fish from Priest Rapids Lake above Priest Rapids Dam). One whole fish was sent to the WDOH. A total of 10 filet and carcass samples (including duplicates) were submitted for analyses. The following are the radiological results for the walleye samples analyzed.

10.2.2.1 Cesium-137.

Manmade gamma-emitting radionuclides including cesium-137 was not detected in any walleye sample above the lab detection limit (0.09 pCi/g [0.003 Bq/g] wet weight) for the filet samples analyzed. These results are consistent with those reported historically near the Hanford Site.

10.2.2.2 Strontium-90.

Strontium-90 was not detected above the lab detection limit (0.04 pCi/g [0.001 Bq/g] wet weight) in any of the walleye filet samples. These results are consistent with those reported historically near the Hanford Site.

10.2.2.3 Uranium.

Uranium isotopes (uranium-234, uranium-235, and uranium-238) were not detected above lab detection limits in any of the walleye filet samples. These results are consistent with those reported historically near the Hanford Site.

10.2.2.4 Trace Metals.

Two walleye filet samples were analyzed for 18 different trace metal concentrations. Only Zinc was detected in samples that were above the analytical detection limit at any location. Table 10-4 provides a summary of the 2019 metal analyses for the whitefish samples. Uranium metal detections in these analyses are not radioactive isotopic analyses as described in the paragraph above.

Table 10-4. Metals Analyses for the Walleye Samples.

Isotope	Samples	Detects
Aluminum	2	0
Antimony	2	1
Arsenic	2	1
Barium	2	1
Beryllium	2	0
Cadmium	2	0
Chromium	2	0
Copper	2	1
Lead	2	0
Manganese	2	1
Mercury	2	0
Nickel	2	0
Selenium	2	2
Silver	2	0
Thallium	2	0
Thorium	2	0
Uranium	2	1
Zinc	2	2

Surveillance data sets for trace-metal concentrations in fish both on and near the Hanford Site are relatively small with variable results. At this time, no established federal or state adverse-effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue. Identifying Hanford

Site contributions to trace-metal concentrations or drawing conclusions about contribution effects are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment. The WDOH lists walleye as medium concern as a species retaining concentrations of chemical contaminants and metals within the Hanford Reach; consumption should be limited to two meals per month (https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories).

10.2.3 Waterfowl

During 2019, 14 Canada geese were collected along the Hanford Reach of the Columbia River: 5 between the Hanford Townsite and the 300 Area, 5 near the 100 Areas, and 4 geese from the reference area in the Wanapum pool area. Sampling efforts focused on young of the year birds whose entire life cycle before collection would have occurred on the Hanford Site. Two geese were submitted to WDOH, the remaining 12 geese were analyzed for cesium-137 in muscle and strontium-90 in bone. Radionuclide levels found in muscle and bone samples analyzed during 2019 were compared with levels measured in waterfowl samples collected at the Hanford Site over the past eight sample evolutions and with samples collected from reference locations, where available.

10.2.3.1 Cesium-137.

Manmade gamma-emitting radionuclides, cesium-137 were below the detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) for all Canada goose muscle samples analyzed in 2019. These results are consistent with those reported over the past 15 years.

10.2.3.2 Strontium-90.

Strontium-90 results were below the analytical detection limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in samples collected in 2019. Comparisons of the maximum and median strontium-90 concentrations reported for waterfowl bone samples (collected at the Hanford Site since 1999) and reference locations are consistent with these results, which do not indicate elevated strontium-90 levels. Figure 10-3 shows the median and maximum strontium-90 concentrations (pCi/g wet weight) and reference waterfowl samples for 2019 compared to previous years. Note that maximum concentrations in the figure are represented by the upper bar.

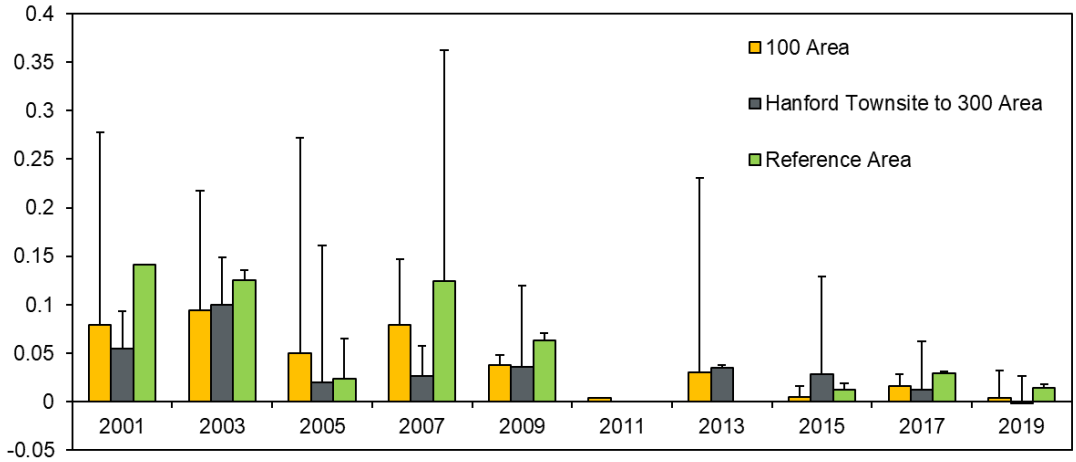


Figure 10-3. Strontium-90 Concentrations in Canada Goose Bone Samples.

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 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 most recently collected in CY 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 2019 are depicted in Table 10-5. The number of vegetation samples per operational area are summarized in Table 10-6.

Table 10-5. Hanford Site Vegetation Monitoring Locations and Sample Analyses.

Location	EDP Codes[a]	Collection Period	Analyses
100-N Area	Y719, Y724	May-June	90Sr, Pu-Iso, U-Iso, GEA
200-East Area	V053, V055, V057, V061, V063b, V065, V075, V077, V079, V141c	May-June	90Sr, Pu-Iso, U-Iso, GEA
200-West Area	V019, V025, V029, V031, V037, V039, V041, V043, V047b, V049, V051	May-June	90Sr, Pu-Iso, U-Iso, GEA
Plutonium Finishing Plant (200-West Area)	V007, V009 , V045b, V111c	May-June	90Sr, Pu-iso, U-iso, GEA, 241Am
300 Area	V123b, V132c	May-June	90Sr, Pu-Iso, U-Iso, GEA
600 Area	V081, V083, V085, V087, V089, V091b, V095, V097, V099, V101, V103, V107, V109, V113c, V143c	May-June	90Sr, 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, 239/240Pu)
U-iso = isotopic uranium (234U, 235U, 238U)
WDOH == Washington State Department of Health

Table 10-6. Number of Vegetation Samples per Operational Area.

Number of Samples	Operational Area (discrete samples analyzed)				
	100-N	200-East [a]	200-West [a]	300 Area[a]	600 Area[a]
44	2	10	15	2	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 2019*. 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 three vegetation monitoring locations (V007, V009, and V045) near the PFP complex.

10.3.1.2 Vegetation Monitoring Results.

The analytical results from Hanford Site vegetation samples collected in CY 2019 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 2019. 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 2019 were similar to or slightly higher than concentrations in samples collected further away, including concentrations measured offsite in 2019. Cesium-137, strontium-90, plutonium-239/240, uranium-234, and uranium-238 were detected in the 2019 vegetation samples at locations and concentrations consistent with previous years. Figure 10-4 shows the annual average vegetation concentrations of selected radionuclides in the 100, 200, 300, and 600 Areas. There were no vegetation samples collected from the 400 Area due to lack of available vegetation. Appendix C, Table C-20 shows the annual average and maximum concentrations of radionuclides in vegetation samples by area during 2019 and for the preceding 5 years.

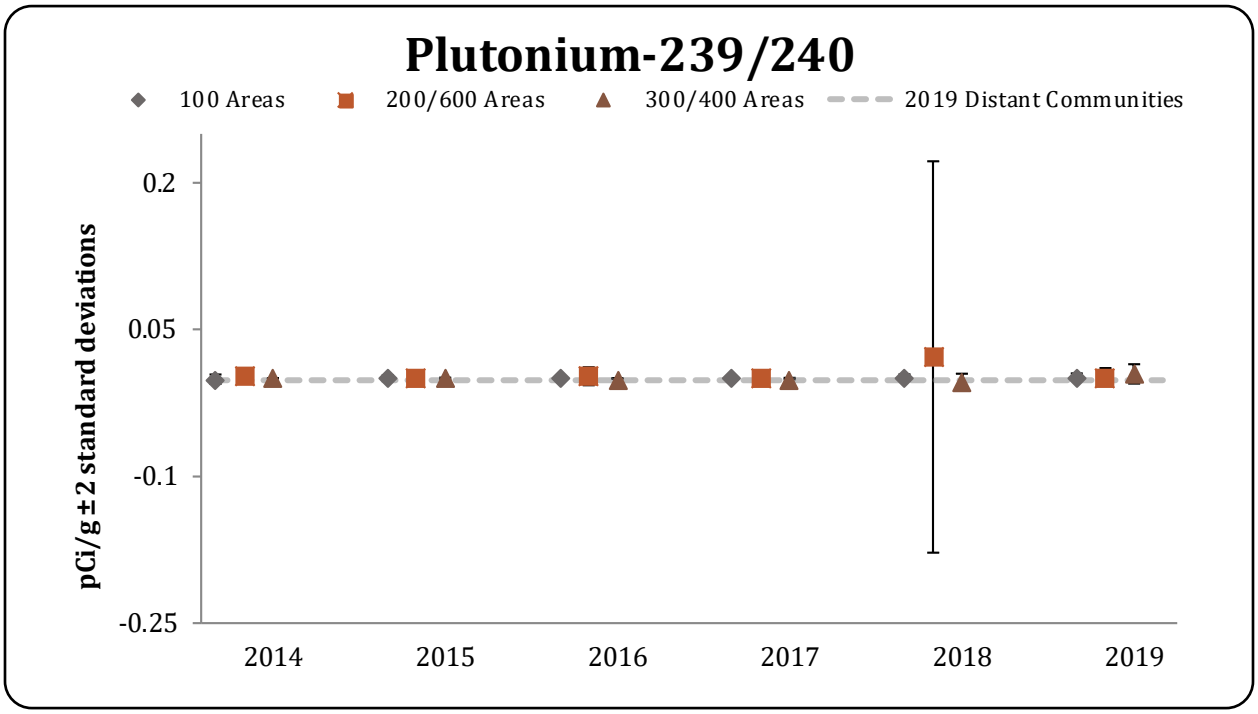
Uranium. Uranium-234 and uranium-238 concentrations were similar to historical levels, however, the frequency of detection was lower than what had been observed in previous years.

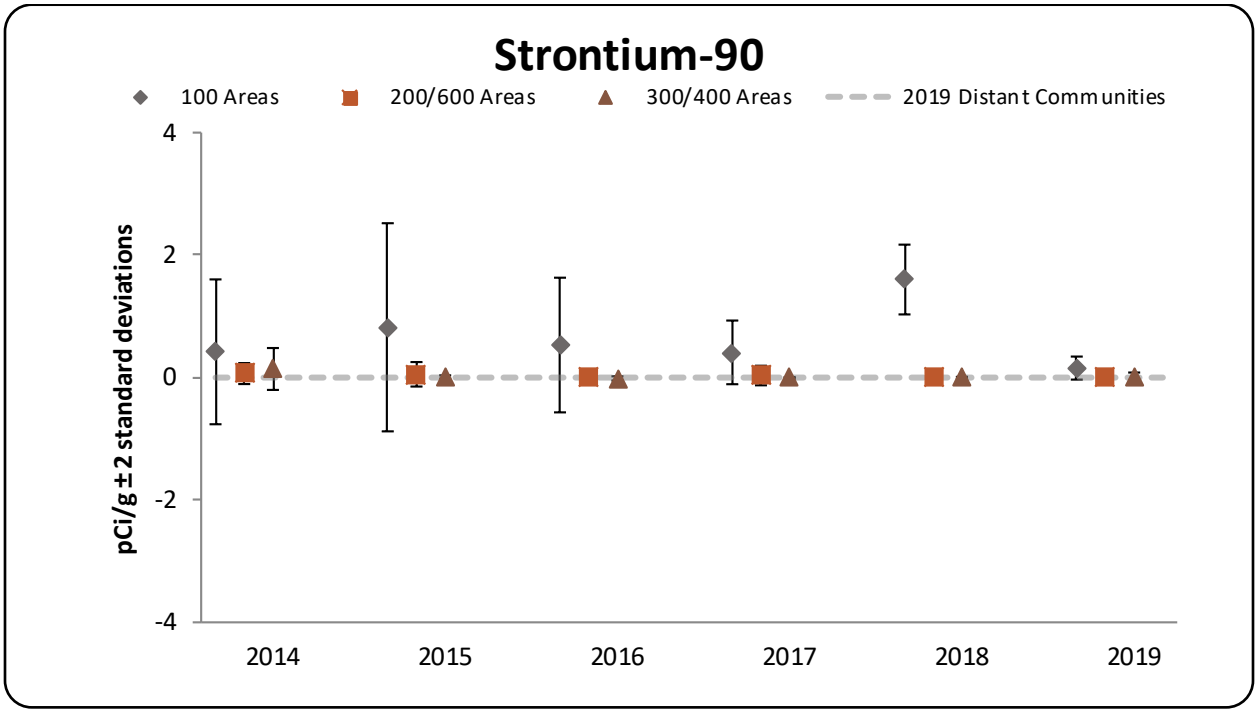
Plutonium. Plutonium-239/240 was detected in 33% of the vegetation samples collected in the 200-West Area. The concentrations measured were within historical ranges.

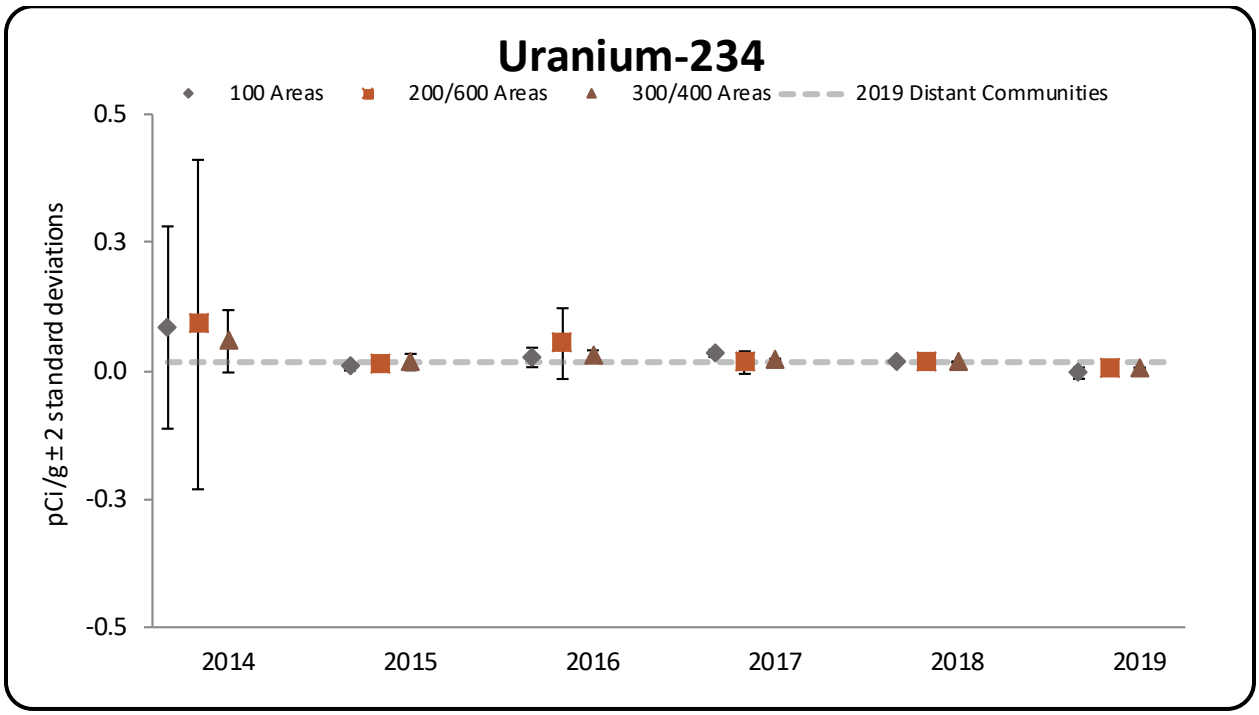
Strontium-90. Strontium-90 was detected in both of the samples collected at 100-N and in approximately 40% of the samples collected in the 200-East Area. Concentrations of strontium-90 were within historical ranges.

Cesium-137. Cesium-137 was detected in approximately 16% of the samples collected in the 200 and 600 at concentrations similar to those seen in historical data.

Americium-241. In support of the 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 three vegetation monitoring locations (V007, V009, and V045, plus a duplicate sample collected at V045) near the PFP complex. Americium-241 was detected in two of the four samples analyzed for americium-241. The americium 241 concentrations were lower than what has been seen in the previous 3 years of analyzing for americium-241.


Plutonium-239/240
100 Areas
200/600 Areas
300/400 Areas
2019 Distant Communities
pCi/g ± 2 standard deviations
0.2
0.05
-0.1
-0.25
2014
2015
2016
2017
2018
2019


Strontium-90
100 Areas
200/600 Areas
300/400 Areas
2019 Distant Communities
pCi/g ± 2 standard deviations
4
2
0
-2
-4
2014
2015
2016
2017
2018
2019



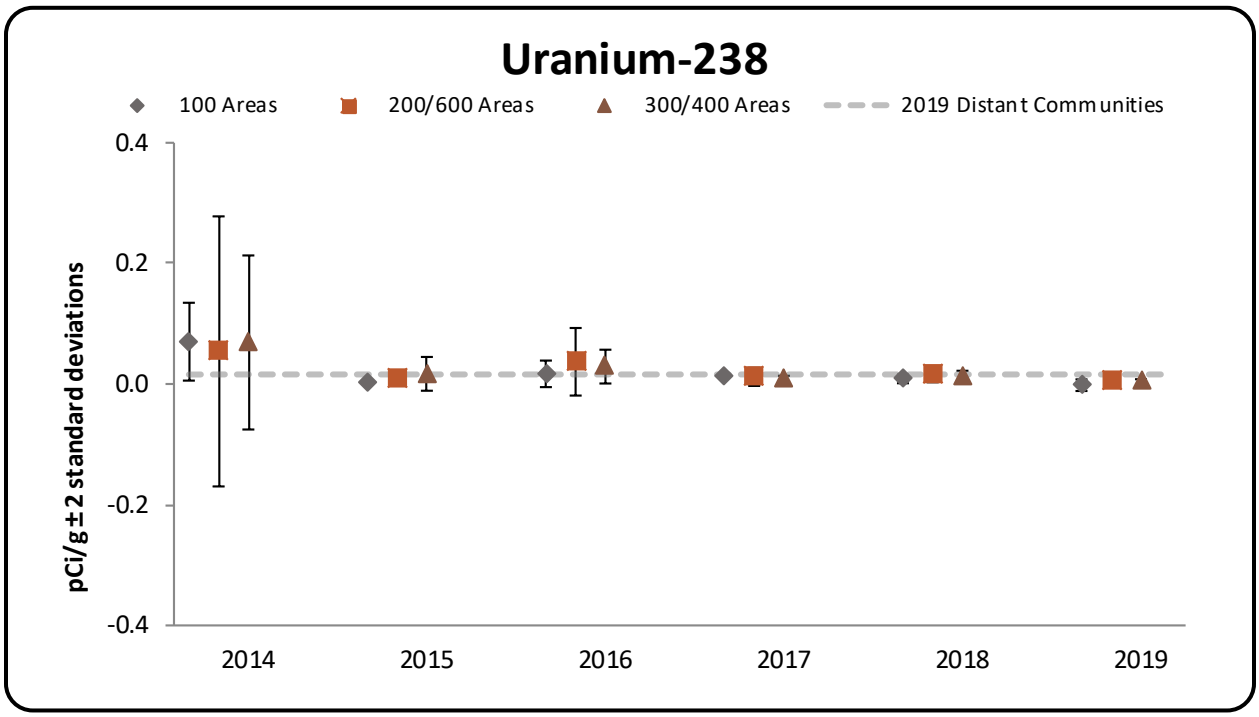


Figure 10-4. Hanford Site Vegetation Average Concentrations of Selected Radionuclides.

10.3.2 Offsite Vegetation Sampling

Vegetation samples from offsite locations are collected every 3 to 5 years. 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 the handbook DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

During 2019, vegetation samples were collected from eight locations around the perimeter of the Hanford Site and nearby and distant communities. The locations and analyses of offsite vegetation samples collected in CY 2019 are depicted in Table 10-7.

Table 10-7. Offsite Vegetation Monitoring Locations and Sample Analyses.

Soil Monitoring Location[a, b]	EDP Codes[c]	Analyses
Ringold	V427	GEA, ^{90}Sr, U-iso, Pu-iso
Sagemoor Farms	V430, V493[d]	GEA, ^{90}Sr, U-iso, Pu-iso
Byers Landing	V431	GEA, ^{90}Sr, U-iso, Pu-iso
Sunnyside	V434	GEA, ^{90}Sr, U-iso, Pu-iso
George	V439[e]	GEA, ^{90}Sr, U-iso, Pu-iso
Othello	V440[e]	GEA, ^{90}Sr, U-iso, Pu-iso
Wanapum	V441[e]	GEA, ^{90}Sr, U-iso, Pu-iso

[a] Samples are collected approximately every 3 to 5 years
[b] Samples were collect in June 2019
[c] EDP Code=environmental data point code = sample location code
[d] Quality assurance duplicate sample
[e] Collocated sampling location with WDOH
GEA = Gamma Energy Analysis
^{90}Sr = strontium-90
Pu-iso = isotopic plutonium (plutionium-238, plutonium-239/240)
U-iso = isotopic uranium (uranium-234, uranium-235, uranium-238)
WDOH = Washington State Department of Health

10.3.2.1 Offsite Vegetation Sampling Results

The analytical results from vegetation samples collected from around the perimeter of the Hanford Site and nearby and distant communities in CY 2019 are summarized in Appendix C, Table C-21. Radionuclide concentrations in vegetation samples collected in CY 2019 at offsite locations were compared to results from 2001, 2004, 2008, and 2015. In 2019, the observed average and maximum concentrations in vegetation samples for all isotopes were generally similar to their respective averages and maximums from 2001, 2004, 2008, and 2015. With the exception of uranium, the Hanford sitewide average vegetation concentrations in 2019 were similar to or slightly higher than those seen at site perimeter and distant locations for the radionuclides measured (Appendix C, Table C-22). The average concentration for uranium was slightly higher in samples collected from offsite locations, with the maximum concentration measured in a sample collected from Othello.

10.3.3 Radiological Contamination Surveys

Radiological surveys were 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 2019 identified 29 instances of radiological contamination in vegetation. All 29 were Russian thistle (*Salsola tragus*) plants or fragments. Of the 29 instances, 2 locations were posted as a contamination areas and 27 were cleaned up and disposed of at a licensed facility.

Section 10.3.4 provides a discussion of the vegetation control on the Hanford Site. Table 10-8 summarizes the general locations of vegetation contamination incidents discovered in CY 2019. Table 10-9 provides the number of contamination incidents from 2000 to 2019.

Table 10-8. Hanford Site Vegetation Contamination Occurrences Discovered in Calendar Year 2019.

Location	2019 Incidents
100 Area	0
200-East Area	
Tank farms	5
Burial grounds	4
Cribs, ponds, and ditches	3
Fence lines	0
Roads and railroads	1
Unplanned release sites	0
Underground pipelines	0
Liquid Effluent Treatment Facility/Effluent Treatment Facility	6
Miscellaneous	0
200-West Area	
Tank farms	1
Burial grounds	2
Cribs, ponds, and ditches	4
Fence lines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	0
Miscellaneous	3
Cross-site transfer line	0
200-North Area	0
300 Area	0
400 Area	0
600 Area	0
Total	**29**

Table 10-9. Hanford Site Vegetation Contamination Occurrences from 2000 through 2019.

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
2019	**29**

10.3.4 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 6,365 ac (2,576 ha) were treated with herbicides in 2019 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.

10.3.4.1 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 72 ac (29 ha) of noxious weeds on the Hanford Site were treated with herbicides in 2019. 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 2019 included: diffuse knapweed (*Centaurea diffusa*), rush skeletonweed (*Chondrilla juncea*), Saltcedar (*Tamarix spp.*), Tackweed (*Tribulus terrestris*), and phragmites (P*hragmites spp.*).

10.4 Waste Site Remediation and Revegetation

RC Roos, JM Rodriguez

In 2019, 125 ac (51 ha) across the Hanford Site were revegetated in an effort to restore native plant communities on revegetation and restoration sites including cleaned-up waste sites and revegetated mitigation sites. Revegetation efforts were uniquely planned for each site depending on condition of the site and expectations. Work at the sites may have included soil preparation, seeding of grass and forb species, mulching, and hand planting forb and shrub seedlings. Sites where revegetation efforts were performed include the following: 600-30, 100-N Reactor, C9L3 Road, 100-N South, 128-D-2 East, 128-D-2 West, 628-3, 600-356, 600-100, 600-301, 600-370, 600-120, 100-K-95, 600-385, 600-358, 124-N-10, 130-N-1, 100-N-CTA, 116-C-5 Retention Basin, and 116-B/C-Misc. Approximately 47,000 seedlings were hand planted as part of the revegetation effort.

10.5 References

DOE-HDBK-1216-2015. *Environmental Radiological Effluent Monitoring and Environmental Surveillance*. U.S. Department of Energy, Washington, D.C.

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NCRP. 2009. *Ionizing Radiation Exposure of the Population of the United States*. Report No. 160. National Council on Radiation Protection and Measurements, Washington, D.C.

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.

2019 Highlight

The initial phase of the Conservation Habitat Assessment and Mitigation Prioritization (CHAMP) for the Hanford Site was completed in 2019. The CHAMP provides an ecosystem-level approach to identifying areas of highest priority for conservation and restoration on the U.S. Department of Energy, Richland Operations Office-managed lands of the Hanford Site.

The peak annual Hanford Reach fall Chinook salmon redd (nest) count for 2019 (7,899) was the ninth lowest count (range: 4,018 – 20,678) in the past 20 years (2000 – 2019) and was well below the previous 10-year average (11,247).

Four Ferruginous Hawk nests were occupied on the Hanford Site in 2019. At least two of these nests were successful, producing two young per nest for a total of four 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 in 2019 was 2,395, while peaks counts at 183-F Clearwell were 1,959 in 2019.

Artificial burrows for Burrowing Owls were monitored for activity. Two new nests were located in the new Artificial Burrow designs. All hatch year young from these nests were banded and released back to the burrow.

Twenty bee nest boxes were installed on the Hanford Site in 2019. These bee nest boxes will be monitored for 5 years post-installation to determine their effectiveness in replacing lost bee nesting habitat. A total of 25% of the nest boxes were occupied in 2019 monitoring.

The riparian vegetation mapping effort along the Hanford Reach of the Columbia River continued in 2019. 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 71 *National Historic Preservation Act* Section 106 cultural resources reviews.

During 2019, 20 items were reviewed, cleared for public release, and /or transferred to the Hanford History Project repository for integration with the Hanford Collection. Nineteen artifacts and 1 linear ft (30.5 cm) 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 20 (2.7%) of the 744 tagged artifacts onsite. They are scheduled for collection between 2020 and 2048.

11.0 Resource Protection

11.1 Ecological Protection

JW Wilde, KJ Cranna, ES Norris, JJ Nugent

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 the Hanford Site 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 Hanford 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* (ESA); *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

[1]The DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement,* uses a different acronym (BRMaP, in place of BRMP used here) for abbreviating the *Hanford Site Biological Resource Management Plan* document.

- Providing data for environmental impact and ecological risk assessments
- Providing information and maps of the distribution and condition of biological resources at the Hanford Site
- Supporting Hanford Site land-use planning and stewardship.

Hanford Site ecological monitoring activities provide information useful to the Hanford Site natural resource stakeholders and the public on the status of some of the 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.

11.1.1 Conservation Habitat Assessment and Mitigation Prioritization

JW Wilde, JJ Nugent

The initial phase of the Conservation Habitat Assessment and Mitigation Prioritization (CHAMP) for the Hanford Site was completed in 2019. This phase of the habitat assessment and prioritization identifies priority conservation areas based on current health, size, and status of native habitats and species and initiates the identification of priority mitigation areas. The products from this analysis form the foundation for continued assessments. The impetus for the CHAMP is to take a landscape approach to evaluating habitat quality on the U.S. Department of Energy, Richland Operations Office (DOE-RL)-managed portion of the Hanford Site (study area) and use the results to determine areas for conserving, restoring, mitigating, and connecting habitats.

The scope and scale of this habitat assessment and prioritization will help integrate key ecological data from the Hanford Site with data from other parties (e.g., U.S. Fish and Wildlife Service [USFWS], Washington Department of Fish and Wildlife [WDFW], Yakima Training Center) who's natural resource protection and restoration goals align within the broader landscape surrounding the Hanford Site, including the Columbia Plateau Ecoregion. This integration of data and coordination of actions is especially important between the DOE-RL-managed portion of the Hanford Site and the adjacent USFWS-managed Hanford Reach National Monument.

The CHAMP provides an ecosystem-level approach to identifying areas of highest priority for conservation and restoration on the DOE-RL-managed lands of the Hanford Site in south-central Washington State. The approach (Marxan analysis) is a spatially explicit habitat assessment and habitat prioritization that analyzes a diverse array of existing vegetation, species-specific data, and abiotic data traditionally collected on the Hanford Site.

This habitat assessment and prioritization is compatible and complementary to other efforts on the Hanford Site (e.g., DOE/EIS-0222-F and DOE/RL-96-32) and in the greater Columbia Plateau Ecoregion (e.g., the Arid Lands Initiative [ALI 2014] and the Washington Wildlife Habitat Connectivity Working Group [WHCWG]).

Marxan is the most widely used systematic conservation planning tool in the world based on the minimum set problem, stated as "What is the minimum number of sites, or minimum total area,

necessary to represent all species/habitats?" Within Marxan, targets for conservation features, weightings (penalties) of conservation features, and costs (constraints) can be varied, allowing for repetitious solutions. Marxan produces a range of results that meet conservation objectives that increase possibility of finding solutions that maximize targets while minimizing negative impacts and can lead to identification of unforeseen solutions (Ardon et al. 2010).

Three focal habitats (shrub-steppe, grasslands, and dunes) and one group of species (burrowing animals) were selected to guide the habitat assessment and prioritization. These focal habitats and species (including nested species and/or microhabitats) had the available data necessary to characterize the highest percentage of all species/habitats found on the study area. They met the following goals:

- Represent biodiversity at the Hanford Site and the functions occurring across this landscape
- Reflect ecoregional priorities for the Columbia Plateau Ecoregion
- Consider viable or restorable within this landscape
- Are threatened and, therefore, in need of conservation attention or strategy adjustment for achieving DOE-RL's objectives for the Hanford Site.

Once the focal habitats and species were identified, a viability assessment was developed for each of the focal groups. The intent of the viability assessment is to organize current understanding and knowledge of each habitat or species in a way that evaluates how to know whether that habitat has ecological integrity or the species is viable. Viability, or ecological integrity, quantifies whether the habitat or species is resistant to change in its structure or composition in the face of external stresses or resilient in light of those stresses — that is, able to recover from occasional severe stress (FOS 2009).

Key ecological attributes (KEAs) were recognized and developed for each focal habitat or species and indicators were identified to assess the quality of each KEA. One or more indicators are necessary to quantify each KEA. Indicators are measurable aspects of the KEA that provide information on its status. In order for the indicator values to be compatible with the Marxan analysis they were categorized using a rating system of Poor, Fair, Good, and Very Good. Marxan requires inputs of spatially explicit, digital layers that represent each KEA-indicator. Each of these input layers represent a Marxan target.

Eleven KEAs were identified for quality focal habitats and species and 21 indicators were used to represent the 11 KEAs. The focal habitats and species along with their KEA-indicator pairs are shown in Table 1. Several KEA-indicator pairs (e.g., fire regime, presence of critical or unique habitats and species, and density of noxious weeds) were shared between focal habitats and species.

Table 11-1. Summary of the Focal Habitats or Species Key Ecological Attributes and their Indicators. (2 Pages)

Focal Habitat or Species and KEA	Indicator
Shared Attributes	
Fire Regime	Low Freq. Fire Regime (Shrub and Dunes)
Fire Regime	High Freq. Fire Regime (Grasslands)

Table 11-1. Summary of the Focal Habitats or Species Key Ecological Attributes and their Indicators. (2 Pages)

Focal Habitat or Species and KEA	Indicator
Critical Habitat or Species	Presence of Critical, Unique Habitats or Species
Vegetative Composition	Density of Noxious Weeds
Shrub-steppe	
Absolute Patch Size	Absolute Shrub Patch Size (Area)
Connectivity	Connectivity/Proximity to Other Shrub Patches
Vegetative Composition	Type of Vegetation Cover in Shrub-steppe
Native Shrub Cover	Percent of Native Shrub Cover (High Freq.)
Wildlife Community	Sagebrush Obligate Wildlife Presence
Dunes	
Soil Type	Presence of Sandy Soil
Absolute Patch Size	Acreage of Open Sand (Area)
Connectivity	Connectivity/Proximity to Other Dune Patches
Vegetative Composition	Type of Vegetation Cover in Dunes
Ecosystem Intactness	Rare Dune Plant Species Presence
Grasslands	
Absolute Patch Size	Absolute Grassland Patch Size (Area)
Connectivity	Connectivity/Proximity to Other Grassland Patches
Vegetative Composition	Type of Vegetation Cover in Grasslands
Native Shrub Cover	Percent of Native Shrub Cover (Low Freq.)
Burrowing Animals	
Ground Squirrel Habitat	Ground Squirrel Habitat Model Areas
Burrowing Owl Habitat	Burrowing Owl Habitat Model Areas
Connectivity	Connectivity Among Ground Squirrel Colonies

After Marxan targets are defined, users must assign a relative level or goal for each target. The goal for each target is the desired percentage of the target's area that should be included in the Marxan conservation solution. When possible, target levels should be based on scientific data to maintain the integrity of ecosystems; however, economic concerns and political goals can be considered.

Another requirement of a Marxan analysis is the development of a single input layer that represents how all constraints vary across the landscape. Constraints (also called costs) can be factors that limit the ability of the habitat to function as normal (e.g., physical barriers like roads) or factors that limit the abilities to intervene or manage biological resources (e.g., contamination or zoned areas). Depending on the particular application that Marxan is being used for, the constraints that this input layer represents can be based on physical or biological limitations, management guidelines, or rules and policies governing the future use of the land. Eleven categories and 73 sub-categories of constraints on the study area were used in the analysis including areas under industrial use or highly disturbed areas zoned for development under the CLUP, National Historical Park sites, waste sites, utility towers and lines, roads, railroads, structures, fences, wells, and borrow pits.

Once the Marxan targets and target goals were selected, calibration was performed to ensure that Marxan-produced solutions were optimized or close to the lowest cost. Values within the function that typically require calibration are the Species Penalty Factor (SPF), Boundary Length Modifier (BLM), number of iterations, and the constraint layer range (effect). With goals invoked by this study, Marxan runs successfully met the targets in most cases over a variety of runs, iterations, and BLM manipulations. Therefore, performing a calibration for SPF to apply to unmet targets would have little bearing on the solutions.

The BLM is used to improve the spatial clustering and compactness of the solutions (Ardon 2010). If a BLM is set to 0, then solutions will be formed with no regard to their overall pattern and are typically dispersed and result in a fragmented solution. As BLM is increased, Marxan solutions show more connection and clumping as the algorithm begins to favor the selection of units adjacent to already selected units over isolated units that otherwise achieve target goals (ALI 2014). Managing compliance and conservation of small, dispersed, and fragmented habitats can be a difficult and undesirable task. Therefore, achieving a level of clustering that maximizes the trade-off of minimizing the boundary length of a solution while minimizing the overall solution cost is the desired goal when calibrating a BLM.

Initial calibrations of BLM were performed from BLM values of 0 to 5, refined and run from 0 to 2, and then further refined to BLM Values between 0.1 and 0.95 BLM. The values were plotted on a graph consisting of total cost on the x-axis and the total boundary length on the y-axis; the point on the curve at which there is a relatively large decrease in total boundary length (clumping) is associated with a relatively small increase cost that can be considered the desired BLM value. Using this technique, a BLM value of 0.46 was selected.

The simulated annealing solver in Marxan requires a large number of iterations to find quality solutions (Ardon et al. 2010). Marxan analysis for this study was performed with 100 runs. Each run produces its own unique solution, increasing the number of iterations per run allows Marxan to spend more time converging towards similar solutions across those runs. Solution time increases with the number of iterations, so there are practical limits on the number of iterations that can be considered reasonable. At some point it becomes far more useful to have an adequate number of restarts (new runs) than to try to ensure the efficiency of an entire solution set (Ardon et al. 2010). This study followed a similar approach to the ALI (2014), running the analysis 100 runs with different iteration versions. Using this analysis, the Environmental Management Team chose 25 million iterations per run, producing less than a 1% difference in solution scores over the 100 runs at the most efficient processing time.

One of the conditions for obtaining meaningful results from a Marxan run is to ensure that the terms (constraint [cost] layer, boundary length, and SPF) of the objective function are of the same magnitude to avoid one of the terms unduly influencing the outcome of the solution. In the case of the Hanford Site analysis, the boundary length was measured to be 88.25; and because all of the targets were met, the SPF was set at 1. In order to scale the constraint layer to the magnitude of the boundary length, the planning unit costs were multiplied by 100. Another 100 (unitless) was added to each of the planning units to make the base planning units, those units with no costs have a cost value of 100.

One caveat to note in this assessment is that although the researchers used the best available data, some indicators of KEAs identified in the viability assessment workshops had to be modified to accommodate poor, incomplete, or lacking data. Another caveat to consider is that the study area

boundary may have an influence on the solution outputs. While the Columbia River acts as an ecological boundary to the north and east of the study area, the south and west boundaries are primarily administrative in nature. The use of administrative boundaries can have an effect on the solution in relationship to clustering (Boundary Length) and limiting selection of planning units on boundary edges.

The Marxan analysis produced solutions that had a range over mean variance of less than 1%. The solution displayed on maps and discussed in this report is the Marxan "Best" solution. This solution represents the areas of highest priority for conservation that most efficiently meet the conservation target goals in the study area with the lowest score. The score can only be used in comparing runs within the same analysis. The best solution produced a score, boundary length (connectivity), and penalty factor for target shortfalls that were all lower than the average of the 100 runs. This solution achieved nearly 100% of target goals with only a fraction more cost and number of planning units required compared to the average.

The solution used 20,144 planning units of the 40,654 units available on the study area. Approximately 50% of the study area displays in the conservation solution (Figure 11-1). The solution is comprised of 13 patches ranging from 10 to 74,216 ac (4 to 30,034 ha) in area and covers approximately 100,720 ac (40,760 ha) of the study area. The largest solution patch, 74,216 ac (30,034 ha), is the bulk of the overall solution covering nearly 74% of the total solution.

Because Marxan produces a unique solution for every run within an analysis, the planning units selected can vary from each solution. Marxan produces a selection frequency output that displays the number of times each planning unit is selected over the 100 runs in an analysis. The best solution of this assessment contained 20,144 planning units, 61.53% (12,394 units) of the solution area was selected in each solution of the 100 runs. An additional 29.59% (5961 units) of the solution area was selected in 67 to 99 runs. Only 8.88% (1789 units) of the solution area was selected in 66 runs or fewer.

The appeal of the Marxan analysis is that Marxan can use a diverse array of input data types (already existing Hanford Site data) and can be compatible and complementary to other efforts on the study area (e.g., the CLUP [DOE/EIS-0222 1999] and the BRMP [DOE/RL-96-32 2017]) and in the greater Columbia Plateau Ecoregion (e.g., the ALI [2014] and the WHCWG [2012, 2013a, 2013b, 2014, 2015]). A key element to understanding the assessment is to evaluate the identified areas of high habitat value. The solution Marxan provided shows areas of good habitat with high value, but areas selected may not always include all high quality examples of that habitat. By nature of the Marxan tool, the solutions are a range of mathematical calculations that attempt to capture the desired quantity of a target while limiting a cost to the solution. Using BRMP and its practices, the areas of highest habitat quality and the best examples of resources will remain conserved through avoidance or minimal intrusion. The Marxan tool can be used to answer other habitat conservation questions (such as "what is a network and spatial configuration of areas that strategically meet conservation goals?") through visual display and statistical analysis. The CHAMP provides an additional decision-making tool that can support the practices of BRMP and highlight areas that may be underrepresented in particular resources but as whole provide value to the landscape.

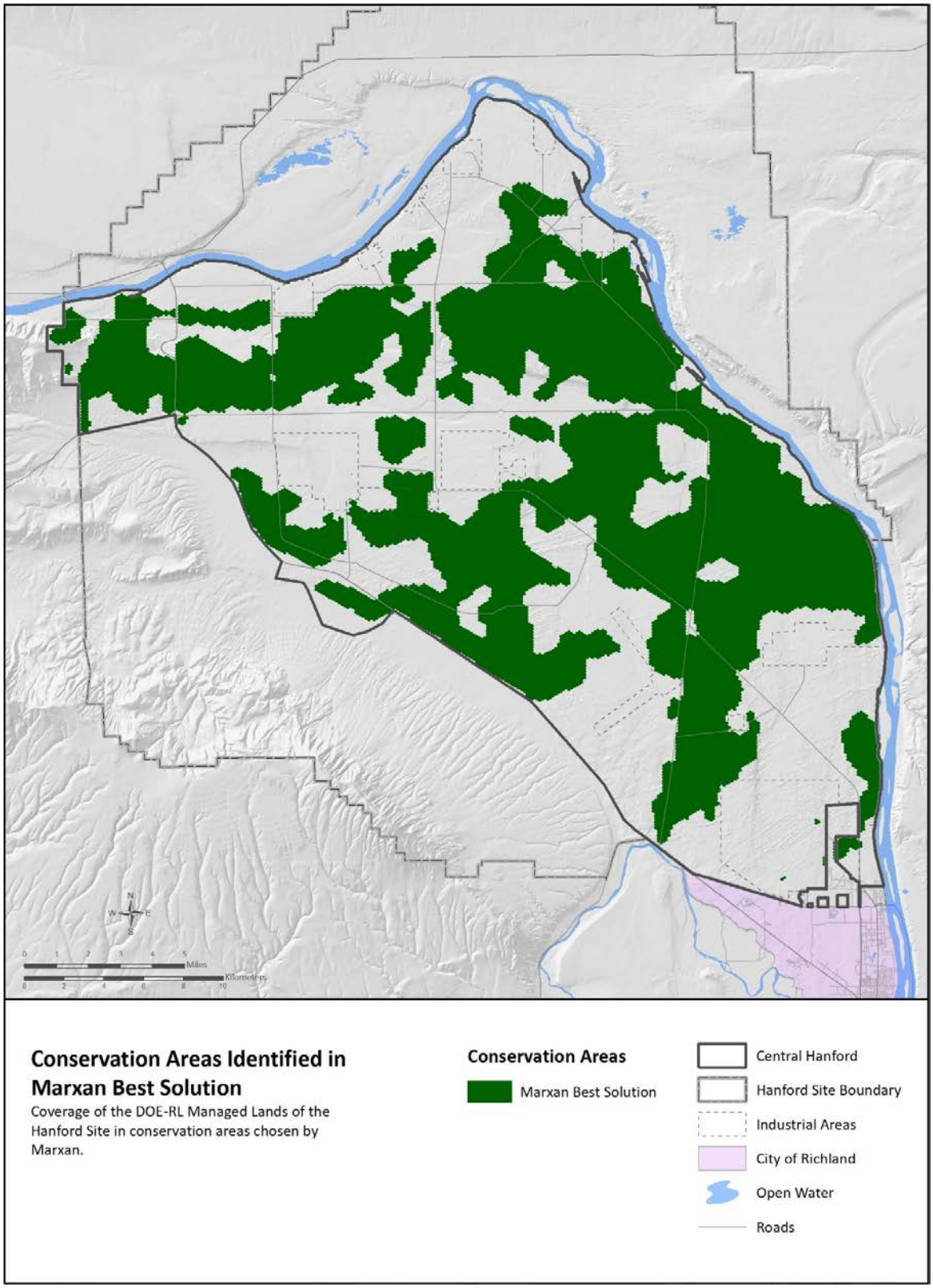

Figure 11-1. Best Solution Determined by Marxan Assessment for Conservation Areas on the DOE-RL-managed Portion of Hanford Site.

Evaluating the frequency of planning unit selection during the assessment can make inferences on the biological value of portions of the study area. Biological value of an area may be defined in terms of irreplaceability, or how important the specific area is for efficient achievement of conservation objectives. The higher the frequency of selection of a planning unit in Marxan, the closer a unit is to being considered irreplaceable within the solution. After establishing areas of irreplaceability from selection frequency of the solution, the next step would be to evaluate potential vulnerabilities to these areas. Vulnerability is the risk of an area being transformed through damage caused to the biodiversity features or threatening ecological processes (Kukkala and Moilanen 2012). For this discussion, vulnerabilities are further defined as the risk of impairment to an area from Hanford Site operations or other human activities. While it is not always possible to predict or limit Hanford Site operations to specific areas, the solution shows areas that are lower in their conservation status and not frequently selected as valuable in the outputs. These areas should be the preferred areas for future development to limit impact to sensitive biological resources. The vulnerability plotted against the irreplaceability can provide inference into potential actions (Figure 11-2). A spatial representation of this concept for the study area is provided in Figure 11-3.

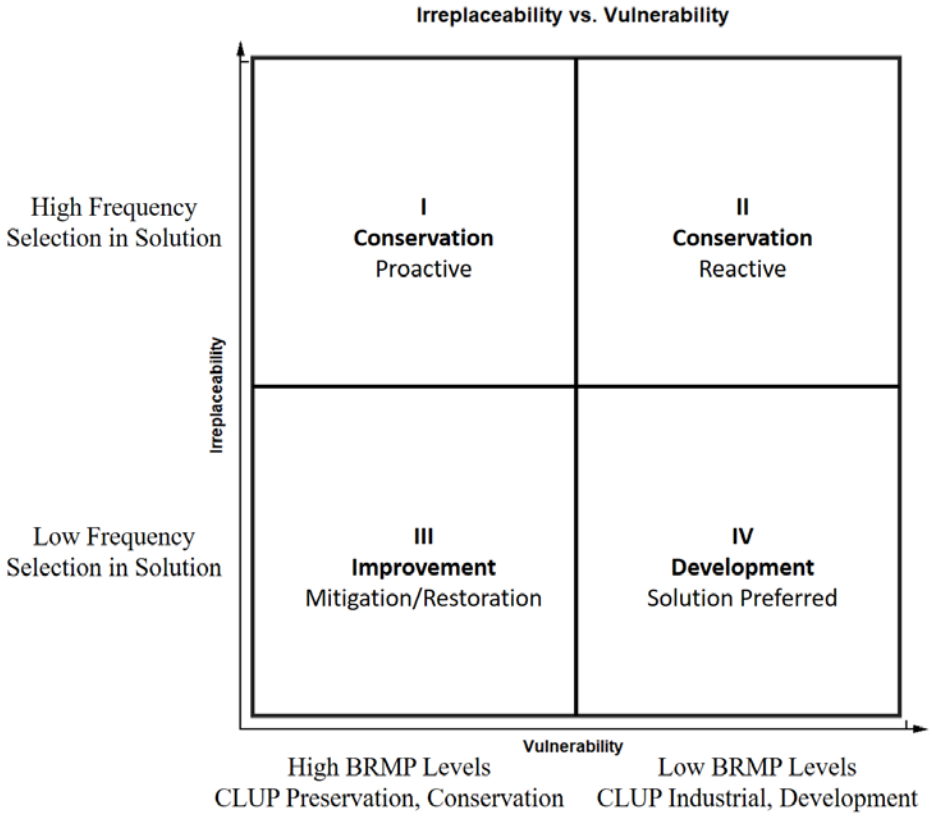

Figure 11-2. Irreplaceability vs Vulnerability Plot. Irreplaceability increases with the Increase in Selection Frequency of a Planning Unit. Vulnerability from Human Threats Increases as BRMP Levels are Reduced or CLUP Land Use Industrial and Development Designations.

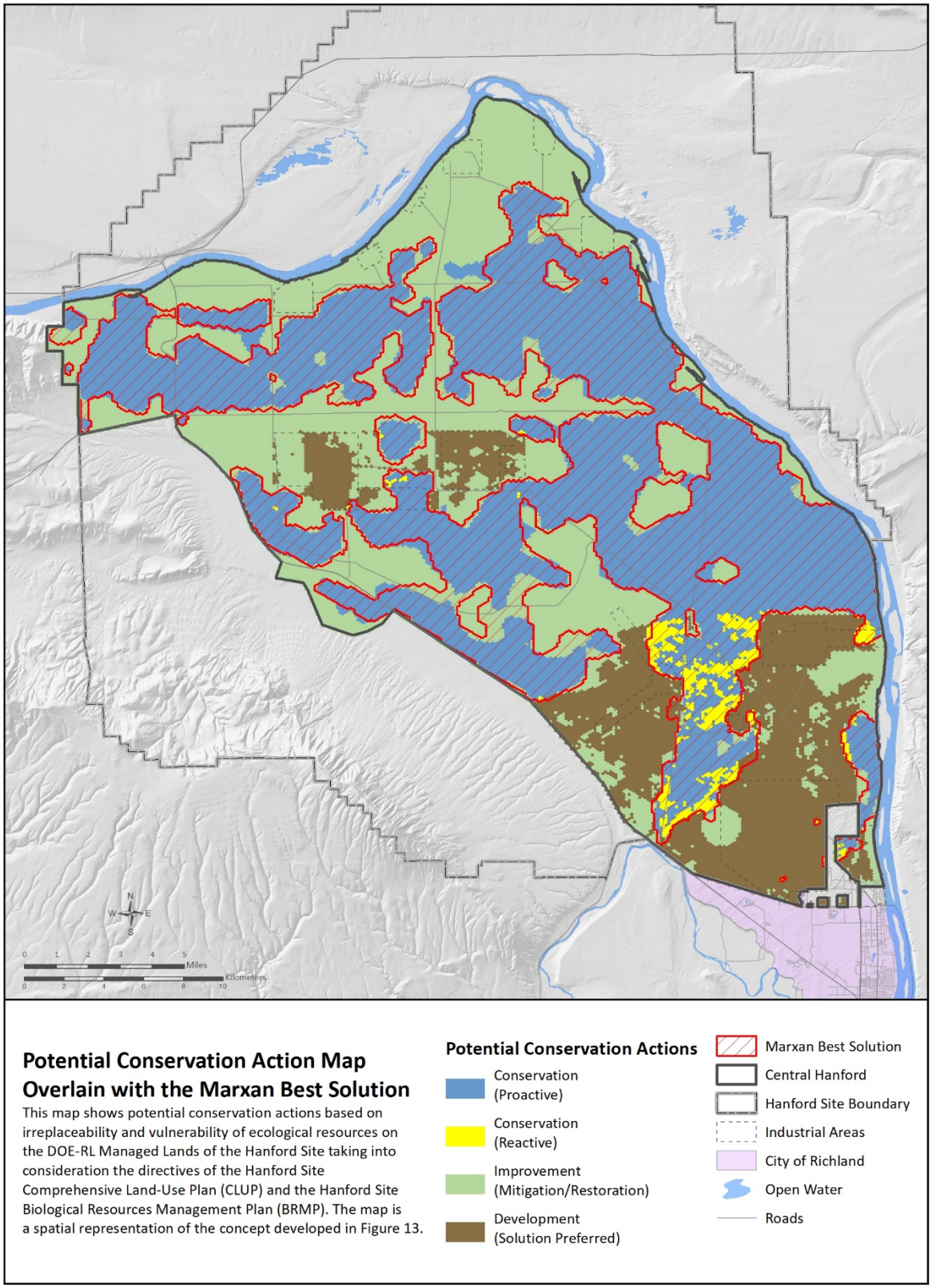

Figure 11-3. Potential Conservation Action Map for the DOE-RL-Managed Portion Hanford Site Overlain with the CHAMP Best Solution.

Integration of the CHAMP with existing site management plans (CLUP and BRMP) and existing regional habitat analysis (Arid Lands Initiative [ALI] and WHCWG) is an important function of the study results. The expectation of the study results is that they are compatible and complementary to the existing plans and analyses and provides reciprocating support. With the current CLUP map and designations, the CHAMP best solution identifying priority conservation areas is in agreement over 82% of its area (Figure 11-4 and Table 11-2) but also showed areas where CLUP designations could be improved. Even with added weight constraints, some areas of industrial (exclusive), industrial, and research and development were selected in the best solution.

The CHAMP best solution is also in reasonable agreement with the BRMP. Approximately 95% of the CHAMP best solution occurs in habitats identified for preservation (Level 4 and 5) or conservation (Level 2 and 3) in the BRMP (Figure 11-5 and Table 11-3). Approximately 90% of the CHAMP best solution appears in the top three highest BRMP resource priority Levels (Levels 3, 4, and 5).

The ALI Marxan analysis recognized the Hanford Site as an important priority core area at all goal levels. The Hanford Site overlays one of the larger priority core areas selected by the ALI analysis. At the planning unit size of 500 ac (202 ha), a large portion of the Hanford Site consistently met the conservation targets. However, at the local scale, it is apparent that some areas of high quality habitat were excluded from the ALI solution while other areas of low quality habitat were included. On the DOE-RL-managed portion of the Hanford Site, roughly 52% of the ALI best solution at the medium goal level intersects with the CHAMP best solution. This disparity reinforced the need for a local analysis with more detailed local data.

The CHAMP best solution aligns with the Washington WHCWG outputs and can provide local detail. A good example can be seen in the WHCWG black-tailed jackrabbit normalized least-cost corridor. This WHCWG output combines habitat concentration areas and linkages into a single map class. The CHAMP best solution generally matches the black-tailed jackrabbit network map, including the corridors.

An intended purpose of the CHAMP was to identify potential areas on the study area that would benefit from mitigation work and restoration efforts. Providing a one-size fits all prescription for mitigation on the Hanford Site is not a feasible expectation of any analysis. Once decisions are made on potential locations of mitigations based on ecological factors of the solution, staff can evaluate the potential success of restoration activities in those areas. The CHAMP can be effective in avoiding unnecessary costs or effort in restoration. In addition to evaluating the ecological and external factors that will impact the success of future mitigation actions, it is important to evaluate the planning units to determine why they were not selected as part of the solution. This information can help guide specific mitigation actions after the planning units are chosen. Once a mitigation area is chosen, Marxan can be used to potentially model the desired outcome of the mitigation actions. To perform these actions, the values of the individual planning units can be altered in the selected target layer to reflect the desired future conditions of the mitigated area, and the Marxan run will be performed under the same conditions. These results can show the potential future effects of the proposed actions at a landscape scale, including changes in connectivity, patch buffering, and habitat quality increase. After this evaluation, the mitigation plan can then be altered, if necessary, to create the desired changes.

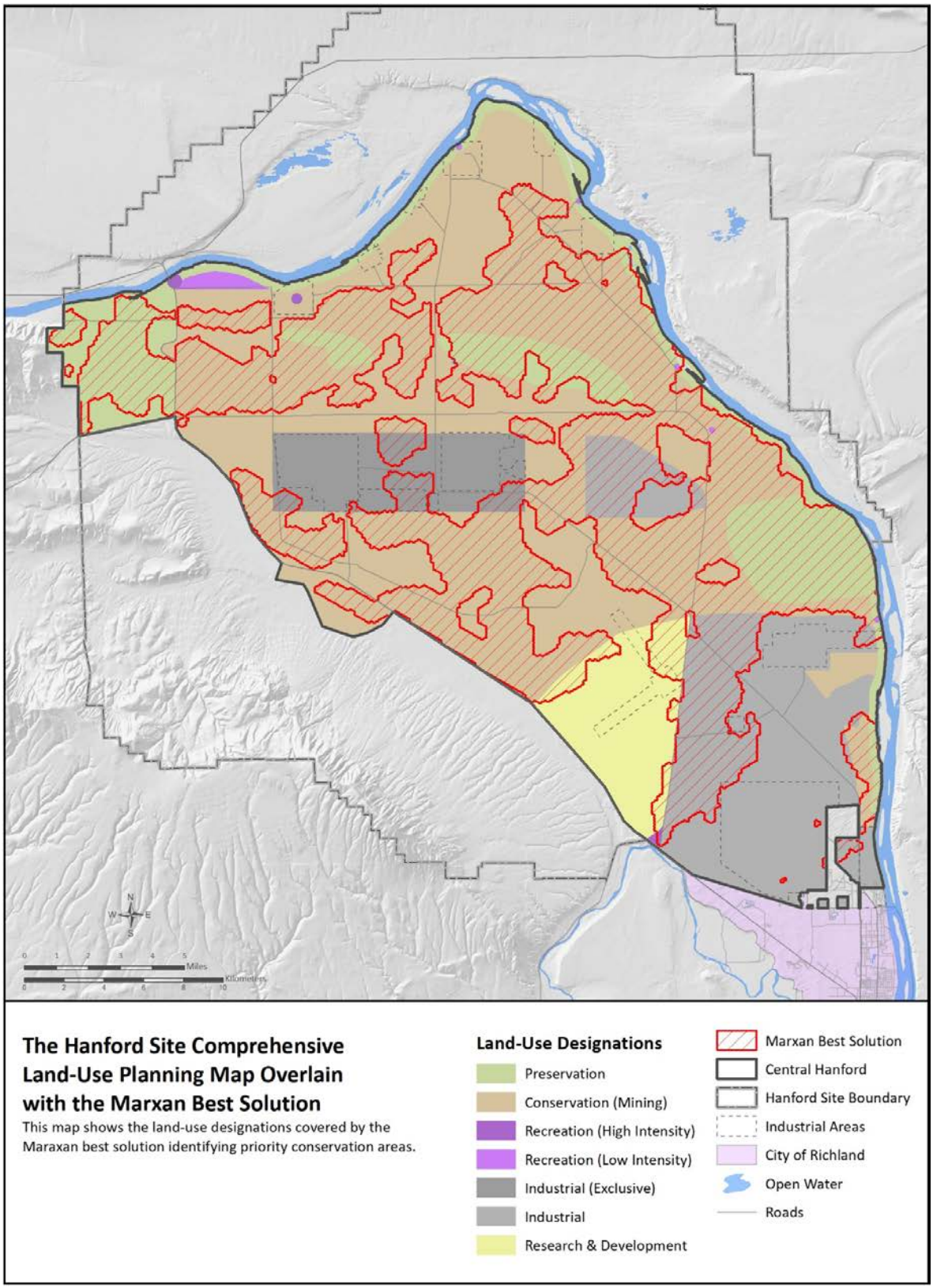

Figure 11-4. The Hanford Site Comprehensive Land-Use Planning Map Overlain with the CHAMP Best Solution.

Table 11-2. Area of the DOE-RL-Managed Portion of Hanford Site and the Marxan Best Solution Covered by Each Hanford Site Comprehensive Land-Use Planning Designations.

Designation	Area of Study Area (Hectares)	Percent of Study Area	Area of Best Solution (Hectares)	Percent of Best Solution
Conservation (Mining)	44,156.2	54.63	25,502.5	62.78
Preservation	11,800.9	14.60	7,877.3	19.39
Recreation (High Intensity)	107.1	0.13	16.9	0.04
Recreation (Low Intensity)	327.2	0.40	22.7	0.06
Industrial (Exclusive)	5,063.9	6.26	1,110.6	2.73
Industrial	14,253.7	17.63	5,060.8	12.46
Research & Development	4,908.6	6.07	1,009.7	2.49
River	212.7	0.26	19.1	0.05
Total	**80,830.2**	**100.00**	**40,619.7**	**100.00**

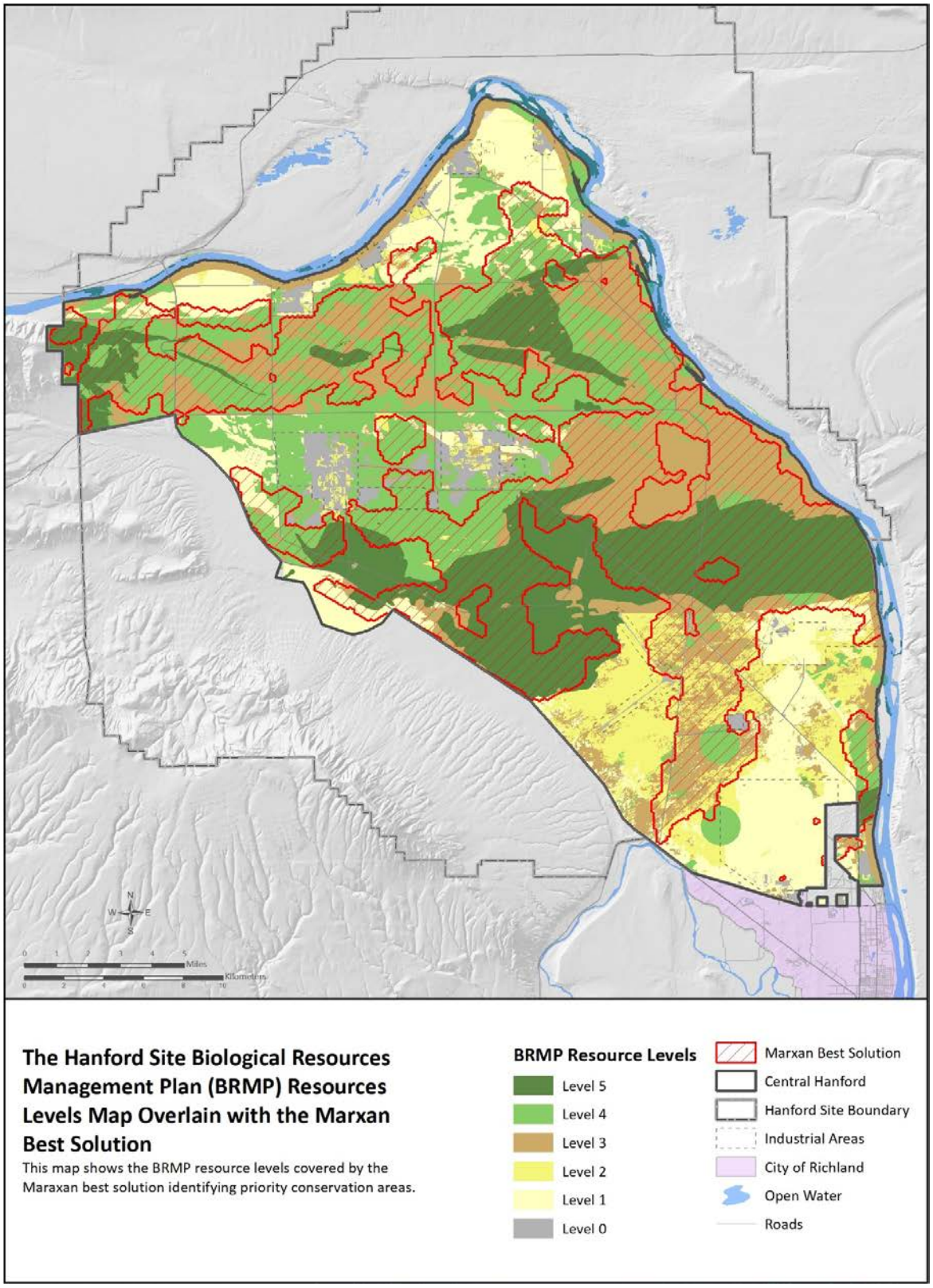

Figure 11-5. The Hanford Site Biological Resources Management Plan Resources Levels Map Overlain with the CHAMP Best Solution.

Table 11-3. Area of the DOE-RL-Managed Portion of Hanford Site and the Marxan Best Solution Covered by Each Biological Resources Management Plan Resource Level of Concern.

BRMP Resource Level of Concern	Area of Study Area (Hectares)	Percent of Study Area	Area of Best Solution (Hectares)	Percent of Best Solution
Level 5	17,611.2	21.80	13,269.5	32.66
Level 4	20,015.8	24.78	11,190.7	27.54
Level 3	19,808.8	24.52	12,276.9	30.21
Level 2	7,255.1	8.98	1,765.5	4.34
Level 1	12,914.7	15.99	2,012.9	4.95
Level 0	3,167.8	3.92	118.7	0.29
Total	**80,773.4**	**100.00**	**40,634.3**	**100.00**

Performing this conservation assessment met the purpose of identifying areas of high habitat value and areas for restoration of habitat that meet the conservation goals and objectives of the Hanford Site. The solution provided, coupled with existing conservation documents and processes, will support ecological impact and mitigation decision making on the Hanford Site. The CHAMP is an adaptive tool that can be employed in various ways to target generic or specific solutions.

Future analysis will shift focus to identify potential areas on the Hanford Site that would benefit from mitigation work. To perform this investigation, input layers will be set to highlight areas that meet mitigation potential goals. Items to consider for focusing solution to mitigation areas may include the following:

- Identify planning units with Fair target ratings that can be moved into the Good category with mitigation actions like revegetation, animal reintroduction, or other habitat restoration activities
- Alter targets to better represent a mitigation habitat so Good ratings are no longer resources or habitats that are quality representations but rather have quality in its mitigation potential
- Make changes to current constraints and add new constraints specific to their impacts on mitigation and long-term success
- Manipulate target goal levels to highlight planning with weaker features that would benefit from mitigation or restoration.

11.1.2 Fish and Wildlife Monitoring

JW Wilde

This section provides inventory, monitoring, and survey information for fish and wildlife evaluated at the Hanford Site during 2019. 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 2019 monitoring also included burrowing owls, pollinator habitat, deer, 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.

11.1.2.1 Fall Chinook Salmon

JJ Nugent

Commonly referred to as king salmon, Chinook (*Oncorhynchus tshawytscha*) are the largest of the Pacific salmon (Myers et al. 1998, Netboy 1958). Adult fall Chinook salmon destined for the Hanford Reach enter the Columbia River in late summer and spawn in the fall. Females fan out nests or redds in suitable gravel substrate and deposit eggs in a pocket while males simultaneously extrude milt to fertilize the eggs. Redds are readily identifiable during this time and appear as clean swept gravel patches amidst darker undisturbed substrate covered by algae (periphyton).

The population of fall Chinook salmon that spawns in the Hanford Reach of the Columbia River is the largest run remaining in the Pacific Northwest and has regional ecological and cultural significance, 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 the Hanford Site to provide an index of relative abundance among spawning areas and years (HNF-52190; HNF-54808; HNF-56707; HNF-58823; HNF-59813; MSA 2018; HNF-64540; HNF-64542). 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 2019, three surveys were completed along the Hanford Reach (October 21, November 4, and November 24). Table 11-4 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 11-5. The peak annual redd count for 2019 (7,899) was the ninth lowest count (range: 4,018 through 20,678) in the past 20 years (2000 through 2019) and was well below the previous 10-year average (11,247). During the final survey (November 24), a silt plume originating along the eastern shoreline near Locke Island and the 100-F Islands obscured any redds observed on

November 4, 2019, downstream of the Hanford Townsite. The historical trend in redd counts since 1948 is shown in Figure 11-6.

Table 11-4. Summary of Fall Chinook Salmon Redd Counts by Areas for the 2019 Aerial Surveys in the Hanford of the Columbia River.

Area	Description	10/21/2019	11/4/2019	11/24/2019	Maximum Count
0	Islands 17-21 (Richland)	0	0	0[a]	0[a]
1	Islands 11-16	11	166	0[a]	166
1a	Savage Island/Hanford Slough	0	0	0	0
2	Islands 8-10	31	665	723	723
3	Near Island 7	7	308	408	408
4	Island 6 (lower half)	25	671	810	810
5	Island 4, 5, and upper 6	35	829	939	939
6	Near Island 3	2	175	300	300
7	Near Island 2	25	440	720	720
8	Near Island 1	0	140	150	150
8a	Upstream of Island 1 to Coyote Rapids	0	0	0	0
9	Near Coyote Rapids	24	112	112	112
9a	Upstream of Coyote Rapids to China Bar	0	0	0	0
China Bar	China Bar/Midway	1	20	30	30
10	Near Vernita Bar	49	2,800	3,530	3,530
11	Upstream of Vernita Bar to Priest Rapids Dam	0	6	11	11

[a] Area obscured by silt plume

Table 11-5. Summary of Fall Chinook Salmon Redd Counts by Sub-areas Adjacent to Hanford Site Operations for the 2019 Aerial Surveys in the Hanford Reach of the Columbia River.

Sub-area	10/21/2019	11/4/2019	11/24/2019	Maximum Count
300 Area	0	0	0	0
Dunes	0	0	0	0
100-F	7	308	408	408
100-H	35	829	939	939
100-D	0	140	150	150
100-N	0	0	0	0
100-K	0	0	0	0
100-BC	24	112	112	112

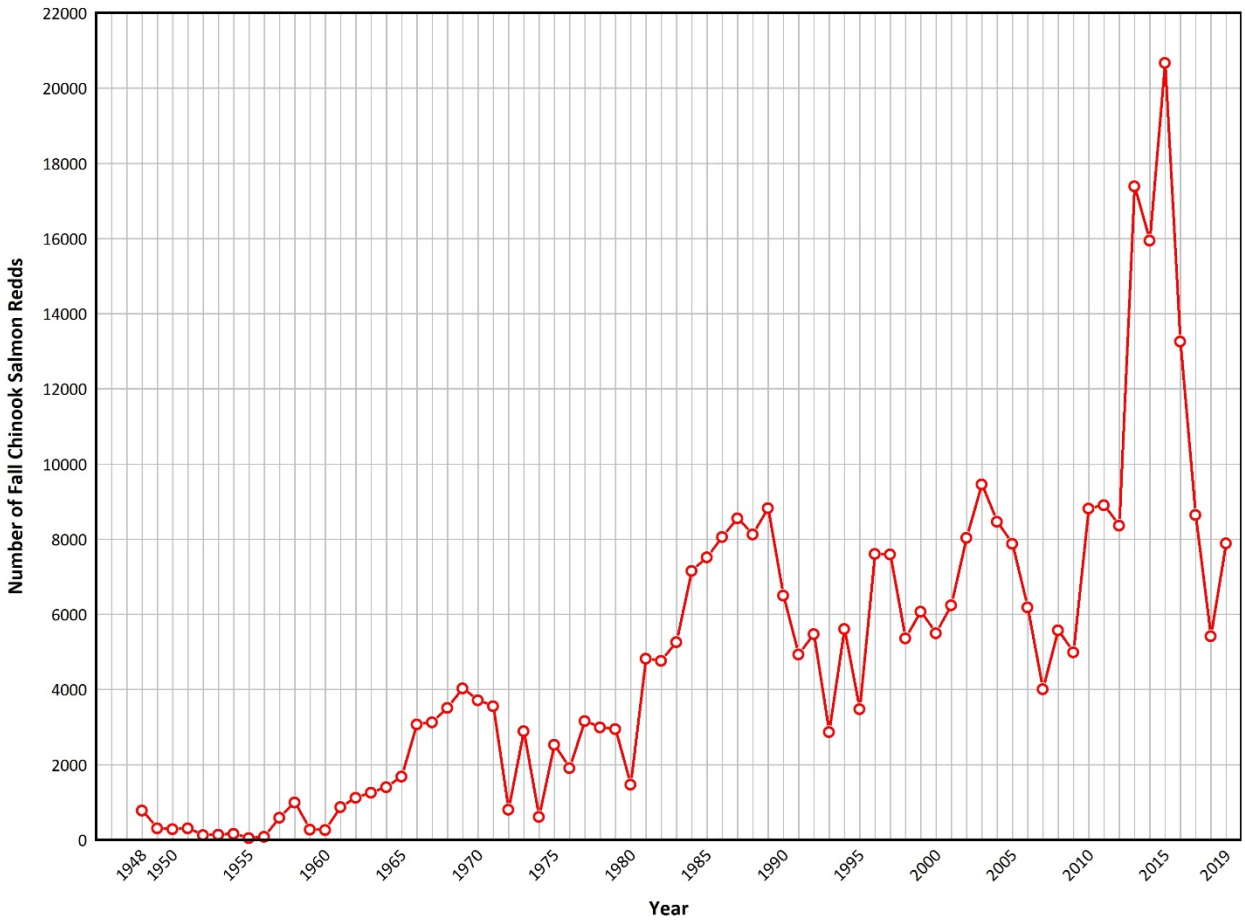

Figure 11-6. Visual Hanford Reach Fall Chinook Salmon Redd Counts 1948 to 2019.

11.1.2.2 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 ESA 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 m^3/sec) are considered too high to survey.

In 2019, two steelhead redd surveys were completed on the Hanford Reach (April 17 and May 13). No steelhead redds were observed during the flights. Columbia River flows rose above 160 kcfs (4,531 m^3/sec) in mid-May, reducing the likelihood of observing redds for the remainder of the spawning season (Figure 11-7). No other surveys were conducted in 2019.

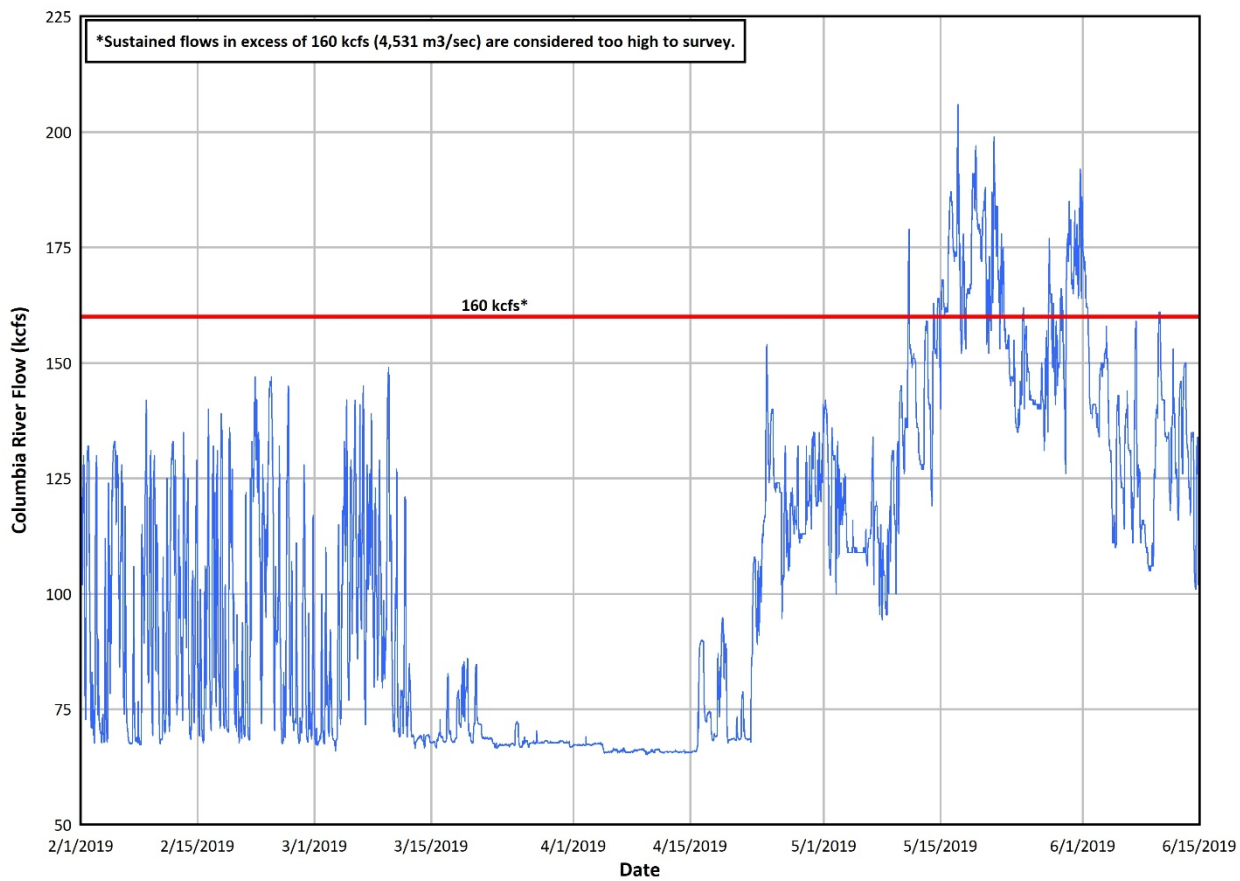

Figure 11-7. Columbia River Flows on the Hanford Reach during Late Winter and Spring 2019.

11.1.2.3 Bald Eagles

JW Wilde, M Paulsen

Bald Eagles are a success story for species protection under the ESA. In 2007, 40 years after the Bald Eagle was listed as endangered and given protection under the ESA, the USFWS determined that the population of Bald Eagles in the lower 48 States had recovered sufficiently to be removed from the ESA list. The state of Washington also down-listed Bald Eagles from threatened to sensitive. Despite the significant recovery of Bald Eagle populations, federal laws including the *Bald and Golden Eagle Protection Act of 1940* and the *Migratory Bird Treaty Act of 1918* still provide protection for eagles, their nest trees, and communal night roosts. In addition, following delisting, the USFWS developed the *National Bald Eagle Management Guidelines*, which provides monitoring and management guidance for Bald Eagles (USFWS 2007).

The DOE/RL-94-150, *Bald Eagle Management Plan for the Hanford Site*, was developed by DOE to provide an overview of Bald Eagle distribution, behavior, and ecology important to understanding the issues related to management and protection of this species on the Hanford Site.

The information provided in this document defines the actions that constitute DOE policy regarding Bald Eagle protection and management on the Hanford Site. Key among these actions are protective measures for roost sites and nests, which are based on federal and state guidelines. Bald Eagles are attracted to the abundant fish and waterfowl found along the river and use the Hanford Reach of the Columbia River as a wintering area, and more recently as nesting area for producing young. Most Bald Eagles arrive on the Hanford Site in mid-November to forage and are usually present until mid-March. Wintering eagles use different habitats for various activities such as perching, foraging, and roosting.

Nest building has occurred most years, but historically the adults abandoned most nests on the Hanford Site by mid-March prior to producing young. The timing of this abandonment coincides with the eagles migrating toward summer feeding areas or other nesting territories. Bald Eagles were first observed successfully producing fledged young from nests on the Hanford Site in 2013. In Washington State, nesting may begin as early as December and young may fledge as late as August (DOE/RL-94-150). Bald Eagle nests are monitored for occupancy (adults present) and productivity (production of young). A successful nest is described as a nest from which at least one young fledged, or one in which at least one young was raised to an advanced stage of development (Postupalsky 1974). Potential nest sites are monitored to determine if new nest protection areas are necessary. When a new nest is identified, nesting exclusion buffers of 660 ft (200 m) are enforced until the nest is abandoned or the young eagles have fledged.

Night roost surveys are conducted at the eight protected night roost sites from November through March (Figure 11-8). The eight areas are divided into three monitoring routes consisting of 2 to 4 night roost monitoring locations each. Surveys are initiated 15 minutes prior to sunset and continue until survey is complete or there is insufficient light to see individual birds. Surveyors approached each location in a vehicle and remained outside of the designated 660-ft (200-m) buffer zones. After staff adequately observe the roost to count all eagles present, generally 3 to 7 minutes, surveyors proceed to the next night roost location until all locations have been surveyed. Nest surveys are performed at all known potential nest locations. An observation location is chosen at an appropriate distance, generally at least 660 ft (200 m) from the nest. Staff view the nest area with binoculars or spotting scope, and nesting behaviors are documented during the observation period.

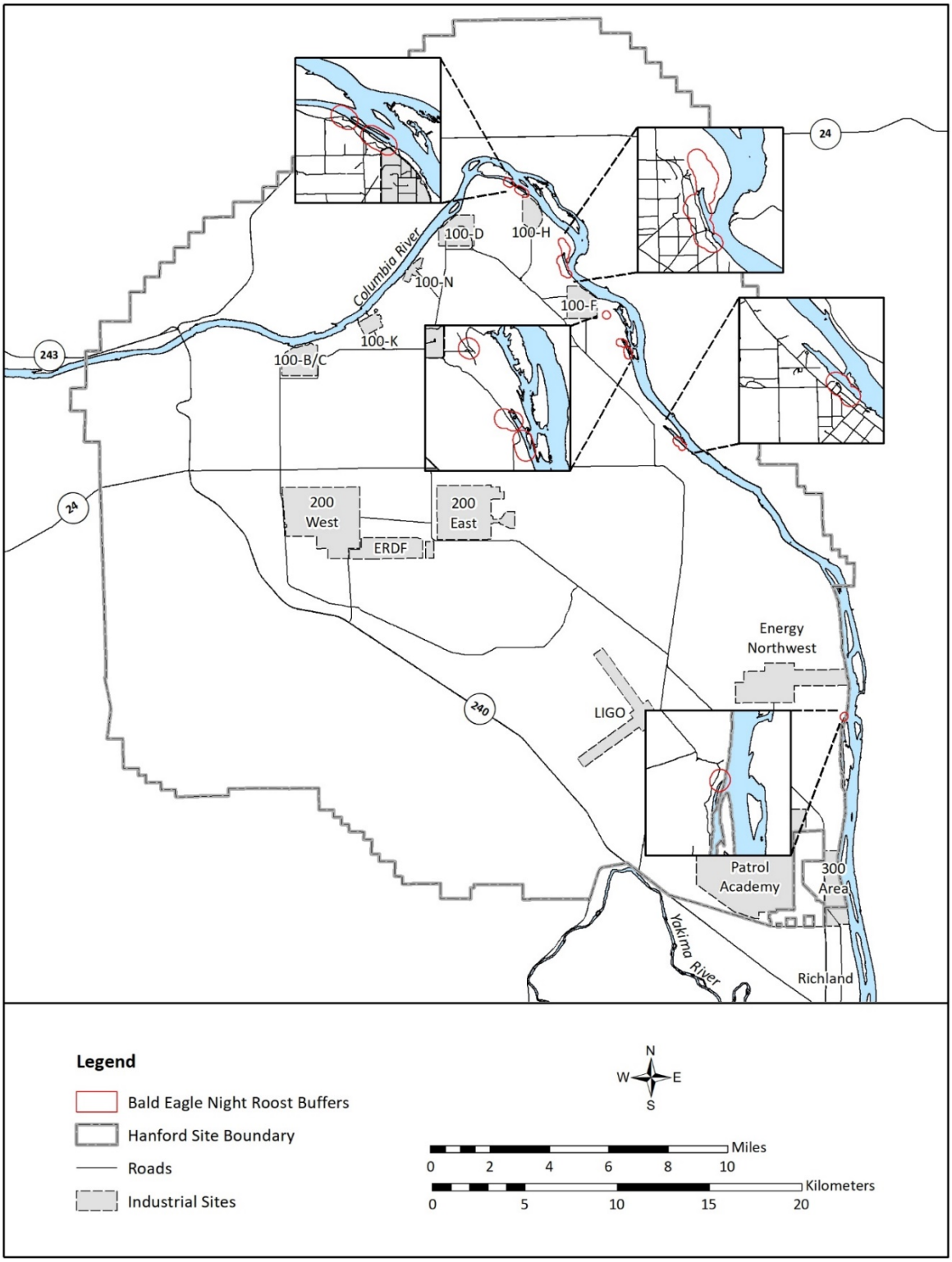

Figure 11-8. Hanford Bald Eagle Night Roost Buffers.

Nest surveys typically consisted of 1-hour observations in the area of interest, documenting any signs of nesting activity (e.g., territory defense, nest tending, pair bonding behaviors).

In addition to the roost and nest surveys, boat surveys are performed at least once a year (target once in November/December and once in March) to determine the age class, distribution, and number of eagles on the Hanford Reach. Both shorelines of the Columbia River along the Hanford Site are surveyed, beginning immediately upstream of Vernita Bridge and ending at the 300 Area. All boat surveys are performed on the same date as a night roost survey. By performing the two surveys in succession, correlations of day and night counts and distributions can be used to determine additional potential night roost areas and nest sites for future Bald Eagle monitoring efforts.

Six night roost surveys at the eight currently protected night roost monitoring locations were completed during the fiscal year (FY) 2019 season with the final night roost survey being conducted in concurrence with a boat survey. Bald Eagle use was documented at all the night roost locations monitored during FY 2019. Roughly 70% of the eagles present during the first three night roost surveys were juveniles, who grouped in large numbers in areas where spawned out fall Chinook salmon carcasses are known to accumulate. As the season progressed, the number of juveniles on the Hanford Reach dropped off dramatically while the number of adults declined less rapidly. This was likely due to juvenile eagles taking advantage of the fall Chinook salmon (*Oncorhynchus tshawytscha*) food resource then leaving after the carcasses were no longer available, while adult eagles continued to use the Hanford Reach likely feeding on waterfowl and carrion. The night roost survey dates and results are summarized in Table 11-6 with summaries of observations described in the paragraphs following. Figure 11-9 displays the total number of individuals by age class observed during each survey.

Table 11-6. Bald Eagle Night Roost Monitoring Data for FY 2019.

Night Roost Location	Number of Eagles Present					
	11/28/18	12/10/18	12/17/18	1/7/19	1/21/19	3/18/19
100-H Upstream	26	11	9	4	4	1
100-H Downstream	0	1	4	0	4	0
White Bluffs Upstream	36	13	16	5	5	2
White Bluffs Downstream	0	0	0	0	4	0
100-F Island Upstream	18	2	0	0	1	0
100-F Slough	0	0	0	0	1	0
Townsite Substation	3	2	0	2	2	1
Upstream of Wooded/Nest Site Area	2	3	4	2	2	3
Totals	**85**	**32**	**33**	**13**	**23**	**7**

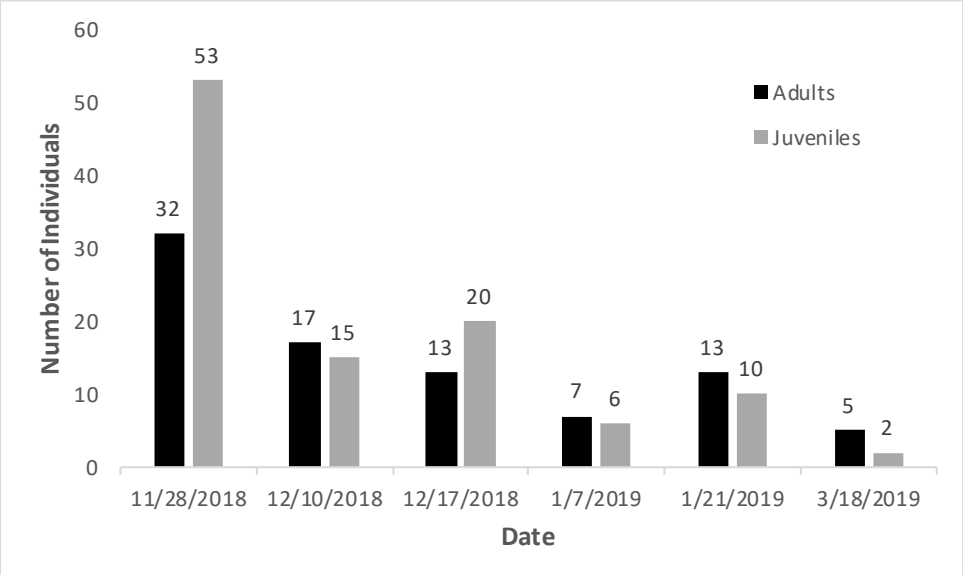

Figure 11-9. Age Class of Bald Eagles Counted During Roost Surveys.

In addition to the night roost surveys, one boat survey was performed on March 18, 2019, to search for potential nesting locations. A peak count during the winter was not conducted due to unforeseen circumstances. A total of 18 eagles, 9 adults and 9 juveniles, were observed during the March 18 boat survey. These numbers are slightly higher than numbers recorded during the March boat survey in FY 2018, which reported a total of 10 eagles (8 adults and 2 juveniles).

Successful nesting was documented in FY 2019 at the Hanford Townsite Substation, White Bluffs Slough, Benton Substation, and 100-N. At least one juvenile Bald Eagle was observed at all nest survey locations in FY 2019 aside from the nest located downstream from the Hanford Townsite.

Beginning in FY 2013 and again in FY 2014, monitoring staff documented a successful nest upstream of Wooded Island that produced a pair of fledglings each year. In FY 2015, the nest was occupied for a third consecutive year with three fledglings observed near the nest in late spring. During FY 2016, monitoring staff were performing other monitoring work in the area and noted that a large stick nest was being constructed on a tower near the Bonneville Power Administration's Benton substation; approximately 0.68 mi (1,100 m) northwest of the Upstream Wooded Island nest site. Monitoring staff later confirmed that the nest was active and the Wooded Island nest was nearly gone, presumably from the Bald Eagles using the old nest materials to build the new nest. On April 27, 2016, monitoring staff confirmed that the nest was occupied with two Bald Eagle chicks in the nest. A pair of adult Bald Eagles were observed utilizing the nest during each night roost survey conducted in FY 2017; once again the nest was found to be occupied with two chicks seen in the nest the following spring (HNF-63012). This nest was observed to be active again in FY 2018, with a pair of adults in and around the nest observed on multiple night roost surveys. After a nest survey on May 10, 2018, it was confirmed that this nest again produced young with one chick observed. This nest was again confirmed as being active in FY 2019, with a juvenile documented on the May 15, 2019, survey.

The nest located on the White Bluffs Peninsula was occupied throughout the FY 2015 nesting season; however, because its location was obscured by foliage later in the nesting season, monitoring staff could

not confirm presence of young in the nest. On June 5, 2015, surveyors performing a roadside breeding bird survey documented a juvenile Bald Eagle perched in the tree containing the nest, which could indicate a successful nest attempt. However, actual success could not be determined. During a nest survey on May 15, 2017, one chick was observed in the nest along with one adult (HNF-63012). In FY 2018, staff performing a nest survey on May 10, 2018, observed one young chick (down feather covered) in the nest. One adult and two juvenile Bald Eagles were observed in this nest during the May 16, 2019, survey, meaning it can be defined as an active and successful nest for FY 2019.

During FY 2019 a nest was monitored in the 100-N Area. One adult was observed at this nest during the April 3, 2019, survey and an adult along with two chicks were observed during the May 2, 2019, survey. This nest was considered active and successful despite being surveyed prior to May 10.

A pair of Bald Eagles appeared to be attempting to nest in a previously constructed rookery nest at the Hanford Townsite Substation night roost in FY 2017. The location was named the Hanford Townsite Substation nest. During night roost surveys, the pair was observed both in and around the nest. As the nesting season continued, nest monitoring proved the nest to be abandoned and the pair absent from the area (HNF-63012). A pair was again observed to be utilizing the nest in FY 2018 during the night roost surveys. While conducting a nest survey on May 10, 2018, two chicks with mature feathers were observed in the nest, while one adult perched nearby. During the final nest survey on June 14, 2018, the two chicks were observed exercising their wings and conducting short hover flights in the nest. No adults were observed in the area. In FY 2019, a pair of eagles were observed in this nest during the March 28 survey. Later in the season, during the May 14, 2019, survey, one adult was observed along with two young chicks.

A possible new nest was observed inland and downstream from the Hanford Townsite High School during the March 19, 2018, boat survey. The location was surveyed and determined to be active on April 9, 2018, with two adults in and around the nest. The location was named the Hanford Townsite Downstream Nest. Subsequent surveys determined the nest to be abandoned. The Hanford Townsite Downstream Nest appeared to be utilized by at least one adult during the March 28, 2019, survey; however, when this nest was surveyed on May 14, 2019, no birds were observed in the nest itself, with only one adult being seen flushing from a nearby tree.

11.1.2.4 Ferruginous Hawk Nesting Territory Occupancy and Productivity Monitoring

JJ Nugent

The Ferruginous Hawk, a Washington State threatened species (WDFW 2019) 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 2018 (HNF-53073; HNF-56769; HNF-58717; HNF-59755; HNF-60469; MSA 2018; DOE/RL-2019-33). 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). In 2018, four occupied nests were identified on 230-kV transmission towers. During a subsequent productivity survey, one nest was reported down with no young (this nest had two small chicks during the occupancy survey) and the other three nests were found to each have two young for a total of six young (DOE/RL-2019-33).

Two surveys were conducted in 2019, one occupancy survey and one productivity survey. The occupancy survey took place May 30. Four occupied nests were found, all of them were on 230-kV transmission towers (Figure 11-10). The productivity survey was performed on June 20. 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 being tended by an adult Ferruginous Hawk during the occupancy survey but no young were observed at that time. No birds were seen at this nest during the productivity survey and was considered unsuccessful. Another nest contained three young during the occupancy survey but during the productivity survey, the nest was dilapidated and the young could not be located and their fate was unknown. The other two nests were found to each have two young for a total of four young.

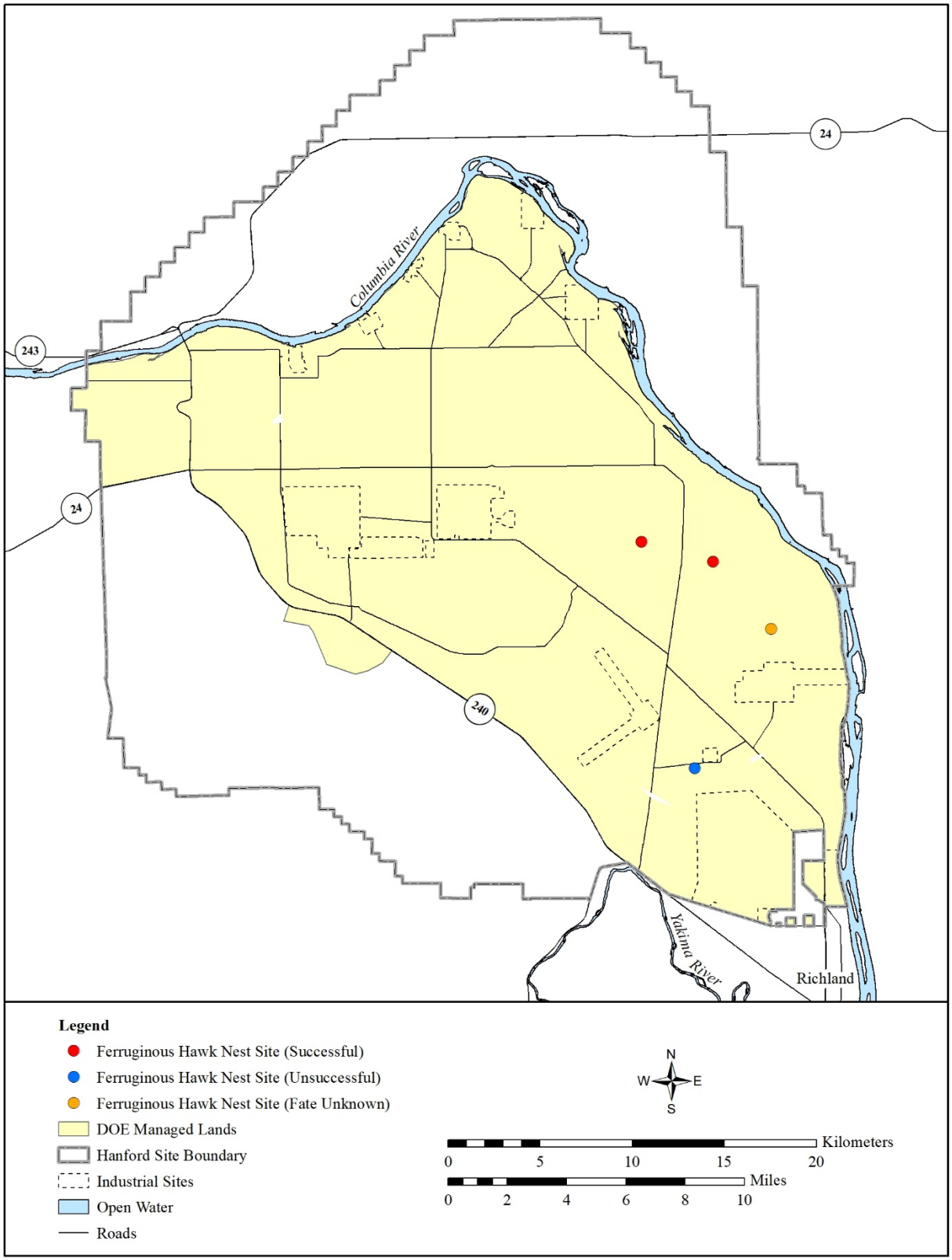

Figure 11-10. Active Ferruginous Hawk Nests Observed on DOE-RL-Managed Lands of the Hanford Site in 2019.

11.1.2.5 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 (Urocitellus 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 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.

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 (MSA) 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 11-11). Use of this improved design in other areas of the Columbia Basin have proven successful in creating nesting habitat for Burrowing Owls (Johnson 2017). 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 11-12). Annual maintenance and monitoring of the new burrow systems began in 2019. Each of the 51 newly installed burrows was maintained by vegetation removal, plunging the tunnel, uncovering and removing the chamber access bucket, and cleaning out any debris in the chamber. If the burrow was deemed occupied upon arrival, the tunnel was blocked with a plunger until chamber could be evaluated.

Overall, burrows were in good condition. A few burrows showed signs of tampering or damage from elk (Cervus elaphus). The damage presented itself as pipes being pulled from under rock armoring, deeming them unusable for owls. Most all chambers were in good condition with no debris, a small number of chambers contained small mammal nests. Two clusters with the newly installed burrows were active and contained nests. Burrow clusters installed along Highway 240 showed signs of use. Burrow 47 and 49 were being used as a cache, containing dead mice and insects. Burrow 48, in the same cluster as 49, contained nine eggs and three newly hatched birds (Figure 11-13). Burrow 39 located west of the

Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Emergency Vehicle Operations Course (EVOC) contained five young owls estimated at approximately 9 days old (Figure 11-14).

These two nest locations were visited on June 18, 2019, to attempt to count and band all hatch year burrowing owls. A total of 11 hatch year birds were counted; 7 from burrow 49, 2 from burrow 48, and 2 from burrow 39 (Figure 11-15). Burrow 39 was the only new design burrow located in the cluster, there may have been additional hatch birds present but located in burrows inaccessible to researchers.

Figure 11-11. Burrowing Owl Artificial Burrow System Chamber Installed on the Hanford Site.

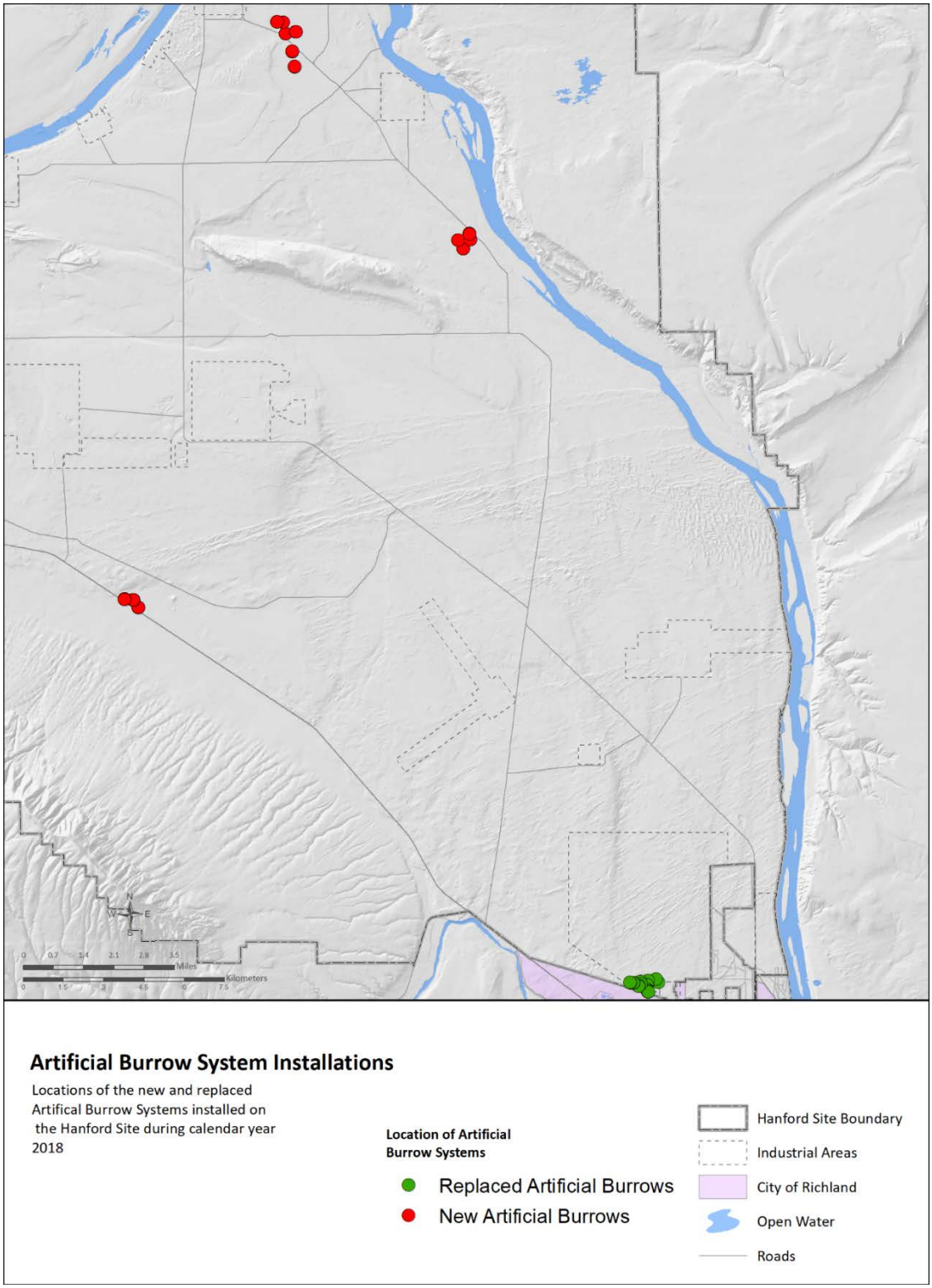

Figure 11-12. Locations of the New and Replaced Artificial Burrow Systems Installed on the Hanford Site During Calendar Year 2018.

Figure 11-13. Burrow 49, Located Along Highway 240, Contained Nine Eggs and Three Newly Hatched Young.

Figure 11-14. Burrow 39, Located Near the HAMMER EVOC Facility Contained Five Hatch Year Owls.

Figure 11-15. Newly Banded Hatch Year Owl Being Returned to Burrow.

11.1.2.6 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 2019, roadside surveys were performed during breeding season (May and June). Three Hanford routes (Figure 11-16) were surveyed one time each in 2019. For the 2018 breeding season surveys, 1,382 individual birds were counted during surveys. The total number of individual birds counted was similar to the average number of individuals since 2013. A total of 46 unique bird species were documented in the 2019 breeding season survey (Table 11-7), which was similar to the average of approximately 47 species since 2013.

The Old Fields survey route had the highest species diversity with 37 identified. The Army Loop Road survey route had the lowest species diversity at 11 species (Table 11-7). The Cliff Swallow (*Petrochelidon pyrrhonota*) was the most abundant species documented in 2019. Surveys counted 356 individuals on two survey routes, 25.8% 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 327 individuals and the Western Meadowlark (*Sturnella neglecta*) had 253 individuals. These three species (Cliff Swallow, Horned Lark, and Western Meadowlark) accounted for 67.73% of the individuals documented.

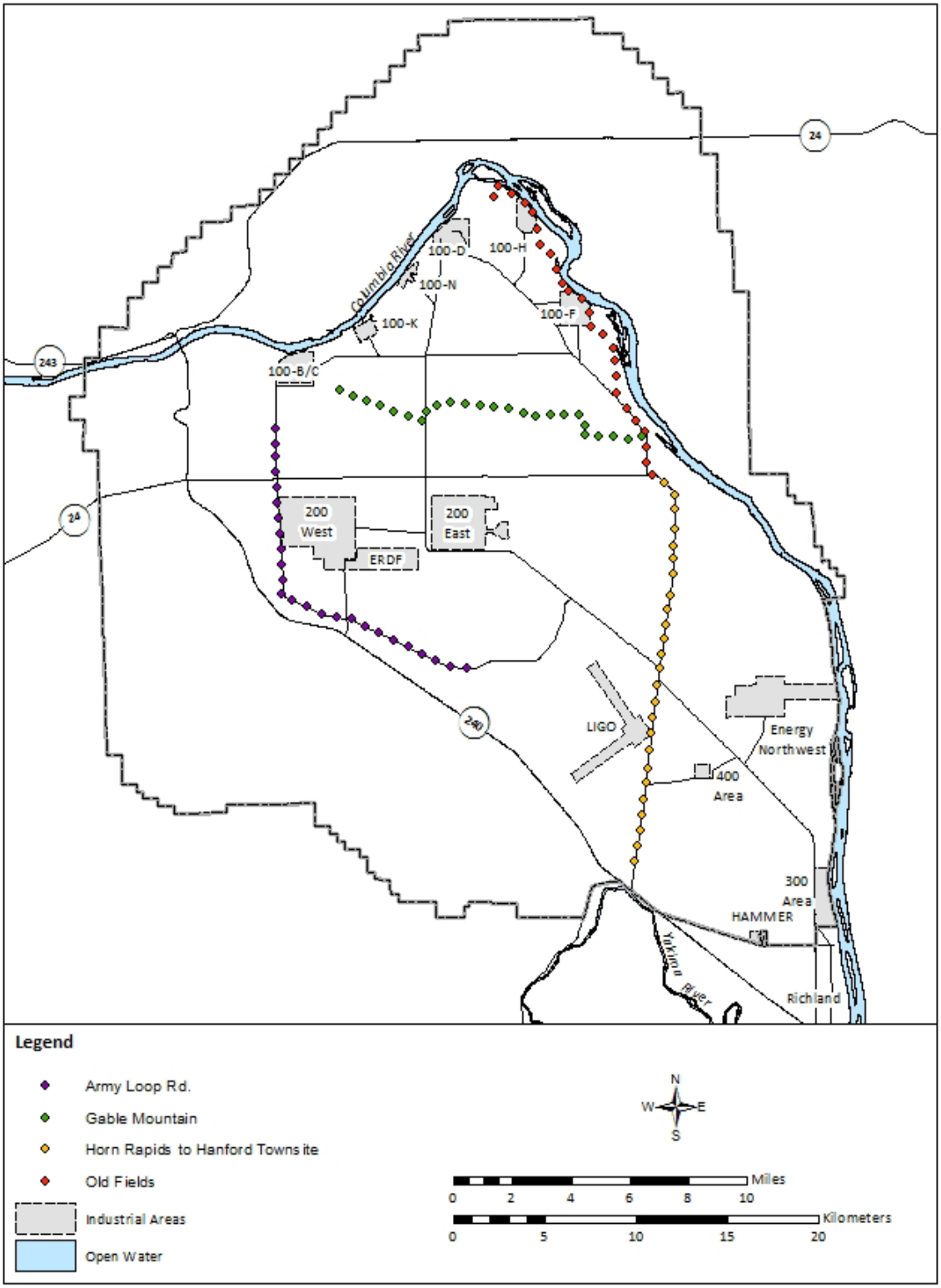

Figure 11-16. Roadside Bird Survey Routes Surveyed for Calendar Year 2019.

Table 11-7. 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	11	265
Gable Mountain	1	15	244
Horn Rapids to Hanford Townsite	1	13	167
Old Fields	1	37	706
Total	**4**	**46[a]**	**1,382**

[a] Unique species identified

The Hanford Site bird monitoring program documents the presence, abundance, and distribution of species of concern on the Hanford Site. Both the USFWS and the WDFW maintain lists of species that are of management concern because populations or habitat availability are limited. In Washington State, 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.

11.1.2.7 Bat Monitoring

JW Wilde

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.

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. The Hanford Site monitors these critical habitats for trends and any needed conservation actions.

The 2019 bat surveys at the 18-3F and 183-D Clearwells were conducted simultaneously by teams of two staff members at each location using the same survey method. The counting methodology followed a bat colony emergence count protocol 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. 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:

$$\frac{(\textbf{Surveyor 1}\ \text{Exiting Total} - \text{Entering Total}) + (\textbf{Surveyor 2}\ \text{Exiting Total} - \text{Entering Total})}{2} = \textbf{Estimated Colony Emergence Total}$$

In addition to staff surveyors, two additional monitoring techniques were deployed during the surveys. A thermal camera (ATN OTS HD Thermal Monocular) was placed on a tripod and faced the opening of the clearwell to record the emergence throughout the survey. Recordings were timestamped with date and time. If data from surveyors provided discrepancies or was put in question, these videos are reviewed to resolves issues. Staff began testing new infrared bat counters produced by Apoemus. These detectors operate by the use of 30 plus modulated infrared barrier beams, providing counts and directions. Three detectors were placed together and fitted over the top of the clearwell openings during the counts (Figure 11-17). All bats exiting the clearwells are required to pass through one of the three detectors to exit. All data is stored on memory cards within the unit, to be downloaded to a computer following the survey.

Figure 11-17. Apodemus Infrared Camera Bat Counters Placed on the 183-F Clearwell Opening.

Both clearwell sites show a continued use as a maternity roost for Yuma myotis. Colony emergence maximum counts of Yuma myotis (*Myotis yumanensis*) in 2019 was estimated with staff surveys at 1,959 bats and 2,395 bats for 183-F and 183-D, respectively, during the June surveys (Figure 11-18). These data show that the 183-D Clearwell population was at a higher count than 183-F population for the first time since the monitoring initiated in 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 or other environmental factors affecting the clearwells. 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. Testing the infrared bat counter provided another view of the emergence counts. It was noted that in both survey nights the use of the bat counter may have impacted the count numbers. These impacts were seen as lower counts to the surveyor only counts. Referencing the WDFW protocol, emergence counts end when exit activity matches entrance activity. The bat counter data was charted and the survey end can be inferred (Figure 11-19). Using these survey end times, the difference between exits and entrances prior to this time is calculated as the roost size. From infrared bat counter data the 183-F colony was calculated at 1,947 bats compared to 1,438 bats counted by surveyors on same date. Surveyors end counts earlier than the infrared counter survey end time due to lack of visibility. Colony for the 183-D was calculated at 1,633 bats to the surveyors 1,053 bats on the same date. Additional work is needed, and proposed for 2020 work, on comparing the three emergence techniques of human survey, thermal camera, and infrared counter.

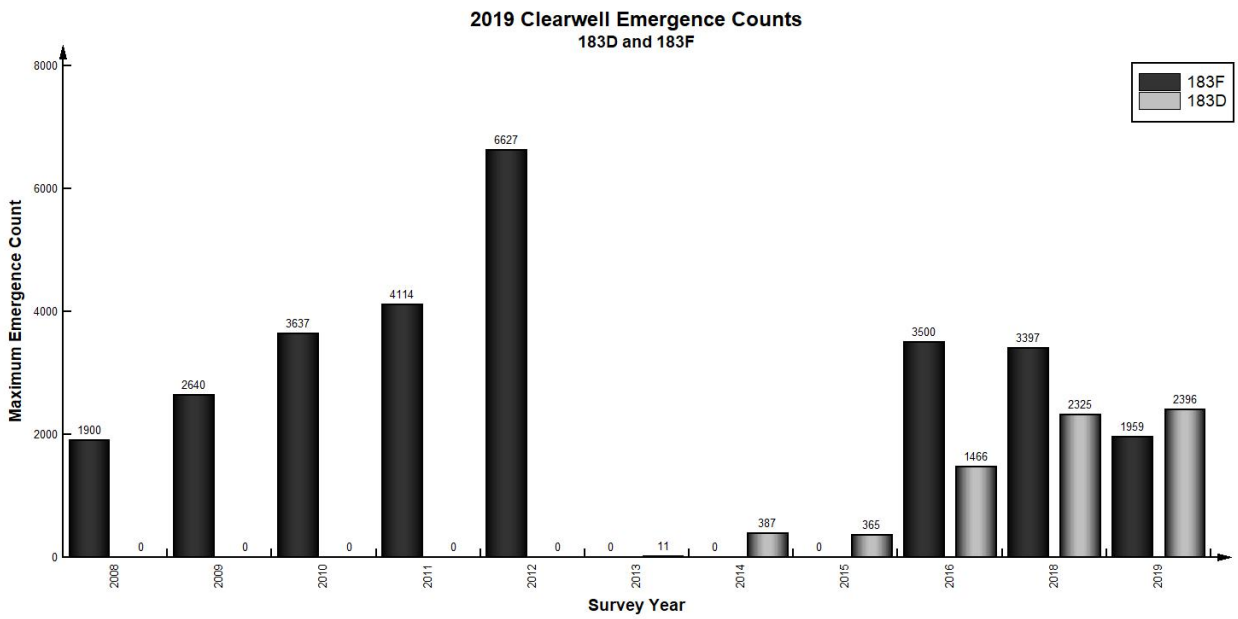

Figure 11-18. Maximum Emergence Counts from the 183-F and 183-D Clearwells Since 2008.

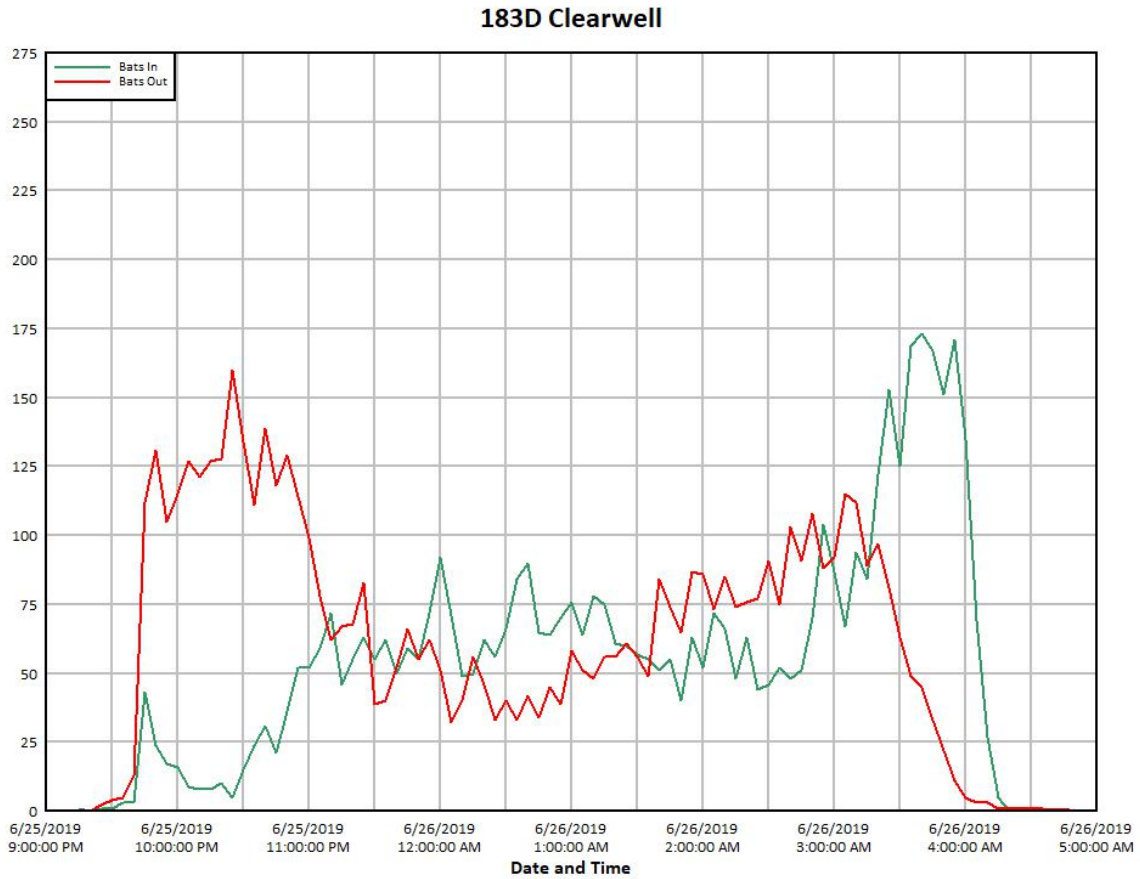

Figure 11-19. Infrared Bat Counter Ins and Outs from June Roost Survey Displayed in Chart View.

Monitoring and protection of roosting locations is becoming increasingly important with the outbreak of the fungal infection referred to as White Nose Syndrome (WNS). WNS is affecting bats in the eastern United States and Canada and is rapidly expanding westward. Bats save energy during the winter by reducing their body temperature and entering a state of hibernation called torpor. They break these torpor bouts by warming their body temperature back up at regular intervals through the winter, these events are termed "arousals." Bats are thought to use these arousals for depuration, defecation, grooming, breeding, and possibly drinking. Although these arousals represent a relatively small portion of the time the bats spend winter roosting, a large amount (up to 80%) of their energy stored for the season is burned during arousals (Thomas et al. 1990). Bats are thought to increase the number of arousals due to WNS, likely for additional grooming. Although other factors may be contributing, the excessive arousals cause bats to exhaust their energy stores prior to the end of the winter, resulting in starvation. This disease spreads quickly through roosting colonies and causes fatality rates up to 100% at infected winter roosts (more information available at whitenosesyndrome.org). The expansion of this disease occurred westward in 2016 when a little brown myotis (*Myotis lucifigus*) was found in Western Washington. With the disease now present in the state, it is extremely important to monitor and characterize roosts to provide a baseline in case the disease reaches this area. Bat researchers must follow strict WNS protocols established by the USFWS and other agencies when working with bats (WNS 2016).

Mist netting activities took place on April 25, 2019, with the support of Hanford Site biologists and radiological control technicians with WDFW biologists. Two single high mist nests (30 ft [9 m] and 40 ft [12 m]) were located immediately south of the 183-F Clearwell entrance with a triple high 40-ft (12-m) net located to the east end of the clearwell. Following sundown, a total of 33 bats were captured in the mist nets as they emerged from the structure.

All bats were bagged for additional measurements. All bats were surveyed both for radiological contamination and ultraviolet for detection of *Pseudogymnoascus destructans* (*Pd*), the fungus that causes WNS. All bats returned negative for both contamination and ultraviolet detection of any fungus. All bats appeared healthy and of normal expected weight, no signs of wing damage. All samples were submitted to the United States Geological Survey National Wildlife Health Center. The center provided final report on June 21, 2019, with results testing negative for the *Pd* fungus.

11.1.2.8 Deer Monitoring

JJ Nugent

Population characteristics of mule deer (*Odocoileus hemionus*) on the Hanford Site have been monitored since 1994. Roadside surveys have been conducted during the post-hunting period from mid-December to January to assess age and sex ratios and the frequency of testicular atrophy in males. Although hunting is not permitted on the Hanford Site, wildlife can enter and leave freely. Due to this movement, surveys are conducted after deer hunting season has ended, which runs from September through early December. Additionally, during the winter months following the fall rut, deer tend to herd into tighter groups, greatly easing monitoring efforts.

Prior to FY 2003, variable numbers of surveys were performed each year. Between FY 2003 and FY 2009, five surveys were conducted during each post-hunt period. In FY 2010 and 2011 this was reduced to three surveys. No surveys were conducted in FY 2012. Since FY 2013, three surveys have been performed every 3 years. During each survey, individual animals were identified according to sex and age class (fawn or adult). For male deer, the presence of misshapen, velvet-covered antlers was used as an indicator of testicular atrophy.

Trends in the ratios of fawns to does over time can be used to monitor changes in mule deer population size and health. Mule deer populations provide a rough indication of overall habitat quality. Additionally, mule deer are a trustee resource of interest and importance to wildlife resource agencies and local tribes.

Rocky Mountain Elk (*Cervus elaphus*) data was also collected during deer surveys, recording locations, gender, and herd counts. It was not until 1972 when elk were first documented on the Hanford Site, and in recent years the population has grown drastically. These surveys provide a valuable opportunity to document areas regularly occupied by elk and the status of population. While roadside surveys may not represent a dependable long-term survey methodology, these observations may be sufficient to maintain an ongoing record of the relative abundance of elk on the central Hanford Site.

Surveys were conducted from a vehicle along a route approximately 37 mi (60 km) long; the northern end of the route is near 100-B/C, the southern end is just north of the 300 Area (Figure 11-20). The survey route is divided into a northern region and a southern region, with the break occurring at the north end of the Hanford Townsite. Surveys begin at dawn or mid-afternoon (to end near dusk) and are driven alternatively from north to south and south to north.

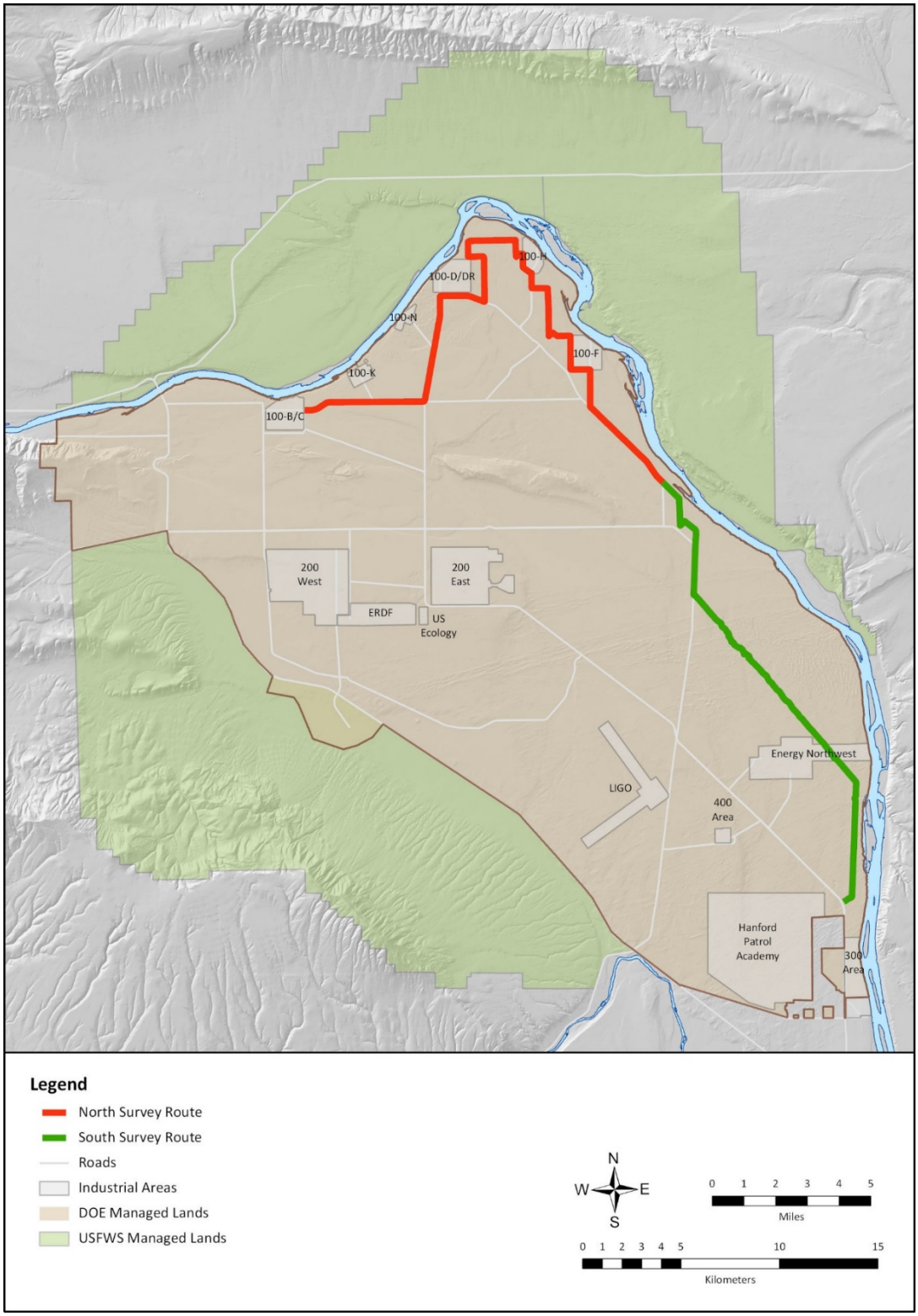

Figure 11-20. Northern and Southern Region Driving Routes used for FY 2019 Hanford Site Mule Deer Surveys.

Deer and elk are most active during early morning and late evening periods. Therefore, to attain maximum sample sizes and help attain representative estimates for these population characteristics, surveys were performed within four hours of twilight and dusk, when deer and elk were most likely to be active.

The FY 2019 northern and southern driving routes were each surveyed four times during the post-hunting period from December 2018 to January 2019. Both regions were surveyed on December 13, 2018, and January 17 and 29, 2019. Additionally, the northern region was surveyed on December 26, 2018, and the southern region was surveyed on December 27, 2018, due to staffing limitations that prevented the surveys from occurring on the same day.

A total of 206 mule deer were observed over the five survey dates (Table 11-8). Total observations were relatively equal between regions, with 43.2% in the southern region and 56.8% in the northern region, however, there were three times more bucks observed in the southern region than the northern. Combined, bucks accounted for 7.8% of observations, which is down from 19.1% in FY 2016 and 14.8% in FY 2013. There were almost twice as many fawns observed in the northern region than the southern region. Combined, fawns accounted for 38.8% of observations, up from 20.6% in FY 2016 and 21.2% in FY 2013.

Table 11-8. Mule Deer Survey Results for FY 2019.

Region / Date	Bucks	Does	Fawns	Antlerless [a]	Total
Northern Region					
December 13, 2018	0	6	6	0	12
December 27, 2018	2	21	9	0	32
January 17, 2019	2	7	8	0	17
January 29, 2019	0	26	30	0	56
Total - North	**4**	**60**	**53**	**0**	**117**
Southern Region					
December 13, 2018	5	13	6	3	27
December 26, 2018	3	17	12	0	32
January 17, 2019	2	2	0	0	4
January 29, 2019	2	11	9	4	26
Total – South	**12**	**43**	**27**	**7**	**89**
Combined					
December 13, 2018	5	19	12	3	39
December 26-27, 2018	5	38	21	0	64
January 17, 2019 [b]	4	9	8	0	21
January 29, 2019	2	37	39	4	82
Total Combined	**16**	**103**	**80**	**7**	**206**

[a] Antlerless are either fawns or does, but age could not be accurately determined.
[b] Inclement weather may have impacted survey numbers on this day.

The number of mule deer observed in the northern region averaged 29.3 ± 19.8 deer in FY 2019. In the southern region, there was an average of 22.3 ± 12.4 deer surveyed. When combining daily counts from both regions in FY 2019, the average number of mule deer was 51.5 ± 26.9 (Figure 11-21), with a range

of 21 to 82 deer observed. This average is similar to averages calculated since data collection started in 1995 and the 95% confidence interval falls within the range of the confidence intervals for all other recorded survey years, indicating that the average from FY 2019 is not statistically different than previous years. The wide confidence interval associated with the averages is likely due to a variety of factors (e.g., imperfect detection and immigration or emigration of deer in the survey areas). Increasing the number of surveys could tighten the confidence interval and provide a better assessment of changes in deer numbers over time.

The largest concentrations of mule deer were observed in the northern region between 100-D/DR and 100-H, with additional clusters between 100-N and 100-D/DR and between 100-H and 100-F (Figure 11-22). The southern region had smaller clusters of deer and were mostly observed in the immediate vicinity of the Hanford Townsite. There were no deer observed in the northern region between 100-B/C and 100-N and very few between the southern end of the Hanford Townsite and Energy Northwest in the southern region.

The number of fawns per 100 does in FY 2019 was estimated to be 94.4 (±22.5) in the northern region and 65.2 (±12.8) in the southern region. Although the yearly ratio of fawns per 100 does has varied, the running 10-year average has remained consistent with a sharp increase in FY 2019 (Figure 11-23).

There were no deer observed with abnormal antler growth in FY 2019. Historical percentage values of observed bucks with abnormal antler growth are documented below in Figure 11-24, which shows that observations have held at no more than around 3 to 4% on any given year since FY 2011. The 10-year rolling average has also remained at around 3 to 4% since FY 2009.

Elk were observed during all four surveys in the northern region and the December 27, 2018, and January 17, 2019, surveys in the southern region. The size of elk herds observed on the Hanford Site during deer surveys has grown in recent years. The largest herd of 118 individuals observed in FY 2019 was up from 77 observed in FY 2016 and 39 in FY 2013.

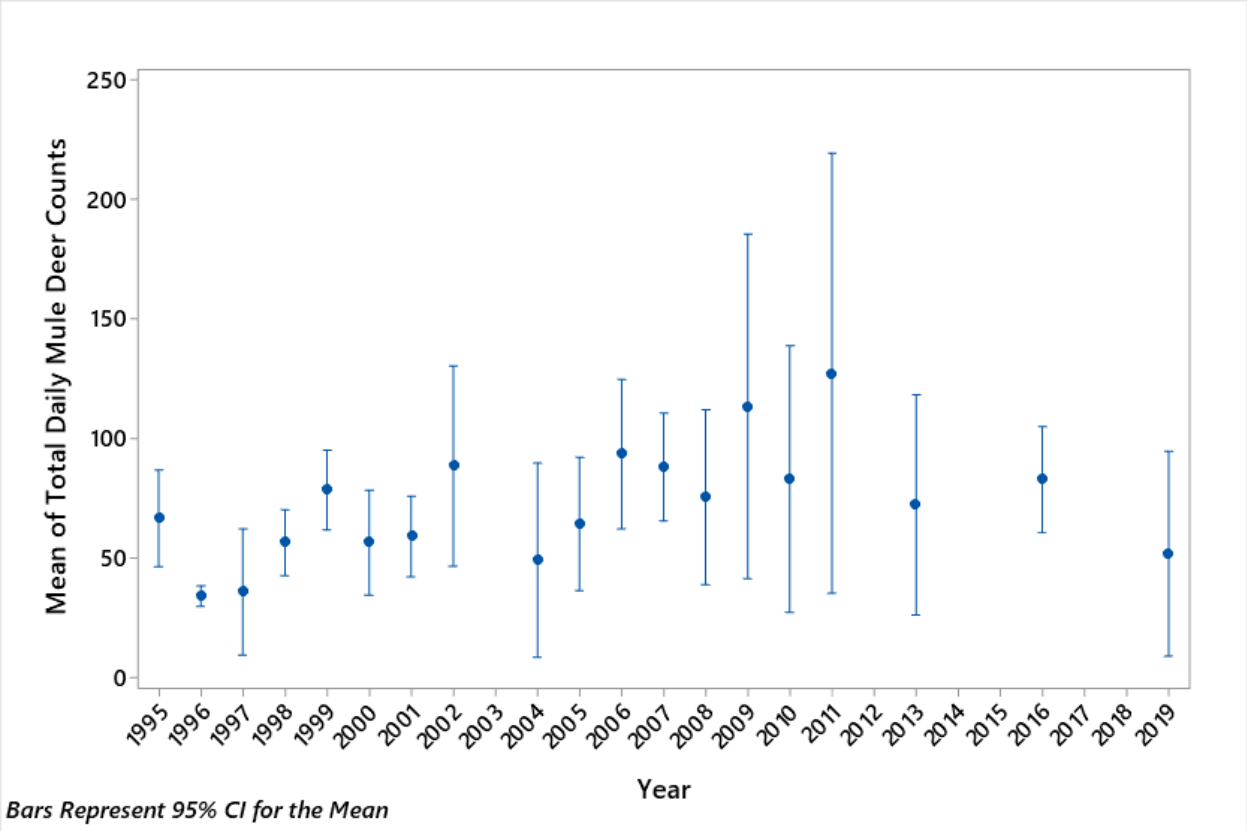

Figure 11-21. Average Number of Deer Observed in Both Regions FY 1995 to FY 2019.

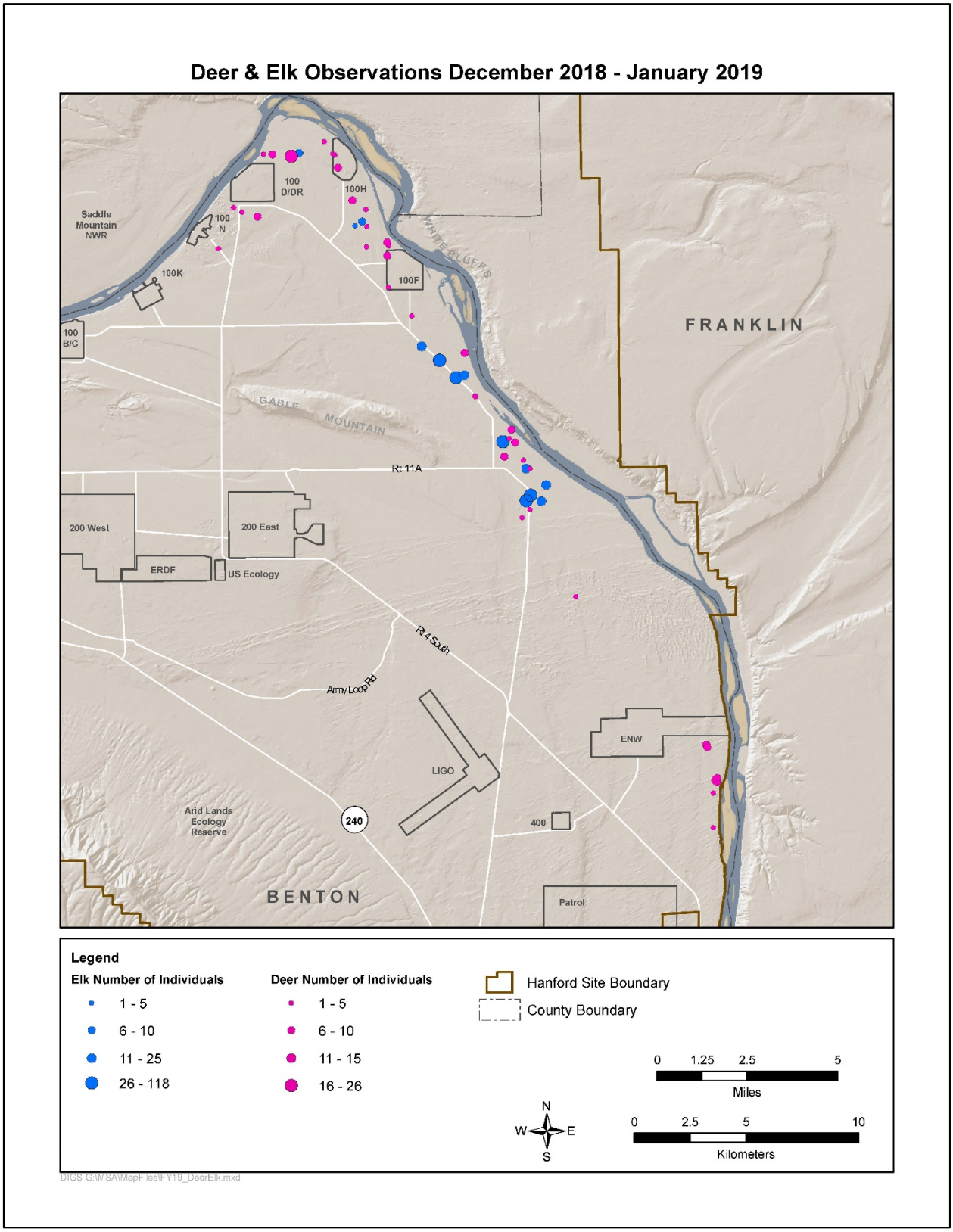

Figure 11-22. Distribution of Observed Mule Deer and Incidental Elk Herds During FY 2019.

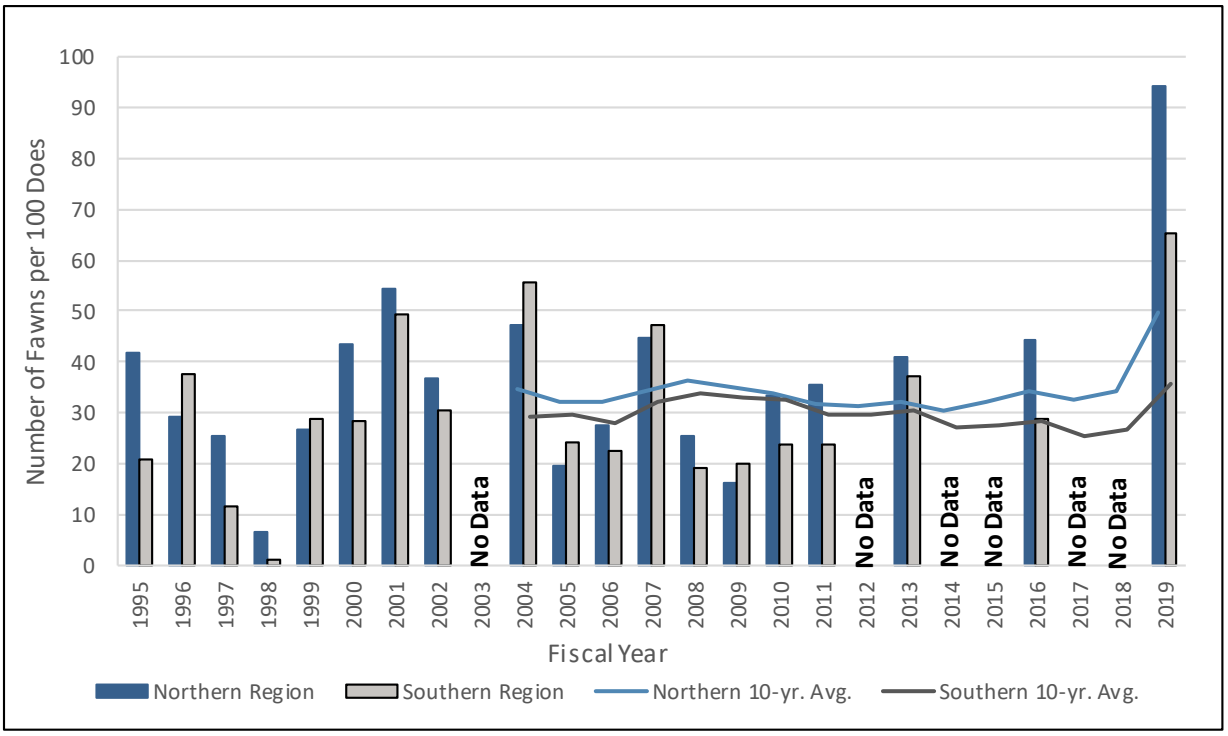

Figure 11-23. Ratio of Fawns to Does in each Region from FY 1995 to FY 2019.

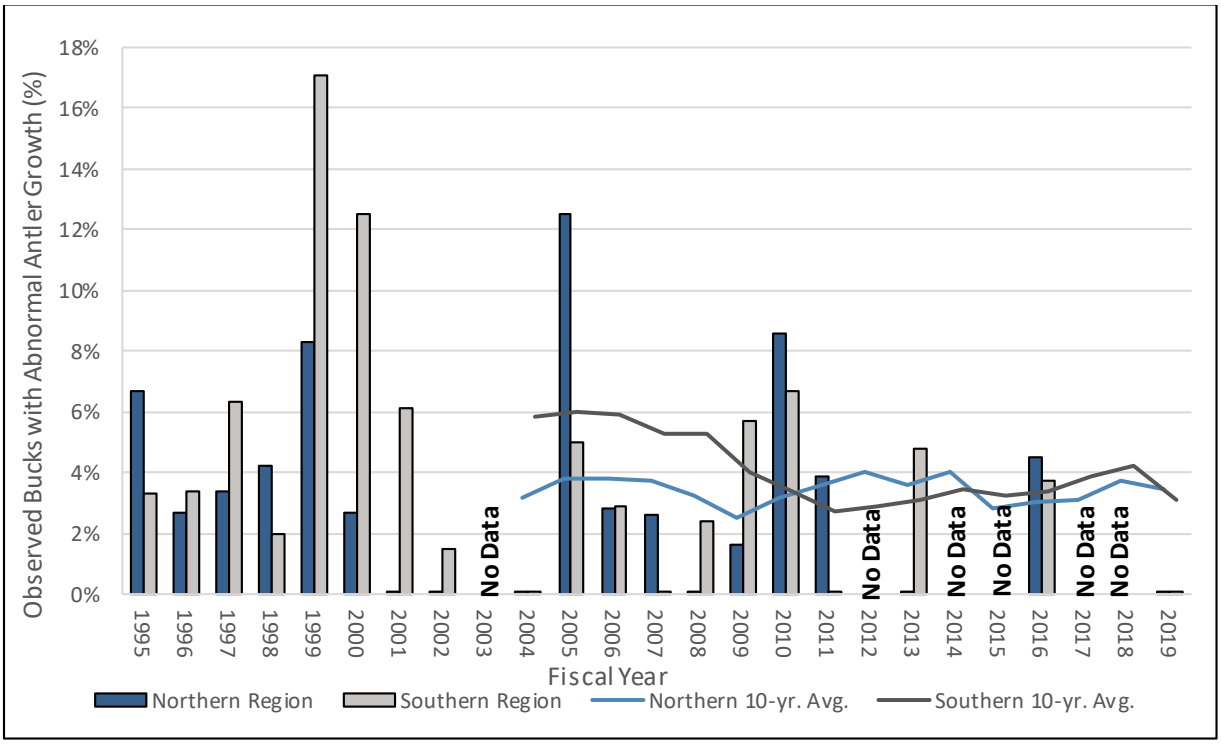

Figure 11-24. Percentage of Bucks with Abnormal Antler Growth, FY 1995 through FY 2019.

11.1.2.9 Pollinators

ES Norris

Pollinators are vital to the health of native environments (Potts et al. 2010). By enabling successful plant reproduction, pollinators support the health of nearly all other organisms in the environment that rely on healthy plant populations. Bees are the most important group of pollinators worldwide (Kearns et al. 1998, Michener 2007) and are the primary pollinating species of the Columbia River Basin (Tepedino and Griswold 1995). Within the last century, rapid declines in both wild and managed bee populations have been recorded throughout the world (Kearns et al. 1998, Goulson et al. 2005, Biesmeijer et al. 2006).

The Hanford Site Pollinator Study identified a number of best management practices to help support pollinator populations on the Hanford Site (HNF-62689). In areas where vegetation is disturbed to support project activities, the study recommends replacing pollinator food resources by restoring with native flowering plants. This study also recommended additional restoration actions to replace bee nesting habitat, as nesting area availability can be the driving factor in solitary bee population sizes (Steffan-Dewenter and Schiele 2008).

Bee nest boxes are designed to replace lost nesting resources by providing areas for solitary bees to nest. Twenty bee nest boxes were installed in July 2019 as a component of compensatory mitigation for the installation of the L-894 water line between the 200-East and 200-West Areas of the Hanford Site. The goal of this compensatory mitigation is to replace lost nesting habitat for above-ground nesting bees in a mature sagebrush ecosystem. Annual monitoring will track the condition and occupation of the bee nest boxes to determine if the compensatory mitigation was successful and to identify best practices when replacing nesting habitat for native bees. The first annual monitoring effort occurred in December 2019.

Two differing designs of bee nest boxes were installed as part of 2019 efforts in order to study the effectiveness of different box designs (Figure 11-25). The different designs, called Design A and Design B, each had varying amounts of nesting space in the form of nest tubes and drilled holes. Occupation monitoring involves visiting each box and counting the total number of nest tubes/holes and the number of occupied nest tubes/holes. Occupied nest holes are identified with the cut pieces of leaf or mud plugging the nest tubes/holes.

Occupation monitoring found that 25% (5 of the 20) bee nest boxes installed in 2019 contained bee nests. Within the 5 boxes that were occupied 15 nests were recorded. For the purposes of this monitoring effort, one nest refers to one occupied nest tube or drilled hole. Thirteen of these nests were within drilled holes and two were within the nest tubes. Seven of the 15 nests were created with mud (47%), 6 were created with leaves (40%), and 2 were created with a cellophane-like substance (13%). Of the 15 recorded nests, 6 nests were in Design A boxes (40%) and 9 nests were in Design B boxes (60%). All of the nests in the Design A boxes were located in drilled holes, while the Design B boxes had seven nests in drilled holes and two nests in nest tubes. When considering total use, 20% of Design A and 30% of Design B nest boxes were occupied by bees in 2019 monitoring.

Figure 11-25. Bee Next Boxes: Design A (Left) and Design B (Right), Not to Scale.

One of the goals of analyzing bee nest box occupation was to determine if the nest boxes were effective at replacing bee nesting habitat. A complicating factor in first-year monitoring of the nest boxes was the timing of installation. The nest boxes were installed in July 2019, approximately 3 months after the active season for bees had begun. The majority of bee activity at the Hanford Site occurs in June (HNF-62689) and the late installation of these boxes may have resulted in lower occupation and skewed the results of year one monitoring. Though 25% of the bee nest boxes were occupied, less than 1% of the available nesting spaces were used. This number is expected to increase as the boxes are available during the entire active season for bees.

The occupied bee nest boxes were numbers 1, 2, 9, 18, and 20, shown in Figure 11-26 below. Boxes 1, 2, and 20 were the closest to areas of high human activity and environmental disturbance. The lack of alternative bee nesting habitat in the areas surrounding boxes 1, 2, and 20 may have contributed to the higher occupation of those boxes.

Continued monitoring is necessary to evaluate the effectiveness of the bee nest boxes in replacing lost bee nesting habitat. Monitoring and maintenance will continue for 5 years following installation of the boxes. Additional information detailing the results of first-year monitoring for bee nest boxes is available at http://www.hanford.gov/page.cfm/ecologicalmonitoring.

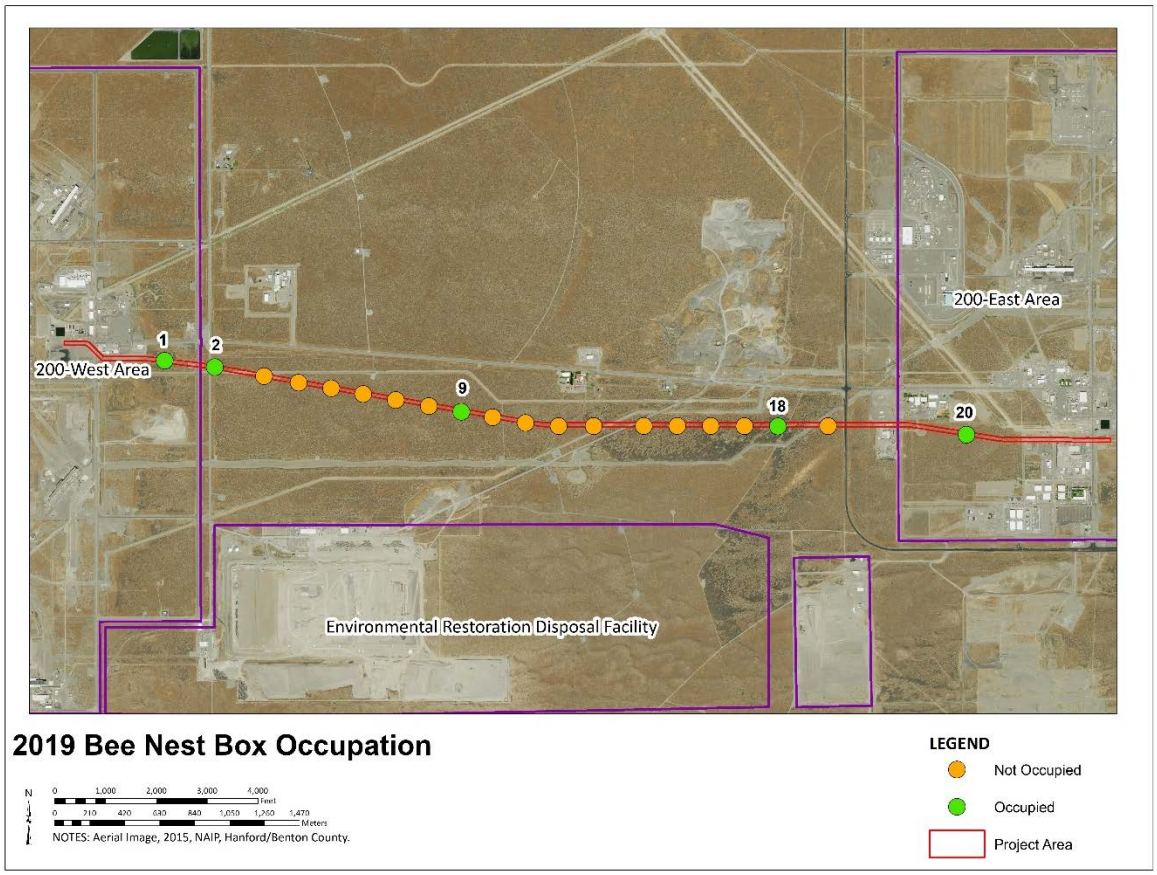

Figure 11-26. The Occupied Bee Nest Boxes in December 2019.

11.1.3 Vegetation and Habitat Monitoring

ES Norris

This section provides inventory, monitoring and survey information for vegetation and habitats evaluated at the Hanford Site during 2019. This information is provided in context with historical data and trend information, if applicable. Vegetation occurring on the Hanford Site has been surveyed periodically for decades. This survey information has been used to create vegetation maps, track rare plant species occurrence and distribution, and classify areas of the Hanford Site as rare element occurrences, as defined by the Washington Natural Heritage Program (WNHP 2019). In addition, monitoring data are used to protect rare and sensitive vegetation and habitats from Hanford Site operations. In 2019, vegetation and habitat monitoring included riparian vegetation classification, riparian rare plant monitoring, and vernal pool monitoring. The following sections provide summaries of the monitoring results; additional reports can be found at: http://www.hanford.gov/page.cfm/EcologicalMonitoring

11.1.3.1 Riparian Vegetation.

In the late summer and fall 2018, riparian vegetation along the Hanford Reach of the Columbia River was mapped. Riparian mapping work continued in 2019 and built upon the work done in 2018 in order to update the riparian vegetation map along high priority areas of the Hanford Reach. The portion of the shoreline mapped in 2019 is depicted in Figure 11-27. The vegetation mapping included applying a

template of vegetation types to observed vegetation assemblages, revisiting known rare plant sites in the study area, and documenting other rare plant occurrences as they were encountered.

Riparian vegetation monitoring in 2019 included establishing 371 geo-referenced photo points to depict changes in the dominant vegetation over time. Additionally, approximately 175 plots were established to further characterize vegetative zones in riparian areas. Vegetative cover types were assigned according to the vegetation cover types as defined by Pacific Northwest National Laboratory, as defined in Table 11-9 (PNNL-14687).

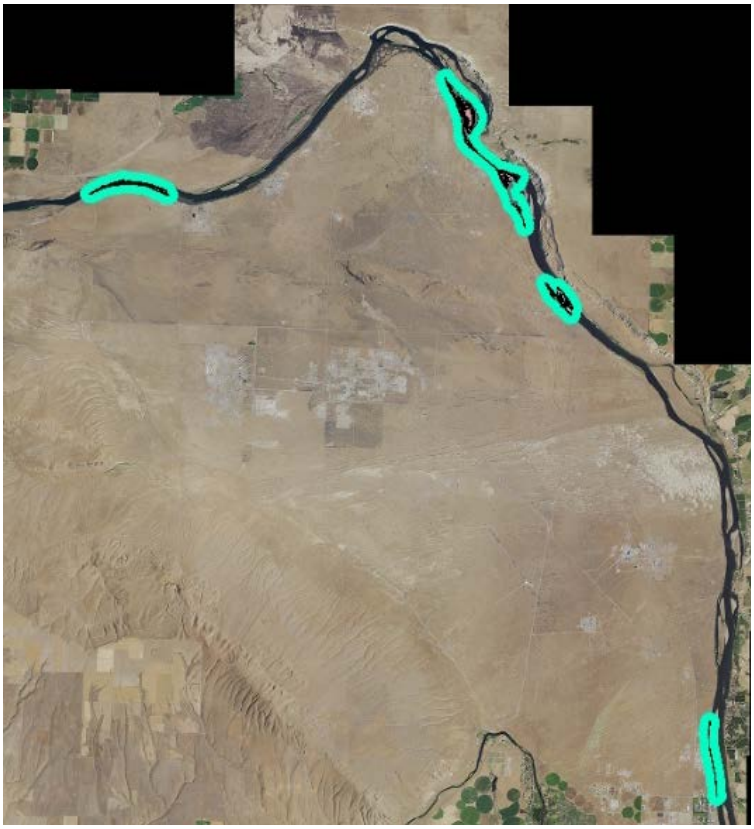

Figure 11-27. Area Monitored in 2019 Riparian Vegetation Mapping Surveys.

Table 11-9. Vegetation Cover Types (PNNL-14687). (2 Pages)

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 (*Apocynum cannabinum*) and western goldenrod (*Euthamea occidentalis)* and scattered herbs.
Exotic weeds	Introduced weedy species such as knapweeds (*Centaurea diffusa* and *Rhaponticum repens*), Russian thistle (*Salsola tragus*), and cheatgrass (*Bromus tectorum*).

Table 11-9. Vegetation Cover Types (PNNL-14687). (2 Pages)

Vegetation Cover Type	Cover Type Description
Horsetail association	Horsetails (*Equisetum* 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 (*Juniperus scopulorum*) at the transition between riparian and upland cover types.
Non-persistent emergent and emergent wetlands	Wetland areas of backwater and sloughs characterized by cattails (*Typha latifololia*), rushes (*Juncus* species and *Bolboschoenus maritimus*), and sedges (*Cyperus* species, *Eleocharis* species, and *Carex* species).
Reed canarygrass	Stands of reed canary grass (*Phalaris arundinaceae*).
Willow	Coyote willow (*Salix exigua*) patches and small groves scattered along the shore with occasional peach leaf willow (*Salix amygdaloides*).
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 (*Eriogonum niveum*)/bunchgrass, sagebrush (*Artemisia tridentata*)/bunchgrass, rabbitbrush (*Chrysothamnus viscidiflorus* or *Ericameria nauseosa*)/bunchgrass, rabbitbrush/cheatgrass, and Antelope bitterbrush (*Purshia tridentata*)/bunchgrass.
Riparian wheatgrass association	Riparian wheatgrass (*Elymus lanceolatus*) 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 *Artemisia* subshrubs with an understory hairy goldaster (*Heterotheca villosa*), western willow aster (*Symphotrichum lanceolatum*), Columbia tickseed (*Coreopsis tinctoria*), sneezeweed (*Helenium autumnale*), leafy beggar ticks (*Bidens frondosa*), and other riparian forbs.
Wormwood/perennial grass	Perennial *Artemisia* subshrub species including Pacific sage or field sagewort (*Artemisia campestris*), Columbia River wormwood or mugwort (*Artemisia lindleyana* ssp. *lindleyana*), and prairie or white sagebrush (*Artemisia lindleyana* ssp. *ludoviciana*).
Sand dropseed grass association	A subset of the wormwood/perennial grass category where the wormwood component is sparse or missing (sand dropseed [*Sporobolus cryptandrus*]).
Wormwood/riparian wheatgrass	Perennial *Artemisia* subshrub species with riparian wheatgrass as the dominant understory grass.
Wild rye association	Great Basin wild rye (*Leymus cinereus*), a large perennial bunchgrass.
Open sand	Open sand beaches occur in small stretches.
Riparian shrub	Small patches of dense choke cherry (*Prunus virginiana*), currant (*Ribes* species) and/or Wood's rose (*Rosa woodsii*), clematis (*Clematis ligusticifolia*), and various forbs or grasses may be present.

11.1.3.2 Rare Plants.

Rare plant data were collected for a number of species during riparian monitoring in 2019 (Table 11-10). These occurrences were located in both known rare plant areas and occurred in previously undocumented areas. During the course of the surveys, an annual spike-rush was located in muddy backwaters at two locations. It has been tentatively identified as *Eleocharis atropurpurea*, or purple spike-rush, but further investigation is required to determine the species. If identified as *Eleocharis*

atropurpurea, it will be the first individual found in the region as it has only been documented once before in Washington State in Lake Chelan in 1892 (WDNR 2019). Occurrence forms of rare plant species will be submitted to the Washington State Natural Heritage Program.

Table 11-10. Rare Plant Data During Riparian Monitoring 2019.

Species	Common Name	Status [a]	Number of Point Locations (2019)
Eleocharis cf. atropurpurea	Purple spike-rush	Possibly Extirpated	12
Epilobium campestre	Smooth willowherb	WA Review List 1	15
Hypericum majus	Canadian St. John's-wort	State Sensitive	40
Lipocarpha aristulata	Awned halfchaff sedge	State Threatened; Federal Sensitive	45
Oenothera cespitosa	Tufted evening-primrose	State Sensitive; Federal Sensitive	1
Rorippa columbiae	Columbia yellowcress	State Threatened; Federal Sensitive	13
Rotala ramosior	Lowland toothcup	State Sensitive; Federal Sensitive	93
Sporobolus compositus	Composite dropseed	State Sensitive; Federal Sensitive	32

[a] Status from Washington Natural Heritage Program 2019 Washington Vascular Plant Species of Special Concern, published July 15, 2019

11.1.3.3 Vernal Pools

Shallow ephemeral wetlands (also known as vernal pools) in very small to rarely large depressions occur throughout the exposed, volcanic scablands on the Columbia Plateau. These pools are characterized by fresh water inundation for much of the winter and spring, followed by dramatic lowering of the water table at the approach of summer. On the Columbia Plateau, vernal pools are geographically limited but can be locally common (Rocchio and Crawford 2015b). In the state of Washington the Columbia Plateau Vernal Pool ecosystem is considered to be "Imperiled," that is with a high to moderate risk of extirpation (Rocchio and Crawford 2015a).

In 1997, during surveys done on the Hanford Site for the DOE, The Nature Conservancy located three previously undocumented clusters of approximately 20 vernal pools. The Hanford Site pools were located on the east end of Umtanum Ridge, in the central part of Gable Butte, and at the eastern end of Gable Mountain (TNC 1998). The majority of these pools were located again in the spring of 2017 after an unusually wet period resulted in 6.86 in. (17.4 cm) of precipitation and 28 in. (71 cm) of snowfall between October 2016 and the end of February 2017. Roughly 25 vernal pools were containing water during monitoring in 2017. The vernal pools were monitored again the following winter, which received less precipitation in the same time period with 4.12 in. (10.46 cm) of precipitation and 6.8 in. (17.27 cm) of snowfall. Pools were monitored for presence/absence and for vegetative composition. No pools were found containing water during monitoring in 2018.

The fall and winter of 2018/2019 was fairly mild until February 2019 when the Hanford Site saw large amounts of snowfall comparable to the snowfall experienced before the 2017 vernal pool monitoring season. Precipitation between October and the end of February totaled 5.15 in. (13.1 cm), more than

the winter of 2017/2018 and less than the winter of 2016/2017. In addition to the 32.1 in. (81.5 cm) of snowfall received from October 2018 to February 2019, 4.4 in. (11.2 cm) of snow fell in March 2019. This unusually large amount of snowfall presented an opportunity to monitor vernal pools for presence/absence. Additionally, monitoring during a year with higher snowfall and lower precipitation than the 2016/2017 season may indicate if precipitation or snowfall have a greater effect on vernal pool water levels.

Vernal pools were monitored in April 2019. Though snowfall in 2019 was significantly higher than in the 2016/2017 season, vernal pools were not as numerous or robust in 2019 as they were in 2017 (Figure 11-28). Gable Butte and Gable Mountain pools were the only pools monitored that contained water, suggesting these pools are more likely to contain water in lower precipitation and snowfall years. Because they held water in a year when not all pools were inundated, pools GB-4, GB-7, GM-1, and GM-2 may host different cohorts of plants than the drier pools. Interestingly, vegetative composition surveys in 2018 found facultative wetland plants at GM-2, GM-3, and GB-4. Gable Butte pool BC-1 was the only pool where facultative wetland plants were found in 2018 and that did not contain water in 2019.

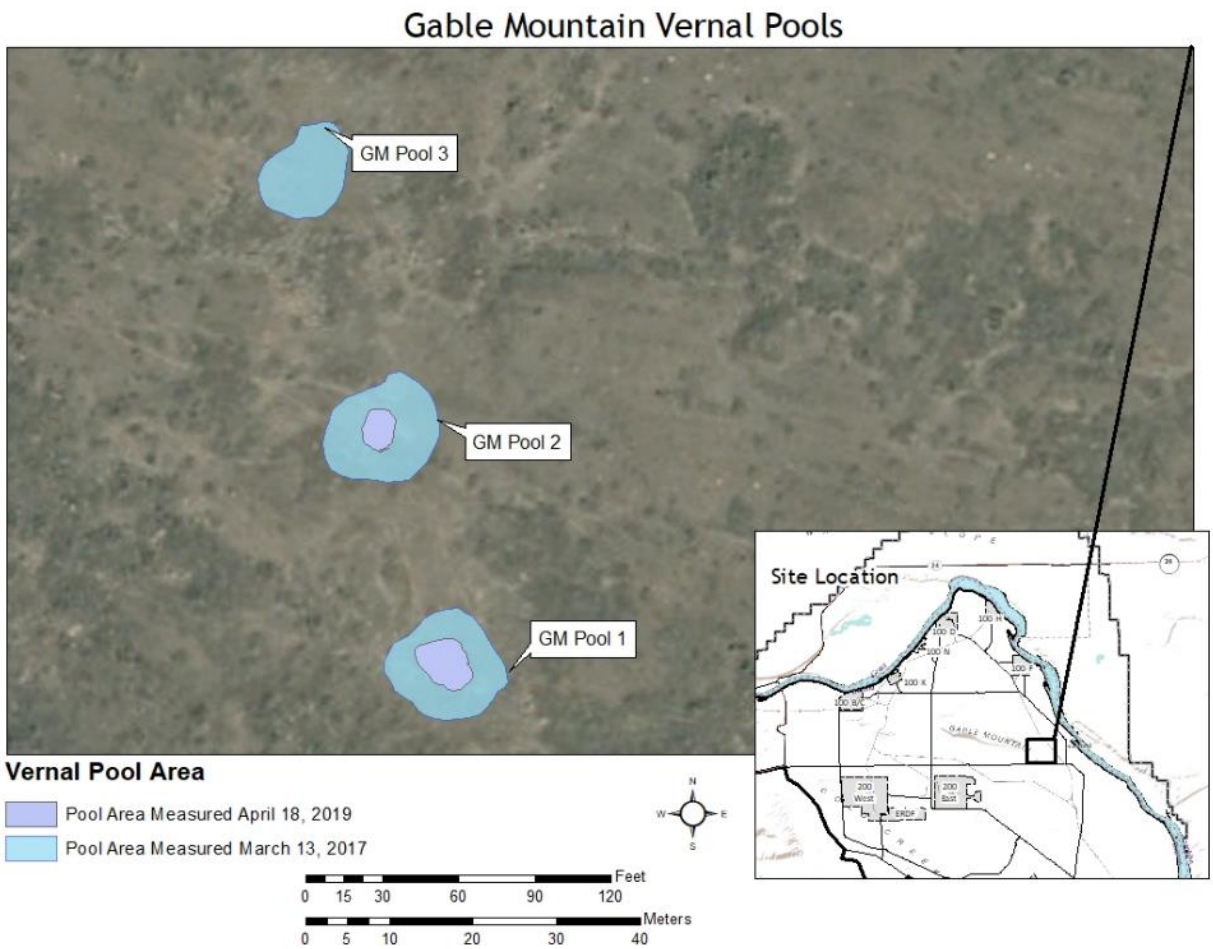

Figure 11-28. Boundaries of the Gable Mountain Pools in 2019 Compared to 2017 Boundaries.

The small size and limited occurrence of the vernal pools after heavy snowfall suggests a few possible scenarios. It is possible that winter precipitation plays a greater role in determining vernal pool water levels than snowfall, and 2018/2019 precipitation was not enough to fill pools to 2017 levels. Vernal pool progression may also be associated with daily temperatures and the speed of snowmelt. It is also possible that monitoring in mid-April was too late in the season to detect all of the vernal pools that had filled that year. For example, 2017 monitoring found the Gable Mountain pools were all present on March 30 but only GM-1 was present on May 8. Future monitoring with the goal of determining presence/absence of vernal pools should aim to visit the pools as soon as snowmelt occurs, ideally early March. Monitoring the vernal pools in early March 2019 was not possible, as it snowed the first week of March 2019 and there was significant snow on the ground through the first half of the month.

Additional information detailing the results of 2019 vernal pool monitoring are available at http://www.hanford.gov/page.cfm/ecologicalmonitoring.

11.2 Endangered and Threatened Species

ES Norris, JW Wilde

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 for both plant and animal species.

The purpose of the ESA 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 ESA. Washington State regulations also list species as endangered and threatened; however, such a listing does not carry the protection of the federal ESA. 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 11-11 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 11-11. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (3 Pages)

Species	Status[a]	
	Federal	State
Plants		
Annual sandwort (*Minuartia pusilla)*		Threatened
Awned halfchaff sedge (*Lipocarpha aristulata*)	Sensitive	Threatened
Beaked spike-rush (*Eleocharis rostellata*)		Sensitive

Table 11-11. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (3 Pages)

Species	Status[a]	
	Federal	State
Canadian St. John's wort (*Hypericum majus*)		Sensitive
Columbia milkvetch (*Astragalus columbianus*)	Sensitive	Sensitive
Columbia yellowcress (*Rorippa columbiae*)	Sensitive	Threatened
Composite dropseed (*Sporobolus compositus*)	Sensitive	Sensitive
Coyote tobacco (*Nicotiana attenuata*)	Sensitive	Sensitive
Desert cryptantha (*Cryptantha scoparia*)		Sensitive
Desert dodder (*Cuscuta denticulata*)		Threatened
Dwarf evening primrose (*Eremothera pygmaea*)	Sensitive	Sensitive
Foxtail mousetail (*Myosurus alopecuroides*)	Sensitive	Threatened
Geyer's milkvetch (*Astragalus geyeri* var. *geyeri*)	Sensitive	Threatened
Grand redstem (*Ammannia robusta*)	Sensitive	Threatened
Gray cryptantha (*Cryptantha leucophaea*)	Sensitive	Threatened
Great Basin gilia (*Aliciella leptomeria*)		Threatened
Hairy bugseed (*Corispermum villosum*)		Sensitive
Hoover's desert parsley (*Lomatium tuberosum*)	Sensitive	Sensitive
Loeflingia (*Loeflingia squarrosa*)		Threatened
Lowland toothcup (*Rotala ramosior*)	Sensitive	Sensitive
Red poverty-weed (*Micromonolepis pusilla*)	Sensitive	Threatened
Rosy pussypaws (*Calyptridium rosea*)	Sensitive	Threatened
Small-flower evening-primrose (*Eremothera minor*)		Sensitive
Snake River cryptantha (*Cryptantha spiculifera*)	Sensitive	Sensitive
Snowball cactus (*Pediocactus nigrispinus*)	Sensitive	Sensitive
Suksdorf's monkey flower (*Erythranthe suksdorfii*)	Sensitive	Sensitive
Thompson's sandwort (*Eremogone franklinii* var. *thompsonii*)		Sensitive
Tufted evening-primrose (*Oenothera cespitosa* ssp. *cespitosa*)	Sensitive	Sensitive
Umtanum desert buckwheat (*Eriogonum codium*)	Threatened	Endangered
White Bluffs bladderpod (*Physaria douglasii* ssp. *tuplashensis*)	Threatened	Endangered
White eatonella (*Eatonella nivea*)		Threatened
Whited's fuzzytongue penstemon (*Penstemon wilcoxii*)	Sensitive	Threatened
Yellow wildrye (*Leymus flavescens*)	Sensitive	Sensitive
Mollusks		
California floater (*Anodonta californiensis*)		Candidate
Ashy pebblesnail (*Fluminicola fuscus*)		Candidate
Shortface lanx (*Fisherola nuttalli*)		Candidate
Insects		
Columbia clubtail (dragonfly; *Gomphus lynnae*)		Candidate
Columbia River tiger beetle (*Cicindela columbica*) [b]		Candidate
Silver-bordered fritillary (*Boloria selene*)		Candidate
Fish		
Bull trout (mid-Columbia River; *Salvelinus confluentus*)[c]	Threatened	Candidate
Chinook salmon (upper Columbia spring-run; *Oncorhynchus tshawytscha*)	Endangered	Candidate
Leopard dace (*Rhinichthys falcatus*) [c]		Candidate
Mountain sucker (*Catostomus platyrhynchus*) [c]		Candidate
River lamprey (*Lampetra ayresii*) [c]	Species of Concern	Candidate
Steelhead (upper Columbia River; *Oncorhynchus mykiss*)	Threatened	Candidate
Birds		
American white pelican (*Pelecanus erythrorhynchos*)		Threatened
Bald eagle (*Haliaeetus leucocephalus*)	Species of Concern	None
Burrowing owl (*Athene cunicularia*)		Candidate
Clark's grebe (*Aechmophorus clarkii*)		Candidate
Common loon (*Gavia immer*)		Sensitive

Table 11-11. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (3 Pages)

Species	Status[a]	
	Federal	State
Ferruginous hawk (*Buteo regalis*)		Threatened
Flammulated owl (*Otus flammeolus*)[c]		Candidate
Golden eagle (*Aquila chrysaetos*)		Candidate
Greater sage grouse (*Centrocercus urophasianus*)	Species of Concern	Threatened
Lewis' woodpecker (*Melanerpes lewis*)[c]		Candidate
Loggerhead shrike (*Lanius ludovicianus*)		Candidate
Northern goshawk(*Accipiter gentilis*)[c]		Candidate
Sagebrush sparrow (*Artemisiospiza nevadensis*)		Candidate
Sage thrasher (*Oreoscoptes montanus*)		Candidate
Sandhill crane (*Grus canadensis*)		Endangered
Western grebe (*Aechmophorus occidentalis*)		Candidate
Amphibians and Reptiles		
Sagebrush lizard (*Sceloporus graciosus*)		Candidate
Striped whipsnake (*Masticophis taeniatus*)		Candidate
Western toad (*Anaxyrus boreas*)		Candidate
Mammals		
Black-tailed jackrabbit (*Lepus californicus*)		Candidate
Merriam's shrew (*Sorex merriami*)		Candidate
Townsend's ground squirrel (*Spermophilus townsendii*)		Candidate
Washington ground squirrel (*Urocitellus washingtoni*)[c]	Candidate	Candidate
White-tailed jackrabbit (*Lepus townsendii*)		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 are known to occur regularly in the Hanford Reach of the Columbia River, spring-run Chinook salmon (*Oncorhynchus tshawytscha*), which is listed as endangered, and steelhead (*O. mykiss*), which is listed as threatened. One additional federally listed threatened 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 ESA 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, 16 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 12 sensitive plant species occurring or potentially occurring on the Hanford Site.

11.3 Cultural and Historic Resource Protection

CD Currie, AP Fergusson, and KM Mendez

Cultural and historic resources protection on the Hanford Site is conducted under the direction of the DOE-RL Cultural and Historic Resources Program, implemented by MSA, to ensure site compliance with federal cultural resources laws and regulations (Section 2.5). Program activities in 2019 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.

Cultural and Historic Resources Program personnel oversee all cultural resource activities at the Hanford Site. Project-specific NHPA Section 106 compliance work scope in 2019 was performed by staff archaeologists from MSA.

The 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. 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. The NHPA is 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.

In 2019, Hanford Site archaeologists completed 71 NHPA Section 106 cultural resources reviews that included the following:

- Twenty-six 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 necessary[2].
  - Twenty were identified as No Historic Properties Affected.
  - Five 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.
- Twenty 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.
- Eighteen projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews (Previously Reviewed Project Analyses).
- Six 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 915.1 ac (370.3 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 11-29).

[2]This number does not reflect all full cultural resources reviews initiated in 2019. Additional reviews were initiated in 2019 but completed in 2020 and are not included in this report.

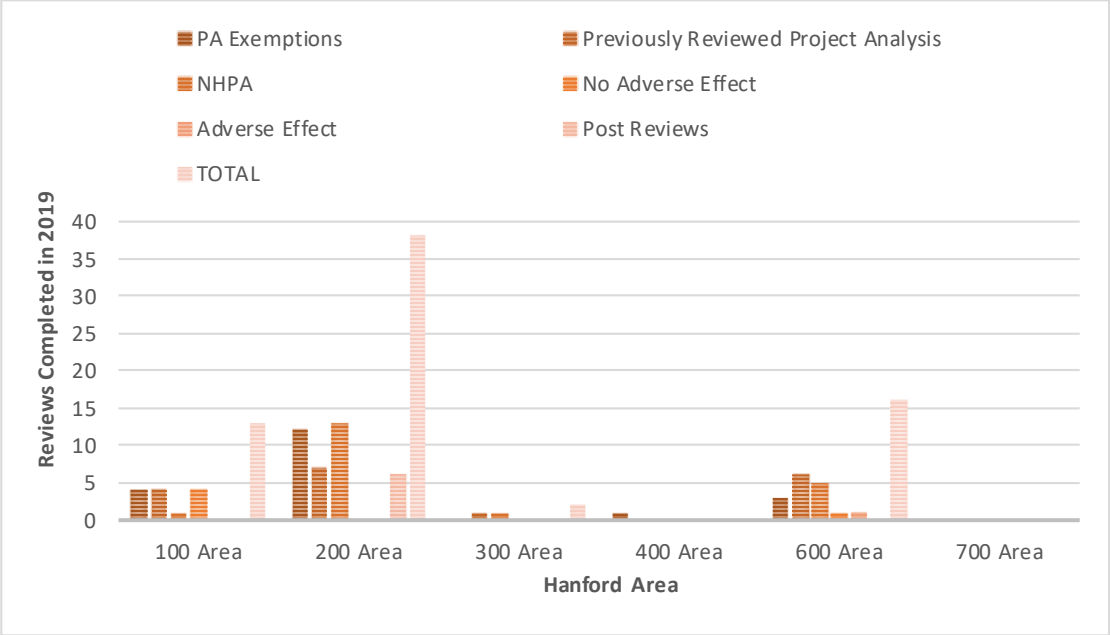

Figure 11-29. Hanford Site National Historic Preservation Act Section 106 Reviews by Area.

DOE-RL 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 26 projects that required a full review because of their potential to affect cultural resources within the project area.

DOE-RL Cultural Resources Program staff members held 11 meetings in 2019 with Tribal Cultural Resources staff members from the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of the Yakama Nation, and Wanapum. Discussions focused on the cultural resources reviews completed and initiated in 2019, 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, Hanford Site archaeologists conducted monitoring activities 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 2019, 18 pre-contact and 5 historic archaeological sites were monitored under the Section 110 site conditions monitoring program. As part of Section 110 block survey Hanford Site archaeologists surveyed 230.11 ac (93.12 ha) and recorded three historic sites and nine historic isolates. Tribal cultural resources personnel participated in site monitoring activities.

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 2019, 16 new archaeological sites were recorded and 20 new isolated finds were located (Table 11-12). National Register evaluations were completed for 13 newly recorded archaeological sites. No new archaeological site forms for 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 11-12. Sites and Isolates Recorded or Updated.

2019	Eligible	Not Eligible	Unevaluated	Total
Site updates	0	0	0	0
New sites	0	13	3	16
New isolates	0	0	20	20
Historic Property Inventory Form	0	0	0	0
Total	**0**	**13**	**23**	**36**

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 2019. The Hanford Site Section 106 database tracks all cultural resources reviews conducted on the Hanford Site. The Section 106 database is used to track 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 2019, 150 new projects were opened, with pertinent information entered as acquired into the Section 106 database. A total of 141 projects were closed out after data entry was complete, with a digital copy of the project documentation added to the digital archive.

The cultural resources Geographic Information System (GIS) database contains cultural resource data collected from Hanford Site contractors including new archaeological surveys completed as part of Section 106 work, newly recorded and updated archaeological site locations, and contextual information describing the survey or site. All Hanford Site contractors use the GIS database for literature reviews, cultural resource compliance reporting and documentation, and research by DOE-approved users. As part of ongoing database management in 2019, a total of 23 polygons delineating completed archaeological surveys were added to the Hanford Site Survey Master shapefiles (map file) and 36 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. The Cultural and Historic Resources Program manages a collection of archaeological artifacts. These artifacts are curated at the Wanapum Heritage Center. The Wanapum Heritage Center repository meets federal standards for archaeological collections storage and meets regulatory requirements outlined in 36 CFR 79, "Curation of Federally Owned and Administered Archaeological Collections." Staff at the Wanapum Heritage Center are documenting, accessioning, and preparing artifacts for long-term storage in a manner consistent with current curation standards.

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 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 11-30). In addition to care, security, and public access to the collection, the partnership provides research opportunities and use in academic programs for undergraduates. Washington State University, Tri Cities (WSU-TC) also provides a repository for the collection that allows DOE to meet the requirements of 36 CFR 79 including protecting these resources from theft, fire, breakage, or deterioration.

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 2019 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 2019, 20 items were reviewed, cleared for public release, and/or transferred to the HHP repository for integration with the Hanford Collection (Figure 11-31). Nineteen artifacts and one linear foot of archival material were evaluated for inclusion in the Hanford Collection. These materials were

delivered to the HHP repository at WSU-TC, leaving 20 (2.7%) of the 744 tagged artifacts scheduled for collection between 2020 and 2048.

Figure 11-30. Storage of Artifacts and Multimedia from the Manhattan Project and Cold War Era.

Figure 11-31. Ground Penetrating Radar Equipment Used on the Hanford Site, Transferred to the Hanford History Project Repository in 2019.

During 2019, the HHP processed and housed artifacts, multimedia were moved , and public access was facilitated to the Hanford Collection and Hanford Outreach Collection. Artifacts continue to be indexed and added to the collections management database (Re:Discovery Proficio) for tracking and management. An additional 351 historic items were catalogued during 2019; to date, approximately 788 (44%) of Hanford Collection and Hanford Outreach Collection items collected since 2011 and now housed by HHP have been fully catalogued.

In coordination with DOE's National Park Program, the HHP worked with the public as well as regional and national institutions to implement access to the collection for education and research. As part of public education and outreach efforts, the HHP received and worked with 16 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 and institutions (e.g., Wanapum Heritage Center, Washington State Historical Society, Spokane Public Library, City of Richland, and Columbia Basin Consulting Group) as well as used for interpretation at the Manhattan Project National Historical Park's B Reactor. In December 2019, 123 Hanford Collection and Hanford Outreach Collection items were moved from the B Reactor National Historic Landmark to the HHP repository (Figure 11-32). This move took place to make room for new interpretive displays at the B Reactor National Historic Landmark. Additionally, MSA presented information on the Hanford Collection at the annual Northwest Anthropological Conference held in Kennewick, Washington, March 20 through 23, 2019.

Figure 11-32. Communication Panels from 105-B Reactor, Transferred to the Hanford History Project Repository in 2019.

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2019 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 2019 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-2019-66, *Hanford Site Groundwater Monitoring Report for 2019*, and are not discussed in this section. However, details of the groundwater monitoring program can be found in Section 8.0.

QAs 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 ES program.

DOE O 414.1D
QA Program Requirements

Management/QA Program
Personnel Training/Qualification
Quality Improvement
Documents and Records
Work Processes
Design
Procurement
Inspection and Acceptance Testing
Management Assessment
Independent Assessment

12.1.1 Personnel Training and Qualifications

Hanford Site personnel are provided with the knowledge and skills necessary to perform specific jobs safely, effectively, and efficiently with minimal supervision. This 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
- 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 2019 were analyzed by General Engineering Laboratories, LLC (GEL), Eurofins (TestAmerica St Louis Laboratory [TASL]), 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
Eurofins (TestAmerica St Louis)		X		
ARS Aleut Analytical, LLC		X		

12.3 Quality Control Samples

Multiple types of 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 2019, 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 2019 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 2019 are shown in Table 12-4.

Table 12-3. 2019 Field Duplicate Samples.

Media	Location	Number of Duplicate Sample Pairs
Air	Various	56
Air - Tritium	Various	15
Soil	Various	6
Natural Vegetation	Various	5
Columbia River Water Transects	Various	2
Columbia River Sediment	100-D-Spring	1
Seeps	300 Area Spring	1
Wildlife – Canada Goose	100 Areas	1
Water - Irrigation	Horn Rapids Area	1
Alfalfa	SageMoor Area	1
Apricots	East Wahluke Area	1
Corn	Riverview Area	1
Leafy Vegetables	East Wahluke Area	1
Melons	Riverview Area	1
Milk	Sagemoore Area	1
Potato	East Wahluke Area	1

Table 12-4. 2019 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits [a]	Percent of Results within Control Limits
Air	Alpha (gross)	51 of 56	91
	Beta (gross)	38 of 56	67
	Americium-241	3 of 3	100
	Antimony-125	6 of 6	100
	Colbalt-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)	15 of 15	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	Antimony-125	6 of 6	100
	Cesium-134	2 of 2	100
	Cesium-137	6 of 6	100
	Cobalt-60	6 of 6	100
	Europium-152	6 of 6	100
	Europium-154	6 of 6	100
	Europium-155	6 of 6	100
	Plutonium-238	6 of 6	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
	Americium-241	2 of 2	100
Natural Vegetation	Antimony-125	5 of 5	100
	Cesium-134	5 of 5	100
	Cesium-137	5 of 5	100
	Cobalt-60	5 of 5	100
	Europium-152	5 of 5	100
	Europium-154	5 of 5	100
	Europium-155	5 of 5	100
	Plutonium-238	5 of 5	100
	Plutonium-239/240	5 of 5	100
	Potassium-40	6 of 6	100
	Ruthenium-106	5 of 5	100

Table 12-4. 2019 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits [a]	Percent of Results within Control Limits
	Strontium-90	5 of 5	100
	Uranium-234	5 of 5	100
	Uranium-235	4 of 4	100
	Uranium-238	5 of 5	100
	Americium-241	2 of 2	100
Irrigation Water	Gross alpha	1 of 1	100%
	Gross beta	1 of 1	100%
	Antimony-125	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Strontium-90	1 of 1	100%
	Tritium	1 of 1	100%
Columbia River Water Transects	Iron	2 of 2	100%
	Lead	2 of 2	100%
	Copper	2 of 2	100%
	Magnesium	2 of 2	100%
	Manganese	2 of 2	100%
	Molybdenum	1 of 2	50%
	Nickel	2 of 2	100%
	Potassium	2 of 2	100%
	Silver	2 of 2	100%
	Strontium	2 of 2	100%
	Sodium	2 of 2	100%
	Thallium	2 of 2	100%
	Thorium	2 of 2	100%
	Tin	2 of 2	100%
	Titanium	2 of 2	100%
	Antimony	2 of 2	100%
	Arsenic	2 of 2	100%
	Barium	2 of 2	100%
	Beryllium	2 of 2	100%
	Boron	2 of 2	100%
	Cadmium	2 of 2	100%
	Cesium	2 of 2	100%
	Chromium	2 of 2	100%
	Cobalt	2 of 2	100%
	Uranium	2 of 2	100%
	Vanadium	2 of 2	100%
	Zinc	2 of 2	100%

Table 12-4. 2019 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits [a]	Percent of Results within Control Limits
	Zirconium	2 of 2	100%
	Bismuth	2 of 2	100%
	Calcium	2 of 2	100%
	Phosphorus	2 of 2	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%
	Aluminum	1 of 2	50%
Seep	Iron	1 of 1	100%
	Lead	1 of 1	100%
	Copper	1 of 1	100%
	Magnesium	1 of 1	100%
	Manganese	1 of 1	100%
	Molybdenum	1 of 1	100%
	Nickel	1 of 1	100%
	Potassium	1 of 1	100%
	Silver	1 of 1	100%
	Strontium	1 of 1	100%
	Strontium-90	1 of 1	100%
	Sodium	1 of 1	100%
	Thallium	1 of 1	100%
	Thorium	1 of 1	100%
	Tin	1 of 1	100%
	Titanium	1 of 1	100%
	Antimony	1 of 1	100%
	Arsenic	1 of 1	100%

Table 12-4. 2019 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits [a]	Percent of Results within Control Limits
	Barium	1 of 1	100%
	Beryllium	1 of 1	100%
	Boron	1 of 1	100%
	Cadmium	1 of 1	100%
	Cesium	1 of 1	100%
	Chromium	1 of 1	100%
	Cobalt	1 of 1	100%
	Uranium	1 of 1	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%
	Uranium-238	1 of 1	100%
	Vanadium	1 of 1	100%
	Zinc	1 of 1	100%
	Zirconium	1 of 1	100%
	Bismuth	1 of 1	100%
	Calcium	1 of 1	100%
	Phosphorus	1 of 1	100%
	Selenium	1 of 1	100%
	Tritium	1 of 1	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 Alakalinity	1 of 1	100%
	Nitrogen in Nitrate	1 of 1	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%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Chromium	1 of 1	100%
	Hexavalent Chromium	0 of 1	0%

Table 12-4. 2019 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits [a]	Percent of Results within Control Limits
	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%
	Aluminum	1 of 1	100%
Wildlife Canada Goose	Cesium-134	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Potassium-40	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Strontium-90	1 of 1	100%
	Cesium-137	1 of 1	100%
Alfalfa	Carbon-14	1 of 1	100%
	Antimony-125	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Strontium-90	1 of 1	100%
Leafy Vegetables	Carbon-14	1 of 1	100%
	Antimony-125	1 of 1	100%

Table 12-4. 2019 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits [a]	Percent of Results within Control Limits
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Strontium-90	1 of 1	100%
Corn	Carbon-14	1 of 1	100%
	Antimony-125	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Strontium-90	1 of 1	100%
Apricots	Carbon-14	1 of 1	100%
	Antimony-125	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Strontium-90	1 of 1	100%
Melons	Carbon-14	1 of 1	100%
	Antimony-125	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Strontium-90	1 of 1	100%
Milk	Carbon-14	1 of 1	100%

Table 12-4. 2019 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits [a]	Percent of Results within Control Limits
	Antimony-125	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Iodine-129	1 of 1	100%
	Strontium-90	1 of 1	100%
	Tritium	1 of 1	100%
Potato	Carbon-14	1 of 1	100%
	Antimony-125	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Potassium-40	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Strontium-90	1 of 1	100%

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 320-125, *Hanford Environmental Radiation Oversight Program: 2018 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 of Hanford Site contractors by evaluating 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 2019 included the following:

- Air filters from 18 locations
- Columbia River continuous water from one location
- Columbia River transects from four locations
- Columbia River shoreline springs (seeps) from six locations
- Offsite irrigation water from two locations
- Columbia River Sediment from eight locations
- Melons from three locations
- Alfalfa from one location
- Apricots from two locations
- Leafy Vegetables from two locations
- Potatoes from two locations
- Corn from four locations
- Wine Must from three locations
- Canada Goose from two locations
- Soil from three locations
- Whitefish from one location.

No comparison data for 2019 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, TASL, 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 2019, the GEL, TASL, and ARS laboratories participated in the MAPEP and DOECAP programs. All three of these laboratories had overall acceptable results under these programs.

Because the TASL and ARS laboratories only analyzed carbon-14 and low level tritium, respectively, for the ES program, and neither of these analytes were directly evaluated by MAPEP in 2019, the TASL and ARS MAPEP results are not presented here. The GEL MAPEP results are summarized in Table 12-5.

Table 12-5. 2019 DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC. (2 Pages)

Environmental Sample Media and Analytes Evaluated		MAPEP 40 Series June 2019 [a]	MAPEP 41 Series January 2020 [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	100% Acceptable
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	100% Acceptable
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	Plutonium – 238[b]	100% Acceptable
Soil	Antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, technetium-99, thallium, uranium-235, uranium-238, uranium-total, vanadium, zinc	100% Acceptable	Technetium-99[b]
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, technetium-99, thallium, uranium-235, ranium-238, uranium-total, vanadium, zinc	Mercury[b] Nickel[b]	Technetium-99[b] Uranium-235[b]
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	100% Acceptable

[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, TASL, ARS) participate in independent QA and QC programs including the MAPEP and the DOECAP. For calendar year 2019, two full MAPEP evaluations were conducted (numbered 40 and 41), each of which included multiple studies of different types of media (e.g., soil, water, vegetation, air filters). The second MAPEP (evaluation number 41), is normally conducted in December but was actually conducted a month later in January of 2020.

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 and matrix. 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. See Table 12-6.

Table 12-6. MAPEP Relative Performance Status Ratings.

Difference from cumulative result	Status
Less than 20 %	Acceptable
20% - 30%	Acceptable with warning
More than 30%	Unacceptable
All ratings based on cumulative results from participating laboratories in the individual studies.	

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 2019 MAPEP results were nearly all acceptable for all media and analytes. A summary of GEL's 2019 MAPEP results is presented in Table 12-5.

Air samples collected for carbon-14 analysis were sent to TASL. This is the only analysis performed for the ES program by TASL. MAPEP does not specifically evaluate the analysis of carbon -14 in air. TASL'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.

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 ES 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 the nucleus of an atom 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 no 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 standard (DCS) – Concentration of a *radionuclide* in either water or air that results in a member of the public receiving 1 millisievert (mSv) (100 millirem (mrem)) effective dose following continuous exposure for one year for each of the following pathways: ingestion of water, submersion in air, and inhalation.

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. 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* in sufficient concentrations; and other highly radioactive material that is determined, consistent with existing law, 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 with differing atomic mass number due to number of neutrons and different physical properties. Plutonium isotopes are man-made, produced in nuclear reactions (e.g., plutonium-239 is produced by neutron absorption by 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 due to the number of neutrons 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 – Radioactive waste with low concentrations of radioactivity.

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 Σ_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 activity 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 the Hanford Site.

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

Table of Contents

B. BACKGROUND INFORMATION B-3
B.1 Public Reading Rooms B-3
B.2 Scientific Notation B-3
B.3 Units of Measure B-3
B.4 Radioactivity Units B-5
B.5 Radiological Dose Limits B-5
B.6 Radiological Dose Limits for Non-human Biota B-6
B.7 Radiological Dose Units B-6
B.8 Chemical and Elemental Nomenclature B-8
B.9 Understanding the Data Tables B-9
B.10 Standard Deviation B-9
B.11 Total Propagated Analytical Uncertainty B-10
B.12 Standard Error of the Mean B-10
B.13 Median, Maximum, and Minimum Values B-10
B.14 Negative Concentrations B-11
B.15 Greater Than (>) or Less Than (<) Symbols B-11
B.16 Understanding Graphs B-12

Figures

Figure B-1. Maximum, Median, and Minimum Values Graphical Representation. B-11
Figure B-2. Data Plotted Using a Linear Scale B-12
Figure B-3. Data Plotted Using a Logarithmic Scale B-13
Figure B-4. Data with Error Bars Plotted Using a Linear Scale B-14

Tables

Table B-1. Units of Measure. B-4
Table B-2. Conversion Table. B-4
Table B.3. Radioactivity Unit Conversions. B-5
Table B-4. Radioactivity Units. B-5
Table B-5. Radioactivity Dose Limits B-6
Table B-6. Radioactivity Dose Limits for Non-human Biota. B-6
Table B-7. Radiological Dose Units Conversions. B-7
Table B-8. Radiation Dose or Exposure Units. B-7

Table B-9. Radionuclides and Half-Lives. B-8
Table B-10. Elemental and Chemical Constituent Nomenclature. B-8

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) 725-9939 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.

Abbreviation	*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		ac	acre
mrem/yr	millirem per year		ha	hectare (1×10^{4} m^2)
Volume				km^2
cm^3	cubic centimeter		mi^2	square mile
ft^3	cubic foot		ft^2	square foot
gal	gallon		**Mass**	
L	liter		g	gram
m^3	cubic meter		kg	kilogram (1×10^{3} g)
mL	milliliter (1×10^{-3} L)		mg	milligram (1×10^{-3} g)
yd^3	cubic yard		µg	microgram (1×10^{-6} g)
			lb	pound

Table B-2. Conversion Table. (2 Pages)

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

Table B-2. Conversion Table. (2 Pages)

Multiply	By	To Obtain		Multiply	By	To Obtain
rem	0.01	Sv		Sv	100	rem
ppm	1,000	ppb		ppb	0.001	ppm
°C	(°C × 9/5) + 32	°F		°F	(°F -32) ÷ 9/5	°C
oz	28.349	g		g	0.035	oz
ton	0.9078	tonne		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 27	fCi 1	fCi 27	pCi 1	pCi 27	nCi 1	nCi 27	µCi 1	µCi 27	mCi 1	mCi 27	Ci 1	Ci 27	kCi 1
1 µBq	37 µBq	1 mBq	37 mBq	1 Bq	37 Bq	1 kBq	37 kBq	1 MBq	37 MBq	1 GBq	37 GBq	1 TBq	37 TBq
New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) (1 Ci = 3.7×10^{10} dps). 1 Becquerel = 1 disintegratios/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-7 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-7 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-7.

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-8.

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-9.

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	^{137}mBa	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 4.5×10^{9} years.

B.8 Chemical and Elemental Nomenclature

Many of the chemical contaminants discussed in this report are listed in Table B-10, 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

Table B-10. Elemental and Chemical Constituent Nomenclature.

Symbol	Constituent	Symbol	Constituent
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±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.

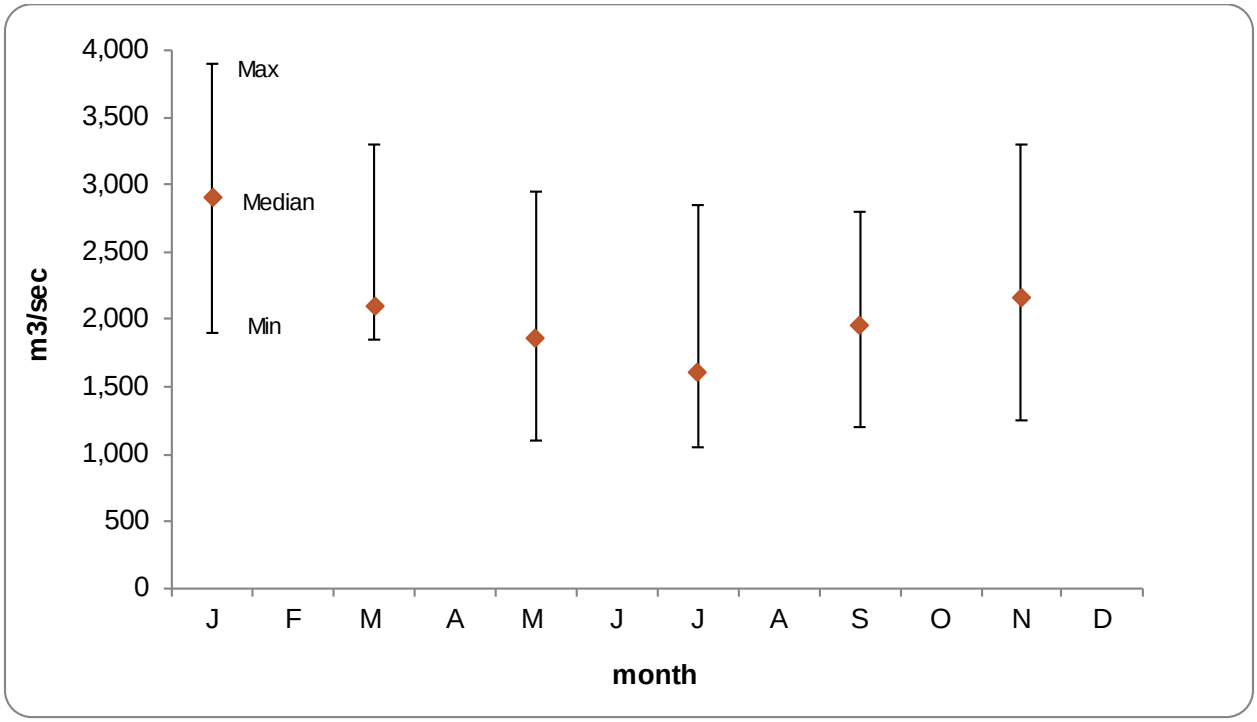

Figure B-1. Maximum, Median, and Minimum Values Graphical Representation.

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 and 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 (≤ or ≥) 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 much select an appropriate minimum value for the y-axis.

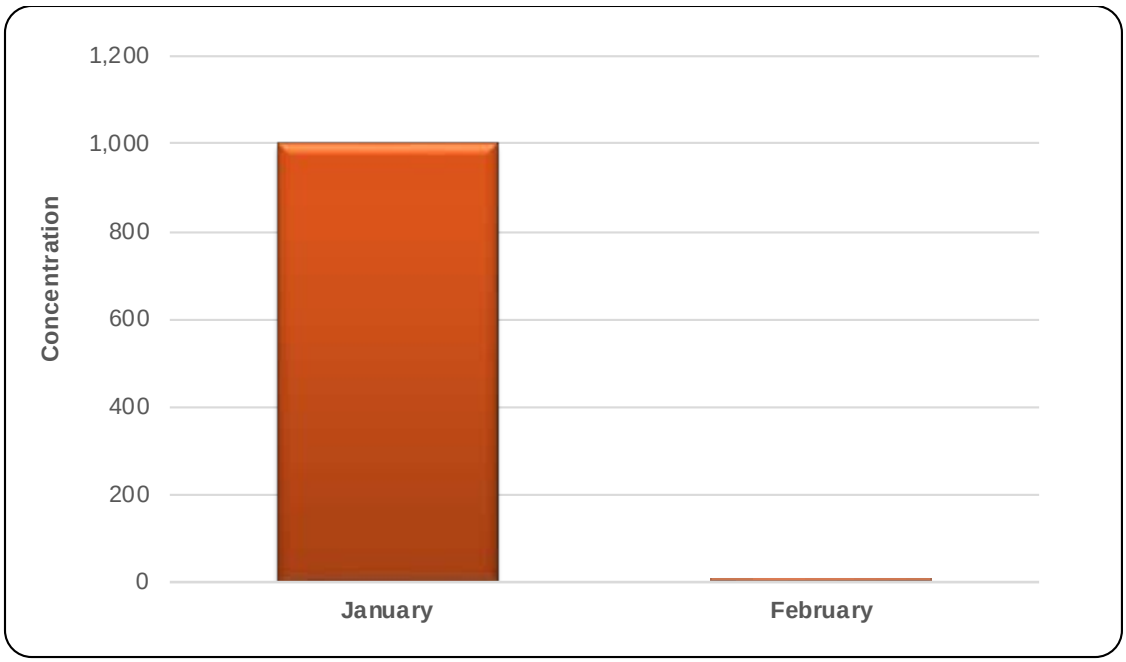

Figure B-2. Data Plotted Using a Linear Scale.

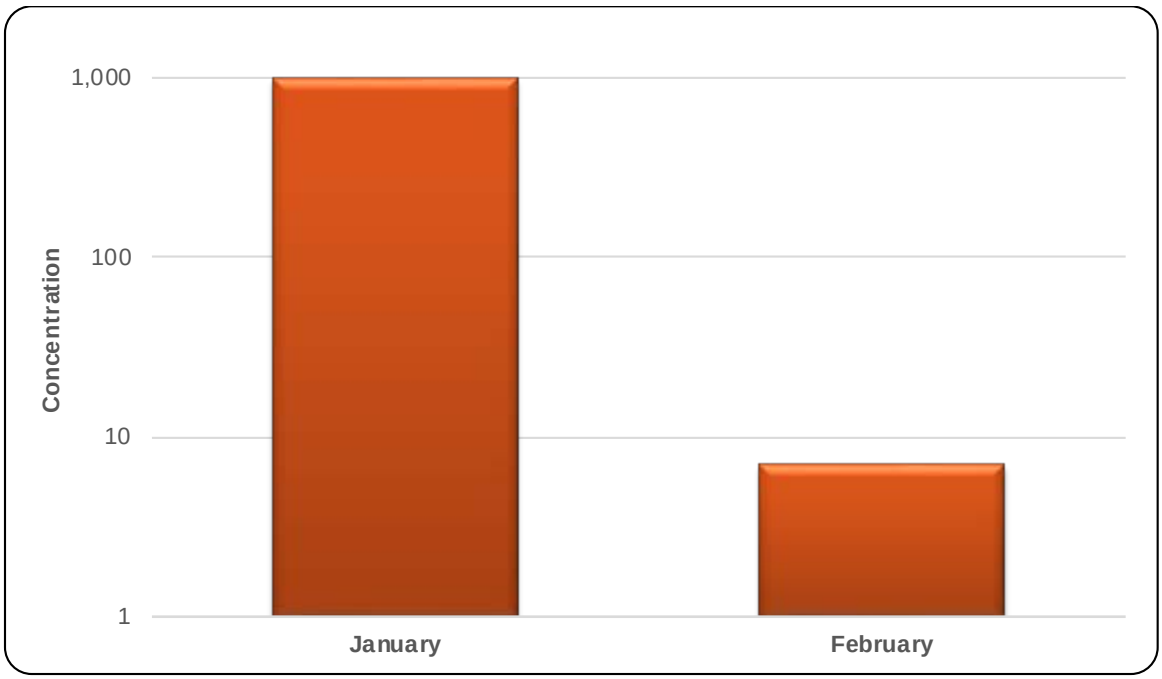

Figure B-3. Data Plotted Using a Logarithmic Scale.

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.

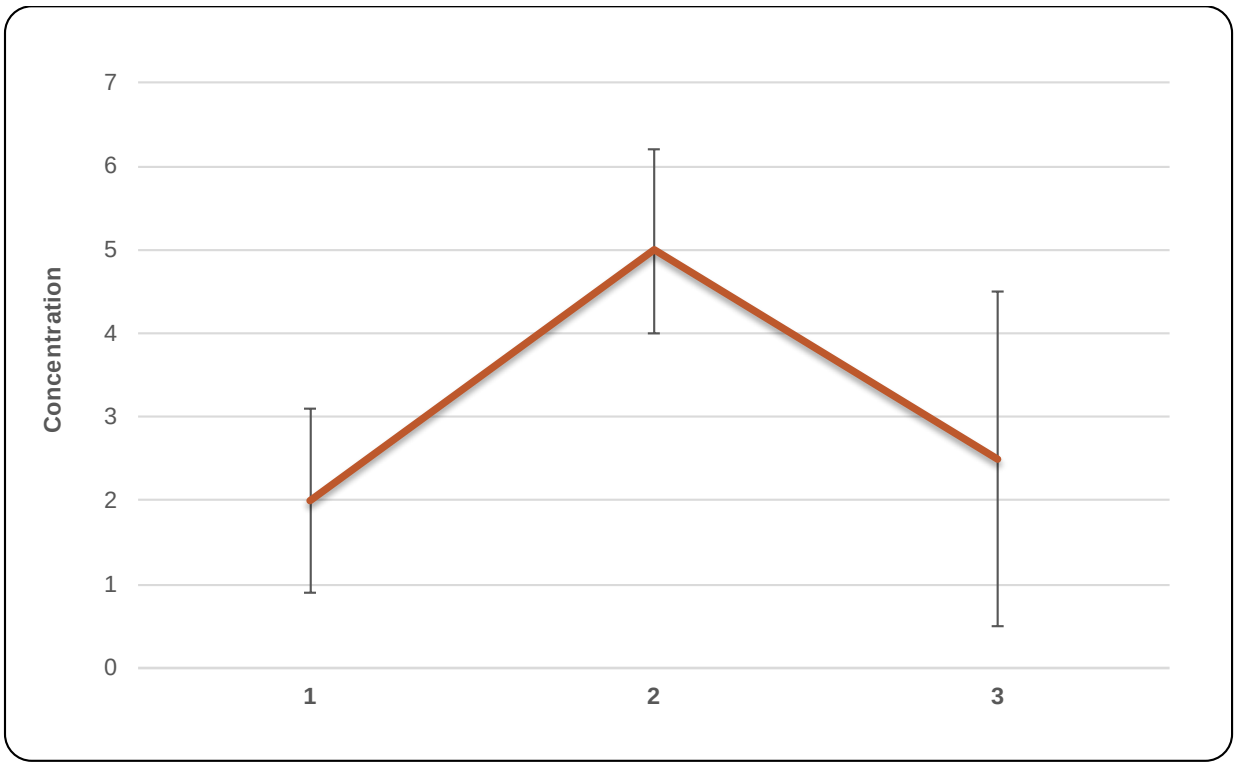

Figure B-4. Data with Error Bars Plotted Using a Linear Scale.

Appendix C. Additional Monitoring Results

Table of Contents

C.0 ADDITIONAL MONITORING RESULTS C-3
C.1 Onsite Pond C-5
C.2 Ambient Air C-6
C.3 Surface Soil C-10
C.4 Columbia River Water C-13
C.5 Shoreline Seep Water C-20
C.6 Vegetation Monitoring C-37
C.7 References C-41

Tables

Table C-1. Selected Radionuclide Concentrations in West Lake Sediment. C-5
Table C-2. Radionuclide Concentrations in West Lake Surface Water. C-5
Table C-3. Concentrations of Select Radionuclides (pCi/m^3)[a] in Onsite Air Samples. C-6
Table C-4. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Soil Samples. C-10
Table C-5. Concentrations of Select Radionuclides (pCi/g)[a] in Offsite Soil Samples. C-11
Table C-6. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Soil Samples Collected Sitewide and Offsite Soil Samples. C-11
Table C-7. Radionuclide Concentrations in Columbia River Water (Richland, Washington). C-13
Table C-8. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, Washington). C-14
Table C-9. 2019 Radionuclide Concentrations in Columbia River Transect Water Samples. C-14
Table C-10. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. C-16
Table C-11. Columbia River Organic Concentrations in Transect Water (2019). C-19
Table C-12. Columbia River Organic Concentrations in Shoreline Seep Water (2019). C-20
Table C-13. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site) (2014-2019). C-20
Table C-14. Radionuclide Concentrations in Columbia River Shoreline Seep Water. C-22
Table C-15. Metal and Anion Concentrations in Columbia River Shoreline Seeps. C-24
Table C-16. Dissolved Metal Concentration Ranges in Columbia River Sediment (Near Hanford Site) C-31
Table C-17. Columbia River Hexavalent Chromium in Sediment Samples. C-31
Table C-18. Total Organic Carbon in Columbia River Sediment (2014-2019). C-32

Table C-19. Horn Rapids Irrigation Water Sample Results. C-35
Table C-20. Riverview Irrigation Water Sample Results C-35
Table C-21. Sagemoor Irrigation Water Sample Results. C-36
Table C-22. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Vegetation Samples. C-37
Table C-23. Concentrations of Select Radionuclides (pCi/g)[a] in Offsite Vegetation Samples. C-38
Table C-24. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Vegetation Samples Collected Sitewide and Offsite Vegetation Samples. C-38
Table C-25. Radionuclide Concentrations in Liquid Effluents C-39

C.0 Additional Monitoring Results

ME Hoefer, CJ Perkins, JE Cranna, DL Dyekman

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	2019					2014-2018							DOE-Derived Concentration Guides
	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	7.8E-01	±	7.0E-02		18	6.1E-01	±	7.2E-01	1.4E+00	±	1.3E-01	3.1E+03
Gross Alpha[d]	2	6.3E+00	±	2.9E+00		18	9.5E+00	±	9.5E+00	2.3E+01	±	7.6E+00	N/A
Gross Beta	2	2.0E+01	±	2.1E+00		18	2.4E+01	±	6.9E+00	3.0E+01	±	2.4E+00	N/A
Strontium-90[d]	2	2.6E-01	±	6.6E-02		18	1.6E-01	±	2.8E-01	4.4E-01	±	9.9E-02	5.8E+02
Technetium-99[d]	2	2.3E-01	±	4.4E-01		18	5.6E-02	±	4.5E-01	6.0E-01	±	2.8E-01	4.2E+04
Uranium-234	2	1.1E+00	±	1.8E-01		18	3.1E+00	±	5.3E+00	9.6E+00	±	1.6E+00	5.3E+03
Uranium-235[d]	2	7.2E-02	±	4.2E-02		18	1.9E-01	±	3.0E-01	6.5E-01	±	1.6E-01	3.7E+03
Uranium-238	2	1.0E+00	±	1.7E-01		18	2.9E+00	±	4.9E+00	9.3E+00	±	1.5E+00	2.5E+03

[a] Result and maximum values are ± total propagated analytical uncertainty.
[b] Averages are ±2 standard deviations of the mean.
[c] 1 pCi = 0.037 Bq.
[d] Results include concentrations below detection limit.
Note: DOE-Derived Biota Concentration Guide values shown for Riparian Animal Receptor (DOE/EH-0676).

Table C-2. Radionuclide Concentrations in West Lake Surface Water.

Radionuclide	2019							2014-2018							DOE-Derived Concentration Guides
	No. of Samples	Concentration						No. of Samples	Concentration						
		Average pCi/L			*Maximum pCi/L*				*Average pCi/L*			*Maximum pCi/L*			
Technetium[c,e]	2	4.3E+00	±	1.5E+00	5.1E+00	±	8.8E+00	2	3.3E+02	±	6.4E+02	6.5E+02	±	9.8E+01	6.7E+05
Tritium[d,e]	2	4.8E+01	±	2.5E+01	6.1E+01	±	1.5E+02	19	5.2E+01	±	1.9E+02	3.1E+02	±	1.4E+02	2.7E+08
Uranium-234[d]	2	1.1E+02	±	1.8E+02	2.0E+02	±	2.6E+01	18	1.3E+03	±	5.4E+03	1.1E+04	±	4.4E+03	2.0E+02
Uranium-235[d]	2	7.1E+00	±	1.2E+01	1.3E+01	±	4.4E+00	18	1.1E+02	±	6.4E+02	1.4E+03	±	1.6E+03	2.2E+02
Uranium-238[d]	2	1.1E+02	±	1.8E+02	2.0E+02	±	2.5E+01	18	1.5E+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)
[e] Results include concentrations below detection limit.

C.2 Ambient Air

Table C-3. Concentrations of Select Radionuclides (pCi/m^3)[a] in Onsite Air Samples. (4 Pages)

Radionuclide	Site	2019					2014 - 2018					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	208	206	1.7E-03 ± 2.3E-03	7.7E-03 ± 1.2E-03	N576	932	910	1.6E-03 ± 2.2E-03	7.8E-03 ± 1.3E-03	N534	
	200-E	690	686	1.7E-03 ± 2.1E-03	7.0E-03 ± 1.0E-03	N969	3291	3195	1.5E-03 ± 2.1E-03	9.1E-03 ± 2.1E-03	N957	
	200-W	570	565	1.8E-03 ± 2.4E-03	8.1E-03 ± 1.2E-03	N974	2977	2939	1.9E-03 ± 5.8E-03	8.4E-02 ± 7.7E-03	N956	
	300	206	205	1.4E-03 ± 1.8E-03	6.1E-03 ± 9.4E-04	N130	1005	900	1.1E-03 ± 1.6E-03	5.7E-03 ± 1.2E-03	N918	
	400	49	49	1.3E-03 ± 1.5E-03	4.0E-03 ± 7.7E-04	N911	257	229	9.6E-04 ± 1.5E-03	5.7E-03 ± 1.4E-03	N912	
	600	118	116	1.4E-03 ± 2.0E-03	8.0E-03 ± 1.5E-03	N587	370	310	8.8E-04 ± 1.3E-03	3.9E-03 ± 8.1E-04	N587	
	ERDF	130	130	1.6E-03 ± 1.9E-03	6.7E-03 ± 1.1E-03	N168	655	654	1.4E-03 ± 1.9E-03	9.3E-03 ± 1.3E-03	N963	
	Perimeter	279	274	1.2E-03 ± 1.6E-03	5.5E-03 ± 9.6E-04	N939	1426	1257	9.4E-04 ± 1.7E-03	7.7E-03 ± 1.2E-03	N934	
	Nearby Comm.	181	180	1.2E-03 ± 1.4E-03	5.2E-03 ± 9.8E-04	N949	803	705	9.0E-04 ± 1.4E-03	6.0E-03 ± 9.2E-04	N948	
	Dist. Comm.	25	25	1.2E-03 ± 1.3E-03	3.4E-03 ± 6.8E-04	N909	131	105	8.3E-04 ± 1.5E-03	4.2E-03 ± 8.5E-04	N909	
gross β	100	208	208	1.8E-02 ± 2.1E-02	5.6E-02 ± 5.1E-03	N476	934	934	1.7E-02 ± 2.1E-02	6.1E-02 ± 4.8E-03	N900	
	200-E	690	690	1.8E-02 ± 2.2E-02	7.1E-02 ± 5.5E-03	N973	3291	3290	1.6E-02 ± 2.1E-02	1.8E-01 ± 1.3E-02	N158	
	200-W	570	569	1.7E-02 ± 2.0E-02	7.4E-02 ± 5.9E-03	N442	2977	2977	1.6E-02 ± 1.9E-02	7.5E-02 ± 6.2E-03	N304	
	300	206	206	1.9E-02 ± 2.0E-02	4.9E-02 ± 5.2E-03	N557	1005	1005	1.9E-02 ± 2.2E-02	7.3E-02 ± 6.3E-03	N903	
	400	49	49	1.9E-02 ± 2.0E-02	5.5E-02 ± 4.4E-03	N911	257	257	1.9E-02 ± 2.2E-02	6.2E-02 ± 5.1E-03	N911	
	600	118	118	1.8E-02 ± 2.4E-02	7.1E-02 ± 7.3E-03	N587	370	370	1.8E-02 ± 2.2E-02	7.5E-02 ± 6.6E-03	N929	
	ERDF	130	130	1.6E-02 ± 1.8E-02	5.5E-02 ± 4.4E-03	N963	655	655	1.5E-02 ± 1.9E-02	5.8E-02 ± 8.4E-03	N482	
	Perimeter	279	279	1.9E-02 ± 2.2E-02	6.6E-02 ± 5.1E-03	N935	1426	1426	1.9E-02 ± 2.2E-02	8.0E-02 ± 6.4E-03	N939	
	Nearby Comm.	181	181	1.9E-02 ± 2.3E-02	7.0E-02 ± 7.1E-03	N945	905	905	1.9E-02 ± 2.4E-02	1.6E-01 ± 1.6E-02	N949	
	Dist. Comm.	25	25	1.7E-02 ± 1.7E-02	3.8E-02 ± 3.1E-03	N909	131	131	1.7E-02 ± 2.0E-02	5.6E-02 ± 4.6E-03	N909	
^{3}H	100	13	0	9.9E-01 ± 3.7E+00	3.3E+00 ± 2.9E+00	N900	66	10	3.1E+00 ± 1.3E+01	4.0E+01 ± 8.5E+00	N900	1.5E+03
	200-E	38	1	1.6E+00 ± 1.0E+01	3.0E+01 ± 9.0E+00	N584	143	19	2.9E+00 ± 7.0E+00	2.2E+01 ± 5.0E+00	N920	
	300	78	2	3.6E+00 ± 7.3E+00	2.4E+01 ± 6.5E+00	N918	360	162	8.7E+00 ± 2.4E+01	1.4E+02 ± 3.0E+01	N130	
	400	13	0	3.1E+00 ± 5.4E+00	8.9E+00 ± 6.5E+00	N912	66	11	3.5E+00 ± 7.8E+00	1.5E+01 ± 3.8E+00	N912	
	Perimeter	91	0	1.1E+00 ± 5.7E+00	7.1E+00 ± 7.5E+00	N934	454	88	3.8E+00 ± 1.1E+01	6.7E+01 ± 1.5E+01	N937	
	Nearby Comm.	26	0	9.7E-01 ± 5.8E+00	9.4E+00 ± 6.5E+00	N943	130	27	6.6E+00 ± 5.6E+01	3.2E+02 ± 6.4E+01	N944	
	Dist Comm	13	0	1.8E+00 ± 5.3E+00	6.5E+00 ± 6.1E+00	N909	65	8	2.8E+00 ± 1.1E+01	2.9E+01 ± 6.5E+00	N909	
^{60}Co	100	16	0	3.4E-06 ± 8.2E-05	6.5E-05 ± 7.8E-05	N900	72	1	1.3E-04 ± 1.9E-03	8.1E-03 ± 3.1E-03	N588	1.7E-02
	200-E	55	0	9.0E-06 ± 1.0E-04	1.4E-04 ± 1.5E-04	N969	292	0	1.0E-05 ± 3.1E-04	3.9E-04 ± 4.1E-04	N985	
	200-W	46	0	-5.1E-06 ± 9.8E-05	1.2E-04 ± 1.4E-04	N168	230	0	5.6E-06 ± 3.3E-04	6.6E-04 ± 6.1E-04	N975	
	300	14	0	1.7E-05 ± 8.9E-05	1.2E-04 ± 1.3E-04	N919	68	1	8.6E-05 ± 1.9E-03	7.6E-03 ± 2.5E-03	N905	
	400	4	0	-2.6E-05 ± 9.6E-05	3.3E-05 ± 9.2E-05	N912	20	0	4.5E-05 ± 4.4E-04	4.3E-04 ± 4.4E-04	N912	

Table C-3. Concentrations of Select Radionuclides (pCi/m^3)[a] in Onsite Air Samples. (4 Pages)

Radionuclide	Site	2019					2014 - 2018					EPA Table 2[e]
		Number of		Average[c]	Maximum[d]	Sampler	Number of		Average[c]	Maximum[d]	Sampler	
		Samples	Detects[b]				Samples	Detects[b]				
	600	10	0	-3.8E-06 ± 8.6E-05	6.3E-05 ± 1.3E-04	N587	31	0	-1.4E-07 ± 2.4E-04	2.9E-04 ± 2.9E-04	N930	
	ERDF	10	0	3.3E-05 ± 9.5E-05	1.2E-04 ± 1.4E-04	N168	50	0	-1.6E-05 ± 2.6E-04	2.0E-04 ± 2.0E-04	N517	
	Perimeter	22	0	-5.3E-06 ± 9.5E-05	8.6E-05 ± 1.3E-04	N935	114	1	3.2E-05 ± 7.6E-04	3.1E-03 ± 1.1E-03	N934	
	Nearby Comm.	14	0	3.0E-05 ± 9.5E-05	8.1E-05 ± 1.1E-04	N944	70	0	9.3E-05 ± 1.5E-03	6.1E-03 ± 2.1E-03	N945	
	Dist. Comm.	2	0	-1.4E-05 ± 5.0E-05	1.2E-05 ± 9.8E-05	N909	10	0	8.0E-05 ± 3.7E-04	4.3E-04 ± 5.4E-04	N909	
^{90}Sr	100	16	0	7.2E-05 ± 5.9E-04	6.5E-04 ± 6.1E-04	N900	72	0	-2.9E-05 ± 5.1E-04	7.5E-04 ± 6.3E-04	N576	1.9E-02
	200-E	55	0	9.9E-06 ± 6.2E-04	6.0E-04 ± 6.1E-04	N985	246	1	2.6E-05 ± 8.1E-04	5.2E-03 ± 2.1E-03	N158	
	200-W	46	0	-2.2E-05 ± 8.6E-04	1.8E-03 ± 2.0E-03	N987	220	0	-8.7E-06 ± 4.8E-04	7.8E-04 ± 7.2E-04	N956	
	300	14	0	2.2E-05 ± 4.6E-04	2.9E-04 ± 4.3E-04	N919	68	0	-8.0E-06 ± 5.5E-04	1.0E-03 ± 8.3E-04	N557	
	400	4	0	-1.2E-04 ± 5.6E-04	2.3E-04 ± 4.2E-04	N912	20	0	-3.9E-05 ± 5.1E-04	6.2E-04 ± 4.9E-04	N911	
	600	10	0	2.5E-05 ± 4.3E-04	3.8E-04 ± 4.5E-04	N930	28	0	-1.2E-05 ± 3.8E-04	4.3E-04 ± 5.1E-04	N928	
	ERDF	10	0	6.5E-05 ± 4.2E-04	4.0E-04 ± 4.6E-04	N517	50	0	7.3E-05 ± 5.0E-04	6.8E-04 ± 5.2E-04	N517	
	Perimeter	18	0	-9.9E-06 ± 4.4E-04	3.5E-04 ± 4.0E-04	N941	90	0	-2.6E-05 ± 4.9E-04	7.8E-04 ± 6.6E-04	N941	
	Nearby Comm.	6	0	-5.4E-05 ± 6.2E-04	4.2E-04 ± 4.3E-04	N944	32	0	3.0E-07 ± 3.2E-04	4.8E-04 ± 5.1E-04	N946	
	Dist. Comm.	2	0	3.0E-05 ± 7.1E-04	3.8E-04 ± 4.5E-04	N909	10	0	-8.6E-07 ± 2.0E-04	2.1E-04 ± 2.9E-04	N909	
^{137}Cs	100	16	2	5.2E-05 ± 1.4E-04	2.6E-04 ± 1.6E-04	N576	72	0	4.7E-05 ± 3.3E-04	4.9E-04 ± 9.2E-04	N588	1.9E-02
	200-E	54	6	1.4E-04 ± 1.1E-03	3.8E-03 ± 1.2E-03	N582	284	3	7.5E-05 ± 4.7E-04	2.1E-03 ± 8.7E-04	N158	
	200-W	46	0	1.5E-05 ± 9.8E-05	1.3E-04 ± 3.6E-04	N987	226	0	3.8E-05 ± 3.6E-04	6.1E-04 ± 3.8E-04	N966	
	300	14	0	9.9E-06 ± 6.4E-05	6.7E-05 ± 1.3E-04	N905	68	1	6.0E-05 ± 3.6E-04	6.5E-04 ± 5.1E-04	N904	
	400	4	0	6.4E-06 ± 2.6E-05	2.0E-05 ± 8.5E-05	N911	20	0	3.4E-05 ± 4.0E-04	3.2E-04 ± 4.6E-04	N911	
	600	9	1	5.4E-05 ± 1.8E-04	2.9E-04 ± 1.9E-04	N587	31	0	5.4E-05 ± 3.7E-04	6.2E-04 ± 6.1E-04	N928	
	ERDF	9	0	1.2E-05 ± 6.0E-05	6.6E-05 ± 6.9E-05	N482	50	0	3.0E-05 ± 2.7E-04	4.0E-04 ± 4.5E-04	N168	
	Perimeter	22	1	3.0E-05 ± 1.0E-04	1.9E-04 ± 1.4E-04	N933	114	0	3.2E-05 ± 3.3E-04	6.0E-04 ± 6.3E-04	N907	
	Nearby Comm.	14	0	1.7E-05 ± 7.7E-05	1.1E-04 ± 1.5E-04	N948	70	0	3.1E-05 ± 3.2E-04	3.8E-04 ± 5.2E-04	N947	
	Dist. Comm.	2	0	7.1E-06 ± 1.9E-05	1.6E-05 ± 6.7E-05	N909	10	0	4.1E-05 ± 2.6E-04	3.0E-04 ± 3.0E-04	N909	
^{238}Pu	100	16	0	2.1E-06 ± 9.7E-06	1.6E-05 ± 2.4E-05	N588	67	0	8.8E-07 ± 1.4E-05	3.9E-05 ± 5.5E-05	N900	2.1E-03
	200-E	55	0	-5.3E-07 ± 6.7E-06	5.9E-06 ± 1.1E-05	N532	236	3	7.8E-06 ± 2.0E-04	1.6E-03 ± 5.1E-04	N583	
	200-W	42	0	9.1E-07 ± 8.2E-06	1.2E-05 ± 1.6E-05	N433	209	10	5.8E-06 ± 6.4E-05	3.7E-04 ± 1.5E-04	N901	
	300	14	0	-1.9E-06 ± 4.7E-06	1.8E-06 ± 1.0E-05	N904	65	0	5.0E-07 ± 1.5E-05	1.9E-05 ± 4.4E-05	N904	
	400	4	0	-1.2E-06 ± 7.0E-06	3.4E-06 ± 9.5E-06	N912	16	0	-2.6E-06 ± 1.7E-05	2.0E-05 ± 3.6E-05	N912	
	600	9	0	-1.4E-06 ± 3.8E-06	2.2E-06 ± 9.7E-06	N928	30	0	3.2E-07 ± 1.2E-05	2.1E-05 ± 2.7E-05	N928	
	ERDF	10	0	-2.4E-08 ± 6.7E-06	6.1E-06 ± 1.3E-05	N963	49	0	2.3E-06 ± 1.0E-05	2.0E-05 ± 3.1E-05	N482	
	Perimeter	22	0	1.1E-06 ± 1.1E-05	1.1E-05 ± 3.4E-05	N933	81	0	6.5E-07 ± 1.6E-05	3.5E-05 ± 3.7E-05	N940	
	Nearby Comm.	12	0	-8.2E-07 ± 1.1E-05	9.5E-06 ± 1.2E-05	N947	40	2	8.1E-07 ± 2.8E-05	5.9E-05 ± 2.8E-05	N944	

Table C-3. Concentrations of Select Radionuclides (pCi/m^3)[a] in Onsite Air Samples. (4 Pages)

Radionuclide	Site	2019					2014 - 2018					EPA Table 2[e]
		Number of		Average[c]	Maximum[d]	Sampler	Number of		Average[c]	Maximum[d]	Sampler	
		Samples	Detects[b]				Samples	Detects[b]				
	Dist. Comm.	2	0	2.6E-06 ± 7.3E-06	6.2E-06 ± 1.1E-05	N909	9	0	-8.8E-07 ± 6.9E-06	3.8E-06 ± 1.4E-05	N909	
$^{239/240}$Pu	100	16	0	2.1E-06 ± 7.1E-06	9.6E-06 ± 1.7E-05	N578	68	0	4.2E-07 ± 1.4E-05	2.6E-05 ± 2.4E-05	N900	2.0E-03
	200-E	54	0	-2.0E-07 ± 8.8E-06	1.0E-05 ± 2.0E-05	N499	242	1	8.0E-07 ± 2.1E-05	9.7E-05 ± 8.4E-05	N976	
	200-W	46	8	1.4E-05 ± 6.6E-05	1.9E-04 ± 8.2E-05	N165	223	38	7.0E-05 ± 6.8E-04	3.2E-03 ± 1.0E-03	N155	
	300	14	0	-6.1E-07 ± 4.3E-06	2.9E-06 ± 6.7E-06	N902	65	0	-1.9E-06 ± 1.3E-05	1.5E-05 ± 2.5E-05	N902	
	400	4	0	-1.4E-06 ± 2.8E-06	-3.0E-07 ± 3.1E-06	N911	18	0	-2.4E-06 ± 1.4E-05	8.4E-06 ± 4.7E-05	N911	
	600	10	0	1.5E-06 ± 1.2E-05	1.9E-05 ± 3.8E-05	N930	31	0	-1.3E-06 ± 1.8E-05	2.9E-05 ± 3.5E-05	N928	
	ERDF	10	0	2.8E-06 ± 1.3E-05	1.9E-05 ± 2.3E-05	N517	48	4	8.6E-06 ± 4.2E-05	1.2E-04 ± 7.4E-05	N518	
	Perimeter	22	0	1.5E-06 ± 1.4E-05	2.1E-05 ± 5.1E-05	N935	88	1	-7.5E-07 ± 1.3E-05	1.8E-05 ± 1.9E-05	N938	
	Nearby Comm.	12	0	-4.0E-07 ± 8.4E-06	8.2E-06 ± 3.6E-05	N949	41	2	-1.5E-06 ± 2.2E-05	1.5E-05 ± 2.1E-05	N946	
	Dist. Comm.	2	0	1.5E-06 ± 1.2E-06	2.2E-06 ± 6.0E-06	N909	10	0	8.4E-08 ± 9.4E-06	1.2E-05 ± 4.7E-05	N909	
^{234}U	100	16	0	4.2E-06 ± 1.3E-05	1.9E-05 ± 1.7E-05	N900	62	12	1.2E-05 ± 3.1E-05	8.4E-05 ± 8.1E-05	N576	7.7E-03
	200-E	55	9	8.5E-06 ± 1.5E-05	2.9E-05 ± 2.2E-05	N583	254	85	2.3E-05 ± 5.2E-05	1.7E-04 ± 6.6E-05	N924	
	200-W	46	2	6.9E-06 ± 1.5E-05	4.0E-05 ± 2.3E-05	N901	229	51	1.4E-05 ± 3.6E-05	9.9E-05 ± 7.9E-05	N901	
	300	14	4	1.3E-05 ± 1.9E-05	3.4E-05 ± 2.9E-05	N918	68	45	4.8E-05 ± 5.5E-05	1.2E-04 ± 7.6E-05	N919	
	600	10	2	1.2E-05 ± 1.6E-05	2.6E-05 ± 1.8E-05	N929	28	17	4.1E-05 ± 6.3E-05	1.7E-04 ± 1.4E-04	N929	
	ERDF	10	0	5.2E-06 ± 1.4E-05	2.4E-05 ± 4.7E-05	N482	46	11	9.6E-06 ± 1.7E-05	3.3E-05 ± 3.6E-05	N482	
	Perimeter	8	4	2.9E-05 ± 3.1E-05	4.8E-05 ± 2.1E-05	N935	40	34	6.2E-05 ± 5.7E-05	1.6E-04 ± 1.1E-04	N937	
	Nearby Comm.	10	5	2.6E-05 ± 2.3E-05	5.0E-05 ± 2.5E-05	N946	52	40	6.2E-05 ± 4.7E-05	1.5E-04 ± 1.4E-04	N943	
	Dist. Comm.	2	1	1.3E-05 ± 9.2E-06	1.7E-05 ± 1.2E-05	N909	10	7	4.6E-05 ± 3.9E-05	8.8E-05 ± 5.6E-05	N909	
^{235}U	100	15	0	5.5E-07 ± 2.8E-06	2.4E-06 ± 6.8E-06	N534	53	1	4.6E-06 ± 1.7E-05	4.5E-05 ± 7.3E-05	N575	7.1E-03
	200-E	48	1	1.7E-06 ± 7.1E-06	1.4E-05 ± 1.2E-05	N957	227	7	5.6E-06 ± 1.9E-05	7.6E-05 ± 8.1E-05	N582	
	200-W	41	0	1.7E-06 ± 6.5E-06	1.8E-05 ± 3.1E-05	N987	204	5	5.7E-06 ± 1.9E-05	6.9E-05 ± 5.0E-05	N161	
	300	11	0	7.0E-07 ± 5.4E-06	6.4E-06 ± 1.2E-05	N905	64	6	1.2E-05 ± 3.1E-05	6.7E-05 ± 6.2E-05	N919	
	600	7	0	4.5E-06 ± 1.3E-05	1.7E-05 ± 2.9E-05	N928	25	5	1.6E-05 ± 3.1E-05	6.5E-05 ± 4.7E-05	N928	
	ERDF	7	0	-1.2E-06 ± 4.4E-06	3.6E-06 ± 7.2E-06	N963	40	1	2.5E-06 ± 7.6E-06	1.4E-05 ± 1.1E-05	N963	
	Perimeter	6	0	3.3E-06 ± 1.0E-05	1.4E-05 ± 2.7E-05	N934	40	7	1.1E-05 ± 3.4E-05	8.4E-05 ± 8.0E-05	N937	
	Nearby Comm.	8	0	3.1E-06 ± 9.0E-06	1.3E-05 ± 2.6E-05	N943	52	10	1.5E-05 ± 4.2E-05	8.9E-05 ± 9.2E-05	N944	
	Dist. Comm.	2	0	-9.2E-07 ± 7.2E-07	-5.6E-07 ± 5.6E-06	N909	9	1	1.2E-05 ± 2.6E-05	3.3E-05 ± 3.0E-05	N909	
^{238}U	100	16	2	7.9E-06 ± 1.0E-05	2.1E-05 ± 1.7E-05	N900	62	11	7.6E-06 ± 2.5E-05	7.1E-05 ± 7.6E-05	N578	8.3E-03
	200-E	55	13	8.4E-06 ± 1.5E-05	3.1E-05 ± 1.8E-05	N957	253	82	1.8E-05 ± 4.7E-05	1.6E-04 ± 6.0E-05	N984	
	200-W	46	4	7.6E-06 ± 1.3E-05	3.8E-05 ± 2.1E-05	N901	228	51	9.1E-06 ± 2.1E-05	6.6E-05 ± 6.1E-05	N901	
	300	14	8	1.9E-05 ± 2.4E-05	5.2E-05 ± 2.9E-05	N918	68	44	4.0E-05 ± 4.4E-05	1.0E-04 ± 6.5E-05	N902	
	600	10	3	8.6E-06 ± 1.0E-05	1.7E-05 ± 1.3E-05	N929	28	16	3.7E-05 ± 3.6E-05	9.0E-05 ± 5.9E-05	N929	
	ERDF	10	0	7.0E-06 ± 1.9E-05	2.4E-05 ± 4.0E-05	N517	49	13	1.0E-05 ± 2.2E-05	5.3E-05 ± 7.9E-05	N518	

Table C-3. Concentrations of Select Radionuclides (pCi/m^3)[a] in Onsite Air Samples. (4 Pages)

Radionuclide	Site	2019					2014 - 2018					EPA Table 2[e]
		Number of		Average[c]	Maximum[d]	Sampler	Number of		Average[c]	Maximum[d]	Sampler	
		Samples	Detects[b]				Samples	Detects[b]				
	Perimeter	8	4	2.6E-05 ± 2.2E-05	4.4E-05 ± 2.3E-05	N934	40	32	5.2E-05 ± 4.7E-05	1.7E-04 ± 1.0E-04	N935	
	Nearby Comm.	10	6	2.6E-05 ± 3.2E-05	4.8E-05 ± 2.4E-05	N946	52	43	5.7E-05 ± 4.7E-05	1.5E-04 ± 8.1E-05	N945	
	Dist Comm	2	1	1.4E-05 ± 2.5E-05	2.6E-05 ± 1.5E-05	N909	10	6	3.3E-05 ± 2.6E-05	5.6E-05 ± 2.5E-05	N909	
^{241}Am	100	15	0	3.1E-06 ± 5.9E-06	9.7E-06 ± 1.5E-05	N534	65	0	2.4E-05 ± 3.3E-04	9.0E-04 ± 2.5E-03	N900	1.9E-03
	200-E	22	0	3.0E-06 ± 6.0E-06	8.9E-06 ± 1.1E-05	N924	225	0	1.8E-05 ± 1.5E-03	4.0E-03 ± 3.2E-03	N920	
	200-W	24	4	6.8E-06 ± 1.7E-05	2.8E-05 ± 2.0E-05	N165	208	21	-6.3E-05 ± 1.4E-03	2.4E-03 ± 2.3E-03	N965	
	600	2	0	-6.7E-07 ± 4.8E-07	-4.3E-07 ± 4.3E-06	N587	26	0	-5.0E-05 ± 1.7E-03	2.2E-03 ± 2.7E-03	N929	
	ERDF	4	0	3.9E-06 ± 7.5E-06	1.0E-05 ± 1.3E-05	N168	20	0	-1.4E-04 ± 1.2E-03	1.1E-03 ± 1.7E-03	N168	
	Perimeter	20	0	1.5E-06 ± 8.3E-06	9.9E-06 ± 3.3E-05	N933	107	0	-6.8E-06 ± 1.3E-03	2.1E-03 ± 2.1E-03	N937	
	Nearby Comm.	12	0	3.4E-06 ± 1.3E-05	1.4E-05 ± 3.6E-05	N943	68	0	2.2E-06 ± 1.1E-03	2.8E-03 ± 2.1E-03	N949	
	Dist. Comm.	2	0	-1.3E-06 ± 5.6E-07	-1.0E-06 ± 4.6E-06	N909	10	0	-4.3E-06 ± 1.5E-04	1.6E-04 ± 1.6E-03	N909	
^{241}Pu	100	14	0	1.8E-04 ± 7.7E-04	9.5E-04 ± 7.6E-04	N578	60	0	-2.4E-05 ± 1.1E-03	2.7E-03 ± 3.3E-03	N534	1.0E-01
	200-E	4	0	1.1E-04 ± 4.0E-04	4.0E-04 ± 7.0E-04	N481	20	0	-1.4E-04 ± 9.9E-04	6.2E-04 ± 9.7E-04	N481	
	200-W	24	0	1.4E-04 ± 5.4E-04	7.1E-04 ± 6.4E-04	N964	58	5	2.3E-04 ± 1.9E-03	4.3E-03 ± 1.8E-03	N975	
	600	2	0	3.6E-04 ± 5.7E-04	6.5E-04 ± 7.4E-04	N587	2	0	6.8E-05 ± 7.5E-04	4.4E-04 ± 8.5E-04	N587	
	ERDF	4	0	3.6E-04 ± 3.1E-04	5.4E-04 ± 6.7E-04	N963	3	0	3.0E-04 ± 7.5E-04	8.2E-04 ± 9.0E-04	N168	

[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

C.3 Surface Soil

Table C-4. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Soil Samples. (2 Pages)

Radionuclide	Hanford Area	2019									2014 - 2018									
		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	23	15	2.8E-02	±	7.8E-02	2.0E-01	±	3.3E-02	D005	54	38	3.7E-02	±	1.0E-01	2.5E-01	±	8.3E-02	D032
^{137}Cs	200-E	18	18	3.0E+00	±	1.0E+01	1.7E+01	±	1.4E+00	D053	88	87	2.9E+00	±	8.7E+00	1.8E+01	±	1.5E+00	D054
	200-W	24	23	9.9E-01	±	1.5E+00	2.7E+00	±	2.3E-01	D035	131	126	1.2E+00	±	2.6E+00	7.8E+00	±	6.3E-01	D030
	300	8	4	2.7E-02	±	6.1E-02	8.9E-02	±	2.5E-02	D121	40	23	4.5E-02	±	1.1E-01	2.9E-01	±	3.2E-02	D125
	400	1	1	2.6E-02[e]			2.6E-02	±	2.2E-02	D130	5	5	3.4E-02	±	2.4E-02	5.3E-02	±	1.5E-02	D130
	600	16	15	4.6E-01	±	1.1E+00	2.3E+00	±	2.1E-01	D091	72	71	4.3E-01	±	8.3E-01	2.5E+00	±	2.9E-01	D091
^{238}Pu	200-E	18	0	1.0E-03	±	7.5E-03	1.3E-02	±	1.5E-02	D073	86	19	1.2E-03	±	6.3E-03	1.1E-02	±	9.9E-03	D461
	200-W	23	3	1.4E-02	±	7.5E-02	1.5E-01	±	4.1E-02	D005	131	58	8.2E-03	±	3.6E-02	1.4E-01	±	2.3E-02	D039
	300	8	0	2.1E-03	±	7.9E-03	9.5E-03	±	1.4E-02	D121	40	7	2.0E-03	±	6.8E-03	1.2E-02	±	1.1E-02	D123
	400	1	0	5.7E-03[e]			5.7E-03	±	9.7E-03	D130	5	1	2.8E-03	±	5.9E-03	8.0E-03	±	2.8E-03	D130
	600	17	1	5.4E-05	±	7.8E-03	7.6E-03	±	5.6E-03	D099	69	17	2.6E-03	±	9.4E-03	2.4E-02	±	1.8E-02	D107
$^{239/240}$Pu	200-E	18	4	1.0E-02	±	2.7E-02	4.5E-02	±	1.3E-02	D143	87	56	1.4E-02	±	3.2E-02	8.4E-02	±	2.0E-02	D078
	200-W	24	20	8.5E-02	±	2.3E-01	5.2E-01	±	9.0E-02	D005	132	118	1.1E-01	±	3.6E-01	1.1E+00	±	1.3E-01	D032
	300	8	2	9.8E-03	±	3.4E-02	4.7E-02	±	2.1E-02	D121	39	19	6.2E-03	±	2.4E-02	5.4E-02	±	7.9E-03	D126
	400	1	0	-1.4E-03[e]			-1.4E-03	±	7.4E-03	D130	5	2	1.5E-03	±	9.6E-04	2.1E-03	±	7.8E-04	D130
	600	17	8	5.1E-02	±	1.8E-01	3.2E-01	±	4.6E-02	D107	71	52	6.4E-02	±	4.2E-01	1.6E+00	±	1.8E-01	D107
^{90}Sr	200-E	18	8	1.3E-01	±	4.1E-01	7.9E-01	±	1.5E-01	D059	88	58	2.9E-01	±	9.7E-01	2.2E+00	±	4.2E-01	D064
	200-W	24	12	2.1E-01	±	1.2E+00	3.1E+00	±	6.0E-01	D009	113	67	1.2E-01	±	2.9E-01	6.0E-01	±	1.3E-01	D051
	300	8	0	1.8E-03	±	5.0E-02	4.1E-02	±	3.1E-02	D120	40	1	7.8E-03	±	6.1E-02	1.4E-01	±	4.8E-02	D121
	400	1	0	1.5E-02[e]			1.5E-02	±	2.8E-02	D130	5	0	-9.3E-03	±	2.1E-02	2.6E-03	±	1.8E-02	D130
	600	17	6	3.5E-02	±	9.2E-02	1.6E-01	±	4.9E-02	D091	72	28	6.9E-02	±	2.7E-01	1.0E+00	±	2.0E-01	D091
^{234}U	200-E	18	18	4.7E-01	±	2.8E-01	8.8E-01	±	1.5E-01	D063	88	88	5.4E-01	±	2.1E-01	1.1E+00	±	1.9E-01	D060
	200-W	24	24	4.4E-01	±	1.7E-01	6.2E-01	±	1.1E-01	D033	113	113	5.0E-01	±	2.1E-01	7.5E-01	±	1.2E-01	D306
	300	8	8	6.6E-01	±	7.7E-01	1.5E+00	±	1.8E-01	D126	40	40	7.9E-01	±	9.9E-01	2.3E+00	±	3.7E-01	D126
	400	1	1	3.3E-01[e]			3.3E-01	±	5.7E-02	D130	5	5	4.7E-01	±	1.2E-01	5.8E-01	±	1.1E-01	D130
	600	17	17	4.6E-01	±	1.0E-01	5.8E-01	±	7.1E-02	D113	72	72	5.3E-01	±	2.2E-01	9.3E-01	±	1.6E-01	D091
^{235}U	200-E	18	15	3.4E-02	±	3.2E-02	7.0E-02	±	2.7E-02	D057	87	78	5.9E-02	±	5.9E-02	1.8E-01	±	8.9E-02	D460
	200-W	24	12	2.8E-02	±	2.6E-02	6.1E-02	±	3.7E-02	D015	113	92	5.0E-02	±	4.3E-02	1.1E-01	±	4.8E-02	D026
	300	8	6	4.1E-02	±	4.0E-02	7.6E-02	±	3.4E-02	D126	40	36	7.3E-02	±	8.6E-02	1.9E-01	±	7.5E-02	D126
	400	1	1	3.1E-02[e]			3.1E-02	±	1.8E-02	D130	5	5	4.7E-02	±	3.5E-02	7.7E-02	±	4.1E-02	D130
	600	17	16	3.3E-02	±	2.0E-02	5.1E-02	±	2.4E-02	D103	72	59	5.7E-02	±	5.1E-02	1.2E-01	±	5.3E-02	D094
^{238}U	200-E	18	18	4.7E-01	±	3.0E-01	1.0E+00	±	1.6E-01	D063	88	88	5.4E-01	±	2.1E-01	1.1E+00	±	1.9E-01	D060
	200-W	24	24	4.5E-01	±	1.5E-01	6.5E-01	±	1.1E-01	D047	113	113	5.0E-01	±	2.0E-01	7.0E-01	±	1.3E-01	D010
	300	8	8	6.4E-01	±	6.3E-01	1.2E+00	±	1.5E-01	D121	40	40	7.5E-01	±	9.1E-01	2.2E+00	±	3.5E-01	D126

Table C-4. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Soil Samples. (2 Pages)

Radionuclide	Hanford Area	2019									2014 - 2018								
		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]							
	400	1	1	3.7E-01[e]			3.7E-01	±	6.0E-02	D130	5	5	4.5E-01	±	1.0E-01	5.3E-01	±	1.0E-01	D130
	600	17	17	4.7E-01	±	9.7E-02	6.1E-01	±	7.3E-02	D113	72	72	5.5E-01	±	2.3E-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.

Table C-5. Concentrations of Select Radionuclides (pCi/g)[a] in Offsite Soil Samples.

Radionuclide	Hanford Area	2019									2001, 2004, 2008, and 2015								
		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	Off Site	3	0	4.4E-03	±	2.5E-03	5.8E-03	±	6.8E-03	D493	6	2	4.7E-03		2.6E-03	4.3E-03	±	9.0E-04	D434
^{137}Cs	Off Site	17	15	1.7E-01	±	3.0E-01	5.6E-01	±	7.6E-02	D427	70	67	1.4E-01	±	2.5E-01	4.8E-01	±	3.1E-02	D441
^{238}Pu	Off Site	16	0	2.3E-04	±	7.7E-03	8.6E-03	±	8.9E-03	D435	67	26	3.1E-04	±	8.9E-04	2.9E-03	±	2.4E-03	D437
$^{239/240}$Pu	Off Site	17	3	5.4E-03	±	1.8E-02	2.5E-02	±	1.3E-02	D433	68	60	5.0E-03	±	1.1E-02	3.0E-02	±	4.4E-03	D424
^{90}Sr	Off Site	18	0	1.7E-02	±	4.6E-02	4.7E-02	±	3.3E-02	D433	70	17	1.7E-02	±	5.1E-02	1.4E-01	±	4.6E-02	D437
^{234}U	Off Site	18	18	4.7E-01	±	1.5E-01	6.2E-01	±	7.8E-02	D427	70	68	4.5E-01	±	3.4E-01	1.5E+00	±	1.8E-01	D429
^{235}U	Off Site	17	6	3.4E-02	±	2.9E-02	6.0E-02	±	5.5E-02	D441	70	46	3.8E-02	±	2.9E-02	1.1E-01	±	4.7E-02	D427
^{238}U	Off Site	18	18	4.7E-01	±	1.3E-01	5.6E-01	±	1.2E-01	D430	70	67	4.7E-01	±	3.4E-01	1.3E+00	±	2.0E-01	D427

[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

Table C-6. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Soil Samples Collected Sitewide and Offsite Soil Samples. (2 Pages)

Location	Radionuclide	2019									2001-2018								
		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]							
Sitewide	^{241}Am	23	15	2.8E-02	±	7.8E-02	2.0E-01	±	3.3E-02	D005	75	47	3.5E-02	±	9.2E-02	2.5E-01	±	8.3E-02	D032
	^{137}Cs	67	61	1.3E+00	±	5.8E+00	1.7E+01	±	1.4E+00	D053	1397	1324	1.3E+00	±	1.1E+01	1.4E+02	±	2.6E+01	D154
	^{238}Pu	67	4	5.5E-03	±	4.6E-02	1.5E-01	±	4.1E-02	D005	1392	138	5.5E-03	±	6.1E-02	7.7E-01	±	2.2E-01	D088
	$^{239/240}$Pu	68	26	4.7E-02	±	1.8E-01	5.2E-01	±	9.0E-02	D005	1395	783	8.5E-02	±	9.1E-01	1.2E+01	±	3.1E+00	D088
	^{90}Sr	68	68	1.2E-01	±	7.8E-01	3.1E+00	±	6.0E-01	D009	1379	340	7.7E-02	±	3.3E+00	5.5E+01	±	7.1E+00	D125
	^{234}U	68	50	4.8E-01	±	3.5E-01	1.5E+00	±	1.8E-01	D126	1378	1369	3.5E-01	±	1.3E+00	1.2E+01	±	2.3E+00	D131
	^{235}U	68	68	3.2E-02	±	2.9E-02	7.6E-02	±	3.4E-02	D126	1358	878	3.0E-02	±	8.3E-02	6.5E-01	±	1.6E-01	D131

Table C-6. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Soil Samples Collected Sitewide and Offsite Soil Samples. (2 Pages)

Location	Radionuclide	2019									2001-2018									
		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	23	15	4.8E-01	±	3.1E-01	1.2E+00	±	1.5E-01	D121	1379	1368	3.5E-01	±	1.3E+00	1.2E+01	±	2.3E+00	D131
Offsite	^{241}Am	3	0	4.4E-03	±	2.5E-03	5.8E-03	±	6.8E-03	D493	6	2	4.7E-03	±	2.6E-03	4.3E-03	±	9.0E-04	D434
	^{137}Cs	17	15	1.7E-01	±	3.0E-01	5.6E-01	±	7.6E-02	D427	70	67	1.4E-01	±	2.5E-01	4.8E-01	±	3.1E-02	D441
	^{238}Pu	16	0	2.3E-04	±	7.7E-03	8.6E-03	±	8.9E-03	D435	67	26	3.1E-04	±	8.9E-04	2.9E-03	±	2.4E-03	D437
	$^{239/240}$Pu	17	3	5.4E-03	±	1.8E-02	2.5E-02	±	1.3E-02	D433	68	60	5.0E-03	±	1.1E-02	3.0E-02	±	4.4E-03	D424
	^{90}Sr	18	0	1.7E-02	±	4.6E-02	4.7E-02	±	3.3E-02	D433	70	17	1.7E-02	±	5.1E-02	1.4E-01	±	4.6E-02	D437
	^{234}U	18	18	4.7E-01	±	1.5E-01	6.2E-01	±	7.8E-02	D427	70	68	4.5E-01	±	3.4E-01	1.5E+00	±	1.8E-01	D429
	^{235}U	17	6	3.4E-02	±	2.9E-02	6.0E-02	±	5.5E-02	D441	70	46	3.8E-02	±	2.9E-02	1.1E-01	±	4.7E-02	D427
	^{238}U	18	18	4.7E-01	±	1.3E-01	5.6E-01	±	1.2E-01	D430	70	67	4.7E-01	±	3.4E-01	1.3E+00	±	2.0E-01	D427

[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

C.4 Columbia River Water

Table C-7. Radionuclide Concentrations in Columbia River Water (Richland, Washington).

Radionuclide		2019								2014-2018								WA Ambient Surface Water Quality Standard [d]
		Number of		Concentration [a]						Number of		Concentration [a]						
		Samples	Detects	Maximum (pCi/L)[c]			Average(pCi/L)			Samples	Detects	Maximum (pCi/L)[c]			Average(pCi/L)[c]			
Composite System																		
Cesium-137[e]		--	--	--	--	--	--	--	--	12	0	1.6E+00	±	2.1E+00	2.5E-01	±	1.6E+00	200
Strontium-90		14	0	5.8E-02	±	3.9E-02	2.0E-02	±	4.2E-02	66	0	5.6E-02	±	3.7E-02	8.8E-03	±	4.4E-02	8
Tritium		14	14	4.4E+01	±	1.4E+01	3.0E+01	±	1.4E+01	66	66	6.3E+01	±	9.7E+00	2.6E+01	±	2.1E+01	20000
Technetium-99		14	0	1.6E+00	±	1.0E+00	1.4E-01	±	1.3E+00	66	2	1.2E+00	±	7.8E-01	1.6E-01	±	7.1E-01	900
Plutonium-238[e]		--	--	--	--	--	--	--	--	12	0	6.7E-03	±	9.5E-03	8.8E-04	±	6.5E-03	--
Plutonium-239/240[e]		--	--	--	--	--	--	--	--	12	0	5.8E-03	±	6.9E-03	-1.6E-03	±	1.3E-02	--
Uranium-234		14	14	3.7E-01	±	6.9E-02	3.0E-01	±	7.5E-02	66	66	4.1E-01	±	8.0E-02	2.8E-01	±	1.1E-01	--
Uranium-235		14	5	4.5E-02	±	2.8E-02	1.9E-02	±	2.7E-02	66	25	7.9E-02	±	3.0E-02	2.2E-02	±	3.4E-02	--
Uranium-238		14	14	2.9E-01	±	5.8E-02	2.3E-01	±	7.8E-02	66	65	3.0E-01	±	8.2E-02	2.2E-01	±	7.6E-02	--
Continuous System																		
Cesium-137	D[b]	14	0	9.1E-04	±	1.8E-03	2.4E-05	±	1.3E-03	49	0	2.4E-03	±	2.3E-03	2.4E-05	±	2.1E-03	200
	P[b]	14	0	2.5E-03	±	3.4E-03	8.9E-05	±	2.7E-03	49	0	6.9E-03	±	3.4E-03	8.9E-05	±	5.0E-03	
Plutonium-238[f]	D[b]	14	0	4.3E-05	±	6.7E-05	-3.6E-07	±	5.2E-05	41	0	8.7E-05	±	7.4E-05	-3.7E-06	±	6.9E-05	600
	P[b]	14	0	1.0E-04	±	1.1E-04	-5.1E-06	±	8.3E-05	41	2	7.9E-04	±	3.1E-04	3.4E-05	±	2.7E-04	
Plutonium-239/240[f]	D[b]	14	0	2.4E-05	±	7.2E-05	-1.4E-05	±	5.5E-05	41	0	9.7E-05	±	1.9E-04	7.1E-06	±	8.5E-05	--
	P[b]	14	0	7.9E-05	±	9.3E-05	-1.3E-05	±	1.0E-04	41	1	1.8E-04	±	9.8E-05	1.2E-05	±	1.3E-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] Richland composite water was analyzed from July of 2017 through June of 2018 as the continuous system was down; No filter/resin data is available for this time.
[f] Plutonium-238 and plutonium-239/240 were analyzed quarterly in 2014.
Note: Dashes indicate no analytical concentrations or concentration guides available.
WA = Washington State.

Table C-8. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, Washington).

Radionuclide		2019								2014-2018								WA Ambient Surface Water Quality Standard [d]
		Number of		Concentration [a]						Number of		Concentration [a]						
		Samples	Detects	Maximum (pCi/L)[c]			Average(pCi/L)[c]			Samples	Detects	Maximum (pCi/L)[c]			Average(pCi/L)[c]			
Composite System																		
Strontium-90		14	1	1.8E-01	±	5.4E-02	1.9E-02	±	1.0E-01	66	0	1.8E-01	±	5.4E-02	1.9E-02	±	1.0E-01	8
Tritium		14	14	2.2E+01	±	8.2E+00	1.8E+01	±	6.0E+00	66	64	3.0E+01	±	6.9E+00	1.6E+01	±	9.6E+00	20000
Technetium-99		14	0	1.7E+00	±	1.1E+00	1.6E-01	±	1.3E+00	66	0	1.5E+00	±	1.0E+00	1.2E-01	±	7.8E-01	900
Uranium-234		14	14	3.2E-01	±	5.9E-02	2.7E-01	±	6.1E-02	66	66	4.4E-01	±	8.7E-02	2.6E-01	±	2.3E-02	--
Uranium-235		14	4	5.7E-02	±	4.3E-02	1.7E-02	±	2.8E-02	66	28	7.4E-02	±	5.9E-02	2.4E-02	±	8.4E-03	--
Uranium-238		14	14	2.6E-01	±	5.0E-02	2.2E-01	±	4.7E-02	66	66	2.9E-01	±	5.9E-02	2.0E-01	±	1.2E-02	--
Continuous System																		
Cesium-137	D[b]	14	0	1.4E-03	±	3.3E-03	-3.9E-04	±	1.4E-03	64	0	2.2E-03	±	2.1E-03	2.0E-04	±	1.9E-03	200
	P[b]	14	0	2.0E-03	±	4.4E-03	-7.7E-06	±	2.5E-03	62	0	5.1E-03	±	2.9E-03	9.0E-04	±	3.9E-03	
Plutonium-238[f]	D[b]	14	0	6.9E-05	±	1.1E-04	-7.3E-07	±	9.1E-05	56	0	2.3E-04	±	3.5E-05	4.7E-06	±	8.5E-05	600
	P[b]	14	0	1.3E-04	±	2.8E-04	-3.9E-06	±	9.8E-05	54	0	5.2E-04	±	1.7E-04	2.0E-05	±	2.4E-04	
Plutonium-239/240[f]	D[b]	14	0	1.3E-04	±	1.2E-04	-8.4E-06	±	1.2E-04	56	1	9.9E-05	±	7.8E-05	-1.0E-06	±	6.5E-05	--
	P[b]	14	0	1.1E-04	±	1.1E-04	2.0E-05	±	7.7E-05	54	1	2.4E-04	±	2.4E-04	3.2E-05	±	1.2E-04	

[a] Maximum values are ± total propagated analytical uncertainty. 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]Does not apply to the Priest Rapids composite/continuous water system.
[f]Plutonium-238 and plutonium-239/240 were analyzed quarterly in 2014.
Note: Dashes indicate no concentration guides available.
WA = Washington State.

Table C-9. 2019 Radionuclide Concentrations in Columbia River Transect Water Samples. (3 Pages)

Transect/Radionuclide	No. of Detections	No. of Samples	Concentration[a]					
			Maximum *pCi/L*[b]			Average *pCi/L*[b]		
Vernita Bridge (HRM 0.3)								
Strontium-90[c]	0	8	5.92E-02	±	3.94E-02	1.84E-02	±	4.59E-02
Technetium-99	1	8	1.46E+00	±	8.38E-01	3.22E-01	±	1.01E+00

Table C-9. 2019 Radionuclide Concentrations in Columbia River Transect Water Samples. (3 Pages)

Transect/Radionuclide	No. of Detections	No. of Samples	Concentration[a]					
			Maximum *pCi/L*[b]			Average *pCi/L*[b]		
Tritium	8	8	1.96E+01	±	7.18E+00	1.71E+01	±	3.64E+00
Uranium-234	8	8	3.02E-01	±	5.48E-02	2.55E-01	±	4.41E-02
Uranium-235	1	8	1.75E-02	±	1.39E-02	1.16E-02	±	9.76E-03
Uranium-238	8	8	2.29E-01	±	4.54E-02	2.04E-01	±	2.85E-02
100-H Area (HRM 15.3)								
Strontium-90[c]	0	5	5.38E-02	±	3.71E-02	4.42E-03	±	3.58E+00
Tritium	5	5	1.75E+01	±	6.82E+00	1.60E+01	±	3.58E+00
Uranium-234	5	5	2.64E-01	±	5.51E-02	2.29E-01	±	6.04E-02
Uranium-235	1	5	5.20E-02	±	2.62E-02	2.39E-02	±	2.88E-02
Uranium-238	5	5	2.12E-01	±	4.95E-02	1.89E-01	±	3.78E-02
100-N Area (HRM 9.5)								
Strontium-90[c]	0	6	5.28E-02	±	3.66E-02	3.73E-02	±	2.68E-02
Tritium	6	6	2.30E+01	±	8.17E+00	1.72E+01	±	5.66E+00
Uranium-234	6	6	2.94E-01	±	6.86E-02	2.35E-01	±	7.70E-02
Uranium-235[c]	0	6	1.92E-02	±	1.68E-02	1.20E-02	±	9.83E-03
Uranium-238	6	6	1.97E-01	±	5.26E-02	1.83E-01	±	1.58E-02
Hanford Townsite (HRM 28.7)								
Strontium-90[c]	0	5	3.07E-02	±	3.53E-02	-2.55E-03	±	5.20E-02
Tritium	5	5	8.65E+01	±	2.63E+01	3.09E+01	±	5.56E+01
Uranium-234	5	5	2.89E-01	±	6.86E-02	2.45E-01	±	5.41E-02
Uranium-235	3	5	4.72E-02	±	2.64E-02	3.11E-02	±	2.51E-02
Uranium-238	3	5	2.52E-01	±	6.33E-02	2.00E-01	±	6.43E-02
300 Area (HRM 43.1)								
Strontium-90[c]	0	5	4.53E-02	±	3.61E-02	1.77E-02	±	6.74E-02
Tritium	5	5	1.96E+01	±	7.37E+00	1.70E+01	±	5.00E+00
Uranium-234	5	5	3.12E-01	±	7.16E-02	2.77E-01	±	6.54E-02
Uranium-235	2	5	3.96E-02	±	2.79E-02	3.14E-02	±	1.46E-02
Uranium-238	5	5	2.34E-01	±	5.56E-02	2.14E-01	±	3.22E-02
Richland (HRM 46.4)								
Strontium-90[c]	0	11	4.31E-02	±	3.62E-02	1.93E-03	±	6.30E-02
Technetium-99[c]	0	11	1.15E+00	±	7.65E-01	1.48E-01	±	8.67E-01
Tritium	11	11	4.43E+01	±	1.39E+01	2.46E+01	±	2.02E+01
Uranium-234	11	11	3.95E-01	±	6.92E-02	3.20E-01	±	5.41E-02
Uranium-235	3	11	2.24E-02	±	1.71E-02	1.44E-02	±	9.65E-03
Uranium-238	11	11	3.46E-01	±	1.01E-01	2.47E-01	±	1.22E-01

Table C-9. 2019 Radionuclide Concentrations in Columbia River Transect Water Samples. (3 Pages)

Transect/Radionuclide	No. of Detections	No. of Samples	Concentration[a]	
			Maximum *pCi/L*[b]	Average *pCi/L*[b]

[a] Maximum values ± total propagated analytical uncertainty; Average values ± 2stdv.
[b] 1 pCi = 0.037 Bq.
[c] All value(s) reported are non-detects.
HRM = Hanford river marker.

Table C-10. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (3 Pages)

Metal	No. of Samples	No. of Detections	Maximum *(µg/L)*[a]	Minimum *(µg/L)*[a]	Average *(µg/L)*[a,c]	Minimum Detectable Concentrations (µg/L)	Washington State Ambient Surface Water Quality Chronic Toxicity Level[b]
Vernita Bridge							
Antimony	8	0	—	—	—	1	N/A
Arsenic	8	4	2.40	2.36	2.28	2	190
Beryllium	8	0	—	—	—	0.2	N/A
Cadmium	8	0	—	—	—	0.3	N/A
Chromium	8	0	—	—	—	3	10
Copper	8	8	0.57	0.48	0.52	0.3	6
Hexavalent Chromium	8	0	—	—	—	1.5	10
Lead	8	0	—	—	—	0.5	1.1
Nickel	8	0	—	—	—	0.6	83
Selenium	8	0	—	—	—	2	5
Silver	8	0	—	—	—	0.3	N/A
Thallium	8	1	0.71	0.71	0.71	0.6	N/A
Uranium	8	8	0.72	0.53	0.62	0.067	30[d]
Zinc	8	3	3.51	3.42	3.46	3.3	55
100-N Area							
Antimony	6	0	—	—	—	1	N/A
Arsenic	6	0	—	—	—	2	190
Beryllium	6	0	—	—	—	0.2	N/A
Cadmium	6	0	—	—	—	0.3	N/A
Chromium	6	0	—	—	—	3	10
Copper	6	6	0.64	0.49	0.56	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

Table C-10. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (3 Pages)

Metal	No. of Samples	No. of Detections	Maximum (µg/L)[a]	Minimum (µg/L)[a]	Average (µg/L)[a,c]	Minimum Detectable Concentrations (µg/L)	Washington State Ambient Surface Water Quality Chronic Toxicity Level[b]
Thallium	6	0	—	—	—	0.6	N/A
Uranium	6	6	0.54	0.50	0.52	0.067	30[d]
Zinc	6	6	6.84	3.68	4.78	3.3	55
100-H Area							
Antimony	5	0	—	—	—	1	N/A
Arsenic	5	3	3.15	2.96	3.03	2	190
Beryllium	5	0	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3	10
Copper	5	5	0.89	0.48	0.62	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	1	0.61	0.61	0.61	0.6	N/A
Uranium	5	5	35.80	1.55	13.77	0.067	30[d]
Zinc	5	5	7.84	5.76	6.82	3.3	55
Hanford Townsite							
Antimony	5	0	—	—	—	1	N/A
Arsenic	5	0	—	—	—	2	190
Beryllium	5	0	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3	10
Copper	5	5	0.75	0.54	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	0.56	0.51	0.53	0.067	30[d]
Zinc	5	5	7.88	4.53	6.13	3.3	55
300 Area							
Antimony	5	0	—	—	—	1	N/A
Arsenic	5	5	2.61	2.18	2.44	2	190
Beryllium	5	0	—	—	—	0.2	N/A

Table C-10. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (3 Pages)

Metal	No. of Samples	No. of Detections	Maximum (µg/L)[a]	Minimum (µg/L)[a]	Average (µg/L)[a,c]	Minimum Detectable Concentrations (µg/L)	Washington State Ambient Surface Water Quality Chronic Toxicity Level[b]
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3	10
Copper	5	5	0.65	0.55	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	0.65	0.57	0.62	0.067	30[d]
Zinc	5	1	4.38	4.38	4.38	3.3	55
Richland							
Antimony	11	0	—	—	—	1	N/A
Arsenic	11	6	2.72	2.26	2.48	2	190
Beryllium	11	0	—	—	—	0.2	N/A
Cadmium	11	0	—	—	—	0.3	N/A
Chromium	11	0	—	—	—	3	10
Copper	11	11	0.62	0.47	0.55	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	0.93	0.55	0.73	0.067	30[d]
Zinc	11	7	32.00	3.46	8.20	3.3	55

[a] Dashes indicate results at or below minimum detectable concentrations.
[b] WAC 173-201A-240, and WAC 173-201A-250. Table 240(3) Toxic Substances Criteria for the protection of aquatic life. For hardness—dependent criteria, the minimum value of 47 mg CaCo3/L, for 1992 through 2000 water samples collected near Vernita Bridge by the U.S. Geological Survey was used. Parts per million (ppm) values are equivalent to the reported micrograms per liter (µg/L) concentrations shown.
[c] Average calculated using reporting limit values for all results above minimum detectable concentrations.
[d] EPA drinking water standard applied.

Table C-11. Columbia River Organic Concentrations in Transect Water (2019).

Location	No. of Samples	1,1,1-Trichloroethane *(mg/L)*[b]	1,2-Dichloroethane *(mg/L)*[b]	Regulatory Standard[a] *(mg/L)*
Richland Pumphouse-1 HRM 46.4	3	0.003	0.003	0.2 ; 0.005
Richland Pumphouse-3 HRM 46.4	2	0.003	0.003	0.2 ; 0.005
Richland Pumphouse-5 HRM 46.4	2	0.003	0.003	0.2 ; 0.005
Richland Pumphouse-7 HRM 46.4	2	0.003	0.003	0.2 ; 0.005
Richland Pumphouse-9 HRM 46.4	2	0.003	0.003	0.2 ; 0.005
300 Area-1 HRM 43.1	1	0.003	0.003	0.2 ; 0.005
300 Area-3 HRM 43.1	1	0.003	0.003	0.2 ; 0.005
300 Area-5 HRM 43.1	1	0.003	0.003	0.2 ; 0.005
300 Area-7 HRM 43.1	1	0.003	0.003	0.2 ; 0.005
300 Area-9 HRM 43.1	1	0.003	0.003	0.2 ; 0.005
Vernita-1 HRM 0.3	2	0.003	0.003	0.2 ; 0.005
Vernita-2 HRM 0.3	2	0.003	0.003	0.2 ; 0.005
Vernita-3 HRM 0.3	2	0.003	0.003	0.2 ; 0.005
Vernita-4 HRM 0.3	2	0.003	0.003	0.2 ; 0.005

[a]EPA National Primary Drinking Water Regulation Standard.
[b]Maximum concentration reported was a non-detect.

C.5 Shoreline Seep Water

Table C-12. Columbia River Organic Concentrations in Shoreline Seep Water (2019)

Location	No. of Samples	1,1,1-Trichloroethane *(mg/L)*[b]	1,2-Dichloroethane *(mg/L)*[b]	Regulatory Standard[a] *(mg/L)*
300 Area Spring DR 42-2	1	0.003	0.003	0.2 ; 0.005
300 Area Spring 42-2	1	0.003	0.003	0.2 ; 0.005
Hanford Townsite 25-4	1	0.003	0.003	0.2 ; 0.005
100F Spring 107-1	1	0.003	0.003	0.2 ; 0.005
100K Spring 63-1	1	0.003	0.003	0.2 ; 0.005
100B Spring 39-2	1	0.003	0.003	0.2 ; 0.005
100B Spring 38-3	1	0.003	0.003	0.2 ; 0.005

[a]EPA National Primary Drinking Water Regulation Standard.
[b]Maximum concentration reported was a non-detect.

Table C-13. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site) (2014-2019). (3 Pages)

Sediment Location	Radionuclide	2019						2014-2018				
		No. of Samples	No. of Detects	Maximum Concentration[a] *pCi/g*				No. of Samples	No. of Detects	Average Concentration[a] *pCi/g*		
Adjacent to Locke Island	Cesium-137[b]	1	0	-4.33E-04	±	2.00E-02		6	0	7.13E-03	±	1.11E-02
	Plutonium-239/240[b]	1	0	-5.12E-04	±	3.58E-03		6	0	-6.89E-04	±	5.39E-03
	Uranium-234	1	1	1.40E+00	±	2.06E-01		6	6	1.26E+00	±	2.42E-01
	Uranium-235	1	1	1.00E-01	±	4.83E-02		6	6	1.22E-01	±	7.20E-02
	Uranium-238	1	1	1.32E+00	±	1.98E-01		6	6	1.20E+00	±	2.50E-01
Adjacent to Savage Island	Cesium-137[b]	1	0	3.16E-02	±	2.13E-02		5	5	4.35E-02	±	1.67E-02
	Plutonium-239/240[b]	1	0	6.73E-04	±	1.24E-03		5	0	-7.82E-04	±	7.18E-03
	Uranium-234	1	1	6.81E-01	±	1.26E-01		5	5	7.73E-01	±	3.06E-01
	Uranium-235[b]	1	0	4.77E-02	±	3.99E-02		5	5	8.42E-02	±	6.40E-02
	Uranium-238	1	1	6.37E-01	±	1.19E-01		5	5	7.46E-01	±	2.54E-01
100-D Spring 102-1	Cesium-137	2	2	9.79E-02	±	2.01E-02		9	9	1.08E-01	±	2.25E-02
	Plutonium-239/240[b]	2	0	2.15E-03	±	2.82E-03		9	3	3.56E-03	±	9.35E-03
	Uranium-234	2	2	4.42E-01	±	8.62E-02		9	9	5.11E-01	±	1.30E-01
	Uranium-235	2	1	5.31E-02	±	3.01E-02		9	9	5.09E-02	±	4.04E-02
	Uranium-238	2	2	4.97E-01	±	9.72E-02		9	9	4.99E-01	±	8.07E-02
100-F Slough	Cesium-137	1	1	8.76E-02	±	1.89E-02		6	6	1.80E-01	±	5.31E-02

Table C-13. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site) (2014-2019). (3 Pages)

Sediment Location	Radionuclide	2019						2014-2018				
		No. of Samples	No. of Detects	Maximum Concentration[a] *pCi/g*				No. of Samples	No. of Detects	Average Concentration[a] *pCi/g*		
	Plutonium-239/240[b]	1	0	6.30E-04	±	1.24E-03		6	2	1.55E-03	±	3.90E-03
	Uranium-234	1	1	8.50E-01	±	1.39E-01		6	6	5.68E-01	±	1.83E-01
	Uranium-235[b]	1	0	4.93E-02	±	3.86E-02		6	6	5.84E-02	±	2.31E-02
	Uranium-238	1	1	6.78E-01	±	1.18E-01		6	6	5.33E-01	±	1.56E-01
100-H Spring 145-1	Cesium-137	1	1	1.44E-01	±	3.55E-02		4	4	1.52E-01	±	7.76E-02
	Plutonium-239/240[b]	1	0	2.98E-03	±	2.15E-03		4	0	3.58E-03	±	2.15E-03
	Uranium-234	1	1	4.83E-01	±	1.25E-01		4	4	7.99E-01	±	2.25E-01
	Uranium-235	1	1	7.48E-02	±	5.54E-02		4	4	6.15E-02	±	4.53E-02
	Uranium-238	1	1	5.93E-01	±	1.38E-01		4	4	7.14E-01	±	9.54E-02
100-K Spring 63-1	Cesium-137	1	1	2.38E-02	±	1.88E-02		5	5	9.54E-02	±	4.82E-02
	Plutonium-239/240[b]	1	0	2.39E-03	±	2.26E-03		5	1	2.32E-03	±	8.61E-03
	Uranium-234	1	1	8.09E-01	±	1.59E-01		5	5	1.14E+00	±	2.00E-01
	Uranium-235	1	1	4.89E-02	±	3.82E-02		5	4	6.85E-02	±	3.84E-02
	Uranium-238	1	1	7.87E-01	±	1.51E-01		5	5	1.03E+00	±	2.27E-01
Hanford Slough	Cesium-137	1	1	2.82E-01	±	4.73E-02		6	6	2.42E-01	±	4.20E-02
	Plutonium-239/240[b]	1	0	4.28E-03	±	4.49E-03		6	4	3.79E-03	±	8.94E-03
	Uranium-234	1	1	7.46E-01	±	1.14E-01		6	6	6.92E-01	±	1.59E-01
	Uranium-235	1	1	7.55E-02	±	3.37E-02		6	6	6.86E-02	±	5.31E-02
	Uranium-238	1	1	8.05E-01	±	1.18E-01		6	6	7.10E-01	±	1.28E-01
McNary Dam	Cesium-137	2	2	1.94E-01	±	2.75E-02		10	10	2.19E-01	±	6.62E-02
	Plutonium-239/240	2	2	1.07E-02	±	3.83E-03		10	4	6.77E-03	±	1.03E-02
	Uranium-234	2	2	1.52E+00	±	2.91E-01		10	10	1.48E+00	±	2.81E-01
	Uranium-235	2	1	7.96E-02	±	4.47E-02		10	10	1.10E-01	±	6.06E-02
	Uranium-238	2	2	1.32E+00	±	2.65E-01		10	10	1.21E+00	±	1.84E-01
Priest Rapids Dam	Cesium-137	2	2	2.25E-01	±	3.19E-02		10	10	2.44E-01	±	6.04E-02
	Plutonium-239/240	2	2	8.01E-03	±	6.32E-03		10	7	1.01E-02	±	6.22E-03
	Uranium-234	2	2	1.37E+00	±	1.93E-01		10	10	1.30E+00	±	3.05E-01
	Uranium-235	2	2	1.11E-01	±	4.28E-02		10	10	1.05E-01	±	3.07E-02
	Uranium-238	2	2	1.31E+00	±	1.86E-01		10	10	1.14E+00	±	2.42E-01
White Bluffs Slough	Cesium-137	1	1	1.45E-01	±	4.48E-02		5	5	3.07E-01	±	1.12E-01
	Plutonium-239/240[b]	1	0	2.19E-03	±	3.24E-03		5	1	4.10E-03	±	4.94E-03

Table C-13. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site) (2014-2019). (3 Pages)

Sediment Location	Radionuclide	2019						2014-2018				
		No. of Samples	No. of Detects	Maximum Concentration[a] *pCi/g*				No. of Samples	No. of Detects	Average Concentration[a] *pCi/g*		
	Uranium-234	1	1	1.07E+00	±	1.56E-01		5	5	9.83E-01	±	3.01E-01
	Uranium-235	1	1	8.33E-02	±	4.07E-02		5	5	1.03E-01	±	6.24E-02
	Uranium-238	1	1	7.92E-01	±	1.25E-01		5	5	9.41E-01	±	2.28E-01

[a]Maximum Concentrations ± Analytical Uncertainty; Average Concentrations ± 2stdv.
[b]Maximum value reported as a non-detect.

Table C-14. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (2 Pages)

Location/Radionuclide	2019					2014-2018					Washington State
	No. of Samples	No. of Detects	Concentration pCi/L[a] Maximum[c]			No. of Samples	No. of Detects	Concentration pCi/L[a] Average[d]			Ambient Surface Water Quality Standard pCi/L[a, b]
100-B Area (100-B Spring 38-3 and 100-B Spring 39-2)											
Strontium-90	2	1	1.2E+00	±	2.0E-01	9	4	5.6E-01	±	2.8E+00	8
Tritium	2	2	8.0E+02	±	2.3E+02	9	8	1.0E+03	±	1.3E+03	20,000
100-D Area (Spring 110-1)											
Alpha (gross)[e]	1	0	9.3E-01	±	1.5E+00	6	0	2.1E+00	±	2.6E+00	15
Beta (gross)[e]	1	0	1.7E+00	±	2.1E+00	6	6	7.1E+00	±	9.2E+00	50
Strontium-90	1	1	1.9E-01	±	5.4E-02	6	5	1.6E+00	±	1.8E+00	8
Technetium-99[e]	1	0	4.7E-01	±	4.4E-01	6	0	-6.0E-01	±	3.7E+00	900
Tritium	1	1	4.3E+02	±	1.8E+02	6	6	1.9E+03	±	1.5E+03	20,000
Uranium-234	1	1	3.0E-01	±	7.8E-02	6	6	9.4E-01	±	5.9E-01	–
Uranium-235[e]	1	0	3.6E-02	±	3.2E-02	6	5	6.4E-02	±	5.5E-02	–
Uranium-238	1	1	2.8E-01	±	7.4E-02	6	6	8.3E-01	±	7.2E-01	–
100-F Area (100F Spring 207-1 and 100-F Spring 211-1)											
Strontium-90[e]	2	0	2.1E-02	±	3.2E-02	13	0	-8.7E-02	±	5.9E-01	8
Tritium	2	2	2.5E+02	±	1.3E+02	13	8	2.8E+02	±	3.4E+02	900
100-H Area (100-H Spring 145-1 and 100-H Spring 152-2)											
Strontium-90	1	1	6.5E-01	±	1.1E-01	3	2	1.5E+00	±	3.2E+00	8
Tritium[e]	1	0	4.3E+01	±	1.5E+02	4	0	1.1E+02	±	1.5E+02	900
100-K Area (Spring 63-1)											
Alpha (gross)[e]	1	0	1.4E-01	±	1.7E+00	6	1	6.0E-01	±	1.9E+00	15
Beta (gross)	1	1	6.2E+00	±	2.7E+00	6	5	4.6E+00	±	3.2E+00	50
Carbon-14	1	1	1.4E+02	±	2.8E+01	13	10	1.4E+02	±	2.6E+02	2,000
Strontium-90[e]	1	0	5.7E-02	±	3.8E-02	6	0	-1.4E-01	±	6.4E-01	8
Technetium-99	1	1	5.3E+00	±	9.3E-01	6	4	3.6E+00	±	6.4E+00	–
Tritium[e]	1	0	1.4E+02	±	1.7E+02	6	1	4.7E+02	±	1.7E+03	20,000

Table C-14. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (2 Pages)

Location/Radionuclide	2019					2014-2018					Washington State Ambient Surface Water Quality Standard pCi/L[a, b]
	No. of Samples	No. of Detects	Concentration pCi/L[a] Maximum[c]			No. of Samples	No. of Detects	Concentration pCi/L[a] Average[d]			
100-N Area (Spring 8-13)											
Alpha (gross)[e]	1	0	1.9E+00	±	2.1E+00	5	0	2.8E-01	±	1.0E+00	15
Beta (gross)	1	1	4.0E+00	±	2.4E+00	5	3	2.6E+00	±	2.3E+00	50
Strontium-90[e]	1	0	-6.6E-05	±	3.3E-02	5	0	-1.3E-01	±	5.5E-01	8
Tritium	1	1	3.7E+03	±	7.6E+02	5	5	4.0E+03	±	2.1E+03	20,000
100-N Area (Spring 89-1)											
Strontium-90	1	1	5.5E+01	±	8.7E+00	5	5	3.7E+01	±	5.1E+01	8
Tritium	1	1	1.1E+03	±	2.9E+02	5	3	7.9E+02	±	1.6E+03	20,000
Hanford Townsite (Hanford Spring 25-4)											
Alpha (gross)	1	1	4.1E+00	±	2.6E+00	5	0	3.8E-01	±	8.8E-01	15
Beta (gross)	1	1	6.5E+00	±	2.4E+00	5	1	2.4E+00	±	4.3E+00	50
Iodine[e]	1	0	1.8E-01	±	5.7E-01	N/A	N/A	N/A			–
Strontium-90[e]	1	0	5.6E-02	±	3.8E-02	5	0	-5.0E-02	±	1.7E-01	8
Technetium-99[e]	1	0	1.8E-01	±	5.1E-01	5	0	2.9E-01	±	7.4E-01	–
Tritium[e]	1	0	-3.7E+01	±	1.4E+02	5	0	1.2E+01	±	2.1E+02	20000
Hanford Townsite (Hanford Spring 28-2)											
Alpha (gross)[e]	1	0	5.2E-01	±	1.5E+00	5	3	3.5E+00	±	3.9E+00	15
Beta (gross)	1	1	4.5E+01	±	4.8E+00	5	5	3.2E+01	±	2.5E+01	50
Iodine[e]	1	0	1.4E-01	±	3.1E-01	5	0	6.1E-02	±	4.9E-01	–
Tritium	1	1	2.4E+04	±	4.7E+03	5	5	1.7E+04	±	1.2E+04	20,000
300 Area (300 Area Spring 42-2 and 300 Area Spring DR 42-2)											
Alpha (gross)	3	3	1.5E+01	±	4.4E+00	11	11	3.0E+01	±	3.2E+01	15
Beta (gross)	3	3	1.1E+01	±	2.9E+00	11	11	2.0E+01	±	1.5E+01	50
Tritium	3	3	2.4E+03	±	5.0E+02	11	11	3.8E+03	±	2.1E+03	20,000
Uranium-234	3	3	7.5E+00	±	8.4E-01	11	11	2.0E+01	±	2.0E+01	–
Uranium-235	3	3	4.7E-01	±	1.0E-01	11	11	1.7E+00	±	1.8E+00	–
Uranium-236[e]	3	0	1.5E-01	±	1.3E-02	4	2	3.1E-01	±	2.6E-01	–
Uranium-238	3	3	7.1E+00	±	7.9E-01	11	12	1.9E+01	±	2.0E+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] Maximum value reported for 2019 is a non-detect.
N/A = Not Applicable (Samples not analyzed for contaminant).
Note: Dashes indicate no concentration guides available.

Table C-15. Metal and Anion Concentrations in Columbia River Shoreline Seeps. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered[a]	Range (min-max)[b]	Unit	Regulatory limit[c] (µg/L)
100-B (39-2 and 38-3)	***Metals***						
	Antimony	2	0	Filtered	1.00E+00	µg/L	12
		2	0	Unfiltered			
	Arsenic	2	2	Filtered	2.36E+00 - 2.87E+00	µg/L	10
		2	2	Unfiltered	2.51E+00 - 2.61E+00		
	Cadmium	2	0	Filtered	3.00E-01	µg/L	0.59
		2	0	Unfiltered			
	Chromium	2	2	Filtered	4.34E+00 - 8.32E+00	µg/L	10[d]
		2	2	Unfiltered	6.16E+00 - 6.16E+00		96[e]
	Copper	2	2	Filtered	2.99E+00 - 1.23E+01	µg/L	1300
		2	2	Unfiltered	1.94E+00 - 2.09E+00		
	Lead	2	1	Filtered	5.00E-01 - 2.11E+00	µg/L	1.1
		2	2	Unfiltered	1.25E+00 - 1.59E+00		
	Nickel	2	1	Filtered	6.00E-01 - 2.41E+00	µg/L	150
		2	2	Unfiltered	1.07E+00 - 1.50E+00		
	Selenium	2	0	Filtered	2.00E+00	µg/L	120
		2	0	Unfiltered			
	Thallium	2	1	Filtered	6.00E-01 - 7.71E-01	µg/L	0.24
		2	0	Unfiltered	6.00E-01		
	Zinc	2	2	Filtered	8.02E+00 - 3.04E+01	µg/L	2,300
		2	2	Unfiltered	1.73E+01 - 2.25E+01		
	Anions						
	Nitrate	2	2	Unfiltered	3.02E+03 - 6.51E+03	µg/L	10[f]
100-D (110-1)	***Metals***						
	Antimony	1	0	Filtered	1.00E+00	µg/L	12
		1	0	Unfiltered			
	Arsenic	1	0	Filtered	2.00E+00	µg/L	10
		1	0	Unfiltered			
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59
		1	0	Unfiltered			
	Chromium	1	0	Filtered	3.00E+00	µg/L	10[d]
		1	0	Unfiltered			96[e]
	Copper	1	1	Filtered	9.36E-01	µg/L	1300
		1	1	Unfiltered	5.13E-01		
	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			

Table C-15. Metal and Anion Concentrations in Columbia River Shoreline Seeps. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered[a]	Range (min-max)[b]	Unit	Regulatory limit[c] (µg/L)
	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	7.49E+00	µg/L	2,300
		1	1	Unfiltered	1.01E+01		
	Anions						
	Nitrate	1	1	Unfiltered	1.95E+03	µg/L	10[f]
100-F (207-1 and 211-1)	***Metals***						
	Antimony	2	0	Filtered	1.00E+00	µg/L	12
		2	0	Unfiltered			
	Arsenic	2	2	Filtered	2.70E+00 - 3.11E+00	µg/L	10
		2	2	Unfiltered	3.26E+00 - 6.50E+00		
	Cadmium	2	0	Filtered	3.00E-01	µg/L	0.59
		2	1	Unfiltered	3.00E-01 - 4.22E-01		
	Chromium	2	2	Filtered	6.13E+00 - 6.20E+00	µg/L	10[d]
		2	2	Unfiltered	6.36E+00 - 1.94E+01		96[e]
	Copper	2	1	Filtered	3.00E-01 - 4.68E-01	µg/L	1300
		2	2	Unfiltered	8.26E-01 - 1.45E+01		
	Lead	2	0	Filtered	5.00E-01	µg/L	1.1
		2	2	Unfiltered	9.23E-01 - 1.92E+01		
	Nickel	2	0	Filtered	6.00E-01	µg/L	150
		2	2	Unfiltered	7.36E-01 - 7.05E+00		
	Selenium	2	0	Filtered	2.00E+00	µg/L	120
		2	0	Unfiltered			
	Thallium	2	1	Filtered	6.00E-01 - 8.89E-01	µg/L	0.24
		2	0	Unfiltered	6.00E-01		
	Zinc	2	2	Filtered	9.17E+00 - 1.05E+01	µg/L	2,300
		2	2	Unfiltered	1.42E+01 - 9.75E+01		
	Anions						
	Nitrate	2	2	Unfiltered	2.68E+04 - 3.13E+04	µg/L	10[f]
100-H (152-2)	***Metals***						
	Antimony	1	0	Filtered	1.00E+00	µg/L	12
		1	0	Unfiltered			
	Arsenic	1	1	Filtered	2.67E+00	µg/L	10
		1	1	Unfiltered	3.48E+00		
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59
		1	1	Unfiltered	3.70E-01		

Table C-15. Metal and Anion Concentrations in Columbia River Shoreline Seeps. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered[a]	Range (min-max)[b]	Unit	Regulatory limit[c] (µg/L)
	Chromium	1	0	Filtered	3.00E+00	µg/L	10[d]
		1	1	Unfiltered	5.02E+00		96[e]
	Copper	1	1	Filtered	1.74E+00	µg/L	1300
		1	1	Unfiltered	5.63E+00		
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
		1	1	Unfiltered	3.46E+00		
	Nickel	1	1	Filtered	1.11E+00	µg/L	150
		1	1	Unfiltered	3.21E+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	1.64E+01	µg/L	2,300
		1	1	Unfiltered	4.36E+01		
	Anions						
	Nitrate	1	1	Unfiltered	1.24E+03	µg/L	10[f]
100-K (63-1)	***Metals***						
	Antimony	1	0	Filtered	1.00E+00	µg/L	12
		1	0	Unfiltered			
	Arsenic	1	1	Filtered	2.17E+00	µg/L	10
		1	1	Unfiltered	4.32E+00		
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59
		1	1	Unfiltered	4.26E-01		
	Chromium	1	0	Filtered	3.00E+00	µg/L	10[d]
		1	1	Unfiltered	1.24E+01		96[e]
	Copper	1	1	Filtered	7.26E-01	µg/L	1300
		1	1	Unfiltered	1.23E+01		
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
		1	1	Unfiltered	1.02E+01		
	Nickel	1	0	Filtered	6.00E-01	µg/L	150
		1	1	Unfiltered	6.25E+00		
	Selenium	1	0	Filtered	2.00E+00	µg/L	120
		1	0	Unfiltered			
	Thallium	1	1	Filtered	7.09E-01	µg/L	0.24
		1	0	Unfiltered	6.00E-01		
	Zinc	1	1	Filtered	1.23E+01	µg/L	2,300
		1	1	Unfiltered	7.56E+01		
	Anions						

Table C-15. Metal and Anion Concentrations in Columbia River Shoreline Seeps. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered[a]	Range (min-max)[b]	Unit	Regulatory limit[c] (µg/L)
	Nitrate	1	1	Unfiltered	4.35E+03	µg/L	10[f]
100-N (8-13 and 89-1[g])	***Metals***						
	Antimony	2	0	Filtered	1.00E+00	µg/L	12
		2	0	Unfiltered			
	Arsenic	2	2	Filtered	2.14E+00 - 2.35E+00	µg/L	10
		2	2	Unfiltered	2.27E+00 - 3.99E+00		
	Cadmium	2	0	Filtered	3.00E-01	µg/L	0.59
		2	0	Unfiltered			
	Chromium	2	1	Filtered	3.00E+00 - 4.67E+00	µg/L	10[d]
		2	1	Unfiltered	3.00E+00 - 5.06E+00		96[e]
	Copper	2	2	Filtered	4.55E-01 - 3.41E+00	µg/L	1300
		2	1	Unfiltered	3.00E-01 - 5.79E+00		
	Lead	2	0	Filtered	5.00E-01	µg/L	1.1
		2	1	Unfiltered	5.00E-01 - 2.43E+00		
	Nickel	2	1	Filtered	6.00E-01 - 1.02E+00	µg/L	150
		2	1	Unfiltered	6.00E-01 - 1.88E+00		
	Selenium	2	0	Filtered	2.00E+00	µg/L	120
		2	0	Unfiltered			
	Thallium	2	1	Filtered	6.00E-01 - 1.34E+00	µg/L	0.24
		2	0	Unfiltered	6.00E-01		
	Zinc	2	2	Filtered	1.00E+01 - 1.81E+01	µg/L	2,300
		2	2	Unfiltered	4.47E+00 - 3.37E+01		
	Anions						
	Nitrate	2	2	Unfiltered	2.54E+04 - 2.64E+04	µg/L	10[f]
Hanford Townsite (25-4)	***Metals***						
	Antimony	1	0	Filtered	1.00E+00	µg/L	12
		1	0	Unfiltered			
	Arsenic	1	1	Filtered	2.15E+00	µg/L	10
		1	1	Unfiltered	2.33E+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[d]
		1	0	Unfiltered			96[e]
	Copper	1	1	Filtered	6.56E-01	µg/L	1300
		1	1	Unfiltered	1.68E+00		
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
		1	1	Unfiltered	1.19E+00		
	Nickel	1	0	Filtered	6.00E-01	µg/L	150

Table C-15. Metal and Anion Concentrations in Columbia River Shoreline Seeps. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered[a]	Range (min-max)[b]	Unit	Regulatory limit[c] (µg/L)
		1	1	Unfiltered	8.13E-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	1.11E+01	µg/L	2,300
		1	1	Unfiltered	1.85E+01		
	Anions						
	Nitrate	1	1	Unfiltered	7.44E+03	µg/L	10[f]
Hanford Spring (28-2)	***Metals***						
	Antimony	1	0	Filtered	1.00E+00	µg/L	12
		1	0	Unfiltered			
	Arsenic	1	1	Filtered	4.27E+00	µg/L	10
		1	1	Unfiltered	4.61E+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[d]
		1	0	Unfiltered			96[e]
	Copper	1	1	Filtered	4.10E-01	µg/L	1300
		1	1	Unfiltered	5.14E-01		
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
		1	0	Unfiltered			
	Nickel	1	1	Filtered	2.80E+00	µg/L	150
		1	0	Unfiltered	6.00E-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	7.53E+00	µg/L	2,300
		1	1	Unfiltered	8.70E+00		
	Anions						
	Nitrate	1	1	Unfiltered	2.22E+04	µg/L	10[f]
300 Area (28-2 and DR 28-2)	***Metals***						
	Antimony	3	0	Filtered	1.00E+00	µg/L	12
		3	0	Unfiltered			
	Arsenic	3	3	Filtered	2.23E+00 - 1.11E+01	µg/L	10
		3	3	Unfiltered	2.69E+00 - 1.22E+01		
	Cadmium	3	0	Filtered	3.00E-01	µg/L	0.59

Table C-15. Metal and Anion Concentrations in Columbia River Shoreline Seeps. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered[a]	Range (min-max)[b]			Unit	Regulatory limit[c] (µg/L)
		3	0	Unfiltered					
	Chromium	3	0	Filtered	3.00E+00			µg/L	10[d]
		3	0	Unfiltered					96[e]
	Copper	3	3	Filtered	3.68E-01	-	8.02E-01	µg/L	1300
		3	3	Unfiltered	4.91E-01	-	4.46E+00		
	Lead	3	0	Filtered	5.00E-01			µg/L	1.1
		3	0	Unfiltered					
	Nickel	3	1	Filtered	6.00E-01	-	1.07E+00	µg/L	150
		3	1	Unfiltered	6.00E-01	-	1.26E+00		
	Selenium	3	0	Filtered	2.00E+00			µg/L	120
		3	0	Unfiltered					
	Thallium	3	0	Filtered	6.00E-01			µg/L	0.24
		3	0	Unfiltered					
	Zinc	3	3	Filtered	7.71E+00	-	9.56E+00	µg/L	2,300
		3	3	Unfiltered	6.35E+00	-	9.78E+00		
	Anions								
	Nitrate	3	3	Unfiltered	1.46E+03	-	2.01E+04	µg/L	10[f]

[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] Value for hexavalent chromium.
[e] Value for trivalent chromium.
[f] Washington State drinking water standard utilized (WAC 246-290).
[g] Laboratory holding time for nitrate analysis was exceeded.

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Table C-16. 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	1.72 - 2.44	0.47 - 7.30	0.71 - 0.79
Arsenic	5.82 - 9.67	2.09 - 11.3	4.84 - 7.56
Beryllium	1.11 - 1.36	0.82 - 2.11	1.87 - 1.92
Cadmium	1.67 - 5.15	0.11 - 0.71	0.73 - 1.33
Chromium	36.7 - 40.7	11.3 - 47.3	25.0 - 30.4
Copper	39.1 - 56.9	6.43 - 27.8	28.2 - 31.2
Lead	41.4 - 49.2	4.06 - 54.9	17.7 - 21.8
Mercury	0.12 - 0.21	0.005 - 0.06	0.06 - 0.10
Nickel	38.3 - 40.8	8.52 - 18.3	22.9 - 28.3
Selenium	1.40 - 1.61	5.90 - 13.5	17.3 - 18.1
Silver	0.28 - 0.32	0.10 - 0.14	0.22 - 0.24
Thallium	30.8 - 39.8	0.98 - 28.5	34.2 - 37.0
Zinc	328 - 503	40.9 - 418	170 - 249
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=1), Adjacent to Savage Island (n=1), 100-H 145-1 (n=1), 100-D Spring 102-1 (n=2), 100-K 63-1 (n=1), 300 Area (n=1); where n = number of samples.

Table C-17. Columbia River Hexavalent Chromium in Sediment Samples. (2 Pages)

Location	No. of Samples	No. of Detects	2019 Max Concentration *(ug/Kg)*	No. of Samples	No. of Detects	2014-2018 Max Concentration *(ug/Kg)*
300 Area Spring DR 42-2 (shoreline)	1	0	137	5	1	4420
Adjacent to Savage Island (shoreline)	1	0	181	5	3	772
Hanford Slough	1	0	169	6	3	530
White Bluffs Slough	1	0	149	5	2	1700
100F Slough	1	0	156	6	3	461

Table C-17. Columbia River Hexavalent Chromium in Sediment Samples. (2 Pages)

Location	No. of Samples	No. of Detects	2019 Max Concentration *(ug/Kg)*	No. of Samples	No. of Detects	2014-2018 Max Concentration *(ug/Kg)*
100H Spring 145-1 (shoreline)	1	0	105	4	1	611
Adjacent to Locke Island (shoreline)	1	0	125	6	2	643
100D 102-1	2	0	188	9	9	5850
100K Spring 63-1 (shoreline)	1	0	115	5	3	2430
Priest Rapids Dam (Grant Side)	1	0	490	5	2	2670
Priest Rapids Dam (Yakima Side)	1	0	278	5	1	2870
McNary Dam (WA Side)	1	0	244	5	2	125000
McNary Dam (OR Side)	1	0	250	5	2	88200

Table C-18. Total Organic Carbon in Columbia River Sediment (2014-2019). (2 Pages)

Sediment Location	2019				2014-2018		
	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	N/A		1	1.17E+03	
Adjacent to Savage Island[b,c]	0	N/A	N/A		1	2.24E+03	

Table C-18. Total Organic Carbon in Columbia River Sediment (2014-2019). (2 Pages)

Sediment Location	2019				2014-2018		
	No. of Samples	Concentration[a]			No. of Samples	Concentration[a]	
		Minimum *mg/kg*	Maximum *mg/kg*			Minimum *mg/kg*	Maximum *mg/kg*
100-D Spring 102-1	2	3.89E+03	5.61E+03		9	1.88E+03	4.35E+03
100-F Slough[c]	1	8.05E+03			6	1.50E+03	6.59E+03
100-H Spring 145-1[c]	1	1.10E+04			4	7.25E+03	1.59E+04
100-K Spring 63-1[c]	1	2.10E+03			5	1.40E+03	1.81E+04
300 Area DR 42-2[c]	1	1.72E+03			4	1.77E+03	7.78E+03
Hanford Slough[c]	1	7.19E+03			6	8.58E+03	1.48E+04
McNary Dam	2	1.86E+04	2.50E+04		10	1.25E+04	2.52E+04
Priest Rapids Dam	2	2.67E+04			10	1.51E+04	3.95E+04
White Bluffs Slough[c]	1	8.76E+03			5	8.35E+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-19. Horn Rapids Irrigation Water Sample Results.

Radionuclide	2019								2014-2018							
	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	4	0	-3.0E-01	±	3.3E+00	2.0E+00	±	3.6E+00	18	0	-4.9E-02	±	4.5E+00	4.7E+00	±	6.8E+00
Cesium-134[c]	4	0	-6.1E-01	±	1.8E+00	5.9E-01	±	1.6E+00	18	0	6.5E-02	±	2.2E+00	2.3E+00	±	2.8E+00
Cesium-137[c]	4	0	5.5E-01	±	9.9E-01	1.2E+00	±	1.5E+00	18	0	4.8E-01	±	1.4E+00	2.2E+00	±	2.0E+00
Cobalt-60[c]	4	0	-4.2E-03	±	6.0E-01	3.0E-01	±	1.4E+00	18	0	6.7E-03	±	2.0E+00	2.4E+00	±	2.1E+00
Europium-152[c]	4	0	-6.9E-01	±	1.1E+00	-1.5E-01	±	4.1E+00	18	0	-6.4E-02	±	5.6E+00	5.1E+00	±	6.9E+00
Europium-154[c]	4	0	-1.1E+00	±	1.9E+00	4.6E-01	±	4.4E+00	18	0	-6.6E-01	±	7.0E+00	3.1E+00	±	4.1E+00
Europium-155[c]	4	0	5.8E-01	±	1.6E+00	1.1E+00	±	5.9E+00	18	0	2.1E+00	±	7.5E+00	7.6E+00	±	7.7E+00
Ruthenium-106[c]	4	0	-3.9E+00	±	2.8E+01	1.4E+01	±	2.7E+01	18	0	-2.0E+00	±	2.1E+01	2.0E+01	±	2.0E+01
Strontium-90[c]	4	0	1.7E-02	±	2.5E-02	3.0E-02	±	3.6E-02	18	0	8.8E-03	±	4.4E-02	4.8E-02	±	3.7E-02
Tritium	4	4	3.0E+01	±	1.8E+01	3.9E+01	±	1.3E+01	18	18	1.9E+01	±	9.4E+00	2.7E+01	±	7.2E+00

[a] Averages are ±2 standard deviations.
[b] Maximum values are ± analytical uncertainty.
[c] Results include concentrations below detection limit.

Table C-20. Riverview Irrigation Water Sample Results

Radionuclide	2019								2014-2018							
	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	3	0	9.0E-01	±	4.0E+00	2.8E+00	±	5.4E+00	17	0	1.1E+00	±	6.0E+00	8.0E+00	±	1.1E+01
Cesium-134[c]	3	0	3.1E-01	±	1.6E+00	1.4E+00	±	1.9E+00	17	0	1.4E-01	±	2.4E+00	2.6E+00	±	2.6E+00
Cesium-137[c]	3	0	-7.8E-01	±	1.5E+00	1.8E-01	±	1.9E+00	17	0	6.1E-02	±	2.4E+00	2.5E+00	±	1.8E+00
Cobalt-60[c]	3	0	9.2E-01	±	5.6E-01	1.3E+00	±	1.3E+00	17	0	6.8E-01	±	2.5E+00	3.9E+00	±	3.2E+00
Europium-152[c]	3	0	-2.3E+00	±	7.0E+00	1.7E-01	±	4.1E+00	17	0	-6.1E-01	±	6.0E+00	3.8E+00	±	5.0E+00
Europium-154[c]	3	0	-6.5E-01	±	1.0E+01	6.5E+00	±	6.7E+00	17	0	5.4E-02	±	4.5E+00	4.0E+00	±	7.1E+00
Europium-155[c]	3	0	-3.3E-01	±	1.6E+00	7.6E-01	±	5.4E+00	17	0	1.5E+00	±	7.5E+00	8.1E+00	±	8.0E+00
Ruthenium-106[c]	3	0	-3.8E+00	±	2.0E+01	9.3E+00	±	1.8E+01	17	0	4.3E-01	±	1.8E+01	1.7E+01	±	1.9E+01
Strontium-90[c]	3	0	2.1E-02	±	1.6E-02	2.9E-02	±	3.5E-02	17	0	5.8E-03	±	4.5E-02	4.4E-02	±	3.7E-02
Tritium	3	3	1.5E+01	±	2.2E+00	1.6E+01	±	6.3E+00	17	16	1.5E+01	±	1.0E+02	2.3E+02	±	1.3E+02

[a] Averages are ±2 standard deviations.
[b] Maximum values are ± analytical uncertainty.
[c] Results include concentrations below detection limit.

Table C-21. Sagemoor Irrigation Water Sample Results

Radionuclide	2019								2014-2018							
	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	3	0	-3.3E-04	±	3.0E+00	1.1E+00	±	3.8E+00	3	0	-5.2E-01	±	3.2E+00	9.6E-01	±	4.3E+00
Cesium-134[c]	3	0	-1.9E-01	±	7.8E-01	1.6E-01	±	2.0E+00	3	0	9.0E-01	±	4.7E+00	4.1E+00	±	2.7E+00
Cesium-137[c]	3	0	4.6E-01	±	8.8E-01	8.6E-01	±	1.5E+00	3	0	5.5E-01	±	6.4E-01	8.7E-01	±	1.6E+00
Cobalt-60[c]	3	0	-2.4E-02	±	1.2E+00	4.9E-01	±	1.9E+00	3	0	-1.1E-01	±	1.5E+00	5.5E-01	±	1.6E+00
Europium-152[c]	3	0	-2.0E-01	±	4.6E+00	2.1E+00	±	6.0E+00	3	0	1.6E+00	±	3.5E+00	3.5E+00	±	5.1E+00
Europium-154[c]	3	0	2.9E+00	±	3.7E+00	5.2E+00	±	3.8E+00	3	0	1.0E-01	±	2.6E+00	1.9E+00	±	4.7E+00
Europium-155[c]	3	0	-2.6E-01	±	7.2E+00	2.4E+00	±	4.9E+00	3	0	1.4E+00	±	1.2E+01	9.2E+00	±	8.6E+00
Ruthenium-106[c]	3	0	8.2E-01	±	9.5E+00	4.9E+00	±	1.3E+01	3	0	1.9E-01	±	1.4E+01	8.0E+00	±	1.7E+01
Strontium-90[c]	3	0	3.3E-03	±	3.0E-02	1.6E-02	±	3.4E-02	3	0	1.3E-02	±	3.5E-02	3.1E-02	±	2.7E-02
Tritium	3	3	1.5E+01	±	6.2E+00	1.9E+01	±	6.9E+00	3	3	1.5E+01	±	2.5E+00	1.7E+01	±	6.3E+00

[a] Averages are ±2 standard deviations.
[b] Maximum values are ± analytical uncertainty.
[c] Results include concentrations below detection limit.

C.6 Vegetation Monitoring

Table C-22. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Vegetation Samples. (2 Pages)

Radionuclide	Hanford Area	2019									2014 - 2018								
		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	4	2	3.8E-03	±	2.8E-03	5.3E-03	±	4.7E-03	V009	12	2	1.5E-02	±	5.60E-02	1.1E-01	±	2.5E-02	V034
^{137}Cs	100	2	0	-3.9E-03	±	4.4E-02	1.8E-02	±	2.5E-02	Y719	12	0	7.2E-03	±	2.90E-02	2.2E-02	±	5.9E-02	Y724
	200-E	8	1	5.0E-03	±	4.6E-02	3.6E-02	±	3.3E-02	V055	44	9	5.0E-02	±	2.40E-01	8.0E-01	±	5.9E-02	V076
	200-W	15	2	1.9E-02	±	4.2E-02	7.4E-02	±	5.2E-02	V037	80	7	1.7E-02	±	3.80E-02	8.6E-02	±	2.9E-02	V036
	300	2	0	3.1E-02	±	1.0E-02	3.6E-02	±	3.3E-02	V123	8	1	2.0E-02	±	3.90E-02	4.4E-02	±	4.7E-02	V132
	600	15	3	9.1E-03	±	5.4E-02	6.3E-02	±	3.1E-02	V089	62	6	1.5E-02	±	4.70E-02	1.3E-01	±	3.5E-02	V086
^{238}Pu	100	2	0	-7.1E-03	±	7.0E-03	-3.6E-03	±	3.9E-03	Y719	10	0	-6.2E-05	±	7.40E-04	7.9E-04	±	6.7E-04	Y724
	200-E	8	0	-4.7E-04	±	5.1E-03	3.7E-03	±	5.8E-03	V063	43	2	1.2E-03	±	6.00E-03	1.1E-02	±	8.1E-03	V060
	200-W	15	0	5.8E-04	±	2.4E-03	3.1E-03	±	9.4E-03	V019	79	8	1.9E-03	±	1.10E-02	4.5E-02	±	1.4E-02	V034
	300	2	0	2.7E-03	±	6.5E-04	3.0E-03	±	6.5E-03	V132	8	0	3.5E-04	±	1.20E-03	1.7E-03	±	6.4E-03	V132
	600	14	0	-2.5E-03	±	6.5E-03	4.6E-03	±	1.1E-02	V083	62	0	5.2E-04	±	4.30E-03	8.8E-03	±	1.2E-02	V092
$^{239/240}$Pu	100	2	0	1.8E-03	±	2.4E-03	3.0E-03	±	7.3E-03	Y724	9	1	7.1E-04	±	1.60E-03	2.2E-03	±	3.8E-03	Y719
	200-E	8	0	-2.2E-04	±	5.6E-03	6.4E-03	±	8.9E-03	V057	45	10	1.1E-03	±	4.40E-03	9.9E-03	±	8.5E-03	V060
	200-W	15	5	5.2E-03	±	8.8E-03	1.4E-02	±	1.5E-02	V025	82	54	1.2E-02	±	1.40E-01	6.3E-01	±	7.8E-02	V034
	300	2	0	4.7E-03	±	7.1E-03	8.2E-03	±	7.1E-03	V132	8	0	-8.4E-04	±	4.60E-03	4.0E-04	±	6.1E-04	V123
	600	14	0	2.4E-05	±	3.8E-03	3.2E-03	±	5.1E-03	V099	62	12	7.7E-04	±	5.10E-03	9.7E-03	±	9.0E-03	V098
^{90}Sr	100	2	2	1.5E-01	±	1.3E-01	2.2E-01	±	6.0E-02	Y724	12	11	7.0E-01	±	1.20E+00	1.8E+00	±	3.4E-01	Y724
	200-E	9	4	3.5E-02	±	7.7E-02	8.1E-02	±	2.1E-02	V065	46	17	7.7E-02	±	2.50E-01	5.0E-01	±	1.2E-01	V063
	200-W	15	0	7.9E-03	±	4.1E-02	4.5E-02	±	3.1E-02	V037	82	9	1.8E-02	±	8.20E-02	1.7E-01	±	4.9E-02	V045
	300	2	0	1.2E-02	±	4.9E-02	3.6E-02	±	2.5E-02	V123	8	1	2.5E-02	±	1.80E-01	2.6E-01	±	6.0E-02	V123
	600	15	0	3.6E-03	±	3.3E-02	3.0E-02	±	2.9E-02	V103	63	4	1.1E-02	±	4.50E-02	7.3E-02	±	3.6E-02	V091
^{234}U	100	2	0	-4.6E-03	±	7.8E-03	-6.8E-04	±	6.8E-03	Y719	12	7	3.7E-02	±	9.90E-02	1.8E-01	±	1.4E-01	Y724
	200-E	9	1	3.4E-03	±	8.8E-03	1.2E-02	±	9.0E-03	V065	46	37	5.6E-02	±	1.60E-01	3.6E-01	±	1.8E-01	V315
	200-W	15	2	8.8E-03	±	1.2E-02	2.5E-02	±	1.7E-02	V051	82	52	2.8E-02	±	1.20E-01	3.4E-01	±	1.7E-01	V305
	300	2	0	5.9E-03	±	4.1E-04	6.1E-03	±	6.2E-03	V132	8	6	3.0E-02	±	4.00E-02	7.9E-02	±	9.5E-02	V123
	600	15	2	3.4E-03	±	8.3E-03	1.1E-02	±	8.5E-03	V091	63	45	2.7E-02	±	8.50E-02	1.4E-01	±	4.7E-02	V108
^{235}U	100	2	0	1.8E-03	±	6.7E-03	5.1E-03	±	6.0E-03	Y719	12	5	1.5E-02	±	2.10E-02	4.4E-02	±	1.1E-01	Y724
	200-E	6	0	-8.4E-04	±	6.6E-03	3.4E-03	±	5.1E-03	V077	46	26	2.7E-02	±	8.00E-02	1.6E-01	±	1.3E-01	V062
	200-W	15	1	2.3E-03	±	7.2E-03	8.5E-03	±	6.2E-03	V009	76	26	1.2E-02	±	9.10E-02	1.6E-01	±	1.2E-01	V304
	300	2	0	2.1E-03	±	2.3E-03	3.3E-03	±	5.7E-03	V123	8	4	6.7E-03	±	2.80E-02	2.3E-02	±	1.2E-02	V123
	600	11	0	2.0E-03	±	2.8E-03	4.6E-03	±	6.8E-03	V097	62	32	1.2E-02	±	6.20E-02	7.7E-02	±	3.9E-02	V108
^{238}U	100	2	0	-1.8E-03	±	6.8E-03	1.6E-03	±	6.1E-03	Y719	12	6	2.6E-02	±	6.10E-02	1.0E-01	±	1.2E-01	Y724
	200-E	9	2	5.5E-03	±	6.4E-03	1.2E-02	±	8.2E-03	V065	46	33	3.6E-02	±	6.90E-02	1.4E-01	±	1.3E-01	V312
	200-W	15	3	6.7E-03	±	8.4E-03	1.2E-02	±	7.5E-03	V045	81	46	1.8E-02	±	6.70E-02	1.4E-01	±	1.1E-01	V304

Table C-22. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Vegetation Samples. (2 Pages)

Radionuclide	Hanford Area	2019									2014 - 2018								
		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]							
	300	2	0	4.1E-03	±	2.8E-03	5.5E-03	±	7.0E-03	V132	8	8	3.4E-02	±	6.70E-02	1.2E-01	±	1.1E-01	V123
	600	14	4	4.8E-03	±	7.6E-03	9.9E-03	±	5.6E-03	V081	62	43	1.9E-02	±	9.10E-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

Table C-23. Concentrations of Select Radionuclides (pCi/g)[a] in Offsite Vegetation Samples.

Radionuclide	Hanford Area	2019									2001, 2004, 2008, and 2015								
		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]							
^{137}Cs	Offsite	8	0	-1.5E-02	±	5.2E-02	1.1E-02	±	3.6E-02	V440	50	1	5.9E-03	±	2.4E-02	5.5E-02	±	2.9E-02	V412
^{238}Pu	Offsite	8	0	-8.5E-04	±	2.8E-03	1.1E-03	±	4.5E-03	V434	46	5	7.5E-05	±	2.1E-04	5.0E-04	±	2.8E-04	V441
$^{239/240}$Pu	Offsite	8	0	-1.7E-03	±	2.7E-03	-2.4E-04	±	2.4E-03	V431	46	24	8.9E-04	±	3.2E-03	7.7E-03	±	1.3E-03	V412
^{90}Sr	Offsite	8	0	-1.6E-03	±	2.4E-02	1.7E-02	±	2.8E-02	V439	48	3	2.1E-02	±	7.6E-02	2.0E-01	±	4.4E-02	V430
^{234}U	Offsite	8	5	1.7E-02	±	1.4E-02	2.9E-02	±	1.2E-02	V427	49	23	1.5E-02	±	3.4E-02	8.9E-02	±	5.6E-02	V430
^{235}U	Offsite	8	4	9.1E-03	±	8.9E-03	1.9E-02	±	9.7E-03	V440	48	9	4.8E-03	±	1.7E-02	5.1E-02	±	4.8E-02	V430
^{238}U	Offsite	8	7	1.5E-02	±	1.8E-02	3.3E-02	±	1.2E-02	V440	50	20	9.6E-03	±	2.0E-02	3.6E-02	±	3.8E-02	V434

[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

Table C-24. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Vegetation Samples Collected Sitewide and Offsite Vegetation Samples. (2 Pages)

Location	Radionuclide	2019									2001-2018								
		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]							
Sitewide	^{241}Am	4	2	3.8E-03	±	2.8E-03	5.3E-03	±	4.7E-03	V009	12	2	1.5E-02	±	5.6E-02	1.1E-01	±	2.5E-02	V034
	^{137}Cs	42	6	1.2E-02	±	4.9E-02	7.4E-02	±	5.2E-02	V037	1010	173	5.0E-02	±	4.9E-01	6.0E+00	±	4.3E+00	V045
	^{238}Pu	41	0	-9.5E-04	±	6.4E-03	4.6E-03	±	1.1E-02	V083	1004	32	1.4E-03	±	1.8E-02	8.7E-02	±	4.7E-02	V120
	$^{239/240}$Pu	41	5	2.2E-03	±	8.2E-03	1.4E-02	±	1.5E-02	V025	1010	227	6.8E-03	±	9.9E-02	1.3E+00	±	2.8E-01	V019
	^{90}Sr	43	6	1.9E-02	±	8.4E-02	2.2E-01	±	6.0E-02	Y724	1015	233	3.9E-01	±	7.0E+00	6.8E+01	±	8.2E+00	Y719
	^{234}U	43	5	5.0E-03	±	1.2E-02	2.5E-02	±	1.7E-02	V051	1015	819	2.3E-02	±	8.5E-02	5.4E-01	±	1.1E-01	V119
	^{235}U	36	1	1.7E-03	±	6.3E-03	8.5E-03	±	6.2E-03	V009	1007	279	7.3E-03	±	7.3E-02	1.0E+00	±	0.0E+00	V079
	^{238}U	42	9	5.3E-03	±	8.3E-03	1.2E-02	±	8.2E-03	V065	1013	786	1.8E-02	±	7.3E-02	5.7E-01	±	1.1E-01	V120
Offsite	^{137}Cs	8	0	-1.5E-02	±	5.2E-02	1.1E-02	±	3.6E-02	V440	50	1	5.9E-03	±	2.4E-02	5.5E-02	±	2.9E-02	V412

Table C-24. Concentrations of Select Radionuclides (pCi/g)[a] in Hanford Site Vegetation Samples Collected Sitewide and Offsite Vegetation Samples. (2 Pages)

Location	Radionuclide	2019									2001-2018									
		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}Pu	8	0	-8.5E-04	±	2.8E-03	1.1E-03	±	4.5E-03	V434	46	5	7.5E-05	±	2.1E-04	5.0E-04	±	2.8E-04	V441
	^{239}/^{240}Pu	8	0	-1.7E-03	±	2.7E-03	-2.4E-04	±	2.4E-03	V431	46	24	8.9E-04	±	3.2E-03	7.7E-03	±	1.3E-03	V412
	^{90}Sr	8	0	-1.6E-03	±	2.4E-02	1.7E-02	±	2.8E-02	V439	48	3	2.1E-02	±	7.6E-02	2.0E-01	±	4.4E-02	V430
	^{234}U	8	5	1.7E-02	±	1.4E-02	2.9E-02	±	1.2E-02	V427	49	23	1.5E-02	±	3.4E-02	8.9E-02	±	5.6E-02	V430
	^{235}U	8	4	9.1E-03	±	8.9E-03	1.9E-02	±	9.7E-03	V440	48	9	4.8E-03	±	1.7E-02	5.1E-02	±	4.8E-02	V430
	^{238}U	8	7	1.5E-02	±	1.8E-02	3.3E-02	±	1.2E-02	V440	50	20	9.6E-03	±	2.0E-02	3.6E-02	±	3.8E-02	V434

[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

Table C-25. Radionuclide Concentrations in Liquid Effluents. (2 Pages)

Facility	Sample Location	Radionuclide or Analysis	Number of		Average Concentration (µCi/mL)	DCS (µCi/mL)	DCS Fraction (%)
			Samples	Samples >MDA			
ETF	Verification Tank	americium-241	7	0	--	--	--
ETF	Verification Tank	curium-243/244	7	0	--	--	--
ETF	Verification Tank	gamma energy	6	0	--	--	--
ETF	Verification Tank	gross alpha	10	2	5.8E-10	1.7E-07[a]	0.3%
ETF	Verification Tank	gross beta	10	3	2.3E-09	3.0E-06[b]	0.1%
ETF	Verification Tank	iodine-129	7	0	--	--	--
ETF	Verification Tank	neptunium-237	7	0	--	--	--
ETF	Verification Tank	plutonium-238	7	0	--	--	--
ETF	Verification Tank	plutonium-239/240	7	0	--	--	--
ETF	Verification Tank	radium-226	7	2	3.1E-10	8.7E-08	0.4%
ETF	Verification Tank	strontium-90	7	0	--	--	--
ETF	Verification Tank	technetium-99	7	0	--	--	--
ETF	Verification Tank	tritium	7	7	3.9E-04	1.9E-03	20.3%
						ETF Sum of Fractions =	21.1%
TEDF	Building 6653	gross alpha	13	1	1.8E-09	1.7E-07[a]	1.1%
TEDF	Building 6653	gross beta	13	2	4.1E-09	3.0E-06[b]	0.1%
TEDF	Building 6653	tritium	5	0	--	--	--
						TEDF Sum of Fractions =	1.2%

Table C-25. Radionuclide Concentrations in Liquid Effluents. (2 Pages)

[a] DCS value for americium-241
[b] DCS value for cesium-137
ETF = Effluent Treatment Facility
TEDF = Treated Effluent Disposal Facility
MDA = minimum detectable activity
DCS = derived concentration standard for ingested water from DOE-STD-1196-2011

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

Table of Contents

D.0 DOSE CALCULATIONS.....3
D.1 Supporting Information for Calculation of Public Doses 3
D.1.1 Maximally Exposed Individual Dose 5
D.1.2 Fifty-Mile (Eighty-Kilometer) Collective Population Dose.....11
D.2 Calculation of Biota Doses.....16
D.3 References.....21

Tables

Table D-1. Liquid Effluent Radionuclide Releases for GENII Dose Calculations..... D-9
Table D-2. Air Pathway Radionuclide Stack Emissions for GENII Modeling.....D-10
Table D-3. Agricultural Pathway Parameters for Hanford Site Dose Calculations. D-13
Table D-4. Consumption Parameters for Hanford Site Dose Calculations. D-14
Table D-5. Residency Parameters for Hanford Site Dose Calculations. D-14
Table D-6. Columbia River Parameters for Hanford Site Dose Calculations.....D-14
Table D-7. Biota Concentration Guides and Sediment to Water Distribution Coefficients. D-16
Table D-8. Tier 1 Soil Biota Concentration Guides.....D-17
Table D-9. Maximum Detected Concentrations Evaluated for Aquatic Biota Dose Assessment. D-17
Table D-10. West Lake 2019 Water and Sediment Samples.....D-19
Table D-11. Tier 3 Biota Concentration Guides Calculated Using RESRAD-BIOTA v1.8. .....D-20
Table D-12. Maximum Detected Concentrations Evaluated in 2019 for the Terrestrial Biota Dose Assessment. D-21

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D.0 Dose Calculations

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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 2019 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.16 mrem (1.6 µSv). This dose is 0.16% of the 100 mrem (1000 µSv)/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 µSv), 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 2019 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 (µSv)[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), 1 mrem = 0.01 mSv = 10 µSv.

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 2019 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 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-2020-08, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2019*.

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 2019 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 2019, 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 the Pacific Northwest National Laboratory Laboratory Support Warehouse (proximal to the Horn Rapids Road MEI location evaluated with GENII) 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 2019 are not very different (0.15 mrem/yr at Sagemoor and 0.16 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 0.0045 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 2019. 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).

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 and uranium-234 as potential Hanford-related contaminants to include in the 2019 water pathway dose assessment using a p-value of 0.05. Concentrations of uranium-238 were greater downstream but p-values were slightly higher than 0.05 for both the t-test and the WRS. Uranium-238 is retained as a potentially Hanford-related contaminant for the 2019 dose assessment because the higher downstream concentrations are considered plausibly site-related,

particularly in light of the uranium-234 results. Uranium-235 might be expected to co-occur with both uranium-234 and uranium-238, yearly average uranium-235 concentrations were higher downstream than upstream and, therefore, uranium-235 is included in the water pathway dose assessment calculations.

Table D-1 summarizes the mean annual differences in downstream and upstream concentrations and calculated annual releases for the 2019 GENII water pathway dose calculations.

Table D-1. Liquid Effluent Radionuclide Releases for GENII Dose Calculations.

Radionuclide	Upstream	Downstream	Difference
Columbia River Annual-Average Radionuclide Concentrations (pCi/L)[a]			
Tritium	1.8E+01	2.9E+01	1.2E+01
Uranium-234	2.7E-01	3.0E-01	2.5E-02
Uranium-235	1.8E-02	2.0E-02	1.3E-03
Uranium-238	2.2E-01	2.3E-01	1.4E-02
Calculated Radionuclide Releases (Ci/year)[b]			
Tritium	NA[c]	NA[c]	9.75E+02
Uranium-234	NA[c]	NA[c]	2.1E+00
Uranium-235	NA[c]	NA[c]	1.1E-01
Uranium-238	NA[c]	NA[c]	1.2E+00

[a] 1 pCi=0.037 Bq
[b] Calculated as the product of the difference in downstream and upstream radionuclide concentrations and the 2019 annual-average river flow rate of 2,628 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-2020-08, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2019,* 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]	92.0	NA [a]
Hydrogen-3 (tritiated water vapor)	NA [a]	NA [a]	163	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]	7.1E-08	5.9E-08	NA [a]
Krypton-85	NA [a]	NA [a]	1.2E-02	NA [a]
Stontium-90	7.4E-06	2.0E-06	8.0E-08	NA [a]
Yttrium-90 [a]	1.1E-06	3.0E-07	1.2E-08	--
Technetium-99	NA [a]	NA [a]	4.3E-06	NA [a]
Ruthenium-106	NA [a]	NA [a]	1.4E-08	NA [a]
Iodine-129	NA [a]	1.2E-03	NA [a]	NA [a]
Cesium-137 [b]	4.2E-05	1.8E-05	4.9E-06	1.6E-06
Barium-137m [b, c]	4.2E-05	1.8E-05	4.9E-06	1.6E-06
Europium-152	NA [a]	NA [a]	2.1E-09	NA [a]
Europium-154	NA [a]	NA [a]	3.1E-08	NA [a]
Gadolinium-153	NA [a]	NA [a]	9.1E-11	NA [a]
Radon-220	NA [a]	NA [a]	520	NA [a]
Lead-212 [c]	--	--	0.7	--
Bismuth-212 [c]	--	--	0.6	--
Radium-226	NA [a]	NA [a]	3.7E-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	8.0E-07	NA [a]	3.5E-08	NA [a]
Plutonium-239/240 [e]	2.9E-05	4.4E-06	1.2E-07	1.9E-07
Plutonium-241	2.8E-05	1.7E-07	NA [a]	NA [a]
Americium-241	4.9E-06	6.3E-07	5.4E-09	NA [a]
Americium-243	NA [a]	NA [a]	5.3E-08	NA [a]
Neptunium-239 [e]	--	--	9.0E-09	--
Curium-243/244	NA [a]	NA [a]	5.6E-11	NA [a]
(gross alpha)	2.2E-05	3.4E-06	1.2E-07	1.9E-07
(gross beta)	3.2E-05	1.4E-05	4.8E-06	1.6E-06

Table D-2. Air Pathway Radionuclide Stack Emissions for GENII Modeling. (2 Pages)

[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 2019 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 200 Areas, all meteorological data were obtained at a height of 33 ft (10 m). In the 200 Area, 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		Fruits	Cereals	Eggs	Poultry	Beef	Milk	Hay (beef cattle, milk cows)	Pasture (milk cows)	Grains (beef cattle, poultry)
	Leafy	Root									
Holdup time[a]; day (MEI)	1	5	5	180	1	1	15	1	100	0	180
Holdup time[a]; day (population)	14	14	14	180	18	34	34	4	100	0	180
Growing period; day	90	90	90	90	NA	NA	NA	NA	45	30	90
Yield; kg/m[b]	1.5	4	2	0.8	NA	NA	NA	NA	2	1.5	0.8
Irrigation rate; cm/yr	77	88	77	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 m^3/hr (35 ft^3/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 Cities[2] 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:

Population dose (person-rem) = MEI dose (mrem) × 0.001 rem/mrem × (annual catch [kg/yr]/IR_fish [kg/yr/person]), where MEI dose=fish ingestion dose for the MEI; annual catch=15,000 kg fish/yr; IR_fish=individual fish ingestion rate used in the MEI calculation (40 kg/yr/person)

Collective dose related to air-mediated exposure pathways was calculated based on the geographic distribution of the population residing within a 50-mi (80-km) radius of the Hanford Site operating areas (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.,

[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.

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 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 2019 radionuclide concentrations in water, sediment, soil, and tissues to see if they exceeded the established biota concentrationwrs guides. Biota concentration guides are concentrations published in DOE-STD-1153-2019, *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
Europium-155	1.58E+04	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 Pumphouse 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	—	19.623
	Technetium-99	—	1.46
	Cesium-137	0.225	—

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]
	Uranium-234	1.37	0.302
	Uranium-235	0.111	0.0175
	Uranium-238	1.31	0.229
	Plutonium-239/240	0.00801	—
100 Area	Hydrogen-3	—	3670
	Carbon-14	—	138
	Strontium-90	—	55.2
	Technetium-99	—	5.3
	Cesium-137	0.145	—
	Uranium-234	1.07	0.295
	Uranium-235	0.0833	0.052
	Uranium-238	0.792	0.279
	Plutonium-238	—	—
	Plutonium-239/240	—	—
Hanford Townsite	Hydrogen-3	—	24100
	Cesium-137	0.282	—
	Uranium-234	1.4	0.289
	Uranium-235	0.1	0.0472
	Uranium-238	1.32	0.252
	Plutonium-238	—	—
300 Area	Hydrogen-3	—	2350
	Cesium-137	0.111	—
	Uranium-234	1.59	7.52
	Uranium-235	0.106	0.472
	Uranium-238	1.51	7.06
Downstream	Hydrogen-3	—	44.291
	Cesium-137	0.194	—
	Uranium-234	1.52	0.395
	Uranium-235	0.0796	0.0224
	Uranium-238	1.32	0.346
	Plutonium-238	0.00328	—
	Plutonium-239/240	0.0107	—

[a] 1 pCi = 0.037 Bq
— = Not detected or not measured
K_d = Water to Sediment Distribution Coefficients (mL/g) from RESRAD-BIOTA v1.8
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-1153-2019.

Table D-10. West Lake 2019 Water and Sediment Samples.

Radionuclide	Water Concentration (pCi/L)[a]		Sediment Concentration (pCi/g)[a]	
	Maximum	Average	Maximum	Average
Hydrogen-3	—	—	—	—
Strontium-90	—	5.945	0.26	0.178
Cesium-137	—	1.049	0.776	0.525
Uranium-234	204	113.25	1.1	0.950
Uranium-235	13.1	7.09	0.072	0.067
Uranium-238	201	111.65	1.03	0.949

[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-1153-2019, 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, also measured in 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 at West Lake 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 on- and off-site soil sample results. Table D-12 lists the maximum concentrations of strontium-90, cesium-137, europium-155, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239/240, and americium-241. Europium-155 was detected in two onsite soil samples; however, the detection of europium-155 is likely related to spectral interference from short-lived naturally-occurring radionuclides such as actinium-228. Furthermore, the half-life of europium-155 is 4.75 years; this, combined with the fact that it is infrequently detected, is why this detect is suspected to be interference from actinium-228 rather than it being site-related. Following the screening protocol, europium-155 was retained through the biota dose assessment. 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 samples 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 2019 for the Terrestrial Biota Dose Assessment.

Location Group	Radionuclide	Maximum Soil Concentration (pCi/g) [a]
Onsite	Strontium-90	3.12
	Cesium-137	16.7
	Europium-155 [b]	0.0877
	Uranium-234	1.450
	Uranium-235	0.0758
	Uranium-238	1.20
	Plutonium-238	0.147
	Plutonium-239/240	0.523
	Americium-241	0.196
Offsite	Cesium-137	0.556
	Uranium-234	0.0255
	Uranium-235	0.623
	Uranium-238	0.0568
	Plutonium-239/240	0.564

[a] 1 pCi=0.037 Bq.

[b] Europium-155 is likely related to spectral inference from short-lived naturally occurring radionuclides such as actinium-228. Following the screening protocol, europium-155 is retained through the biota dose assessment.

D.3 References

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